Electrical Notes

Revision-1.25

Jignesh.Parmar
(B.E (Elec), Mtech, FIE, MIE, CEng)

www.electricalnotes.wordpress.com

Note: All Notes/Abstract s are based on some electrical References. All References are mentions at the end of Note.

: INDEX:

Part-1: Electrical Quick Reference:

Part-2: Electrical Calculation

Part-3: Electrical Calculation

PART-1

Electrical Quick Reference

General Equation

Electrical	Star Connection	Length
1HP=0.746KW	Line Voltage=√3 Phase Voltage	1Foot=30.48 cm=12 inch
1KW=1.36HP	Line Current=Phase Current	1cm =0.394 inch=0.0328 Foot
1Watt=0.846 Kla/Hr	**Delta Connection**	1Meter= 39.3 Inch = 3.33 Feet
1Watt=3.41 BTU/Hr	Line Voltage=Phase Voltage	1Meter= 1.094 Yard
1KWH=3.6 MJ	Line Current=√3 Phase Current	1inch= 2.54 cm
1Cal=4.186 J	**Area**	1Yard=91.4 cm
1Tone= 3530 BTU	1 Sq.mt=1.19560 Sq. Yard	1Gaj=36 inch
1Tone= 12000 BTU/Hr	1 Sq.mt=10.763 Sq. Foot	1cm=1000 micron
1Tone= 3.5 KW	1 Sq.cm=0.155 Sq. Inch	1Mile= 1.60 Km
85 Sq. Foot Floor Area=1200 BTU	**Temp**	1 Km=0.62137 Mile
1Kcal=4186 Joule	C°=5/9x(F°-32)	1Yard=36 inch =3 feet
1KWH=860 Kcal	K°=C°+273.15	
1Cal=4.183 Joule		

A.C Capacity

Ton	KW	H.P
0.64	2.1	0.8
0.8	2.8	1
1	3.7	1.25
1.28	4.6	1.6
1.6	5.6	2
2	7.31	2.5
2.56	9.35	3.2
3.2	11.6	4
4	14.4	5
4.48	16.7	5.6
6.4	22.1	8
8	29.1	10
1TON=	3000 K. Cal/Hr	
	1200 BTU/Hr	
	3.516 KW	
	1.25 HP (VRV / VRF Only)	
	4.7 HP	
	12660 KJ/Hr	

Electrical Equations

Power Factor (CosØ)=	KW / KVA
Motor In Put Power (KW)=	HPx0.746 / Efficiency (%)
KVA=	√3 x VxI / 1000
KVA=	√(kwxkw)+(kvarxkvar)
Kvar=	2x3.14xfxcx(kvxkv) / 1000
Kvar=	√(kvarxkvar)+(kwxkw)
Capacitance (c)=	(Kvarx1000) / (2x3.14xfx(kvxkv)
Luminance (E) Lux=	Phi / Area (Sq.Meter)
Lux =	Lumens / Area (sq meter)
Sinusoidal Current Form Factor=	RMS Value/Average Value=1.11
Sinusoidal Current Peak Factor=	Max Value/RMS Value =1.414
Avg Value of Sinusoidal Current (Iav)=	0.637xIm (Im= Max.Value)
RMS Value of Sinusoidal Current (Irms)=	0.707xIm (Im= Max.Value)
A.C Current=	D.C Current / 0.636
Phase Difference between Phase=	360 / No of Phase
	(1 Phase=360/1=360°,2 Phase=360/2=180°)

Short Circuit Level of Cable in KA (Isc)=	(0.094xCable Dia in Sq.mm) /√ Short Circuit Time (Sec)
Maximum Cross Section Area of Earthing Strip(mm2) =	√(2xFault Current x Operating Time of Disconnected Device) / K
	Where K=Material Factor, K for Cu=159, K for Alu=105, K for steel=58 , K for GI=80
Most Economical Voltage at given Distance=	5.5x√ ((km/1.6)+(KW/100))
Cable Voltage Drop (%) =	(1.732xFull Load Current x (RcosØ+jsinØ) xLength (km) x 100) / (Volt(L-L) x Cable Run).
Spacing of Conductor in Transmission Line (mm)=	500 + 18 x (P-P Volt) + (2x (Span in Length) / 50)
Protection radius of LightingArrestor =	√hx (2D-h) + (2D+L)
	Where h= height of L.A, D-distance of equipment (20, 40, 60 Meter), L=Vxt (V=1m/ms, t=Discharge Time)
Size of Lighting Arrestor=	1.5x Phase to Earth Voltage or 1.5x (System Voltage/1.732)
Maximum Voltage of the System=	1.1xRated Voltage (Ex. 66KV=1.1x66=72.6KV)
Load Factor=	Average Power / Peak Power
	If Load Factor is 1 or 100% = This is best situation for System and Consumer both.
	If Load Factor is Low (0 or 25%) =you are paying maximum amount of KWH consumption.
	Load Factor may be increased by switching or use of your Electrical Application.
Demand Factor (Demand Factor <1)=	Maximum Demand / Total Connected Load
	(Demand factor should be applied for Group Load)
Diversity Factor (Demand Factor >1)=	Sum of Maximum Power Demand / Maximum Demand
	(Diversity factor should be consider for individual Load)
Plant Factor(Plant Capacity)=	Average Load / Capacity of Plant
Fusing Factor (Fusing Factor>1)=	Minimum Fusing Current / Current Rating
Voltage Variation (1 to 1.5%)=	(Average Voltage-Min Voltage)x100 / Average Voltage
	Ex: 462V, 463V, 455V, Voltage Variation= ((460-455) x100)/455=**1.1%**
Current Variation (10%)=	(Average Current-Min Current) x100 / Average Current.
	Ex:30A,35A,30A, Current Variation=((35-31.7)x100)/31.7=**10.4%**
Fault Level at TC Secondary=	TC (VA) x100 / TC Secondary Volt x Impedance (%)
Motor Full Load Current=	Kw /1. 732xKVxP.FxEfficiency
HV/LV Distribution Transformer Size= (In Radial System) =	1.2xPeak Electrical Power / No of Transformer x cosǾ
Voltage Rise in Transformers due to Capacitor Bank in Distribution Line=	% Voltage Rise in Transformer=(Kvar / Kva)x Z
	Where, Kvar =Applied Kvar ,Kva = Kva of the transformer ,z = Transformer Reactance in % Example: 300 Kvar bank connected to 1200 KVA transformer with 5.75% reactance.% Voltage Rise in Transformer=(300/1200)x 5.75 =1.43%
Number of Lighting Fixtures=	Illumination x Area / Lamp per fixture x Lumens x cu x mf
Area per Lighting Fixture=	Lamp per fixture x Lumens per Lamp x cu x mf / Illumination
Street illumination level in Lux (E)=	Al x cu x mf / w x d
	Where, E = The illumination in Lux, w = Width of the Roadway, d = Distance between luminaries, cu = Coefficient of utilization. mf = maintenance factor (Normally 0.8 to 0.9) ,
	Al = Average lumens, Al = (E x w x d) / Cu x mf
	The typical value of Al is 20500 lumens for 400 watts,11500 lumens for 250 watts,5400 lumens for 125 watts
Allowed illumination time in T (Hr)=	kxtx1000/E

	Where: k = extension factor, t = permissible time in hours at 1000 lux, unfiltered daylight ,E = luminance (lx)
Running cost of Lamp=	Cost of electricity in $/kWh x wattage of lamp x lifetime in hours
Cross Section area of Cable (mm2) =	I x √t / K
	Where, t = fault duration (S), I = effective short circuit current (kA), K = 0.094 for aluminum conductor insulated with XLPE
Electrical Line Ground Clearance (Meter) =	5.812 + 0.305 X K
	Where K= (Volt-33)/33
Economical Voltage for Power Transmission (kV line to line) =	5.5x√0.62 L + kVA /150 (Indian Practice)
	5.5x√0.62 L + kVA /150 (American Practice)
	Where L is length of transmission line in km
For Cu Wire Current Capacity (Up to 30 Sq.mm)	**=6X Size of Wire in Sq.mm**
	Example for 2.5 Sq.mm=6x2.5=15 A, For 1 Sq.mm=6x1=6 A, 1.5 Sq.mm=6x1.5=9 A
For Cable Current Capacity =	**=4X Size of Cable in Sq.mm ,**
	Example for 2.5 Sq.mm=4x2.5=9 Amp
1 Phase Motor draws Current=	7 Amp/HP.
3 Phase Motor draws Current=	1.25 Amp/HP.
Diesel Generator Set Produces=	3.87 Units (KWH) in 1 Litter of Diesel.
Requirement Area for Diesel Generator =	for 25KW to 48KW=56 Sq.meter, 100KW=65 Sq.meter
DG noise levels to be less than=	75dBA @ 1meter
DG Set must be Required in a canopy=	<= 1000kVA DG set
DG Set can either be in a canopy or skid mounted in an acoustically treated room=	>= 1000kVA DG set
DG fuel storage tanks=	Should be a maximum of **990 Litter per unit** Storage tanks above this level will trigger more stringent explosion protection provision.
Earthing Resistance =	Single Pit <5Ω ,Earthing Grid=0.5Ω
As per NEC 1985 Earthing Resistance =	<5Ω.
Voltage between Neutral and Earth=	<=2 Volts
Resistance between Neutral and Earth=	<=1Ω
Creepage Distance=	18 to 22mm/KV (Moderate Polluted Air) or
Creepage Distance=	25 to 33mm/KV (Highly Polluted Air)
Min. Bending Radius for LT Power Cable=	12xDia of Cable.
Min. Bending Radius for HT Cable=	20xDia of Cable.
Min. Bending Radius for Control Cable=	10xDia of Cable.
Insulation Resistance for Rotating Machine=	(KV+1) MΩ.
Insulation Resistance for Motor (IS 732)=	((20xVoltage (L-L)) / (1000+ (2xKW)).
Insulation Resistance for Equipment (<1KV)=	Minimum 1 MΩ
Insulation Resistance for Equipment (>1KV)=	KV 1 MΩ per 1KV
Insulation Resistance Value for Panel=	2 x KV rating of the panel.
Min Insulation Resistance Value (Domestic) =	50 MΩ / No of Points.
	(All Electrical Points with Electrical fitting & Plugs). Should be less than 0.5 MΩ
Min Insulation Resistance Value (Commercial) =	100 MΩ / No of Points.
	(All Electrical Points without fitting & Plugs).Should be less than 0.5 MΩ.
Test Voltage (A.C) for Meggering =	(2X Name Plate Voltage) +1000

Test Voltage (D.C) for Meggering =	(2X Name Plate Voltage).
Submersible Pump Take=	0.4 KWH of extra Energy at 1 meter drop of Water
Arrestor have Two Rating=	(1) MCOV=Max. Continuous Voltage (Line to Ground Operating Voltage.
	(2) Duty Cycle Voltage. (Duty Cycle Voltage>MCOV)
Nomenclature for cable Rating =	Uo/U ,where Uo=Phase-Ground Voltage, U=Phase-Phase Voltage, Um=Highest Permissible Voltage
Current Rating of Transformer=	KVAx1.4
Short Circuit Current of T.C /Generator=	Current Rating / % Impedance
No Load Current of Transformer=	<2% of Transformer Rated current
Full Load Current of 3 Phase Motor=	HPx1.5
Full Load Current of 1 Phase Motor=	HPX6
No Load Current of 3 Phase Motor =	30% of FLC
KW Rating of Motor=	HPx0.75
Approximate Current =	1.39xKVA (for 3 Phase 415Volt)
Approximate Current =	1.74xKW (for 3 Phase 415Volt)
Capacitor Current (Ic)=	KVAR / 1.732xVolt (Phase-Phase)
For LT metered supplies the maximum connected load will be	150kW
The diversity for apartments =	60%
Earthing for each Transformer	2No. for body and 2No. for neutral earthing
Clearances around TC allow for transformer movement for replacement=	Approximate 1000mm
Nomenclature of CT=	**Ratio:** input / output current ratio
Ratio, VA Burden, Accuracy Class, Accuracy Limit Factor.	**Burden (VA):** total burden including pilot wires.
	(2.5, 5, 10, 15 and 30VA.)
	Accuracy Class: Accuracy required for operation (Metering: 0.2, 0.5, 1 or 3, Protection: 5, 10, 15, 20, 30)
	Accuracy Limit Factor:
Example CT 1600/5, 15VA 5P10	Ratio=1600/5, Burden=15VA, Accuracy Class=5P, ALF=10
As per IEEE Metering CT=	0.3B0.1 rated Metering CT is accurate to 0.3 percent if the connected secondary burden if impedance does not exceed 0.1 ohms
As per IEEE Relaying (Protection) CT=	2.5C100 Relaying CT is accurate within 2.5 percent if the secondary burden is less than 1.0 ohm (100 volts/100A)
Rating of Lighting Arrestor=	1.5 X Phase to Earth Voltage OR
	1.5 X system Voltage/1.732 OR
	0.81 X highest System Voltage
Lighting Arrestor Protection Radius(Rp)=	**Sqrt** (**H X (2D-H)+L(2D+L)**)
	H= Actual Height of L.A
	D= 20 meter, 40 meter or 60 meter
	L= V X T (T=Discharge Time & V= 1m/ms)
Cree page Distance=	18 to 22 mm /KV for Moderate Polluted Air.
	25 to 33 mm /KV for Heavily Polluted Air.
	In HVDC System The value is double from above value

Cable Coding (IS 1554) :(A2XFY/A2XWY/A2XY/FRLS/FRPVC/FRLA/PILC)			
A	Aluminium	**YY**	Steel double Strip Armoured
2X	XLPE	**FR**	Fire Retardation
F	Flat Armoured	**LS**	Low Smoke
W	Wire Armoured	**LA**	Low Acid Gas Emission
Y	Outer PVC Insulation Sheath	**WA**	Non-Magnetic round wire Armoured

W	Steel Round Wire	**FA**	Non-Magnetic Flat wire Armoured
WW	Steel double round wire Armoured	**FF**	Double Steel Round Wire Armoured
Example: **A2XFY**= Aluminium Conductor, XLPE Insulation, Flate Armoured, Outer PVC Insulation			

Earthed / Unearthed Cable Nomenclature (Uo/U)	
Voltage Grade (Uo/U)	Where Uo is Phase to Earth Voltage & U is Phase to Phase Voltage.
Earthed system has insulation grade of KV / 0.686 x KV	For Earthed System (Uo/U): 1.9/3.3 kV, 3.8/6.6 kV, 6.35/11 kV, 12.7/22 kV and 19/33 kV
Unearthed system has insulation grade of KV / KV	For Unearthed System (Uo/U): 3.3/3.3 kV and 11/11 kV
Thumb Rule	6.6KV unearthed cable is equal to 11k earthed cable i.e. 6.6/6.6kv Unearthed cable can be used for 6.6/11kv earthed system.

Chapter: 2 Cable Current Capacity Chart Reference

1.1Kv PVC Flexible Wire / Cable (Make: Havells)					
Nominal Conductor Area (Sq.mm)	Copper		Copper	Overall Dia	Short Circuit Current
	Resi	React	Current		
1cX0.5	39 Ω/km	0	**4 A**	2.1 mm	0.4 KA
1cX0.75	26 Ω/km	0	**7 A**	2.3 mm	0.4 KA
1cX1	19.5 Ω/km	0	**11 A**	2.7 mm	0.4 KA
1cX1.5	13.3 Ω/km	0	**15 A**	3 mm	0.4 KA
1cX2.5	7.98 Ω/km	0	**19 A**	3.6 mm	0.4 KA
1cX4	4.95 Ω/km	0	**26 A**	4.1 mm	0.46 KA
1cX6	3.3 Ω/km	0	**35 A**	4.6 mm	0.69 KA
1cX10	1.91 Ω/km	0	**46 A**	6.1 mm	1.15 KA
1cX16	1.21 Ω/km	0	**62 A**	7 mm	1.84 KA
1cX25	0.78 Ω/km	0	**80 A**	8.6 mm	2.88 KA
1cX35	0.554 Ω/km	0	**102 A**	9.7 mm	4.03 KA
1cX50	0.386 Ω/km	0	**138 A**	11.5 mm	5.75 KA
1cX70	0.272 Ω/km	0	**214 A**	13 mm	8.05 KA
1cX95	0.206 Ω/km	0	**254 A**	14.9 mm	10.9 KA
1cX120	0.161 Ω/km	0	**300 A**	16.4 mm	13.8 KA
2cX0.5	39 Ω/km	0	**4 A**	6.2 mm	0.4 KA
2cX0.75	26 Ω/km	0	**7 A**	6.6 mm	0.4 KA
2cX1	19.5 Ω/km	0	**11 A**	6.9 mm	0.4 KA
2cX1.5	13.3 Ω/km	0	**15 A**	7.4 mm	0.5 KA
2cX2.5	7.98 Ω/km	0	**19 A**	8.8 mm	0.5 KA
2cX4	4.95 Ω/km	0	**26 A**	10.2 mm	0.5 KA
3cX0.5	39 Ω/km	0	**4 A**	6.6 mm	0.4 KA
3cX0.75	26 Ω/km	0	**7 A**	6.9 mm	0.5 KA
3cX1	19.5 Ω/km	0	**11 A**	7.3 mm	0.4 KA
3cX1.5	13.3 Ω/km	0	**15 A**	7.8 mm	0.5 KA
3cX2.5	7.98 Ω/km	0	**19 A**	9.4 mm	0.5 KA
3cX4	4.95 Ω/km	0	**26 A**	10.9 mm	0.5 KA

1.1 KV PVC Insulated Cable (Ref: IS 1554) (Make: Havells) ,AYY/YY														
Conductor Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Overall Dia	Overall Weight	Short Circuit Current Rating for 1Sec	
	Resi	React	Resi	React	Ground	Duct	Air	Ground	Duct	Air			Alu	Cu
	Ω/km	Ω/km	Ω/km	Ω/km	Amp	Amp	Amp	Amp	Amp	Amp	mm	Kg/Km	K.A	K.A
1cX4	8.8	0.158	5.52	0.015	—	—	—	39	38	**35**	9	150	0.30	0.46
1cX6	5.53	0.148	3.69	0.148	39	37	**35**	49	48	**44**	10	180	0.45	0.69
1cX10	3.7	0.138	2.19	0.138	51	51	**47**	65	64	**60**	11	230	0.76	1.15
1cX16	2.29	0.128	1.38	0.128	66	65	**64**	85	83	**82**	11	370	1.22	1.84
1cX25	1.44	0.12	0.87	0.12	86	84	**84**	110	110	**110**	12	460	1.90	2.88
1cX35	1.04	0.114	0.627	0.114	100	100	**105**	130	125	**130**	13	460	2.66	4.03
1cX50	0.77	0.11	0.463	0.11	120	115	**130**	155	150	**165**	15	610	3.80	5.75
1cX70	0.53	0.103	0.321	0.103	140	135	**155**	190	175	**205**	17	800	5.32	8.05
1cX95	0.38	0.101	0.231	0.101	175	155	**190**	220	200	**245**	19	1100	7.22	10.90
1cX120	0.3	0.096	0.184	0.096	195	170	**220**	250	220	**280**	21	1350	9.12	13.80
1cX150	0.25	0.094	0.149	0.094	220	190	**250**	280	245	**320**	23	1650	11.4	17.30
1cX185	0.2	0.092	0.12	0.092	240	210	**290**	305	260	**370**	25	2000	14.10	21.30
1cX240	0.15	0.09	0.091	0.09	270	225	**335**	345	285	**425**	27	2550	18.20	27.30
1cX300	0.12	0.088	0.074	0.088	295	245	**380**	375	310	**475**	30	3200	22.8	34.50
1cX400	0.094	0.088	0.059	0.088	325	275	**435**	400	335	**550**	34	4000	30.40	46.00
1cX 500	0.072	0.087	0.046	0.087	345	295	**480**	425	355	**590**	38	5100	38.00	57.50
1cX 630	0.056	0.086	0.037	0.086	390	320	**550**	470	375	**660**	43	6550	47.90	72.50
1cX800	0.044	0.083	0.031	0.083	450	380	**610**	530	425	**725**	46	8220	60.80	92.00
1cX1000	0.034	0.082	0.03	0.082	500	415	**680**	590	740	**870**	50	10150	76.00	115.0
2cX1.5	21.72	0.126	14.5	0.126	18	16	**16**	23	20	**20**			0.3	0.4
2cX2.5	14.52	0.119	8.87	0.119	16	21	**21**	32	27	**27**			0.3	0.4
2cX4	8.89	0.116	5.52	0.116	32	27	**27**	41	35	**35**	14	320	0.30	0.46
2cX 6	5.53	0.11	3.69	0.11	40	34	**35**	50	44	**45**	16	370	0.45	0.69
2cX10	3.7	0.1	2.19	0.1	55	45	**47**	70	58	**60**	18	520	0.76	1.15
2cX16	2.29	0.097	1.38	0.097	70	58	**59**	90	75	**78**	18	550	1.22	1.84
2cX25	1.44	0.097	0.87	0.097	90	76	**78**	115	97	**105**	20	800	1.90	2.88
2cX35	1.04	0.097	0.627	0.097	110	92	**99**	140	120	**125**	22	980	2.660	4.03
2cX50	0.77	0.094	0.463	0.094	135	115	**125**	165	145	**155**	24	1300	3.800	5.75
2cX70	0.53	0.09	0.321	0.09	160	140	**150**	205	180	**195**	26	1700	5.320	8.05
2cX95	0.38	0.09	0.231	0.9	190	170	**185**	240	215	**230**	30	2300	7.220	10.9
2cX120	0.3	0.087	0.184	0.087	210	190	**210**	275	235	**265**	32	2750	9.120	13.8
2cX150	0.25	0.087	0.149	0.087	240	210	**240**	310	270	**305**	34	3350	11.40	17.30
2cX185	0.2	0.087	0.12	0.087	275	240	**275**	350	300	**350**	37	4150	14.10	21.28
2cX240	0.15	0.087	0.091	0.087	320	275	**325**	405	345	**410**	42	5350	18.20	27.60
2cX300	0.12	0.086	0.073	0.086	355	305	**365**	450	385	**465**	46	6650	22.80	34.50
2cX400	0.09	0.086	0.059	0.086	385	345	**420**	490	485	**530**	52	8450	30.40	46.00
2cX500	0.09	0.086	0.059	0.086	425	380	**475**	540	460	**605**	58	10700	38.00	57.50
2cX630	0.09	0.086	0.059	0.086	465	415	**540**	640	550	**785**	65	13800	47.90	72.55
3cX1.5	21.72	0.126	14.5	0.126	16	14	**13**	21	17	**17**			0.3	0.4
3cX2.5	14.52	0.119	8.87	0.119	21	18	**18**	27	24	**24**			0.3	0.4
3cX4	8.89	0.116	5.52	0.116	28	23	**23**	36	30	**30**	15	360	0.304	0.460
3cX 6	5.53	0.11	3.69	0.11	35	30	**30**	45	38	**39**	16	450	0.456	0.690
3cX 10	3.7	0.1	2.19	0.1	46	39	**40**	60	50	**52**	18	620	0.760	1.150

3cX 16	2.29	0.097	1.38	0.097	60	50	**51**	77	64	**66**	19	740	1.220	1.840
3cX 25	1.44	0.097	0.87	0.097	76	63	**70**	99	81	**90**	22	1100	1.900	2.880
3cX 35	1.04	0.097	0.627	0.097	92	77	**86**	120	99	**110**	24	1400	2.660	4.030
3cX 50	0.77	0.094	0.463	0.094	110	95	**105**	145	125	**135**	27	1800	3.800	5.750
3cX 70	0.53	0.09	0.321	0.09	135	115	**130**	175	150	**165**	30	2500	5.320	8.050
3cX 95	0.38	0.9	0.231	0.09	165	140	**155**	210	175	**200**	34	3300	7.220	10.90
3cX 120	0.3	0.087	0.184	0.087	185	155	**180**	240	195	**230**	36	4000	9.120	13.80
3cX 150	0.25	0.087	0.149	0.087	210	175	**205**	270	225	**265**	40	4900	11.40	17.30
3cX 185	0.2	0.087	0.12	0.087	235	200	**240**	300	255	**305**	44	6065	14.10	21.30
3cX 240	0.15	0.087	0.0912	0.087	275	235	**280**	345	295	**355**	50	7850	18.20	27.60
3cX 300	0.12	0.086	0.074	0.086	305	260	**315**	385	335	**400**	55	9750	22.80	34.50
3cX 400	0.09	0.086	0.059	0.086	335	290	**375**	425	360	**435**	62	12400	30.40	46.00
3cX 500	0.09	0.086	0.059	0.086	370	320	**425**	470	390	**520**	70	15800	38.00	57.50
3cX 630	0.09	0.086	0.059	0.086	405	350	**480**	555	470	**675**	78	20200	47.90	72.50
3.5X16	1.44	0.097	0.73	0.097	70	65	**62**	99	81	**90**			1.8	2.5
3.5X25	0.77	0.094	0.387	.0.094	76	63	**70**	99	81	**90**	23	1250	1.90	2.88
3.5X35	0.53	0.09	0.268	0.09	92	77	**86**	120	99	**110**	26	1600	2.66	4.03
3.5X50	0.38	0.09	0.193	0.09	110	95	**105**	145	125	**135**	28	2100	3.80	5.75
3.5X70	0.3	0.087	0.153	0.087	135	115	**130**	175	150	**165**	32	2850	5.32	8.05
3.5X95	0.2	0.087	0.099	0.087	165	140	**155**	210	175	**200**	37	3800	7.22	10.90
3.5X120	0.15	0.087	0.075	0.087	185	155	**180**	240	195	**230**	40	4750	9.12	13.80
3.5X150	0.12	0.086	0.06	0.086	210	175	**205**	270	225	**265**	44	5650	11.40	17.30
3.5X185	0.09	0.086	0.047	0.086	235	200	**240**	300	255	**305**	48	7050	14.10	21.30
3.5X240	0.08	0.085	0.046	0.085	275	235	**280**	345	295	**355**	55	9150	18.20	27.60
3.5X300	0.08	0.085	0.046	0.085	305	260	**315**	385	335	**400**	60	11300	22.80	34.50
3.5X400	0.08	0.084	0.045	0.084	335	290	**375**	425	360	**435**	68	14300	30.40	46.00
3.5X500	0.08	0.084	0.045	0.084	370	320	**425**	470	390	**520**	77	18300	38.00	57.50
3.5X630	0.08	0.084	0.045	0.084	405	350	**480**	555	470	**675**	87	23300	47.90	72.50
4cX 1.5	21.72	0.126	14.5	0.126	16	14	**13**	21	17	**17**			0.3	0.4
4cX 2.5	14.52	0.119	8.87	0.119	21	18	**18**	27	24	**24**			0.3	0.4
4cX4	8.89	0.116	5.52	0.116	28	23	**23**	36	30	**30**	16	430	0.304	0.46
4cX 6	5.53	0.11	3.69	0.11	35	30	**30**	45	38	**39**	18	540	0.456	0.69
4cX 10	3.7	0.1	2.19	0.1	46	39	**40**	60	50	**52**	20	750	0.760	1.15
4cX16	2.29	0.097	1.38	0.097	60	50	**51**	77	64	**66**	21	950	1.220	1.84
4cX 25	1.44	0.097	0.87	0.097	76	63	**70**	99	81	**90**	24	1400	1.900	2.88
4cX35	1.04	0.097	0.62	0.097	92	77	**86**	120	99	**110**	26	1750	2.660	4.03
4cX 50	0.77	0.094	0.46	0.094	110	95	**105**	145	125	**135**	30	2350	3.800	5.75
4cX70	0.53	0.09	0.32	0.09	135	115	**130**	175	150	**165**	33	3150	5.320	8.05
4cX 95	0.38	0.09	0.23	0.09	165	140	**155**	210	175	**200**	38	4300	7.220	10.90
4cX 120	0.3	0.087	0.18	0.087	185	155	**180**	240	195	**230**	41	5250	9.120	13.80
4cX 150	0.25	0.087	0.14	0.087	210	175	**205**	270	225	**265**	45	6450	11.40	17.30
4cX 185	0.2	0.087	0.12	0.087	235	200	**240**	300	255	**305**	50	8000	14.10	21.30
4cX 240	0.15	0.087	0.091	0.087	275	235	**280**	345	295	**355**	57	10350	18.20	27.60
4cX 300	0.12	0.086	0.073	0.086	305	260	**315**	385	335	**400**	63	12900	22.80	34.50
4cX 400	0.09	0.086	0.059	0.086	335	290	**375**	425	360	**435**	71	16300	30.40	46.00
4cX 500	0.09	0.086	0.059	0.086	370	320	**425**	470	390	**520**	80	20900	38.00	57.50
4cX 630	0.09	0.086	0.059	0.086	405	350	**480**	555	470	**675**	90	26600	47.90	72.50

1.1 KV XLPE Insulated Cable (Ref: IS 1554) (Make: Havells), AYY/YY

Conductor Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Over all Dia	Overal l Weigh t	Short Circuit Current Rating for 1Sec	
	Resi	React	Resi	React	Grou nd	Duct	Air	Grou nd	Duct	Air			Alu	Cu
	Ω/km	Ω/km	Ω/km	Ω/km	Amp	Amp	Amp	Amp	Amp	Amp	mm	Kg/ Km	K.A	K.A
1cX4	1.555	0.102	1.555	0.102	—	—	**—**	48	47	**45**	9	150	0.376	0.572
1cX6	1.553	0.102	1.553	0.102	48	45	**45**	60	59	**57**	10	180	0.564	0.858
1cX10	1.553	0.102	1.553	0.102	62	62	**61**	80	78	**77**	11	230	0.940	1.430
1cX16	1.54	0.102	1.540	0.102	81	80	**83**	104	102	**106**	11	370	1.504	2.288
1cX25	1.54	0.102	0.930	0.102	99	90	**115**	130	115	**145**	12	460	2.350	3.575
1cX35	1.11	0.097	0.671	0.097	117	110	**135**	155	140	**175**	13	460	3.290	5.005
1cX50	0.82	0.092	0.495	0.092	138	125	**170**	185	165	**215**	15	610	4.700	7.150
1cX70	0.56	0.088	0.343	0.088	168	155	**210**	225	200	**270**	17	800	6.580	10.01
1cX95	0.41	0.085	0.247	0.085	204	185	**255**	265	235	**330**	19	1100	8.930	13.59
1cX120	0.32	0.082	0.196	0.082	230	210	**300**	300	265	**380**	21	1350	11.28	17.16
1cX150	0.265	0.082	0.159	0.082	265	230	**342**	335	300	**430**	23	1650	14.10	21.45
1cX185	0.211	0.082	0.127	0.082	295	260	**385**	380	335	**495**	25	2000	17.39	26.46
1cX240	0.162	0.079	0.097	0.079	340	300	**450**	435	385	**590**	27	2550	22.56	34.32
1cX300	0.13	0.078	0.077	0.078	390	335	**519**	490	430	**670**	30	3200	28.20	42.90
1cX400	0.1023	0.077	0.061	0.077	450	380	**605**	550	480	**780**	34	4000	37.60	57.20
1cX 500	0.0808	0.076	0.047	0.076	500	430	**700**	610	530	**900**	38	5100	47.00	71.50
1cX 630	0.0648	0.075	0.036	0.075	555	485	**809**	680	590	**1020**	43	6550	59.22	90.09
1cX800	0.053	0.075	0.028	0.075	625	530	**935**	740	630	**1140**	46	8220	75.20	114.40
1cX1000	0.0444	0.068	0.023	0.068	690	570	**1065**	780	660	**1250**	50	10150	94.00	143.00
2cX1.5	—	—	—	—	—	—	**—**	—	—	**—**	—	—	—	—
2cX2.5	—	—	—	—	—	—	**—**	—	—	**—**	—	—	—	—
2cX4	1.555	0.097	1.555	0.097	34	28	**30**	44	37	**39**	14	320	0.376	0.572
2cX 6	1.553	0.097	1.553	0.097	43	37	**40**	55	47	**50**	16	370	0.564	0.858
2cX10	1.553	0.085	1.553	0.085	57	48	**53**	74	61	**67**	18	520	0.940	1.430
2cX16	1.54	0.080	1.540	0.08	78	61	**70**	94	78	**85**	18	550	1.50	2.29
2cX25	1.54	0.080	0.930	0.08	95	80	**99**	120	100	**125**	20	800	2.35	3.58
2cX35	1.11	0.080	0.671	0.08	116	94	**117**	145	120	**155**	22	980	3.29	5.01
2cX50	0.082	0.078	0.495	0.078	140	110	**140**	170	145	**190**	24	1300	4.70	7.15
2cX70	0.57	0.077	0.343	0.077	170	140	**176**	210	175	**235**	26	1700	6.58	10.01
2cX95	0.41	0.074	0.247	0.074	200	165	**221**	250	210	**290**	30	2300	8.93	13.59
2cX120	0.33	0.072	0.196	0.072	225	185	**258**	285	240	**330**	32	2750	11.28	17.16
2cX150	0.27	0.072	0.159	0.072	255	210	**294**	315	270	**375**	34	3350	14.10	21.45
2cX185	0.21	0.072	0.127	0.072	285	235	**339**	355	300	**435**	37	4150	17.39	26.46
2cX240	0.16	0.072	0.097	0.072	325	270	**402**	410	350	**510**	42	5350	22.56	34.32
2cX300	0.13	0.071	0.077	0.071	370	305	**461**	460	390	**590**	46	6650	28.20	42.90
2cX400	0.1	0.070	0.060	0.07	435	350	**542**	520	440	**670**	52	8450	37.60	57.20
2cX500	0.1	0.070	0.060	0.07	481	405	**624**	580	480	**750**	58	10700	47.00	71.50
2cX630	0.1	0.070	0.060	0.07	537	470	**723**	680	575	**875**	65	13800	59.22	90.09
3cX1.5	—	—	—	—	—	—	**—**	—	—	**—**	—	—	—	—
3cX2.5	—	—	—	—	—	—	**—**	—	—	**—**	—	—	—	—
3cX4	1.581	0.097	1.581	0.097	34	28	**30**	44	37	**39**	15	360	0.376	0.572
3cX 6	1.57	0.097	1.570	0.097	43	37	**40**	55	47	**50**	16	450	0.564	0.858
3cX 10	1.55	0.080	1.550	0.08	57	48	**53**	74	61	**67**	18	620	0.940	1.430

3cX 16	1.557	0.080	1.557	0.08	78	61	**70**	94	78	**85**	19	740	1.50	2.29
3cX 25	1.54	0.080	0.930	0.08	95	80	**99**	120	100	**125**	22	1100	2.35	3.58
3cX 35	1.11	0.080	0.671	0.08	116	94	**117**	145	120	**155**	24	1400	3.29	5.01
3cX 50	0.82	0.780	0.495	0.078	140	110	**140**	170	145	**190**	27	1800	4.70	7.15
3cX 70	0.57	0.077	0.343	0.077	170	140	**176**	210	175	**235**	30	2500	6.58	10.01
3cX 95	0.41	0.074	0.247	0.074	200	165	**221**	250	210	**290**	34	3300	8.93	13.59
3cX 120	0.33	0.072	0.196	0.072	225	185	**258**	285	240	**330**	36	4000	11.28	17.16
3cX 150	0.27	0.072	0.159	0.072	255	210	**294**	315	270	**375**	40	4900	14.10	21.45
3cX 185	0.21	0.072	0.127	0.072	285	235	**339**	355	300	**435**	44	6065	17.39	26.46
3cX 240	0.16	0.072	0.097	0.072	325	270	**402**	410	350	**510**	50	7850	22.56	34.32
3cX 300	0.13	0.071	0.077	0.071	370	305	**461**	460	390	**590**	55	9750	28.20	42.90
3cX 400	0.1	0.070	0.060	0.07	435	350	**542**	520	440	**670**	62	12400	37.60	57.20
3cX 500	0.1	0.070	0.060	0.07	481	405	**624**	580	480	**750**	70	15800	47.00	71.50
3cX 630	0.1	0.070	0.060	0.07	537	470	**723**	680	575	**875**	78	20200	59.22	90.09
3.5X16	—	—	—	—	—	—	**—**	—	—	**—**	—	—	—	—
3.5X25	1.54	0.080	0.930	0.08	95	80	**99**	120	100	**125**	23	1250	2.35	3.58
3.5X35	1.11	0.080	0.671	0.08	116	94	**117**	145	120	**155**	26	1600	3.29	5.01
3.5X50	0.82	0.078	0.050	0.078	140	110	**140**	170	145	**190**	28	2100	4.70	7.15
3.5X70	0.57	0.077	0.343	0.077	170	140	**176**	210	175	**235**	32	2850	6.58	10.01
3.5X95	0.41	0.074	0.247	0.074	200	165	**221**	250	210	**290**	37	3800	8.93	13.59
3.5X120	0.33	0.072	0.196	0.072	225	185	**258**	285	240	**330**	40	4750	11.28	17.16
3.5X150	0.27	0.072	0.159	0.072	255	210	**294**	315	270	**375**	44	5650	14.10	21.45
3.5X185	0.21	0.072	0.127	0.072	285	235	**339**	355	300	**435**	48	7050	17.39	26.46
3.5X240	0.16	0.072	0.097	0.072	325	270	**402**	410	350	**510**	55	9150	22.56	34.32
3.5X300	0.13	0.071	0.077	0.071	370	305	**461**	460	390	**590**	60	11300	28.20	42.90
3.5X400	0.1	0.070	0.060	0.07	435	350	**542**	520	440	**670**	68	14300	37.60	57.20
3.5X500	0.1	0.070	0.060	0.07	481	405	**624**	580	480	**750**	77	18300	47.00	71.50
3.5X630	0.1	0.070	0.060	0.07	537	470	**723**	680	575	**875**	87	23300	59.22	90.09
4cX 1.5	—	—	—	—	—	—	**—**	—	—	**—**	—	—	—	—
4cX 2.5	—	—	—	—	—	—	**—**	—	—	**—**	—	—	—	—
4cX4	5.53	0.110	3.690	0.11	34	28	**30**	44	37	**39**	16	430	0.376	0.572
4cX 6	3.7	0.100	2.190	0.1	43	37	**40**	55	47	**50**	18	540	0.564	0.858
4cX 10	2.29	0.097	1.380	0.097	57	48	**53**	74	61	**67**	20	750	0.940	1.430
4cX16	2.45	0.080	1.470	0.08	78	61	**70**	94	78	**85**	21	950	1.50	2.29
4cX 25	1.54	0.080	0.930	0.08	95	80	**99**	120	100	**125**	24	1400	2.35	3.58
4cX35	1.11	0.080	0.671	0.08	116	94	**117**	145	120	**155**	26	1750	3.29	5.01
4cX 50	0.082	0.078	0.495	0.078	140	110	**140**	170	145	**190**	30	2350	4.70	7.15
4cX70	0.57	0.077	0.343	0.077	170	140	**176**	210	175	**235**	33	3150	6.58	10.01
4cX 95	0.41	0.074	0.247	0.074	200	165	**221**	250	210	**290**	38	4300	8.93	13.59
4cX 120	0.33	0.072	0.196	0.072	225	185	**258**	285	240	**330**	41	5250	11.28	17.16
4cX 150	0.27	0.072	0.159	0.072	255	210	**294**	315	270	**375**	45	6450	14.10	21.45
4cX 185	0.21	0.072	0.127	0.072	285	235	**339**	355	300	**435**	50	8000	17.39	26.46
4cX 240	0.16	0.072	0.097	0.072	325	270	**402**	410	350	**510**	57	10350	22.56	34.32
4cX 300	0.13	0.071	0.077	0.071	370	305	**461**	460	390	**590**	63	12900	28.20	42.90
4cX 400	0.1	0.070	0.060	0.07	435	350	**542**	520	440	**670**	71	16300	37.60	57.20
4cX 500	0.1	0.070	0.060	0.07	481	405	**624**	580	480	**750**	80	20900	47.00	71.50
4cX 630	0.1	0.070	0.060	0.07	537	470	**723**	680	575	**875**	90	26600	59.22	90.09

3.8 / 6.6 KV (3.8Kv Un-Earthed / 6.6 KV Earthed) AL/COPPER COND, XLPE INSULATED CABLES (Ref: IS 7098) (Make: Havells) , A2XFY/2XFY, A2XWY/2XWY

Conductor Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Overall Dia	Overall Weight	Short Circuit Current Rating for 1Sec.	
	Resi	React	Resi	React	Ground	Duct	Air	Ground	Duct	Air			Alu	Cu
	Ω/km	Ω/km	Ω/km	Ω/km	Amp	Amp	Amp	Amp	Amp	Amp	mm	Kg/Km	K.A	K.A
1cX25	1.1	0.129	1.1	0.129	100	90	**120**	130	115	**155**	21	700	2.35	3.58
1cX35	1.1	0.129	1.1	0.129	120	105	**145**	155	140	**185**	22	720	3.29	5.00
1cX50	0.822	0.129	0.822	0.129	140	125	**170**	185	160	**220**	23	1000	4.70	7.15
1cX70	0.568	0.120	0.568	0.120	175	155	**215**	225	195	**275**	25	1200	6.58	10.01
1cX95	0.411	0.113	0.411	0.113	205	180	**260**	265	235	**340**	27	1500	8.93	13.59
1cX120	0.325	0.109	0.325	0.109	235	205	**305**	300	265	**390**	28	1750	11.28	17.16
1cX150	0.265	0.106	0.265	0.106	260	230	**345**	335	295	**440**	30	2050	14.10	21.45
1cX185	0.211	0.103	0.211	0.103	295	260	**395**	380	330	**510**	31	2450	17.39	26.46
1cX240	0.161	0.101	0.161	0.101	340	300	**470**	435	380	**600**	35	3100	22.56	34.32
1cX300	0.13	0.099	0.13	0.099	385	335	**540**	490	425	**680**	37	3700	28.20	42.90
1cX400	0.102	0.096	0.102	0.096	0.57	440	**380**	630	550	**480**	41	4650	790	37.60
1cX 500	0.08	0.094	0.08	0.094	0.60	495	**430**	730	610	**530**	46	5800	910	47.00
1cX 630	0.063	0.092	0.063	0.092	0.67	560	**480**	840	680	**580**	50	7200	1030	59.22
1cX800	0.052	0.090	0.052	0.090	0.76	620	**530**	960	740	**630**	55	9100	1140	75.20
1cX1000	0.043	0.088	0.043	0.088	0.82	680	**580**	1070	790	**670**	60	11200	1250	94.00
3cX 25	1.1	0.134	1.1	0.134	95	82	**105**	120	105	**135**	38	2850	2.35	3.58
3cX 35	1.1	0.134	1.1	0.134	115	97	**125**	145	125	**165**	40	3300	3.29	5.01
3cX 50	0.822	0.136	0.822	0.136	130	115	**150**	170	150	**195**	44	3900	4.70	7.15
3cX 70	0.568	0.124	0.568	0.124	160	140	**190**	210	180	**240**	47	4700	6.58	10.01
3cX 95	0.411	0.117	0.411	0.117	190	165	**230**	250	215	**295**	52	6100	8.93	13.59
3cX 120	0.325	0.113	0.325	0.113	220	190	**260**	280	240	**335**	55	7150	11.28	17.16
3cX 150	0.265	0.110	0.265	0.110	245	210	**295**	310	270	**380**	59	8200	14.10	21.45
3cX 185	0.211	0.107	0.211	0.107	275	240	**335**	350	305	**430**	62	9550	17.39	26.46
3cX 240	0.161	0.104	0.161	0.104	315	275	**395**	400	350	**500**	69	12300	22.56	34.32
3cX 300	0.13	0.100	0.13	0.100	355	310	**450**	445	390	**570**	75	14700	28.20	42.90
3cX 400	0.102	0.097	0.102	0.097	400	350	**520**	500	440	**650**	86	19200	37.60	57.20

6.6 /11 KV(6.6KV Un-Earthed / 11KV Earthed) AL/COPPER COND, XLPE INSULATED CABLES (Ref: IS 7098) (Make: Havells) ,A2XFY/2XFY, A2XWY/2XWY

Conductor Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Over all Dia	Overall Weight	Short Circuit Current Rating for 1Sec.	
	Resi	React	Resi	React	Ground	Duct	Air	Ground	Duct	Air			Alu	Cu
	ohm/km	ohm/km	ohm/km	ohm/km	Amp	Amp	Amp	Amp	Amp	Amp	mm	Kg/Km	K.A	K.A
1cX25	1.1	0.134	1.1	0.134	100	90	120	130	115	155	23	800	2.35	3.58
1cX35	1.1	0.134	1.1	0.134	120	105	145	155	140	185	24	900	3.29	5.00
1cX50	0.822	0.136	0.822	0.136	140	125	170	185	160	220	25	1050	4.70	7.15
1cX70	0.568	0.124	0.568	0.124	175	155	215	225	195	275	27	1300	6.58	10.01
1cX95	0.411	0.117	0.411	0.117	205	180	260	265	235	340	28	1550	8.93	13.59
1cX120	0.325	0.113	0.325	0.113	235	205	305	300	265	390	30	1850	11.28	17.16
1cX150	0.265	0.110	0.265	0.110	260	230	345	335	295	440	31	2150	14.10	21.45
1cX185	0.211	0.107	0.211	0.107	295	260	395	380	330	510	34	2600	17.39	26.46
1cX240	0.161	0.104	0.161	0.104	340	300	470	435	380	600	36	3200	22.56	34.32
1cX300	0.13	0.100	0.13	0.100	385	335	540	490	425	680	38	3800	28.20	42.90
1cX400	0.102	0.097	0.102	0.097	440	380	630	550	480	790	42	4650	37.60	57.20
1cX 500	0.08	0.094	0.08	0.094	495	430	730	610	530	910	47	5850	47.00	71.50

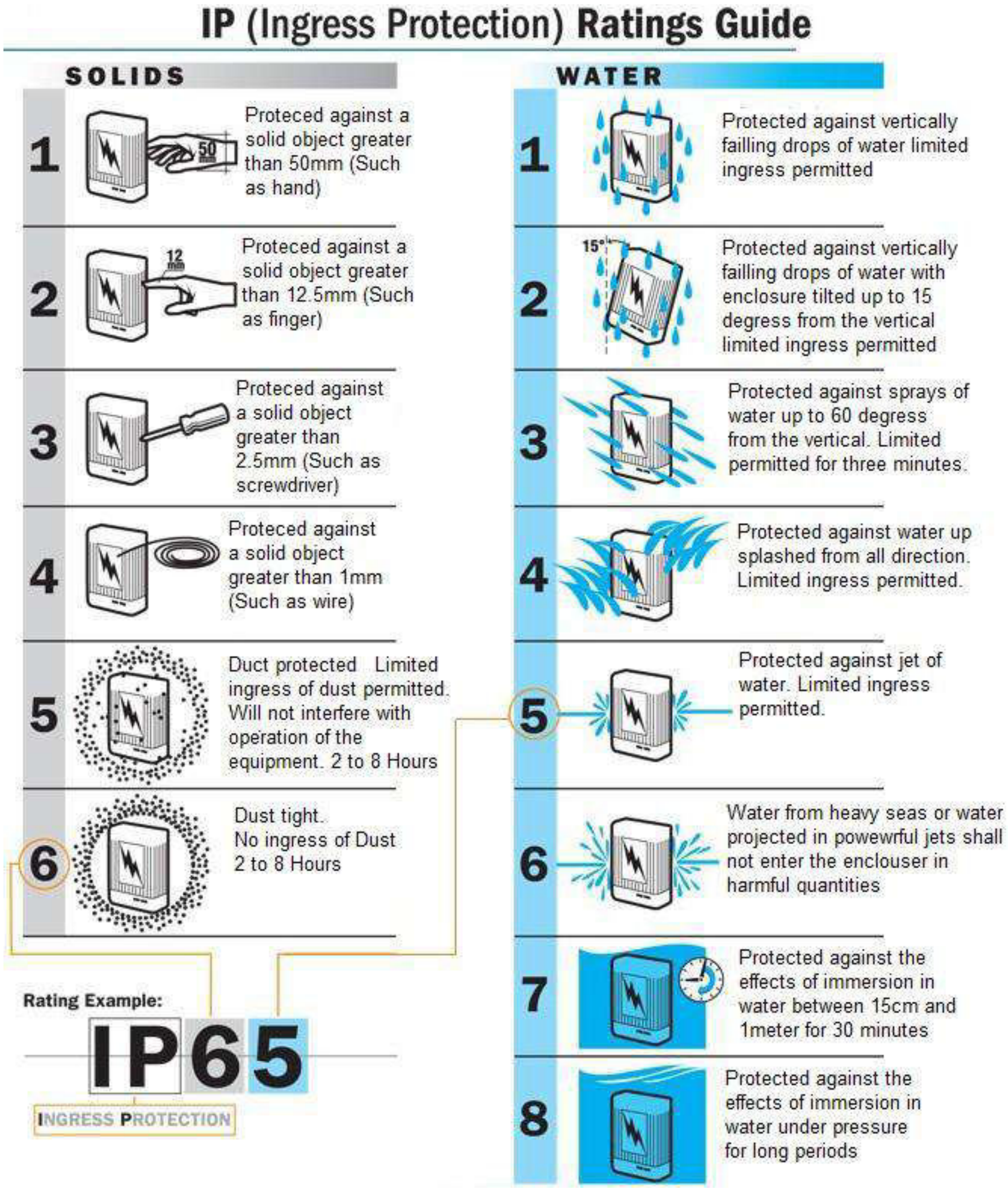
BASIC DATA FOR ALL ALUMINIUM CONDUCTORS STEEL REINFORCED (IS 398)

CODE WORD	Aluminum Area Sqmm		Total Sectional Area Sq mm	Stranding and Wire Diameter				Overall Dia. (mm) approx	WEIGHT MASS			Resistance at 20 degC Ohms/Km (MAX)	Ultimate Breaking Load (KN)
				Conductor (AL)		Conductor (ST)							
	Nominal	Sectional		NO.	DIA (mm)	NO	DIA (mm)		Total Kg/Km	AL. Kg/Km	ST. Kg/Km		
MOLE	10	10.60	12.37	6	1.50	-	1.50	4.50	43	29	14	2.780	3.97
ROSE	18	18.10	21.12	6	1.96	1	1.96	5.88	73	49.5	23.5	1.618	6.74
SQUIRREL	20	20.98	24.48	6	2.11	1	2.11	6.33	85	58	27	1.394	7.61
WEASEL	30	31.61	36.88	6	2.59	1	2.59	7.77	128	87	41	0.9289	11.12
RABBIT	50	52.88	61.70	6	3.35	1	3.53	10.05	214	145	69	0.5524	18.25
RACOON	80	78.83	91.97	6	4.09	1	4.09	12.27	318	215	103	0.3712	26.91
DOG	100	105.0	118.5	6	4.72	7	1.57	14.15	394	288.3	105.7	0.2792	32.41
WOLF	150	158.1	194.9	30	2.59	7	2.59	18.13	727	438	289	0.1871	67.34
PANTHER	200	212.1	261.5	30	3.00	7	3.00	21.00	976	588.5	387.5	0.1390	89.67
KUNDAH	400	404.1	425.2	42	3.50	7	1.96	26.88	1282	1119	163	0.07311	88.79
ZEBRA	420	428.9	484.5	54	3.18	7	3.18	28.62	1621	1182	439	0.06868	130.32
MOOSE	520	528.5	597.0	54	3.53	7	3.53	31.77	1998	1463	535	0.05595	159.60
MORCULLA	560	562.7	591.7	42	4.13	7	2.30	31.68	1781	1553	228	0.05231	120.16
GOPHER	16	25.90	30.62	6	2.36	1	2.36	7.08	106	72	34	1.0980	952
FERRET	25	41.87	49.98	6	3.00	1	3	9	171	116	55	0.6795	1503
MINK	40	63.32	73.65	6	3.66	1	3.66	10.98	255	173	82	0.4565	2207
HORSE	42	71.58	116.20	12	2.75	7	2.79	13.95	542	204	338	0.3977	6108
BEAVER	45	74.07	87.53	6	3.99	1	3.99	11.97	303	205	98	0.3841	2613
OTTER	50	82.85	97.91	6	4.22	1	4.22	12.66	339	230	109	0.3434	2923
CAT	55	94.21	111.30	6	4.5	7	4.50	13.50	385	261	124	0.3020	3324
LEOPARD	80	129.70	148.40	6	5.28	7	1.76	15.48	493	360	133	0.2193	4137
COYOTE	80	128.50	151.60	26	2.54	7	1.90	15.86	521	365	156	0.2214	4638
TIGER	80	128.10	161.80	30	2.36	7	2.36	16.52	604	363	241	0.2221	5758
LYNX	110	179.00	226.20	30	2.79	7	2.79	19.53	844	506	338	0.1589	7950
LION	140	232.50	293.90	30	3.18	7	3.18	22.26	1097	659	438	0.1223	10210
BEAR	160	258.10	326.10	30	3.35	7	3.35	23.45	1219	734	485	0.1102	11310
GOAT	185	316.5	400	30	3.71	7	3.71	25.97	1492	896	596	0.0898	13780
SHEEP	225	366.1	462.6	30	3.99	7	3.99	27.93	1726	1036	690	0.0777	15910
DEER	260	419.3	529.8	30	4.27	7	4.27	29.89	1977	1188	789	0.0678	18230
FLK	300	465.7	588.4	30	4.5	7	4.5	31.5	2196	1320	876	0.0611	20240
CAMEL	300	464.5	537.7	54	3.35	7	3.35	30.15	1804	1318	486	0.0612	14750
SPARROW	20	33.16	39.22	6	2.67	7	2.67	8.01	135	92	43	0.8578	1208
FOX	22	36.21	42.92	6	2.79	7	2.79	8.37	149	101	48	0.7857	1313
GUINEA	49	78.56	127.2	12	2.92	7	2.92	14.6	590	224	366	0.362	6664
LARK	125	196.1	247.8	30	2.92	7	2.92	20.44	922	556	366	0.1451	8559

IP Rating Digits			
IP Rating	**First Digit** **Solid Objects Protection**	**Second Digit** **Liquids Protection**	**Third Digit (Optional)** **Mechanical impacts**
0	No special protection	No protection.	No protection.
1	Protected against solid objects greater than 50mm in diameter (such as large part of the body like hand)	Protection against vertically falling drops of water e.g. condensation.	Protects against impact of 0.225 joule (150 g weight falling from 15 cm height)
2	Protected against solid objects over 12 mm in diameter (person's fingers)	Protection against direct sprays of water up to 15° from the vertical.	Protected against impact of 0.375 joule (250 g weight falling from 15 cm height)
3	Protected against solid objects not greater than 80mm in length and 12mm in diameter (tools and wires).	Protected against direct sprays of water up to 60° from the vertical.	Protected against impact of 0.500 joule (250 g weight falling from 20 cm height)
4	Protected against solid objects larger than 1 mm diameter (tools, wires, and small wires).	Protection against water sprayed from all directions (limited ingress permitted).	Protected against impact of 2.0 joule (500 g weight falling from 40 cm height)
5	Protected against dust limited ingress (no harmful deposit).	Protected against low pressure jets of water from all directions (limited ingress).	Protected against impact of 6.0 joule (1.5 kg weight falling from 40 cm height)
6	Totally dust tight.	Protected against temporary flooding of water, e.g. for use on ship decks (limited ingress permitted).	Protected against impact of 20.0 joule (5 kg weight falling from 40 cm height)
7	N/A	Protected against the effect of immersion between 15 cm and 1 m.	N/A
8	N/A	Protects against long periods of immersion under pressure.	N/A

Example:

- **IP65 Enclosure:** IP rated as protection against dust (5) and protection from low water pressure (6).
- **IP66 Enclosure**: IP rated as protection against dust (5) and protected against heavy seas or powerful jets of water (6)



IP (Ingress Protection) Ratings Guide
SOLIDS
1
50
Proteced against a solid object greater than 50mm (Such as hand)
2
12 mm
Proteced against a solid object greater than 12.5mm (Such as finger)
3
Proteced against a solid object greater than 2.5mm (Such as screwdriver)
4
Proteced against a solid object greater than 1mm (Such as wire)
5
Duct protected Limited ingress of dust permitted. Will not interfere with operation of the equipment. 2 to 8 Hours
6
Dust tight. No ingress of Dust 2 to 8 Hours
WATER
1
Protected against vertically failling drops of water limited ingress permitted
2
15°
Protected against vertically failling drops of water with enclosure tilted up to 15 degress from the vertical limited ingress permitted
3
Protected against sprays of water up to 60 degress from the vertical. Limited permitted for three minutes.
4
Protected against water up splashed from all direction. Limited ingress permitted.
5
Protected against jet of water. Limited ingress permitted.
6
Water from heavy seas or water projected in powewrful jets shall not enter the encloser in harmful quantities
7
Protected against the effects of immersion in water between 15cm and 1meter for 30 minutes
8
Protected against the effects of immersion in water under pressure for long periods
Rating Example:
IP65
INGRESS PROTECTION

RELAY CODE (ANSI)			
Code	**Type of Relay**	**Code**	**Type of Relay**
1	Master Element	32	Directional Power Relay
2	Time-delay Starting or Closing Relay	32L	Low Forward Power
3	Checking or Interlocking Relay	32N	Watt metric Zero-Sequence Directional
4	Master Contactor	32P	Directional Power
5	Stopping Device	32R	Reverse Power
6	Starting Circuit Breaker	33	Position Switch
7	Rate of Change Relay	34	Master Sequence Device
8	Control Power Disconnecting Device	35	Brush-Operating or Slip-ring Short Circuiting Device
9	Reversing Device	36	Polarity or Polarizing Voltage Device
10	Unit Sequence Switch	37	Undercurrent or Under power Relay
11	Multifunction Device	37P	Under power
12	Over speed protection	38	Bearing Protective Device / Bearing Rtd
13	Synchronous-Speed Device	39	Mechanical Condition Monitor
14	Under speed Device	40	Field Relay / Loss of Excitation
15	Speed or Frequency Matching Device	41	Field Circuit Breaker
16	Data Communications Device	42	Running Circuit Breaker
17	Shunting or Discharge Switch	43	Manual Transfer or Selector Device
18	Accelerating or Decelerating Device	44	Unit Sequence Starting Relay
19	Starting-to-Running Transition Contactor	45	Atmospheric Condition Monitor
20	Electrically-Operated Valve	46	Reverse-Phase or Phase Balance Current Relay or Stator Current Unbalance
21	Distance protection Relay	47	Phase-Sequence or Phase Balance Voltage Relay
21G	Ground Distance	48	Incomplete Sequence Relay / Blocked Rotor
21P	Phase Distance	49	Machine or Transformer Thermal Relay / Thermal Overload
22	Equalizer circuit breaker	49RTD	RTD Biased Thermal Overload
23	Temperature control device	50	Instantaneous Overcurrent Relay
24	Volts per hertz relay	50BF	Breaker Failure
25	Synchronizing or synchronism-check device	50DD	Current Disturbance Detector
26	Apparatus thermal device	50EF	End Fault Protection
27	Under voltage relay	50G	Ground Instantaneous Overcurrent
27P	Phase Under voltage	50IG	Isolated Ground Instantaneous Overcurrent
27S	DC under voltage relay	50LR	Acceleration Time
27TN	Third Harmonic Neutral Under voltage	50N	Neutral Instantaneous Overcurrent
27TN/59N	100% Stator Earth Fault	50NBF	Neutral Instantaneous Breaker Failure
27X	Auxiliary Under voltage	50P	Phase Instantaneous Overcurrent
27 AUX	Under voltage Auxiliary Input	50SG	Sensitive Ground Instantaneous Overcurrent
27/27X	Bus/Line Under voltage	50SP	Split Phase Instantaneous Current
27/50	Accidental Generator Energization	50Q	Negative Sequence Instantaneous Overcurrent
28	Flame Detector	50/27	Accidental Energization
29	Isolating Contactor	50/51	Instantaneous / Time-delay Overcurrent relay

30	Annunciator Relay	**50Ns/51 Ns**	Sensitive earth-fault protection
31	Separate Excitation Device	**50/74**	Ct Trouble
50/87	Instantaneous Differential	**59P**	Phase Overvoltage
51	Phase Inverse Time Overcurrent IDMT (Time delay phase overcurrent)	**59X**	Auxiliary Overvoltage
51G	Ground Inverse Time Overcurrent	**59Q**	Negative Sequence Overvoltage
51LR	AC inverse time overcurrent (locked rotor) protection relay	**60**	Voltage or current balance relay
51N	Neutral Inverse Time Overcurrent	**60**	Voltage or Current Balance Relay
51P	Phase Time Overcurrent	**60N**	Neutral Current Unbalance
51R	Locked / Stalled Rotor	**60P**	Phase Current Unbalance
51V	Voltage Restrained Time Overcurrent	**61**	Density Switch or Sensor
51Q	Negative Sequence Time Overcurrent	**62**	Time-Delay Stopping or Opening Relay
52	AC circuit breaker	**63**	Pressure Switch Detector
52a	AC circuit breaker position (contact open when circuit breaker open)	**64**	Ground Protective Relay
52b	AC circuit breaker position (contact closed when circuit breaker open)	**64F**	Field Ground Protection
53	Exciter or Dc Generator Relay	**64R**	Rotor earth fault
54	Turning Gear Engaging Device	**64REF**	Restricted earth fault differential
55	Power Factor Relay	**64S**	Stator earth fault
56	Field Application Relay	**64S**	Sub-harmonic Stator Ground Protection
57	Short-Circuiting or Grounding Device	**64TN**	100% Stator Ground
58	Rectification Failure Relay	**65**	Governor
59	Overvoltage Relay	**66**	Notching or Jogging Device/Maximum Starting Rate/Starts Per Hour/Time Between Starts
59B	Bank Phase Overvoltage	**67**	AC Directional Overcurrent Relay
59P	Phase Overvoltage	**67G**	Ground Directional Overcurrent
59N	Neutral Overvoltage	**67N**	Neutral Directional Overcurrent
59NU	Neutral Voltage Unbalance	**67Ns**	Earth fault directional
67P	Phase Directional Overcurrent	**86**	Lock-Out Relay, Master Trip Relay
67SG	Sensitive Ground Directional Overcurrent	**87**	Differential Protective Relay
67Q	Negative Sequence Directional Overcurrent	**87B**	Bus Differential
68	Blocking Relay / Power Swing Blocking	**87G**	Generator Differential
69	Permissive Control Device	**87GT**	Generator/Transformer Differential
70	Rheostat	**87L**	Segregated Line Current Differential
71	Liquid Switch	**87LG**	Ground Line Current Differential
72	DC Circuit Breaker	**87M**	Motor Differential
73	Load-Resistor Contactor	**87O**	Overall Differential
74	Alarm Relay	**87PC**	Phase Comparison
75	Position Changing Mechanism	**87RGF**	Restricted Ground Fault
76	DC Overcurrent Relay	**87S**	Stator Differential
77	Telemetering Device	**87S**	Percent Differential
78	Phase Angle Measuring or Out-of-Step Protective Relay	**87T**	Transformer Differential
78V	Loss of Mains	**87V**	Voltage Differential
79	AC Reclosing Relay / Auto Reclose	**88**	Auxiliary Motor or Motor Generator
80	Liquid or Gas Flow Relay	**89**	Line Switch
81	Frequency Relay	**90**	Regulating Device

81O	Over Frequency	91	Voltage Directional Relay
81R	Rate-of-Change Frequency	92	Voltage And Power Directional Relay
81U	Under Frequency	93	Field-Changing Contactor
82	DC Reclosing Relay	94	Tripping or Trip-Free Relay
83	Automatic Selective Control or Transfer Relay		
84	Operating Mechanism		
85	Pilot Communications, Pilot-Wire Relay		

Abbreviation Code

AFD	Arc Flash Detector	MET	Substation Metering
CLK	Clock or Timing Source	PDC	Phasor Data Concentrator
CLP	Cold Load Pickup	PMU	Phasor Measurement Unit
DDR	Dynamic Disturbance Recorder	PQM	Power Quality Monitor
DFR	Digital Fault Recorder	RIO	Remote Input/output Device
DME	Disturbance Monitor Equipment	RTD	Resistance Temperature Detector
ENV	Environmental data	RTU	Remote Terminal Unit/Data Concentrator
HIZ	High Impedance Fault Detector	SER	Sequence of Events Recorder
HMI	Human Machine Interface	TCM	Trip Circuit Monitor
HST	Historian	LRSS	Local/Remote selector switch
LGC	Scheme Logic	VTFF	Vt Fuse Fail

Suffixes Description

_1	Positive-Sequence	L	Line or Logic
_2	Negative-Sequence	M	Motor or Metering
A	Alarm, Auxiliary Power	MOC	Mechanism Operated Contact
AC	Alternating Current	N	Neutral or Network
AN	Anode	O	Over
B	Bus, Battery, or Blower	P	Phase or Pump
BF	Breaker Failure	PC	Phase Comparison
BK	Brake	POTT	Pott: Permissive Overreaching Transfer Trip
BL	Block (Valve)	PUTT	Putt: Permissive Under reaching Transfer Trip
BP	Bypass	R	Reactor, Rectifier, or Room
BT	Bus Tie	S	Synchronizing, Secondary, Strainer
BU	Backup	SOTF	Switch On To Fault
C	Capacitor, Condenser, Compensator	T	Transformer or Thyratron
CA	Cathode	TD	Time Delay
CH	Check (Valve)	TDC	Time-Delay Closing Contact
D	Discharge (Valve)	TDDO	Time Delayed Relay Coil Drop-Out
DC	Direct Current	TDO	Time-Delay Opening Contact
DCB	Directional Comparison Blocking	TDPU	Time Delayed Relay Coil Pickup
DCUB	Directional Comparison Unblocking	THD	Total Harmonic Distortion
DD	Disturbance Detector	TH	Transformer (High-Voltage Side)
DUTT	Direct Under reaching Transfer Trip	TL	Transformer (Low-Voltage Side)
E	Exciter	TM	Telemeter
F	Feeder, Field, Filament, Filter, or Fan	TT	Transformer (Tertiary-Voltage Side)
G	Ground or Generator	U	Under or Unit
GC	Ground Check	X	Auxiliary
H	Heater or Housing	Z	Impedance

Size of MCB / MCCB Compartment (Cable Connections are in front of Panel)				
MCB / MCCB Size	Position	Width (mm)	Height (mm)	Depth (mm)
Up to 63A	Horizontal	300	275	300
63A to 100A	Horizontal	350	300	300
125A to 250A	Horizontal	350 to 400	300 to 350	300 to 350
400A to 630A	Horizontal	600	400	350 to 400
MCCB 800A	Horizontal	600	600	700
MCCB 1250A to 3200A	Horizontal	800	850	1000
* Cable Connections are in front side of Panel, If Cable Connection are in Back Side add 300mm in Depth of Panel				
* Cable Termination Space in Panel (From Cable Entry at Panel to Termination Location) Up to 800A =more than 400 mm, Above 800A It should be more than 800mm.				

Size of ACB Compartment (Cable Connections are in front of Panel)				
ACB Size	Position	Width (mm)	Height (mm)	Depth (mm)
800A	Horizontal	700	800	800
1600A	Horizontal	800	800	850
ACB up to 3200A	Horizontal	800	850	1000
ACB Above 3200A	Horizontal	1400	1000	1200
For Cable Entry from Bottom of Panel=Min 700mm Height from Bottom to Cable Termination				
* Cable Termination Space in Panel (From Cable Entry at Panel to Termination Location) Up to 800A =more than 400 mm, Above 800A It should be more than 800mm.				

Size of SFU Compartment (Cable Connections are in front of Panel)				
SFU Size	Position	Width (mm)	Height (mm)	Depth (mm)
125A	Horizontal	400	350	300
200A	Horizontal	400	350	300
200A	Horizontal	400	400	300
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side add 300mm in Depth of Panel				

Size of ATS Compartment (Cable Connections are in front of Panel)				
ATS Size	Position	Width (mm)	Height (mm)	Depth (mm)
100A	Vertical	400	700	350
160A	Vertical	400	900	350
200A	Vertical	400	750	350
400A	Vertical	400	750	350
630A	Vertical	400	1000	350
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side add 300mm in Depth of Panel				

Size of Motorized MCCB Compartment (Cable Connections are in front of Panel)				
Motorized MCCB Size	Position	Width (mm)	Height (mm)	Width (mm)
125A	Vertical	500	500	300
200A	Vertical	500	500	300
400A	Vertical	500	500	300
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side add 300mm in Depth of Panel				

Size of Starter Compartment (Cable Connections are in front of Panel)				
Motor KW	Position	Width (mm)	Height (mm)	Depth (mm)
Up to 6KW	Horizontal	500	300	300
7.5KW to 11 KW	Horizontal	600	200	300
15KW to 30KW	Horizontal	600	300	450
37KW to 55KW	Horizontal	600	400	600
55KW to 132KW	Vertical	600	600	800
250KW to 300KW	Vertical	800	1500	1000
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side add 300mm in Depth of Panel				

Size of BUSBAR & Cable Alley Compartment

Type	Position	Width (mm)	Height (mm)	Depth (mm)
BUS BAR	Horizontal	-	300 to 400	300
BUS BAR	Vertical	300 to 400	-	300
CABLE ALLEY	Vertical	300	-	300

Size of MCB Compartment (For No's of MCB)				
MCB Size	**Position**	**Width (mm)**	**Height (mm)**	**Depth (mm)**
10A to 63A,4P MCB=5NO	Vertical	700	300	300
10A to 63A,4P MCB=5NO	Vertical	700	300	300
10A to 63A,4P MCB=3NO	Vertical	500	300	300
10to 63A,4P RCCB=2NO + 10A to 40A, SP MCB=20NO	Vertical	600	300	300
10A to 63A,4P RCCB=5NO + 10A to 40A, DP MCB=2NO	Vertical	600	600	300
10A to 63A,4P MCB=2NO,ON/OFF	Vertical	350	300	300
*Required 25mm to 35mm for Each Pole, Ex for Four Pole MCB required 100mm Space				

Power Factor correction Panel			
Total KVAR	**Height (mm)**	**Width (mm)**	**Depth (mm)**
100 KVAR	1000	800	600
200 KVAR	1500	800	600
300/400 KVAR	2000	800	600

Size of Cable Alley as per MCCB Rating		
CIRCUIT BREAKER	**Front Cable Alley (MCCB)**	**Rear Cable Alley (MCCB)**
Ampere Rating	**Dimension of the Box**	**Dimension of the Box**
630Amp	400X400MM	600X400MM
400Amp	400X400MM	600X400MM
320Amp	400X400MM	600X400MM
280Amp	300X300MM	450X300MM
100Amp	300X300MM	450X300MM
80Amp	300X250MM	450X250MM
16Amp	300X250MM	450X250MM

ACB Compartment Size	
Ampere rating	**Dimension of the Box**
630Amp to 800Amp	700X700MM
3200Amp to 4000Amp	1000X700MM
5000Amp to 6300Amp	1200X700MM

Bus bar Ampere Rating:	
Phase Bus bar	Aluminium 130 Amp / Sq.cm or 800Amp / Sq. Inch.
Phase Bus bar	Copper 160 Amp / Sq.cm or 1000Amp / Sq. Inch
Neutral Bus bar	Same as Phase Bus bar up to 200 Amp than Neutral Bus bar is at least half of Phase Bus bar.

Bus Bar Spacing:	
Between Phase and Earth	26mm (Min)
Between Phase and Phase	32mm (Min)
Bus bar Support between Two Insulator	250mm.

Voltage Limit for Electrical Load (CPWD & Kerala Electricity Board):	
Voltage	**Total Load**
240V	< 5 KW
415V	<100 KVA
11KV	<3 MVA
22KV	<6 MVA
33KV	<12 MVA
66KV	<20 MVA
110KV	<40 MVA
220KV	>40 MVA

Economic generation voltage (CBIP Manual):	
Total Load	**Economical Voltage**
Up to 750 KVA	415 V
750 KVA to 2500 KVA	3.3 KV
2500 KVA to 5000 KVA	6.6 KV
Above 5000 KVA	11 KV or Higher

Voltage Variation:	
> 33 KV	(-) 12.5% to (+) 10%
< 33 KV	(-) 9% to (+) 6%
Low Voltage	(-) 6% to (+) 6%

Electrical Wire Ground Clearance	
Voltage Level	**Ground Clearance**
<=33KV	5.2 Meter
66KV	5.49 Meter
132KV	6.10 Meter
220KV	7.0 Meter
400KV	8.84 Meter

Economic Voltage for Power Transmission:		
Required Power Transfer	**Distance**	**Economical Voltage Level**
3500 MW	500 KM	765 KV
500 MW	400 KM	400 KV
120 MW	150 KM	220 KV
80 MW	50 KM	132 KV

Insulation Class:	
Insulation	**Temperature**
Class A	105°C
Class E	120°C
Class B	130°C
Class F	155°C
Class H	180°C
Class N	200°C

Standard Voltage Limit:			
Voltage	**IEC (60038)**	**IEC (6100:3.6)**	**Indian Elect. Rule**
ELV	< 50 V		
LV	50 V to 1 KV	<=1 KV	< 250 V
MV		<= 35 KV	250 V to 650 V
HV	> 1KV	<= 230 KV	650 V to 33 KV
EHV		> 230 KV	> 33 KV

Sub Station Capacity & Short Circuit Current Capacity:(GERC)		
Voltage	**Sub Station Capacity**	**Short Circuit Current**
400 KV	Up to 1000 MVA	40 KA (1 to 3 Sec)
220 KV	Up to 320 MVA	40 KA (1 to 3 Sec)
132 KV	Up to 150 MVA	32 KA (1 to 3 Sec)
66 KV	Up to 80 MVA	25 KA (1 to 3 Sec)
33 KV	1.5 MVA to 5 MVA	35 KA (Urban) (1 to 3 Sec)
11 KV	150 KVA to 1.5 MVA	25 KA (Rural) (1 to 3 Sec)
415 V	6 KVA to 150 KVA	10 KA (1 to 3 Sec)
220 V	Up to 6 KVA	6 KA (1 to 3 Sec)

Sub Station Capacity:(Central Electricity Authority)		
Voltage	**Sub Station Capacity**	**Short Circuit Current**
765 KV	4500 MVA	31.5 KA for 1 Sec
400 KV	1500 MVA	31.5 KA for 1 Sec
220 KV	500 MVA	40 KA for 1 Sec
110/132 KV	150 MVA	40 or 50 KA for 1 Sec
66 KV	75 MVA	40 or 50 KA for 1 Sec

Minimum Ground Clearance and Fault Clearing Time:		
Voltage	**Min. Ground Clearance**	**Fault Clear Time**
400 KV	8.8 Meter	100 mill second
220 KV	8.0 Meter	120 mill second
132 KV	6.1 Meter	160 mill second
66 KV	5.1 Meter	300 mill second
33 KV	3.7 Meter	
11 KV	2.7 Meter	

Insulation Resistance Value of Transformer:			
Voltage	**30°C**	**40°C**	**50°C**
>66KV	600MΩ	300MΩ	150MΩ
22KV to 33KV	500MΩ	250MΩ	125MΩ
6.6KV to 11KV	400MΩ	200MΩ	100MΩ
<6.6KV	200MΩ	100MΩ	50MΩ
415V	100MΩ	50MΩ	20MΩ

Standard Electrical Connection / HT Connection (GERC):	
As per Type of Connection	
Connection	**Voltage**
LT Connection	<=440V
HT connection	440V to 66KV
EHT connection	>= 66KV
As per Electrical Load Demand	
Up 6W Load demand	1 Phase 230V
6W to 100KVA(100KW)	3 Phase 440V
100KVA to 2500KVA	11KV,22KV,33KV
Above 2500KVA	66KV
HT Connection Earthing	
H.T Connection's Earthing Strip	20mmX4mm Cu. Strip
CT & PT bodies	2Nos
PT Secondary	1Nos
CT Secondary	1Nos
I/C and O/G Cable+ Cubicle Body	2Nos

Span of Transmission Line (As per Central Electricity Authority):	
Voltage	**Normal Span**
765 KV	400 to 450 Meter
400 KV	400 Meter
220 KV	335,350,375 Meter
132 KV	315,325,335 Meter
66 KV	240,250,275 Meter

Overhead Conductor /Cable Size:		
Voltage	**Overhead Conductor**	**Cable Size**
33 KV	ACSR-Panther/Wolf/Dog , AAAC	150,185,300,400,240 mm2 Cable
11 KV	ACSR-Dog/Recon/Rabbit , AAAC	120, 150,185,300 mm2 Cable
LT	ACSR-Dog/Recon/Rabbit , AAC,AAAC	95,120, 150,185,300 mm2 Cable

Transmission / Distribution Line:	
Span	**Height of Tower**
400KV=400 Meter	400KV=30Meter (Base 8.8 Meter)
220KV=350 Meter	220KV=23Meter (Base 5.2 Meter)
132KV=335 Meter	220KV Double Circuit=28 Meter
66KV=210 Meter	66KV=13Meter
Conductor Ampere	**Voltage wise Conductor**
Dog=300Amp	400KV=Moose ACSR=500MVA Load
Panther=514Amp	220KV=Zebra ACSR=200MVA Load
Zebra=720Amp	132KV=Panther ACSR=75MVA Load
Rabbit=208Amp	66KV=Dog ACSR=50MVA Load
Moose=218Amp	

Type of Transmission Tower:		
Type	**Used**	**Angle/Deviation**
A	Suspension Tower	Up to 2°
B	Small Angle Tower	2° to 15°
C	Medium Angle Tower	15° to 30°
D	Large Angle / Dead End Tower	30° to 60° & Dead End

Tower Swing Angle Clearance (Metal Part to Live Part):				
Swing Angle	**Live Part to Metal Part Clearance (mm)**			
	66KV	**132KV**	**220KV**	**400KV**
0°	915mm	1530mm	2130mm	3050mm
15°	915mm	1530mm	2130mm	-
22°	-	-	-	3050mm
30°	760mm	1370mm	1830mm	-
44°	-	-	-	1860mm

44°	610mm	1220mm	1675mm	-

Current Density	
Surface Current Density(mA/m2)	**Health Effect**
<1	Absence of any established effects.
1 To 10	Minor biological effects.
10 To 100	Well established effects , (a) Visual effect.(b) Possible nervous system effect
100 To 1000	Changes in central nervous System
>1000	Ventricular Fibrillation (Heart Condition 0. Health hazards.

Type of Distribution System (IEC 60364-3)	
Unearthed System	**Earthed System**
IT	TT / TN (TN-S,TN-C,TN-C-S)
1st Letter =The neutral point in relation to earth: T= directly earthed neutral (French word Terre) & I =unearthed or high impedance-earthed neutral (2,000 Ω)	
2nd letter=Exposed conductive parts of the electrical installation in relation to earth: T =directly earthed exposed conductive parts & N =exposed conductive parts directly connected to the neutral	

System Highest and Lower Voltage (NEC(India) :2011)		
System Voltage	**Highest Voltage**	**Lowest Voltage**
240 V	264 V	216 V
415 V	457 V	374 V
3.3 kV	3.6 kV	3.0 kV
6.6 kV	7.2 kV	6.0 kV
11 kV	12 kV	10 kV
22 kV	24 kV	20 kV
33 kV	36 kV	30 kV
66 kV	72.5 kV	60 kV
66 kV	72.5 kV	60 kV
132 kV	145 kV	120 kV
220	kV 245 kV	200 kV
400 kV	420 kV	380 kV

Distribution Losses (Gujarat Electricity Board)		
Voltage (Point of Injection)	**At 11 KV**	**Point of Energy Delivered**
11KV / 22KV / 33KV	10%	10.82%
400 Volt	-	16.77%

Aluminium/ Copper Bus Bar Sections CPWD - TABLE VI				
Current Ratings in amps. Upto	**Recommended Rectangular Cross-section**			
	Aluminium		**Copper**	
	No. of Strips/ Phase	**Size in mm**	**No. of Strips/ Phase**	**Size in mm**
100	1	20 x 5	1	20 x 3
200	1	30 x 5	1	25 x 5
300	1	50 x 5	1	40 x 5
400	1	50 x 6	1	50 x 5
500	1	75 x 6	1	60 x 5
600	1	80 x 6	–	
800	1	100 x 6	–	
1000		100 x 10	–	
1200		125 x 10	–	
1600	2	100 x 10	–	
2000	2	125 x 10	–	
2500	3	125 x 10	–	

Harmonic Distortion As per Central Electricity Authority ,India		
System Voltage (kV)	**Total Harmonic Distortion (%)**	**Individual Harmonic of any Frequency (%)**
765	1.5	1
400	2	1.5
220	2.5	2
33 to 132	5	3

Chapter: 7 MCB / MCCB/ RCCB Reference

Approximate Cable Current Capacity		
Cable Size	**Current Capacity**	**MCB / MCCB Size**
1.5 Sq.mm	7.5 To 16 A	8A
2.5 Sq.mm	16 To 22 A	15A
4 Sq.mm	22 To 30 A	20A
6 Sq.mm	39 To 39 A	30A
10 Sq.mm	39 To 54A	40A
16 Sq.mm	54 To 72A	60A
25 Sq.mm	72 To 93A	80A
50 Sq.mm	117 To 147A	125A
70 Sq.mm	147 To 180A	150A
95 Sq.mm	180 To 216A	200A
120 Sq.mm	216 To 250A	225A
150 Sq.mm	250 To 287A	275A
185 Sq.mm	287 To 334A	300A
240 Sq.mm	334 To 400A	350A

MCB Class according to Appliances			
Appliance	**Capacity / watt**	**MCB Rating**	**MCB Class**
Air Conditioner	1.0 Tone	10A	C Class
	1.5 Tone	16A	C Class
	2.0 Tone	20A	C Class
Freeze	165 Liter	3 A	C Class
	350 Liter	4 A	C Class
Oven /Grill	4500 Watt	32 A	B Class
	1750Watt	10 A	B Class
Oven / Hotplate	750Watt	6 A	B Class
	2000Watt	10 A	B Class
Room Heater	1000Watt	6 A	B Class
	2000Watt	10 A	B Class
Washing Machine	300Watt	2 A	C Class
	1300Watt	8 A	C Class
Water Heater	1000Watt	6 A	B Class
	2000Watt	10 A	B Class
	3000Watt	16 A	B Class
	6000Watt	32 A	B Class
Iron	750Watt	6 A	B Class
	1250Watt	8 A	B Class
Toaster	1200 Watt	8 A	B Class
	1500 Watt	10 A	B Class

Selection of MCB			
MCB curve	**Type of Load**	**Residential**	**Commercial**
B curve	**Resistive Loads**	Incandescent lights	Incandescent lights
		Geyser	Boilers
		Heater	Heaters
		Fan blower heaters	Oil radiator heaters
	Slight Inductive Loads	Florescent Lights	Florescent lights
		Small motors (FHP)	High pressure mercury vapor lamps
C curve	**Slight Inductive Loads**	Fans & small pumps	Sodium vapor lamps
		Window / Split ACs	
		Lights with ballasts	
		Microwave	
		Refrigerators	
		General household equipment	

D curve	**Inductive Loads**	Water lifting pumps	Florescent lights
		UPS	ID & FD fans
			Small control transformers
			Medium size motors
			Refrigerators for commercial use

Type of MCB

MCB Curve	Type of Load	Response	Tripping	Application	Uses
B curve	Resistive loads	MCBs react quickly to overloads	3 To 5 times F.L current (0.04 To 13 Sec)	Domestic & Commercial applications	Suitable for incandescent lighting, socket-outlet, bulbs, heaters etc. Protection of DG sets (since DG sets have low short-circuit capacity)
C curve	Slightly inductive loads	MCBs react more slowly,	5 To 10 times F.L current (0.04 To 5 Sec)	Commercial and Industrial applications	Highly Inductive loads such as motors, air conditioners, fluorescent lighting lights, fans & household electrical appliances.
D curve	Inductive loads	MCBs are slower	10 To 20 times F.L current (0.04 To 3 Sec)	Commercial and Industrial applications	Very high inrush Inductive currents, Small transformers, welding machines. UPS, small motor & pumps, x-ray machines etc. Note, however, that MCBs with Type K characteristics may provide better protection in some applications of this type.
K curve	Inductive loads	MCBs are slower	8 To 10 times F.L current (0.04 To 3 Sec)		Placing them between the traditional Type C and Type D breakers. In most cases, they allow improved cable protection to be provided in circuits that include motors, capacitors and transformers, where it would previously have been necessary to use Type D devices. This enhanced protection is achieved without increasing the risk of nuisance tripping.

Sensitivity of RCCB

RCCBs	Application
30 mA	personal protection domestic installation / direct contact
100 mA	limited personal protection / indirect contact
300 mA	building / fire protection

TYPE of RCCB

TYPE	AC Current 50Hz	AC Current 50Hz To 1KHZ	Pulsating Current with DC Component	Multi Frequency Current Generated By 1Phase Inverter	Multi Frequency Current Generated By 3Phase Inverter
AC	√				
A	√		√		
F	√		√	√	
B	√	√	√	√	√
AS	√		√		
BS	√	√	√	√	√

Selection of RCCB

Type of RCCB	Sensitive	Application
Type AC	Sensitive to AC Currents Only	Suitable for most domestic and commercial applications.

Type A	Sensitive to AC Currents + Pulsating DC Currents (Produced by Rectifier, Thyristors)	Used where there are a lot of "electronic" loads, such as computer or lighting systems with electronic ballasts.
Type B	Sensitive to AC Currents + Pulsating DC Currents+ Pure DC Currents	Use in photovoltaic (PV) solar energy installations because the PV panels produce a DC Output and some types of fault can result in the leakage of DC Currents to Earth.
Type B+	Similar to Type B, but respond to ac leakage currents over a wider frequency range	Type B and Type B+ devices can be used wherever a Type AC or Type A device is specified, as they provide the same functionality as these types and more.

Type of Faults

Types of Fault	Reason	Consequences	Protective Device
Overload	When Equipment tries to run beyond its rated capacity, or there is a fault in the equipment E.g. When you keep a heater on without any water in it.	It can lead to reduction in life of equipment, Failure of insulation and hence damaging the equipment.	MCB / RCBO
Short Circuit	Insulation Failure, Shorting of the Phase to Phase or Phase and Neutral Wires.	High Inrush Current, causing permanent damage to equipment and may lead to a Fire.	MCB
Earth Fault	Short circuit between Phase and Earth Conductor.	Can result in Fire due to sparking.	RCBO / RCCB
Earth Leakage	Human Body Touching Live Wires. Insulation failure		RCBO / RCCB
Over Voltage	Opening of Neutral Connection increase in Phase-to-Phase Voltage, Surge through Lighting or transients, Over voltage from Utility.	Damage to sensitive Electronic Equipment.	OV protection Device
Under Voltage	Drop in supply voltage, starting of heavy loads	Damage of Equipment, Flickering of Lights.	UV relays

Switch Gear Protection

Switch Gear	Protection		Isolation	Control
	Over Load	Short Circuit		
Fuse	YES	YES	NO	NO
Switch	NO	NO	YES	YES
Circuit Breaker	YES	YES	YES	YES
Contactor	NO	NO	NO	YES
Disconnector	NO	NO	YES	NO

Braking Capacity of CB

Type	Voltage	Breaking Capacity
MCB	400V to 600V	
ACB	400V to 11KV	5MVA to 750MVA
MOCB	3.3KV to 220KV	150MVA to 2000MVA
VCB	3.3KV to33KV	250MVA to 2000MVA
SF6	2.2KV to 765KV	1000MVA to 50000MVA
Air Blast CB	66KV to 1100KV	2500MVA to 60000MVA

BS EN 60898-2 Range

Trip Curve	Instantaneous Trip (< 0.1 s)	Load Type	Typical Load
B	3 to 5 In (AC) 4 to 7 In (DC)	Resistive	Heaters, showers, cookers, socket outlets.
C	5 to 10 In (AC) 7 to 15 In (DC)	Inductive	Motors, general lighting circuits, power supplies.
D	10 to 20 In	High Inductive	Transformers, motors, discharge lighting circuits, computers

MCB Selection Chart For Motor Protection								
KW	HP	1Phase 230V DOL Starting		3Phase 400V DOL Starting		3 Phase 400V Star Delta		
		Full Load Current	MCB Selection	Full Load Current	MCB Selection	Full Load Current	MCB Selection	MCB Selection
0.18	0.24	2.8A	10A	0.9A	6A	—	—	—
0.25	0.34	3.2A	10A	1.2A	6A	—	—	—
0.37	0.5	3.5A	10A	1.2A	6A	—	—	—
0.55	0.74	4.8A	16A	1.8A	6A	—	—	—
0.75	1.01	6.2A	20A	2A	6A	—	—	—
1.1	1.47	8.7A	25A	2.6A	6A	—	—	—
1.5	2.01	11.8A	32A	3.5A	10A	—	—	—
2.2	2.95	17.5A	50A	4.4A	10A	—	—	—
3	4.02	20A	63A	6.3A	16A	6.3A	16A	10A
3.75	5.03	24A	80A	8.2A	20A	8.2A	20A	10A
5.5	7.37	26A	80A	11.2A	25A	11.2A	32A	16A
7.5	10.05	47A	125A	14.4A	40A	14.4A	40A	25A
10	13.4	—	—	21	50A	21A	50A	32A
15	20.11	—	—	27	100A	27A	63A	40A
18.5	24.8	—	—	32	125A	32A	—	50A
22	29.49	—	—	38	125A	38A	—	63A
30	40.21	—	—	51	125A	51A	—	63A

Standard Size of MCB/MCCB/ELCB/RCCB/SFU/Fuse:	
MCB	Up to 63 Amp (80Amp and 100 Amp a per Request)
MCCB	Up to 1600 Amp (2000 Amp as per Request)
ACB	Above 1000 Amp
MCB Rating	6A,10A,16A,20A,32A,40A,50A,63A
MCCB Rating	0.5A,1A,2A,4A,6A,10A,16A,20A,32A,40A,50A,63A,80A,100A (Domestic Max 6A)
RCCB/ELCB	6A,10A,16A,20A,32A,40A,50A,63A,80A,100A
Sen. of ELCB	30ma (Domestic),100ma (Industrial),300ma
DPIC (Double Pole Iron Clad) switch	5A,15A,30 A for 250V
TPIC (Triple Pole Iron Clad) Switch	30A, 60A, 100A, 200 A For 500 V
DPMCB	5A, 10A, 16A, 32A and 63 A for 250V
TPMCCB	100A,200A, 300Aand 500 A For 660 V
TPN main switch	30A, 60A, 100A, 200A, 300 A For 500 V
TPNMCB	16A, 32A,63A For 500 V, beyond this TPN MCCB: 100A, 200A, 300A, 500 A For 660 V
TPN Fuse Unit (Rewirable)	16A,32A,63A,100A,200A
Change over switch (Off Load)	32A,63A,100A,200A,300A,400A,630A,800A
SFU (Switch Fuse Unit)	32A,63A,100A,125A,160A,200A,250A,315A,400A,630A
HRC Fuse TPN (Bakelite)	125A,160A,200A,250A,400A.630A
HRC Fuse DPN (Bakelite)	16A,32A,63A
MCB/MCCB/ELCB Termination Wire / Cable	
Up to 20A MCB	Max. 25 Sq.mm
20A to 63A MCB	Max. 35 Sq.mm
MCCB	Max. 25 Sq.mm
6A to 45A ELCB	16 Sq.mm
24A to 63A ELCB	35 Sq.mm
80A to 100A ELCB	50 Sq.mm

Selection of MCB and MCCB		
Characteristics	**MCB**	**MCCB**
Standard	IEC60898-1	IEC60947-2

Rated current	6A to 100A	10A to 2500A.
Interrupting rating	Up to 18KA	10KA to 200KA
Trip Mechanism	Thermal / Magnetic	Thermal / Magnetic / Static
Trip characteristics Settings	Not adjusted	Fixed /Adjustable Thermal operated for overload and Magnetic operation for instant trip in Short circuit conditions
Application	Indoor Type	Indoor / Outdoor Type
Pollution Degree	0 to 2	3
Suitable for	Low current circuits (homes, shops, school and offices).	High power rating i.e. commercial and industrial use
User	This is designed for unskilled user / uninstructed user and not being maintained consequently	This is designed for skilled user and supposed to be maintained properly
Type of Protection	over current protection	over current / Short Circuit / Earth Fault protection
Mounting	Rail Mounted	Rail / Fixed / Draw out Mounted
Operating Mechanism	Electrical /Mechanical Operating	Electrical /Mechanical / Motorized Operating

Sample of MCB /MCCB Name Plate Specification

Frame:	F750
Rated Operational Voltage (Ue):	415V
Rated Insulation Voltage (Ui) :	690V
Rated Impulse withstand Voltage (Uimp):	6KV
Rated Current (Ie) :	80A
Ultimate Breaking Capacity (Icu):	10KA
Service Breaking Capacity (Ics) :	75 % of Icu
Utilization Category :	A Type
No. of Poles:	3
Suitability for Isolation:	Yes
Electrical Life Cycles :	5000
Mechanical Life Cycles:	25000
Release Type :	Thermal – Magnetic
Thermal:	Fixed
Magnetic:	Fixed
Terminal Capacity Cable:	50 mm2
Dimensions (mm) WXHXD :	75X130X60
Weight:	0.84Kg
Operating Temp Range:	-5 to +50°C
Reference Temperature:	50°C

Meaning of each Adjustable Switches of MCCB

Setting	Name	Adjustment	Protection For
Ir	Long time Pick up Current Setting (or thermal Setting)	This is a multiplication coefficient of the rating of the device. **(Ir=xIn)**	Protection against overloads
tr	Long time delay Setting in seconds	Enabling in particular the starting current of a motor to be tolerated. **(tr=Sec)**	Protection against overloads
Im / Isd	Short time (Magnetic Setting)	This is a multiplier of the Ir setting, often 1.5 to 10 times the Ir current **(im=xIr)**	Protection against short circuits.
tm / tsd	Short time delay Setting	Enabling in particular the discrimination (time) to be increased with downstream feeders and the magnetization peaks of a transformer or a motor to be tolerated. It is recommended that the I^2t selector switch is set to the ONposition.**(tm=Sec)**	Protection against short circuits.

Ii	Instantaneous current Setting	Protecting the installation against strong short circuits (dead short circuits) by instantaneous tripping without Time Delay and self-protection of the circuit breaker **(Ii > Isd).**	Protection against Dead Short circuits.
Ig	Earth FaultCirculating Current	for monitoring the earth fault current circulating in the Phase and Earth conductor in TNS systems	Earth protection
tg	Earth protection time delay	Earth protection time delay	Earth protection
I delta n	Earth leakage protection	Adjustment of the sensitivity of the earth leakage protection	Earth leakage protection
delta t	Earth leakage protection	Earth leakage protection delay.	Earth leakage protection

Chapter: 8 Earthing Value / Wire / Strip Reference

The resistance offered by the earth electrode to the flow of current into the ground is known as the earth resistance or resistance to earth.
Ideally a ground resistance should be of zero ohms but It is always greater than Zero .System ground resistances can be reduce by the use of a number of individual electrodes connected together.
Total earthing resistance is the sum of the resistance of earth lead wires, Contact resistance between the surface of the earth electrode and the soil and The resistance of the body of the soil surrounding the earth electrode.
The value of earthing resistance varies on the Type of Soil, Soil characteristic, soil resistivity and the climatic condition. Moisture content in soil plays a vital role in the soil resistivity. value of individual earthing pit resistance is not so important. Different codes specifies the required value of earthing system.
Electrical Systems can work with earth resistance of 20 ohms, though generally 10 ohms is the specified Maximum limit.
But communication systems need very stringent limit, typically one ohm. This is because the higher the ground resistance, higher would be noise interference in the systems.

Earthing Resistance Value (USAID):

Particular	Max Earthing Resistance
Power Station	0.5Ω
EHT Sub Station	1Ω
33KV Sub Station	2Ω
Double Pole Structure	5Ω
Tower foot Resistance	10Ω
Transmission Line	10 Ω
Distribution Transformer	5Ω
220KV Sub Station	1Ω To 2Ω
400KV Sub Station	0.5Ω
Single Isolate Earth Pit	5.0 Ω
Earthing Grid	0.5 Ω

Earthing Resistance value: IEEE STANDARD 142 (Chapter: 4.1.3, page 164)

For industrial plant substations and buildings and large commercial installations.	**1Ω to 5 Ω**
Resistances of less than **1 Ω** may be obtained using a number of individual electrodes connected together. Such a low resistance is only required for large substations, transmission lines, or generating stations.	

Earthing Resistance value: National Electric code(NEC- Chapter: 3.0.9)/IS SP30- Chapter 14

Unless otherwise specified, It is recommended that the value of any earth system resistance shall not be more than	**5Ω**

Earthing Resistance value: IS 3043 (India)- Chapter: 22.2.3

The continuity resistance of the earth return path through the **earth grid** should be maintained as low as possible and in no case greater than	**1Ω**
This applicable for main earth grid connected with the transformer/return path	

Oil Industry Safety Directorate Government of India (OISD STANDARD:137)

Chapter: (7. ii. b) Allowable Earth-Resistance Values	
Allowable earth-Resistance Values The resistance value of an earthing system to general mass of the earth should not exceed.	
For electrical systems and metallic structures.	**4Ω**
For storage tanks.	**7Ω**
for main earth grid, and bonding connections between joints in pipelines and associated facilities.	**1Ω**
for each electrode to the general mass of the earth	**2Ω**

Earthing Resistance value: IS 2309 (India) / BS 7430:1998

Clause:12.3.1 Page 32, Resistance to Earth	
Lightning arrestors ground resistance for Protection of buildings and allied structures is	**10Ω**
An earth electrode should be connected to each down conductor. Each of these earths should have a resistance not exceeding the product given by 10 a multiplied by the number of earth electrodes to be provided.	

The whole of the lightning protective system, including any ring earth, should have a combined resistance to earth not exceeding **10 Ω** without taking account of any bonding.
If the value obtained for the whole of the lightning protective systems exceeds 10 Ω, a reduction can be achieved by extending or adding to the electrodes or by interconnecting the individual earth terminations of the down conductors by a conductor installed below ground, sometimes referred to as a ring conductor

Earthing Resistance value: IS 2689:1989- Table 4 page 28 (Reaffirmed March 2010)	
Lightning arrestors ground resistance for Protection of buildings and allied structures is	**10Ω**

Earthing Resistance value: NEC 250.56	
Clause: 250.53 Grounding Electrode System Installation.	
The maximum resistance for a single electrode consisting of a rod, pipe, or plate.	**25Ω**
If a higher resistance is obtained for a single electrode, a second electrode of any of the types specified in the NEC is required.	
This should not be interpreted to mean that **25Ω** is a satisfactory resistance value for a grounding system.	

Earthing Resistance value: IEEE Std 80-2000	
Ground resistance for the most transmission and other large substations, the ground resistance is usually about	**1Ω or less**
In smaller distribution substations, the usually acceptable range is	**1Ω to 5Ω**

Earthing Resistance value: NFC 17-102, July 1995	
The resistance value measured using conventional equipment should be	**1Ω or less**
This resistance should be measured on the earthing termination insulated from any other conductive component.	

Earthing Resistance value: IEC 62305-1- edition 2.0 – 2010-12	
the conventional earthing impedance related to the earth termination system is (*for the soil resistivity less than or equal to 100 Ω)	**4 Ω**

Earthing Resistance value: Ministry of Railways (Government of India)	
The acceptable Earth Resistance at earth MEEB bus bar shall not be more than	**1Ω**
For achieving this value more than one earth pits can be installed if necessary, depending upon the soil resistivity. In places where space is not available to provide parallel earth pits then longer earth rods may be provided.	
The longer earth rods thus provided should be in multiples of three meters.	
The combined resistance of the earthing system shall be not more than the following values	
Traction substation	**0.5Ω**
Switching station	**2Ω**
Booster transformer station	**10Ω**
Auxiliary transformer station	**10Ω**
Maximum values of earth resistances specified for earthing of Signalling and Telecommunication equipment's are as under	
Telegraph and Block Instrument using earth return circuit	**10 Ω**
Earths for surge arrestors/ lightening dischargers	**10Ω**
Earthing of Signalling equipment	**10Ω**
Earthing of signalling cable screen in AC electrified areas	**10Ω**
Earthing of Telephone Exchange	**5Ω**
Earthing of aluminium sheathed telecom cable in AC electrified area	**1Ω**
Earthing of equipment in VF repeater stations and cable huts.	**5Ω**
Axle counter cable screened in AC electrified area	**1Ω**
Electronic Interlocking installation	**1Ω**
Integrated Power Supply System & its individual modules	**2Ω**
Digital Axle Counter EJB and its apparatus case connected to same earth All cable armour connected to same earth.	**1Ω**
Reset box of Digital Axle Counter connected to earth (indoor) near SM's Room.	**1Ω**

Earthing Resistance value: Railway Vikas Nigam Limited- RVNL/Elect/GS/11	
The earth continuity test of metallic envelopes shall be done for electrical continuity. Electrical resistance of the same, along with the earthing lead, excluding any added resistance of earth leakage circuit breaker, measured from the connection with the earth electrode to any point in the earth conductor in the completed installation, shall not exceed	**1Ω**
No earth electrode shall have resistance greater than	**5Ω**
In rocky soil, the resistance may be up to	**8Ω**
Locations having more than one electrode shall be connected in parallel to reduce the resistance.	

Earthing Resistance value: Specification for Railway Electrification (India)- RDSO/SPN/197/2008	
Equipment's with solid state components which are more susceptible to damage due to surges, transients and over voltages being encountered in the system due to lightning, sub-station switching such as Electronic Interlocking, Integrated Power supply equipment, Digital Axle counter, Data logger etc. shall Value of earth resistance shall not be more than	**1Ω**
For conventional signalling equipment's the earth resistance shall not be more than	**10Ω**

Earthing Resistance value: Dhashin Haryana Bijli Vitran Nigam (DHBVN)	
Specification no CSC-140 / DH/UH/P&D	
Hose hold Earthing (3KA)	**<8Ω**
Commercial / Industrial Buildings (5KA)	**<2Ω**
Transformer / LT Line Earthing (15KA)	**1Ω to 2Ω**
Transformer / Substation /HT Line ,HT Switchgear (40KA)	**<1Ω**
Lighting Arrester /Extra High Current appliances (50KA)	**<1Ω**
UPS / Data centre / ATM	**<0.5 Ω**
*Earthing may be Single or Multiple Electrode.	

Earthing Resistance value: General Practice

Earthing Condition	**Earthing Value**
Best	**0.1Ω to 2Ω**
Good	**2.1Ω to 5Ω**
Need to be Maintenance	**5.1Ω to 10Ω**
Need to be Replacement	**>10Ω**

Earthing / Ground Resistance Values

Industrial plant:	5 Ω
Chemical plant:	3 Ω
Computer System	3 Ω
Lighting Protection	1 Ω
Generating station:	1 Ω
Large HV sub-station, Generating Station (IEEE Std 142 clause 4.1.2)	1 Ω
Small Distribution sub-station (IEEE Std 142 clause 4.1.2)	5 Ω
Telecommunication facilities	<5 Ω
Water pipe ground should	<3 Ω

Soil Resistivity (approximate ohm-meters)

Soil Description	**Minimum**	**Median**	**Maximum**
Topsoil, loam	1	26	50
Inorganic clays of high plasticity	10	33	55
Fills – ashes, cinders, brine wastes	6	38	70
Gravelly clays, sandy clays, silty clays, lean clays	25	43	60
Slates, shale	10	55	100
Silty or clayey fine sands with slight plasticity	30	55	80
Clayey sands, poorly graded sand-clay mixtures	50	125	200
Fine sandy or silty clays, lean clays	80	190	300
Decomposed gneisses	50	275	500
Silty sands, poorly graded sand-silt mixtures	100	300	500
Clayey gravel, poorly graded gravel, sand-clay mixture	200	300	400
Well graded gravel, gravel-sand mixtures	600	800	1000

Granites, basalts, etc.	-	1000	-
Sandstone	20	1010	2000
Poorly graded gravel, gravel-sand mixtures	1000	1750	2500
Gravel, sand, stones, little clay or loam	590	2585	4580
Surface limestone	100	5050	10000

Soil Resistivity Ranges

1000 Ohm cm	Wet organic soil
10000 Ohm cm	Moist soil
100000 Ohm cm	Dry soil
1000000 Ohm cm	Bed rock
590 to 7000 Ohm cm	Ashes, cinders, brine, waste
340 to 1630 Ohm cm	Clay, Shale, Loam
59000 to 458000 Ohm cm	Gravel , Sand , Stone with little Clay
300 to 500 Ohm meter	Concrete
900 to 1100 Ohm meter	Granite
20 to 2000 Ohm meter	Sand Stone
100 - 15,000 Ohm cm	Standard Design OK
15,000- 25,000 Ohm cm	Standard Design Maybe
25,000 - 50,000 Ohm cm	Special – Contact the carrier, owner or engineering firm
50,000 + Ohm cm	Very Special - Perhaps not practical

Motor Earthing Wire / Strip Size:

Size of Motor	Body Earthing
< 5.5 KW	85 SWG GI Wire
5.5 KW to 22 KW	25x6 mm GI Strip
22 KW to 55 KW	40x6 mm GI Strip
>55 KW	50x6 mm GI Strip

Panel Earthing Wire / Strip Size:

Type of Panel	Body Earthing
Lighting & Local Panel	25x6 mm GI Strip
Control & Relay Panel	25x6 mm GI Strip
D.G & Exciter Panel	50x6 mm GI Strip
D.G & T/C Neutral	50x6 mm Cu Strip

Earthing Strip Size:

Equipment	Body Earthing
LA (5KA,9KA)	25x3 mm Cu Strip
HT Switchgear	50x6 mm GI Strip
Structure	50x6 mm GI Strip
Cable Tray	50x6 mm GI Strip
Fence / Rail Gate	50x6 mm GI Strip

Earthing Wire (As per BS 7671)

Cross Section Area of Phase, Neutral Conductor(S) mm2	Minimum Cross Section area of Earthing Conductor (mm2)
S<=16	S (Not less than 2.5 mm2)
16<S<=35	16
S>35	S/2

GI Earthing Conductor sizes for various Equipment

Equipment's	Earth Strip Size
HT switchgear, structures, cable trays & fence, rails, gate and steel column	55 X 6 mm (GI)
Lighting Arrestor	25 X 3 mm (Copper)
PLC Panel	25 X 3 mm (Copper)
DG & Transformer Neutral	50X6 mm (Copper)
Transformer Body	50X6 mm (GI)
Control & Relay Panel	25 X 6 mm (GI)
Lighting Panel & Local Panel	25 X 6 mm (GI)

Distribution Board	25 X 6 mm (GI)
Motor up to 5.5 kw	4 mm2 (GI)
Motor 5.5 kw to 55 kw	25 X 6 mm (GI)
Motor 22 kw to 55 kw	40 X 6 mm (GI)
Motor Above 55 kw	55 X 6 mm (GI)

Size of Plate /Pipe/Strip for Earthing	
GI Plate	600 mm x600 mm x6 mm
CI Plate	600 mm x600 mm x12 mm.
Copper Plate	600 mm x 600 mm x 3.15 mm
GI Pipe	75 mm diameter, 10 feet long
GI Strip	30 mm X 10 mm

Size of Earthing Conductor (IS 3043 &Handbook on BS 7671)		
Area of Phase Conductor S (mm2)	**Area of Earthing conductor (mm2) When It is Same Material as Phase Conductor**	**Area of Earthing conductor (mm2) When It is Not Same Material as Phase Conductor**
S < 16 mm2	S	SX(k1/k2)
16 mm2<S< 35 mm2	16 mm2	16X(k1/k2)
S > 35 mm2	S/2	SX(k1/2k2)
K1 is value of Phase conductor,k2 is value of earthing conductor		
Value of K for GI=80, Alu=126,Cu=205 for 1 Sec		

Transformer Earthing Wire / Strip Size:		
Size of T.C or DG	**Body Earthing**	**Neutral Earthing**
<315 KVA	25x3 mm Cu / 40x6 mm GI Strip	25x3 mm Cu Strip
315 KVA to 500 KVA	25x3 mm Cu / 40x6 mm GI Strip	25x3 mm Cu Strip
500 KVA to 750 KVA	25x3 mm Cu / 40x6 mm GI Strip	40x3 mm Cu Strip
750 KVA to 1000 KVA	25x3 mm Cu / 40x6 mm GI Strip	50x3 mm Cu Strip

Earthing Strip for Sub-Station Equipment (CPWD-TABLE VIII)		
Type of Installation	**Earth Electrode**	**Earth Strip**
Indoor sub-station with HT panel, Transformer capacity up to 1600 KVA, LT panel, D.G Set.	Copper Plate	25 x 5 mm Copper Strip
Indoor sub-station with HT panel, Transformer capacity above 1600 KVA, LT panel, D.G Set	Copper Plate	32 x 5 mm Copper Strip
HT Outdoor sub-station	Copper Plate	25 x 5 mm Copper Strip
LT Indoor sub-station with generator	Copper Plate	25 x 5 mm Copper Strip
LT switch room with Main LT D.B	Copper Plate	20 x 3 mm Copper Strip

Neutral Earthing of Transformers and Generators (CPWD-TABLE VIII)		
Type of Installation	**Earth Electrode**	**Earth Strip for Neutral**
Transformer of capacity up to 1600 KVA	Copper Plate	25 x 5 mm Copper strip
Transformer of capacity above 1600 KVA	Copper Plate	32 x 5 mm Copper strip
Generating set of all capacity	Copper Plate	26 x 5 mm Copper strip

Earth Continuity Strip for Bus Trunking and Rising Main (CPWD-TABLE VIII)		
Type of Installation	**Material of Main Conductor**	**Earth Strip**
Bus trunking up to 2500 A capacity	Copper/ Aluminium	2 No 25 x 5 mm Copper Strip
Bus trunking above 2500 A capacity	Copper/ Aluminium	2 No 32 x 5 mm Copper Strip
Bus trunking for generating set and LT panel	Copper/ Aluminium	2 No 25 x 5 mm Copper Strip
Rising main up to 400 A capacity	Copper/ Aluminium	2 No 20 x 5 mm Copper Strip
Rising main above 400 A and up to 800 A	Copper/ Aluminium	2 No 20 x 3 mm Copper Strip

The Material and size of Protective conductors (As per CPWD)	
Size of phase conductor	**Size of protective conductor of the same material as phase conductor**
Up to 4 sq.mm.	Same size as that of phase conductor
Above 4 sq.mm. up to 16 sq.mm.	Same size as that of phase conductor
Above 16 sq.mm. up to 35 sq.mm.	16 sq.mm.
Above 35 sq.mm.	Half of the phase conductor

Materials and Sizes of Earth Electrodes (CPWD- TABLE IX)		
Type of Electrodes	**Material**	**Size**
Pipe	GI medium class	40 mm dia 4.50 m long (without any joint)
Plate	(i) GI	60 cm x 60 cm x 6 mm thick
	(ii) Copper	60 cm x 60 cm x 3 mm thick
Strip	(i) GI	100 sq. mm section
	(ii) Copper	40 sq. mm section
Conductor	(i) Copper	4 mm dia (8 SWG)
Note : Galvanization of GI items shall conform to Class IV of IS 4736 : 1986.		

Minimum Sizes of Earthing Conductors for Above Ground (CPWD- TABLE X)	
Material and Shape	**Minimum Size**
Round copper wire or copper clad steel wire	6 mm diameter
Stranded copper wire	50 sq. mm or (7/3.00 mm dia)
Copper strip	20 mm x 3 mm
Galvanized iron strip	20 mm x 3 mm
Round Aluminium wire	8 mm diameter
Aluminium strip	25 mm x 3 mm

Minimum Sizes of Earthing Conductors for Below Ground (CPWD- TABLE XI)	
Material and Shape	**Minimum Size**
Round copper wire or copper clad steel wire	8 mm diameter
Copper strip	32 mm x 6 mm
Round galvanized iron wire	10 mm x 6 mm
Galvanized iron strip	32 mm x 6 mm

Selection of Type of Earthing Electrodes (CPWD)	
Type of electrode	**Application**
GI pipe	Internal electrical installations like Distribution Board and Meter Boards (in residential quarters), feeder pillars and poles etc.
GI plate	(i) For Fire Fighting pumps and water supply pumps.
	(ii) Lightning conductors.
Copper plate	Neutral earthing of transformers/ generating sets.
Strip/ Conductor	Locations where it is not possible to use other types.

Number of Earth Electrodes (CPWD)	
Equipment's	**No of Earthing**
For neutral earthing of each transformer	**2 sets**
For body earthing of all the transformers,	**2 sets**
HT/LT Panels and other electrical equipment	
in the Sub-station/ power house	
For neutral earthing of each generating set	**2 sets**
For body earthing of all the generating sets,	**2 sets**
LT panels, other electrical equipment in the generator room	

Size of protective conductor (As per CPWD)	
Size of phase conductor	**Size of protective conductor of the same material as phase conductor**
Up to 16 sq.mm.	Same as Phase Conductor Size
16 to 35 sq.mm.	16 sq.mm.
35 sq.mm	Half Size of Phase Conductor

Weight per Meter for GI Earthing Strip:	
Size (mm2)	**Weight**
20 x 3	500 gm Per meter
25 x 3	600 gm Per meter
25 x 6	1/200 Kg Per meter
32 x 6	1/600 Kg Per meter
40 x 6	2 Kg Per meter

50 x 6	2/400 Kg Per meter
65 x 10	5/200 Kg Per meter
75 x 12	7/200 Kg Per meter

Weight per Meter for GI Earthing Plate:

Plate	Weight
600 x 600 x 3 mm	10 Kg App.
600 x 600 x 4 mm	12 Kg App.
600 x 600 x 5 mm	15 Kg App.
600 x 600 x 6 mm	18 Kg App.
600 x 600 x 12 mm	36 Kg App.
1200 x 1200 x 6 mm	70 Kg App.
1200 x 1200 x 12 mm	140 Kg App.

Weight of GI Earthing Pipe:

Pipe	Weight
3 meter Long BISE	5 Kg App.
3 meter r Long BISE	9 Kg App.
4.5 meter (15' Long BISE)	5 Kg App.
4.5 meter (15' Long BISE)	9 Kg App.
4.5 meter (15' Long BISE)	14 Kg App

Weight of GI Earthing Wire:

Plate	Weight
6 Swg	5 meter in 1 Kg
8 Swg	9 meter in 1 Kg

Weight of G.I. wire (Steel Tube India)

Guage Gms.	mm	Weight Kg / Meter.
4	5.892	0.216
6	4.876	0.148
8	4.064	0.103
10	3.251	0.066
12	2.641	0.045
14	2.032	0.026
16	1.625	0.017

Weight of G.I Flat Strip

Sizes in (HxW)	Kgs/Per meter	Application
20x3 mm	0.49	Lighting Arrestor
20x6 mm	0.98	PLC Panel
25x3 mm	0.6	
25x5 mm	0.97	
25x6 mm	1.3	Control & Relay Panel
32x5 mm	1.21	Lighting Panel & Local Panel
32x6 mm	1.625	Distribution Board
40x3 mm	0.964	Motors 5.5kw-55Kw
40x5 mm	1.476	
40x6 mm	1.92	HT switchgear, structures, cable trays & fence, rails, gate and steel column
50x3 mm	1.28	
50x5 mm	1.92	
50x6 mm	2.56	
50x10 mm	4	Transformers Substations
62x6 mm	3.07	
65x10 mm	5.2	
75x10 mm	6	
75x12 mm	7.2	

Hot dip galvanization. (IS 2629)

Product	Minimum thickness	Min. Average Mass of Coating (g/m2)
MS flats 5mm thick & over	75 microns	610
MS flats under 5mm thickness	60 microns	460

Pipes/ conduits with thickness & over 5 mm	75 microns	610
Pipes/ conduits with thickness under 5mm	60 microns	460
GI Wire	20 Microns	150 gms. / sq. mtr.

Mass of Zinc Coating: IS 4759: 1996 (Table 1)

Product	Min. Average Mass of Coating (g/m2)	Minimum thickness
Castings-grey iron, malleable iron	610	86.32 microns
5 mm thick and over Fabricated steel	610	86.32 microns
2 to 5 mm thick Fabricated steel	460	65.09 microns
1.2 to 2 mm thick Fabricated steel	340	48.11 microns
Threaded work other than tubes and tube fittings		
(a) 10 mm dia and over	300	42.45 microns
(b) Under 10 mm dia	270	38.21 microns

OVERLAPING OF EARTHING STRIP

Size of Earthing Strip	Minimum Over Lapping
20x3	20MM
20x6	20MM
25x3	25MM
25x6	25MM
32x6	25MM
40x5	50MM
40x6	50MM
50x6	50MM
50x10	50MM
75x6	50MM
75x10	50MM

NO'S AND SIZE OF NUT BOLT FOR JOINTING EARTHING STRIP

Size of Earthing Strip	Minimum Nut Bolt Required	Minimum Size of Nut Bolt
20x3	2 NO'S	8X25MM
20x6	2 NO'S	8X25MM
25x3	2 NO'S	8X25MM
25x6	2 NO'S	8X25MM
32x6	2 NO'S	8X25MM
40x5	4 NO'S	8X25MM
40x6	4 NO'S	8X25MM
50x6	4 NO'S	10X25MM
50x10	4 NO'S	10X25MM
75x6	4 NO'S	10X25MM
75x10	4 NO'S	10X25MM

Earthing Points (As per CPWD)

Earthing	Description
Location for Earth Electrodes	Normally an earth electrode shall not be located closer than 1.5 m from any building.
Installation of Pipe	Pipe electrode shall be buried in the ground vertically with its top at not less than 20 cm below the ground level
Installation of Plate	Plate electrode shall be buried in ground with its faces vertical, and its top not less than 3.0 m below the ground level.
The strip or conductor	The strip or conductor electrode shall be buried in trench not less than 0.5 m deep
More Earthing Electrode	When more than one electrode (plate/pipe) is to be installed, a separation of not less than 2 m shall be maintained between two adjacent electrodes.
Earthing Electrode	If the electrode cannot be laid in a straight length, it may be laid in a zigzag manner with a deviation upto 45 degrees from the axis of the strip. It can also be laid in the form of an arc with curvature more than 1 m or a polygon
Earthing Pit Cover	A cast iron / MS frame with MS cover, 6 mm thick, and having locking arrangement shall be suitably embedded in the masonry enclosure.

Earthing Wire Protection	The earthing conductor from the electrode up to the building shall be protected from mechanical injury by a medium class, 15 mm dia. GI pipe in the case of wire, and by 40 mm dia, medium class GI pipe in the case of strip. The protection pipe in ground shall be buried at least 30 cm deep (to be increased to 60 cm in case of road crossing and pavements)
No of Earthing Conductor	Two protective conductors shall be provided for a switchboard carrying a 3-phase switchgear thereon.
Earthing Electrode	No earth electrode shall have a greater ohmic resistance than 5 ohms as measured by an approved earth testing apparatus. In rocky soil the resistance may be up to 8 ohms.
Earthing Resistance	Each of the earth stations should have a resistance not exceeding the product given by 10 ohms multiplied by the number of earth electrodes to be provided therein. The whole of the lightning protective system, including any ring earth, should have a combined resistance to earth not exceeding 10 ohms without taking account of any bonding
More Earthing Resistance	If the value obtained for the whole of the lightning protection system exceeds 10 ohms, a reduction can be achieved by extending or adding to the electrodes, or by interconnecting the individual earth terminations of the down conductors by a conductor

Size and Practice of Plate / Pipe Earthing	
Plate Earthing Electrode	For copper = 600X600X31mm and
	For Hot dip GI =600X600X63mm.
Pipe Earthing Electrode.	Earthing electrode shall consist of a GI pipe (class B of approved make), not less than 40 mm dia. and 3 meters long.
	CL pipe electrode shall be cut tapered at the bottom and provided with holes of 12 mm dia. drilled at 75 mm interval up to 2.5 meters length from bottom
	The electrode shall be buried vertically in the ground as far as practicable below permanent moisture level, but in any case not less than 3 meters below ground level
	The electrode shall be in one piece and no joints shall be allowed in the electrode.
Size of Excavation:	Size of 1 meter diameter and 3 meter length shall be excavated after depth of 3 meter the size of excavation shall be 900X300X900mm depth.
	Plate / Pipe Electrode shall be in vertical position.
	GI/PVC pipe for Watering shall be used of 40mm Diameter, length of 3 meter (contain hole of 12mm Diameter in Zigzag manner starting from 15cm away from bottom to 2 meter height).
	At bottom 150mm layer of Salt and charcoal power shall be installed than Plate shall be installed.
	Alternate layer of 150mm of Salt and charcoal power shall be used up to 2.5 meter.
	Min 120kg of charcoal power and 120kg of salt shall be used for each earthing pit.
	The plate \ pipe electrode, as far as practicable, shall be buried below permanent moisture level but in no case not less than 2.5 M below finished ground level.
	The Copper plate earthing shall be buried deep in the ground with its face vertically and top not less than **3 meters below ground**
Chamber & Frame	A cast iron/MS frame with cover having locking equipment shall be suitable embedded in the brick masonry to protect the watering arrangement (funnel with mesh and 20 mm diameter G.I. pipe of medium class quality fixed on the top of the electrode) and the earth pit from mechanical damages
	The brick masonry and closures should be not less than 30 cms X 30 cms X 30 cms. Layers of charcoal/coke and salt are to be made in the earth pit after putting the electrode in its place.
Earth Resistance	3. No earth electrode should have a resistance more 10 three ohms measured by an earth resistance meter. In rocky soil the resistance may be up to 8 ohms.
Plate Earthing	Earthing electrode shall consist of plate, not less than **600 mm x 600 mm x 12 mm thick.** The plate electrode shall not be buried less than 3 metersbelow ground level.
	Earth electrodes shall not be installed in proximity to a metal fence. Itshall be kept clear of the buildings foundations and in no case it shallbe nearer than 2 meters from the outer face of the wall
	The earthplate shall be set vertically and surrounded with 150 mm thick layer of Charcoal dust and salt mixture. 20 mm GI pipe shall run from the topedge of the plate to the ground level.
	The top of the pipe shall beprovided with a G.I. threaded cap for watering the earth through apipe. The G.I. cap over the GI pipe shall be housed in a masonrychamber, approximately

	300 mm x 300 mm x 300 mm deep. Themasonry chamber shall be provided with a cast iron inspection coverresting over a GI frame, embedded in masonry.
Pipe Earthing	Earthing electrode shall consist of a CI pipe (class B), not less than 40 mm dia. and 3 meters long. CL pipe electrodeshall be cut tapered at the bottom and provided with holes of 12 mmdia. drilled at 75 mm interval up to 2.5 meters length from bottom.
	The electrode shall be buried vertically in the ground but in any case not less than 3 meters below ground level. The electrode shall be in one piece and no joints.
	Earth electrode shall not be nearer than 2 meters from the outer face of the wall.The pipe earth electrode shall be kept vertically and surrounded with150mm thick layer of charcoal dust and salt mixture up to a height of2.5 meters from the bottom.
	At the top of the electrode a G.I. threaded cap shall be provided for watering the earth. The main earth conductors shall be connected to the electrode just below the G.I cap, with proper terminal lugs and check nuts. The G.I. cap over the CL pipe and earth connection shall be housed in a masonry chamber, approximately 300 mm length x 300 mm wide and 300 mm deep.
	The masonry chamber shall be provided with a cast iron inspection coverresting over a C.I. frame, embedded in masonry.

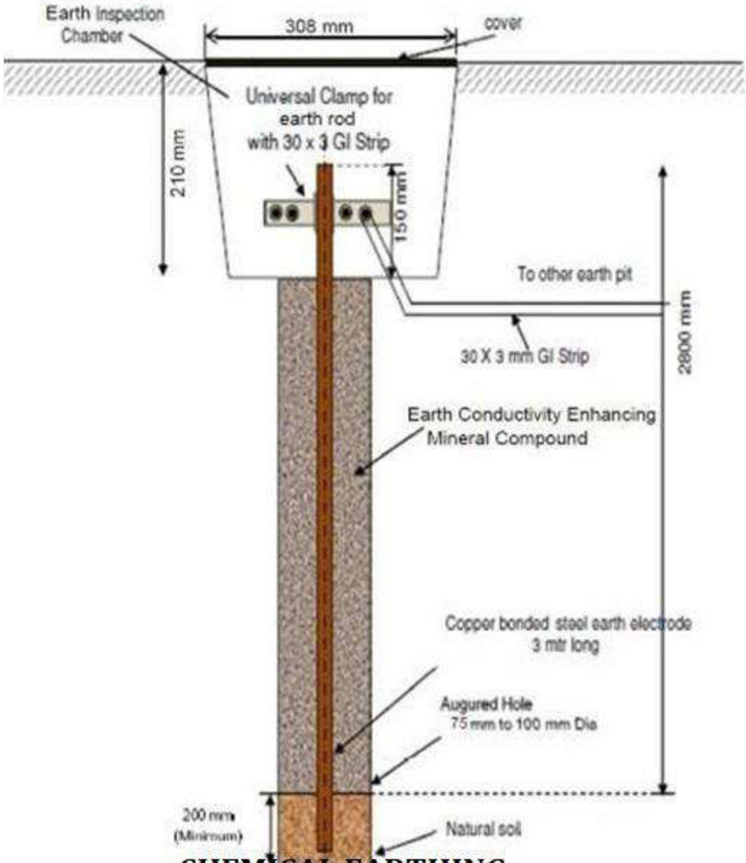
Earthing Practice -As per IS: 3043	
Earthing Seperation	All medium voltage equipment shall be earthed by two separate and distinct connections with earth In the case of high.
Neutral Earthing	And extra high voltage the neutral points shall be earthed by not Less than two separate and distinct connections with earth, each having its own electrode at the generating station or substation and may be earthed at any other point provided 'no interference is caused by such earthing.
	If necessary, the neutral may be earthed through suitable impedance.
	Earthed or earthed neutral conductor and the live conductors shall be inserted on any supply System. This however does not include the case of a switch for use in controlling a generator or a transformer or a link for test purposes.
	In cases where direct earthing may prove harmful rather than provide safety (for example, high frequency and main. frequency coreless induction furnaces). Relaxation may be obtained from the competent authority.
Visibility of Earthing	As far as possible, all earth connections shall be visible for inspection.
Cut Out / Link	No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the Link
Grounding	Grounding is not likely to reduce the total magnitude of over-voltage produced by lighting or switching surges. It can, however, distribute the voltage between phases and reduce the possibility of excessive voltage stress on the phase-to-ground insulation of a particular phase.
Plate Earthing	Plate electrodes shall be of the size at least 60 c m X 60 cm, Plates are generally of cut iron not less than 12 mm thick and preferably ribbed. The earth connection should be joined to the plate at not less than two separate points. Plate electrodes, when made of GI or steel, shall be not less than 63 mm in thickness.
	Plate electrodes of Cu shall be not less than 3.15 mm in thickness.
	Plate electrodes shall be buried ouch that ii. Top edge is at a depth not less than 15m from the surface of the ground. However, the depth at which plates are set should be such as to ensure that the surrounding soil is always damp
Pipe Earthing	Pipes may be *of* cast iron of not less than 100mm diameter, 2.5 to 3 m long and 13 mm thick. Such pipes cannot be driven satisfactorily and may, therefore, be more expensive to install than plates for the same effective Area. Water pipes shall not be use as consumer earth electrodes.
Under fault conditions	Under fault conditions, the earth electrode is raised to a potential with respect to the general mass of the earth that can be calculated from the prospective fault current and the earth resistance of the electrode. The results in the existence of voltage. In the soil around the electrode, that may be injurious to telephone and pilot cables, whose cores are substantially at earth potentional, owing to the voltage to which the sheaths of such cables are raised
The voltage gradient	The voltage gradient at the surface of the ground may also constitute a danger to life, especially where cattle are concerned. The former risk arises mainly in connection with large elect rode systems as at power stations and substation.
Earth electrodes	Earth electrodes, other than the used for the earthing of the fence itself, should not be installed In proximity to a metal fence to avoid the possibility of the fence becoming live

	and thus. Dangerous at points remote from the substation. The materials used for making connections have to be compatible with the earth rod and the copper earthing conductor so that galvanic corrosion is minimized. In all cases, the connections have to be mechanically strong.
cross-sectional	The cross-sectional area of every protective conductor which does not form part of the supply cable or cable enclosure shall be in any case, not less than **2.5 mm2,** if mechanical protection is provided and **4 mm2,** if mechanical protection ii not provided. Joints of protective conductors shall be accessible for inspection and testing except m compound-filled or encapsulated joints. No switching device .hall is inserted in the protective conductor, but joints which can be disconnected for test purposes by use of a tool may be provided.
	In TN systems, for cables in fixed installations having a cross sectional area not less than 10 mm2 for copper and 16 mm2 for aluminum, a single conductor may serve both as protective conductor and neutral conductor, provided that the part of the installation concerned is not protected by a residual current-operated device. However, the minimum cross sectional area of a PEN conductor may be 4 mm2, provided that the cable is of a concentric type conforming to Indian Standards and that duplicate continuity connections exist at all joints and terminations in the run of the concentric conductors.
Auxiliary earth electrode	An auxiliary earth electrode shall be provided electrically' independent of all other earthed metal, for example, constructional metalwork, pipers, or metal-sheathed cables. This requirement i. considered to be fulfilled if the auxiliary earth electrode is installed at a specified distance from all other earthed metal (value of distance under consideration).
	The earthing conductor leading to the auxiliary earth electrode shall be isolated to avoid contact with the protective conductor or any of the parts connected thereto or extraneous conductive parts which are, or may be, in contact with them
Earthing Strip	Size of GI Strip: 300mmX10mm Size of GI Pipe: 2.5" Diameter
IR Value	Minimum 1Ω Resistance should be available at a distance of 15mt. IR value of Earth resistance is less than 10Ω. Earthing Res.of earthing rod is very from 0.3Ω to 0.8Ωbetween summer to winter
	If ground resistance is less than plate earthing (if hard rock) than Pipe earthing shall be used. Resistance between two earthing pit is negligible. Earthing of lighting protection should not mix with power system earthing. Lighting protection earhing should be 10 time stronger than normal earthing (use copper bus strip instend of wire) Jointing of earthing strip shall be overlap of min 50mm and for earthing wire overlapping shall be min 40mm
Distance between two Earthing Pit	Distance between two earthing pit is 2 X Length of earthing electrode.
Plate Size	GI/Copper Plate Size: 500mmX500mmX10mm. Wood coal powder and salt are in same quantity.
RCD	RCD's Having Minimum Operating Currents Greater Than 30 mA - These devices are intended to give indirect shock risk protection. The neutral points of each separate electricity system which has to be earthed at the power station or substation.

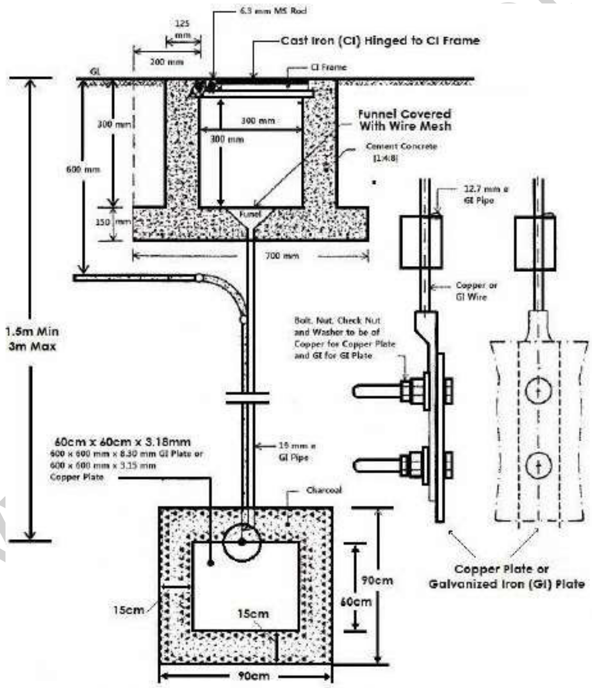
Size of Plate / Pipe Earthing	
Plate Earthing Electrode	For copper = 600X600X31mm and
	For Hot dip GI =600X600X63mm.
Pipe Earthing Electrode.	Earthing electrode shall consist of a GI pipe (class B of approved make), not less than 40 mm dia. and 3 meters long.
	CL pipe electrode shall be cut tapered at the bottom and provided with holes of 12 mm dia. drilled at 75 mm interval up to 2.5 meters length from bottom
	The electrode shall be buried vertically in the ground as far as practicable below permanent moisture level, but in any case not less than 3 meters below ground level
	The electrode shall be in one piece and no joints shall be allowed in the electrode.
Size of Excavation:	Size of 1 meter diameter and 3 meter length shall be excavated after depth of 3 meter the size of excavation shall be 900X300X900mm depth.
	Plate / Pipe Electrode shall be in vertical position.

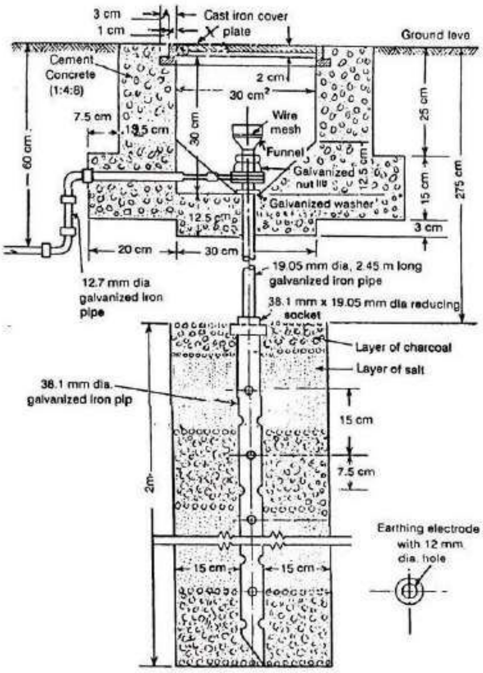
	GI/PVC pipe for Watering shall be used of 40mm Diameter, length of 3 meter (contain hole of 12mm Diameter in Zigzag manner starting from 15cm away from bottom to 2 meter height).
	At bottom 150mm layer of Salt and charcoal power shall be installed than Plate shall be installed.
	Alternate layer of 150mm of Salt and charcoal power shall be used up to 2.5 meter.
	Min 120kg of charcoal power and 120kg of salt shall be used for each earthing pit.
	The plate \ pipe electrode, as far as practicable, shall be buried below permanent moisture level but in no case not less than 2.5 M below finished ground level.

Earthing (As per CPWD)
Type of earthling are Pipe earthling/Plate earthling/Strip earthling.
Length of Buried strip shall not be less than 15 meter.
Two copper strip, each size 50mmX5mm shall be provided as each bus bar in 11KV S/S or D.G generally.
Each strip should be connected separately to earth.
2no of Body earthling of T/C,Panel,D.G are connected to earth Bus.
Neutral Leads of T/C,D.G shall not be connected to earth Bus.
The minimum Cross-section are of protective conductor (Not contained within cable or wire) 2mm Dia(14SWG) for Copper, 2.5mm Dia(12SWG) for G.I, 2.24mm Dia(13SWG) for Aluminum.
Earthing Pit shall not be closer than 1.5meter from Building.
Top of Pipe earthling electrode shall not be less than 20cm below the ground
Plate electrode shall be buried in ground with face vertical and it's Top not less than 3meter below ground level.
The strip of earthling electrode shall be buried in trench not less than 0.5m deep.
If strip electrode cannot be laid in straight length. It may be Zigzag with deviation up to 45 Degree from axis of strip.
In Plate Earthing Dia of water pipe shall not be less than 20mm and in Pipe earthling reducer of 40mmX20mm shall be used.
Earthing Pit Size shall be not less than 30cmX30cmX30cm.
Thickness of MS cover of earthling pit shall be not less than 6mm and having locking arrangements.
Earthing resistance of each electrode shall be less than 5Ω and for Rocky Soil not less than 8Ω
Earthing conduit for earthling wire shall be Medium class 15mm Dia GI pipe and for Earthing Strip shall be medium class 40mm Dia GI Pipe.



CHEMICAL EARTHING





Chapter: 9 Electrical Room / Substation / Fense Reference

IEC 61936-1	
DOOR:	Doors shall have a fire resistance of at least 60 minutes
	Doors which open to the outside are adequate if they are of fire-retardant material and construction
	Ventilation openings necessary for the operation of the transformers are permitted
	When designing the openings, the possible escape of hot gases shall be considered
	The doors of switchgear cubicles or bays should close in the direction of escape.
Length of Escape Route in Electrical Room	Exits shall be arranged so that the length of the escape route within the room does not exceed 40 m for installation of rated voltages Um greater than 52 kV, and 20 m for installation of rated voltages up to Um = 52 kV. This does not apply to accessible bus ducts or cable ducts
	Permanently installed ladders or similar are permissible as emergency exits in escape routes.
No of Door	If an operating aisle does not exceed 10 m, one exit is enough. An exit or emergency possibilities shall be provided at both ends of the escape route if its length exceeds 10 Meter
Service areas	Service areas comprise aisles, access areas, handling passages and escape routes
	Aisles and access areas shall be adequately dimensioned for carrying out work, operating switchgear and transporting equipment.
	Aisles shall be at least 800 mm wide. The width of the aisles shall not be reduced even where equipment projects into the aisles, for example permanently installed operating mechanisms or switchgear trucks in isolated positions.
	Space for evacuation shall always be at least 500 mm, even when removable parts or open doors, which are blocked in the direction of escape, intrude into the escape routes. For erection or service access ways behind closed installations (solid walls), a width of 500 mm is sufficient.
Windows	Windows shall be designed so that entry is difficult. This requirement is considered fulfilled if one or more of the following measures are applied
	The window is made of unbreakable material.
	The window is screened
	The lower edge of the window is at least 1.8 Meter above the access level
	The building is surrounded by an external fence at least 1.8 Meter high.
External fences or walls and access doors	Unauthorized access to outdoor installations shall be prevented. Where this is by means of external fences or walls, the height and construction of the fence/wall shall be adequate to deter climbing.
	Height and construction of the fence/wall shall be adequate to deter climbing.
	The external fence/wall shall be at least 1 800 mm high. The lower edge of a fence shall not be more than 50 mm from the ground.
	Access doors to outdoor installations shall be equipped with security locks.
	External fences/walls and access doors shall be marked with safety signs
	Any adjacent fences, other structures and trees outside the installation should also deter climbing.

IS 3034: 1993 / IS 12459	
Cable Entry	All cable entries in the switch gear room shall be effectively sealed by use of fire stops

Section 50A in The Indian Electricity Rules, 1956	
FIRE BARRIER	No other service pipes shall be taken along the ducts provided for laying power cables. All ducts provided for power cables and other services shall be provided with fire-barrier at each floor crossing

4.2-Substations and Switch Rooms (NATIONAL BUILDING CODE 2016)	

At Basement	Location of substation in the basement should be avoided, as far as possible.
Only One Basement	In case there is only one basement in a building, the substation/switch room shall not be provided in the basement.
	Also, the floor level of the substation shall not be lowest point of the basement.
Central of Load Centre	Ideal location for an electrical substation for a group of buildings will be at the electrical load centre.
	Generally the load centre will be somewhere between the geometrical centre and the air conditioning plant room, as air conditioning plant room will normally be the largest load, if the building(s) are centrally air conditioned.
Prevention of Strom Water / Water seepages	In order to prevent storm water entering the transformer and switch rooms through the soak pits, the floor level of the substation/ switch room shall be **at least 300 mm above the highest flood water level** that may be anticipated in the locality.
	Also, facility shall be provided for automatic removal of water.
Not Above Water Tank / Sewage Plant	Substation shall not be located immediately above or below plumbing water tanks or sewage treatment plant (STP) water tanks at the same location.
Sub Station Door	All door openings from substation, electrical rooms, etc, should open outwards.
	Vertical shutters (like fire rated rolling shutters) may also be acceptable provided they are combined with a single leaf door opening outwards for exit in case of emergency
	For large substation room/electrical room having multiple equipment, two or more doors shall be provided which shall be remotely located from each other
More Distance between Transformer and HT Panel	In case of HV panel and Transformers located at different floors or at a distance more than **20 Meter**, HV isolator shall be provided at transformer end
More Distance between Transformer and MV/LV Panel	In case transformer and main MV/LV panel room are located at different floors or are at a distance more than **20 Meter** , MV/LV isolator shall be provided at transformer end. In case transformer and main MV/LV panel room are located at different floors, the designer should also take care of the safety requirements caused by lack of direct visibility of the status of the controlling switch. To cater to the safety requirements under different conditions of operation as well as maintenance, it may be necessary to provide additional isolator or an emergency push button in the vicinity to trip the supply. Decision has to be taken based on the possible risks.
HT CABLE / HT Services	The power supply HV cables voltage shall not be more than 12 kV and a separate dedicated and fire compartmented shaft should be provided for carrying such high voltage cables to upper floors in a building. These shall not be mixed with any other shaft and suitable fire detection and suppression measures shall be provided throughout the length of the cable on each floor.
	Horizontal routing of HT cable through functional/occupied areas should be avoided in view of safety.
	Wherever transformers are planned at higher floors, the HT cables shall be routed through a separate shaft having its own fire resistance rating of 120 min. Wherever HT generators are planned centrally at ground or first basement level, redundant transformers and HT cables shall be planned for buildings above 60 Meter in height.
No Shaft Opening in Sub Station Room	No services or ventilation shafts shall open into substation or switch room unless specific to substation or switch room.
Derating Factor	If substation is located at a height 1000 Meter above MSL, then adequate derating of equipment shall be considered.
Electrical Room	The minimum height of the substation/HV switch room/MV switch room shall be arrived at **considering 1200 mm clearance** requirement from the top of the equipment to the below of the soffit of the beam.

	For all buildings above 15 Meter in height and in special occupancies, like educational, assembly, institutional, industrial, storage, hazardous and mixed occupancies with any of the aforesaid occupancies having area more than 500 Sq. Meter on each floor, provision shall be made for an independent and ventilated meter (service) room, as per requirements of electric (service) supply undertakings on the ground floor with direct access from outside for the purpose of termination of electric supply from the licensees service and alternative supply cables. The door/doors provided for the service room shall have fire resistance of not less than two hours.
Cable Trench	In case of cable trench in substation/HV switch room/MV switch room, the same shall be adequately drained to ensure no water is stagnated at any time with live cables
Power supply to emergency fire and life safety systems	Emergency power supplying distribution system for critical requirement for functioning of fire and life safety system and equipment (i) Fire pumps; (ii) Pressurization and smoke venting systems including dampers and actuators (iii) **Fireman's lifts (including all lifts).** (iv) Exit signage lighting; (v) Emergency lighting; (vi) Fire alarm system; (vii) Public address (PA) system (viii)Magnetic door hold open devices; and (ix) Lighting in fire command centre and security room.
Cables for fire alarm and PA system	Cables for fire alarm and PA system shall be laid in metal conduits or armoured to provide physical segregation from the power cables.
Stand By Supply (D.G Set)	Diesel generator set(s) shall not be installed at any floor other than ground Floor or below first basement. In case of DG set located in basement, the ceiling of the DG room shall be the ground floor slab. It is preferable If the same are installed indoors, proper ventilation and exhaust shall be planned. The DG set room shall be separated by 120 min fire resistance rated walls and doors.
	electrical supply, present at the time of fire. The height of diesel generating (DG) set rooms shall however be not more than 3 000 mm above the DG set height, unless required due to DG room ventilation requirements
	The oil tank for the DG sets (if not in the base of the DG) shall be provided with a enclosure having a volumetric capacity of at least 10 percent more than the volume of the oil tank. The enclosure shall be filled with sand for a height of 300 mm.
Location of MV/LV Switch Room Other than in Substation	provided, a separate switch room shall be provided this shall be located as close to the electrical load centre as possible, on the ground floor or on the first basement level of the building.
Substation Safety	Enclose any part of the substation which is open to the air, with a fence (earthed efficiently at both ends) or wall not less than 1 800 mm (preferably not less than 2 400 mm) in height to prevent, so far as is reasonably practicable, danger of electric shock or unauthorized access;
Supply Company High Voltage Meter Board (HTMC PANEL)	Suitable isolating device fixed in a conspicuous position at not more than 1.7 m above the ground so as to completely isolate the supply to the building in case of emergency.
HV Cables	When HV cable is hanging/running below the basement ceiling slab, the cable shall be laid in a fire rated enclosure/ cable tray.
Transformers	The total installed transformer capacity shall be at least 15 to 20 percent higher than the anticipated maximum demand

Section 64 in The Indian Electricity Rules, 1956	
Where it is necessary to locate the sub-	The room shall necessarily be in the first basement at the periphery of the basement.

station/switch station in the basement following measures shall be taken	The entrances to the room shall be provided with fire resisting doors of 2 hours fire rating. A curb (sill) of a suitable height shall be provided at the entrance in order to prevent the flow of oil from a ruptured transformer into other parts of the basement. Direct access to the transformer room shall be provided from outside.
	The transformer shall be protected by an automatic high velocity water spray system or by carbon dioxide or BCF(Bromo chlorodi feuromethane) or BTM (Bromo trifluro methane) fixed installation system;
	Oil filled transformers installed indoors shall not be on any floor above the ground or below the first basement.]
	A sub-station or a switch station with apparatus having more than 2000 litres of oil shall not be located in the basement where proper oil draining arrangement cannot be provided.

Standard Meter Room Size (GERC):	
Meter Box Height	Upper level does not beyond 1.7 meter and Lower level should not below 1.2 meter from ground.
Facing of Meter Box	Meter Box should be at front area of Building at Ground Floor.
Meter Room / Closed Shade	4 meter square Size

Sub Station Guideline (As per NBC)	
Substation Location	Location of substation in the basement should be avoided, as far as possible.
	If there is only one basement in a building, the substation/switch room shall not be provided in the basement and the floor level of the substation shall not be lowest point of the basement.
	Substation shall not be located immediately above or below plumbing water tanks or sewage treatment plant (STP) water tanks at the same location
Substation Door/Shutter	All door openings from substation, electrical rooms, etc, should open outwards
	Vertical shutters (like rolling shutters) may also be acceptable provided they are combined with a single leaf door opening outwards for exit in case of emergency
	For large substation room/electrical room having multiple equipment, two or more doors shall be provided which shall be remotely located from each other
	No services or ventilation shafts shall open into substation or switch room unless specific to substation or switch room
Transformer Location	In case of HV panel and transformers located at different floors or at a distance more than 20 m, HV isolator shall be provided at transformer end
	In case transformer and main MV/LV panel room are located at different floors or are at a distance more than 20 m, MV/LV isolator shall be provided at transformer end
	In case of two transformers (dry type or transformers with oil quantity less than 2 000 liter) located next to each other without intermittent wall, the distance between the two shall be minimum 1 500 mm for 11 kV, minimum 2 000 mm for 22 kV and minimum 2 500 mm for 33 kV. Beyond 33 kV, two transformers shall be separated by baffle wall of 4 h fire rating.
	If dry type transformer is used, it may be located adjacent to medium voltage switchgear in the form of unit type substation. In such a case, no separate room or fire barrier for the transformer is required either between transformers or between transformer and the switchgear, thereby decreasing the room space requirement; however, minimum distances as specified.
Oil Filled Equipment (Transformer / C.B)	Substations with oil-filled equipment/apparatus transformers and high voltage panels shall be either located in open or in a utility building
	They shall not be located in any floor other than the ground floor or the first basement of a utility building not be located below first basement slab of utility building.
	They shall have direct access from outside the building for operation and maintenance of the equipment.
	It shall be separated from the adjoining buildings including the main building by at least 6 m clear distance to allow passage of fire tender between the substation/utility building and adjoining building/main building.
	Substation equipment having more than 2 000 liter of oil whether located indoors in the utility building or outdoors shall have baffle walls of 4 h fire rating between apparatus.
	Provision of suitable oil soak-pit, and where use of more than 9 000 liter of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tank, receptacle or chamber containing

	the same
Power Supply Voltage	supply is at 240 V single phase up to 5 kVA, 415/240 V 3-phase from 5 kVA to 100 kVA, 11 kV (or 22 kV) for loads up to 5 MVA and 33 kV or 66 kV for consumers of connected load or contract demand more than 5 MVA.
	In case of connected load of 100 kVA and above, the relative advantage of high voltage three-phase supply should be considered.
	In case of single point high voltage metering, energy meters shall be installed in building premise,such a place which is readily accessible to the owner/operator of the building and the Authority. The supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device fixed in a conspicuous position at not more than 1.7 m above the ground so as to completely isolate the supply to the building in case of emergency
Trench Drain	In case of cable trench in substation/HV switch room/MV switch room, the same shall be adequately drained to ensure no water is stagnated at any time with live cables.
Fence for Substation	Enclose any part of the substation which is open to the air, with a fence (earthed efficiently at both ends) or wall not less than 1800 mm (preferably not less than 2400 mm) in height
HV Distribution in Building	The power supply HV cables voltage shall not be more than 12 kV and a separate dedicated and fire compartmented shaft should be provided for carrying such high voltage cables to upper floors in a building. These shall not be mixed with any other shaft and suitable fire detection and suppression measures shall be provided throughout the length of the cable on each floor.
Switch Room / MV switch room	Switch room / MV switch room shall be arrived at considering 1200 mm clearance requirement from top of the equipment to the below of the soffit of the beam .In case cable entry/exit is from above the equipment (transformer, HV switchgear, MV switchgear), height of substation room/HV switch room/MV switch room shall also take into account requirement of space for turning radius of cable above the equipment height.

SAFETY MEASURES IN ELECTRIC SUB-STATION

Model Building-Bye-laws-2016, Urban Development, Government of India

Clause	Description
7.19.1	Clear independent approach to the sub-station from outside the building shall be made available round the clock
7.19.2	The approaches/corridors to the sub-station area shall be kept clear for movement of men and material at all times.
7.19.5	Cable trenches of 0.6 m. X 0.6 m. dummy floor of 0.6 mt. depth shall be provided to facilitate laying of cable inside the building for connecting to the equipment.
7.19.6	Steel shutters of 8'X 8' with suitable grills shall be provided for transformers and sub-station room.
7.19.7	The floor of the sub-station should be capable of carrying 10 tons of transformer weight on wheels.
7.19.9	Sub-station space should be clear from any water, sewer, air conditioning, and gas pipe or telephone services. No other service should pass through the sub station space or the cable trenches.
7.19.10	Proper ramp with suitable slope may be provided for loading and unloading of the equipment and proper approach will be provided.
7.19.11	RCC pipes at suitable places as required will be provided for the cable entries to the sub station space and making suitable arrangement for non-ingress of water through these pipes
7.19.14	Adequate arrangement for fixing chain pulley block above the fixing be available for load of 15 tons.
7.19.16	Arrangement should be made for the provision of fire retardent cables so as to avoid chances of spread of fire in the sub-station building.
7.19.17	Sufficient pumping arrangement should exist for pumping the water out, in case of fire so as to ensure minimum loss to the switchgear and transformer.
7.19.18	No combustible material should be stacked inside the substation premises or in the vicinity to avoid chances of fire.
7.19.19	The sub-station must not be located below the 1st basement and above the ground floor.

7.19.21	The sub station space should be totally segregated from the other areas of the basement by fire resisting wall. The ramp should have a slope of 1 : 10 with entry from ground level. The entire Sub-station space including the entrance at ground floor be handed over to the licensee of electricity free of cost and rent.
7.19.22	The sub-station area shall have a clear height of 12 feet (3.65 m.) below beams. Further the Sub-station area will have level above the rest of basement level by 2 feet.
7.19.23	It is to be ensured that the Sub-station area is free of seepage / leakage of water.
7.19.26	The Sub-station should be located on periphery /sub basement and (not above ground floor).
7.19.27	Additional exit shall be provided if travel distance from farthest corner to ramp is more than l5 m.
7.19.28	Perfect independent vent system 30 air changes per hour linked with detection as well as automatic high velocity water spray system shall be provided.
7.19.29	All the transformers shall be protected with high velocity water spray system / Nitrogen Injection System Carbon Dioxide total flooding system in case of oil filled transformer. In addition to this, manual control of auto high velocity spray system for individual transformers shall be located outside the building at ground floor.
7.19.34	Cable trenches shall be filled with sand
7.19.35	Party walls shall be provided between two transformers as per the rules.
7.19.36	Electric control panels shall be segregated.
7.19.37	Exits from basement electric substation shall have self-closing fire smoke check doors of 2-hours fire rating near entry to ramp.

Indian Electricity Act, 1910 And Indian Electricity -Rules, 1956 RULE 68(b)	
Fence	In the case of outdoor type of sub-station, a metallic fencing of not less than 1.8 m height shall be erected around the transformer.

BS 1722-10:2019	
Fence	Anti-intruder fences in chain link and welded mesh for anti-intruder chain link or welded mesh fences and gates of at least 2.4 m in height for situations that require a higher level of protection

NEC 110.31 Enclosure for Electrical Installations	
Fence	A fence shall not be less than 2.1 m (7 ft) in height or a combination of 1.8 m (6 ft) or more of fence fabric and a 300 mm (1 ft) or more extension utilizing three or more strands of barbed wire or equivalent.

Rajasthan Rajya Vidyut Prasaran Nigam Limited	
Fence	Fencing and Gates shall be provided for Switchyard area as per General Electrical Layout Plan. **The height of fence post shall be at least 3050 mm.**

THE HARYANA BUILDING CODE, 2017	
Fence	Boundary wall up to the height of **2400mm** may be permitted by the Competent Authority in electric sub-stations, transformer stations, industrial buildings (workshops, factories) , institutional buildings (hospitals), educational buildings (schools, colleges, including hostels and other uses of public utility undertakings and strategically sensitive buildings.

Guide to the Safety, Health and Welfare at Work-IRELAND	
Fence	The transformer or switchgear is adequately protected either by suitable fencing not less than **2400MM high**, or by some other effective means such as high walls or some other effective means for preventing any unauthorised person gaining access to the equipment or to anything connected there to which is used as a conductor unless it is completely enclosed by (i) a metal casing which is connected to earth, or (ii) some other equally suitable non-metal casing.

NATIONAL BUILDING CODE OF INDIA 2016 (Clause 4.6 (b) / 5.3.6.10	
FENCE	Enclose any part of the substation which is open to the air, with a fence (earthed efficiently at both ends) or wall not less than 1 800 mm (preferably not less than 2400 mm) in height; to prevent, so far as is reasonably practicable, danger of electric shock or unauthorized access;

FENCE	Electrical installations in a room or cubicle or in an area surrounded by wall fence, access to which is controlled by lock and key shall be considered accessible to authorized persons only. Such installations shall be efficiently protected by fencing not less than 1 800 mm in height or other means so as to prevent access to the electric supply lines and apparatus therein by an undesignated person and the fencing of such area shall be earthed efficiently.

MINIMUM DISTANCE FROM FENCE TO LIVE PARTS (NEC TABLE 110.31)	
NOMINAL VOLTAGE	**MINIMUM DISTANCE FROM LIVE PART**
1KV TO 13.7KV	3.05 METER
13.8KV TO 23KV	4.57 METER
OVER 23KV	5.49 METER

ESKOM TRANSMISSION SUBSTATIONS Table 1: Security and safety fences			
Fence	**Fence Type**	**IP spacing**	**Strain Posts Spacing**
Security	2.4 Meter high, welded mesh fence	4.0m maximum	40m maximum where distance between corner posts exceed 90m
Safety	1.8 Meter high, diamond mesh	4.5m maximum	60m maximum where distance between corner posts exceed 90m

Outdoor Transformer / Panel Fencing as per UGVCL	
Fence Height	**1600 MM (1500+100 mm) above ground and 450 mm in ground**; minimum Width and Length as per site conditions and as decided by EIC (Engineer In-charge).
Fencing Gate	Fencing gate should have door with two shutters with one Heavy duty S.S. aldrop of size not less than 16 mm Día and 350 mm length. Gate is to be provided as per site conditions.
	Gate should be suitably stiffened to prevent sagging. 3nos. of Hinges of 100 mm size on each door and shall be of heavy duty S.S. and facilitate of outward 180 degree movement of the gate flaps.
	Left door of gate should be provided with stopper of 300 mm and Dia. of 10 mm at upper and lower part of fencing with proper locking arrangement.
Grade of Material for Fencing	Pultruded FRP - UV and Fire Resistant conforming to IS 6746
Bracing Flat	SMC molded / FRP Flat 35 x5mm and length 300 mm
Vertical Post (Pultruded FRP)	The vertical post shall be made out of FRP Pultruded square hollow section of size 50x50x5 mm. Such posts shall be kept at a distance not exceeding 1000 mm
	and shall be grouted in the ground with c.c. of ratio 1:2:4 in the pit of size 300x300x450 mm
	Post should be buried in foundation at least 450 mm from ground level. Posts at corners and gate openings may be of different size/shape so as to take care of the fencing requirements
Sub frame	FRP Box section of 50 x 25 x 5mm
Rails	Rails shall be made out of FRP notch bars of 12 mm dia. provided at equal spacing not exceeding200 mm Centre to Centre. The rails are placed horizontally and height of the 1st rail from the ground as well as gap between the rails shall be maintained
Pickets	Pickets shall be made of flats of size 35x5 mm SMC or FRP provided at equal spacing not exceeding 100 mm Centre to Centre mechanically locked between vertical post as well as top and bottom member of sub frame
	At top the whole fencing shall be tied with FRP Angle section 50x50x5 to provide suitable stiffness. Angle . Hardware for fixing / assembling shall be of stainless steel
Danger Board	Danger Board of size 300X300 mm (1.6 mm thick M.S. Plate) is to be provided on left hand side of fencing with standard drawing as attached herewith

Substations and Switch Rooms (NATIONAL BUILDING CODE 2016-4.2)	
Oil Filled Transformer at Basement Level (Indoor	Substations with oil-filled equipment/ apparatus Transformers and high voltage panels shall be either located in open or in a utility building.

Type)	They shall not be located in any floor other than the ground floor or the first basement of a utility building.
	They shall not be located below first basement Slab (On Second Basement) of utility building.
	They shall have direct access from outside the building for operation and maintenance of the equipment.
	In respect of all oil type transformers located at basement, a kerb (sill) of a suitable height shall be provided at the entrance in order to prevent the flow of oil from a ruptured transformer into other parts of the basement in the event of the possibility of oil spillage from the transformer on its failure.
Oil Filled Transformer/ Sub Station (Outdoor Type)	The substation or oil-filled transformer is located shall be separated from the adjoining buildings including the main building by at least **6 Meter** clear distance to allow passage of fire tender between the substation/utility building and adjoining building/main building.
	There shall be no interconnecting basement with the main building underneath the oil-filled transformers. Provisions for oil drainage to a point at a lower level and separated by adequate fire barrier shall be provided.
	If there is a floor directly below the ground floor level or first basement where the oil-filled transformers and oil-filled circuit breakers are placed, then they shall be separated by a fire barrier of appropriate fire rating as per Part 4 Fire and Life Safety' of the Code and proper oil drainage system shall be provided to avoid possible leakage of oil into the lower floor.
	Substation equipment (exceeding oil capacity of 2 000 litre) in utility building shall have fire rated baffle walls of 240 min rating constructed between such equipment, raised to at least 600 mm above the height of the equipment (including height of oil conservators) and exceeding 300 mm on each side of the equipment
	All transformers where capacity exceeds 10 MVA shall be protected by high velocity water spray systems or nitrogen injection system.
Oil Filled Transformer (9000 Liter) (Indoor / Outdoor Type)	Provisions shall be made for suitable oil soak-pit, and where use of more than 9 000 litre of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tank, receptacle or chamber containing the same. Special precautions shall be taken to prevent the spread of any fire resulting from the ignition of the oil from any cause and adequate provision shall be made for extinguishing any fire which may occur.
Dry-Type Transformer Within Multi-Storeyed Building—	Dry-type installation In case electric substation has to be located within the main multi-storeyed building itself for unavoidable reasons, it shall be a dry-type installation with very little combustible material, such as, a dry type transformer with vacuum (or SF6) breakers as HT switchgear and ACB or MCCB as medium voltage (MV) switchgear.
	Such substations shall be located on the ground level or on first basement, and shall have direct access from the outside of the building for operation and maintenance of the equipment. Exceptionally, in case of functional buildings, such as air traffic control towers, data centres and buildings of height more than 100 m having high electrical load requirement, dry-type installations/substations may also be provided at upper level. This measure will decrease the current flow and short-circuit rating at various points, thereby reducing vulnerability to fire. In such cases, a base substation shall be located at ground floor/first basement to cater to the main MV/LV panel which feeds life and safety services loads as defined in 4.2.1 (29)
	The base substation shall be located in such a way to provide direct access to the firemen in case of any emergency. The power supply control to any substation or transformer located at upper floors shall be from the base substation so that in case of fire, the electrical supply can be easily disconnected to avoid additional losses.
	Transformers located inside a building shall be of dry type and all substation/switch room walls, ceiling, floor, opening including doors shall have a fire resistance rating of 120 min. Access to the substation shall be provided from the nearest fire exit/exit staircase for the purpose of electrical isolation.

Two Transformer (Dry type or transformers with oil quantity less than 2000 litres)	In case of two transformers (Dry type or transformers with oil quantity less than 2000 litres) located next to each other without intermittent wall, the distance between the two shall be minimum 1500 mm for 11 kV, minimum 2000 mm for 22 kV and minimum 2500 mm for 33 kV. Beyond 33 kV, two transformers shall be separated by a baffle wall 4 h fire rating.
	If dry type transformer is used, it may be located adjacent to medium voltage switchgear in the form of unit type substation. In such a case, no separate room or fire barrier for the transformer is required either between transformers or between transformer and the switchgear, thereby decreasing the room space requirement; however, minimum distances as specified in 4.2.1 (17) shall be maintained between the apparatus depending upon voltage ratings. Layout of equipment should take care of the need that any one piece of equipment or sub assembly can be taken out of service and out of the installed location, while keeping the remaining system in service. Working space for access for maintenance of equipment, while keeping an adjoining section of the substation live to maintain power supply to essential loads,
CSS	In case of compact substation {see accepted standard [8-2(4)]}, design and location of the substation shall ensure safety of the people around the compact substation installed along walkways, playgrounds, etc.
	Compact substation with incomer **voltage of 12 kV or less**, when located in open areas shall have fencing or barrier (of any metal based protection, such as wire mesh or chain link, which is duly earthed) against unauthorized contact possibility around it at a **minimum distance of 750 mm around it** with access for maintenance from all four sides.
	For incomer **voltage more than 12 kV and less than 24 kV** the fencing distance from substation may be **1000 mm minimum.** In case of more than 24 kV incomer, the distance may be further increased accordingly. The fencing design should take care of the servicing and maintenance requirements of the substation equipment.

Insulating Mat- IS: 15652

	Class	AC Voltage	DC Voltage	Thicknes
Insulating Rubber Mat	Class A	AC (Rms)KV=3.3	DC(V) =240	2.0mm
	Class B	AC (Rms)KV=11	DC(V) =240	2.5mm
	Class C	AC (Rms)KV=33	DC(V) =240	3.0mm
	Class D	AC (Rms)KV=66	DC(V) =240	3.5mm
	Class A	AC (Rms)KV=3.3	DC(V) =240	2.0mm
Resistance	Most of all classes hall be resistant to acid and oil and low temperature and shall be identified by the respective class symbol. However a category with special property of resistance to extreme 'low' ternperature will be identified by a subscript'S 'to, the 'respective "C" Class symbol.			
Length	Roll of Mat shall be in multiple Length of 5000mm and ion width of 1000mm.Standard Shape in length of 1000, 2000, 3000mm.			
	In Case of Mat in Roll It shall be min 1m X 1m.			
Leakage current	Leakage current for all Class of Mat shall not be more than 10 Micro Amp.			

Distribution Pillar (<1KV AC&DC)- IS:5039

Distribution pillars	Distribution pillars are used by a number of distributing agencies to interconnect, terminate, control, protect and sectionalize distribution feeders.
	They are generally located on public footpaths abutting the building line or along the kerb line of footpaths.
	The distribution pillars covered by this standard are intended to incorporate HRC type fuses/links only and of current rating not exceeding 630 amperes.
	This standard covers distribution pillars for voltages not exceeding 1 000 V ac or 1 200 V dc, the current rating in each outgoing or incoming circuit not exceeding 630 A, for use on ac or dc systems, in outdoor conditions.
Rating of Individual Circuits:	The rated current of the outgoing or incoming circuits shall be as follows: 160, 200, 250, 400 and 630 amperes.
	NOTE 1: These ratings correspond to those of fuse-bases.
	NOTE 2 : All the incoming circuits of the same distribution pillar shall have

	the Same current rating and similarly all the outgoing circuits of the same distribution pillar shall have the same current rating. Unless otherwise specified the sum of the rated current of the incoming circuits shall be fixed at the 2/3 of the sum of the current ratings of outgoing circuits, rounded up to the nearest higher value of the preferred current
Rated Diversity Factor:	The rated diversity factor of the distribution pillar having several incoming and outgoing circuits is the ratio of the maximum sum at any one time, of the assumed circuits of all the circuits involved, to the sum of the rated currents of all the circuits of the distribution pillar.
	NUMBER OF FUSE-WAYS — **DIVERSITY FACTOR** 2 and 3 — 0.9 4 and 5 — 0.8 6 to 9 inclusive — 0.7 10 and above — 0.6
Enclosure:	It shall be in all respect suitable for outdoor installations. It shall be made from a suitable material to withstand rough usage and weather. If fabricated out of MS sheets the thickness of the sheet shall be at least 3.15 mm
Doors:	Distribution pillars shall have a set of double hinged doors at the front. Similar doors shall be provided at the back also; if specified.
	The doors shall be so fitted as to provide the interior with maximum protection from atmospheric conditions. The hinges shall be of such construction that the doors can be swung open by not less than 150°.
	In addition the hinged design shall permit doors being completely removed when necessary. The base horizontal member shall be completely removable to facilitate cable jointing
Canopy:	The top of the pillar shall be fitted with a sloping canopy design of which shall be such that rain water shall not accumulate on the top.
Aprons:	If required, an apron (two if there are doors at the rear also) shall be provided below the door level of the pillar. They shall be easily removable. The apron shall be made from a suitable material to withstand rough usage. If made from sheet steel, the thickness of the sheet shall be at least 3.15 mm.
Pillar Lighting:	A bayonet lamp holder complying with IS : 1258-1987, with a tumbler switch, competing with IS : 3854-1988†, a three pin plug and socket complying with IS : 1293-1988 with necessary fuses and wiring shall be provided inside the pillar.
	Unless otherwise agreed between the manufacturers and user, on TPN fuse boards, terminals for the neutral conductor shall allow the connection of aluminium conductors having a current carrying capacity:
	(a) equal to half the current carrying capacity of the phase conductor with a minimum of 25 mm2, if the size of the phase conductor exceeds 25 mm2
	(b) equal to the full current carrying capacity of the phase conductor if the size of the latter is less than or equal to 25mm2.
Earthing	The distribution pillar shall be provided with two separate earthing terminals and the framework shall be metallically connected with the casing.

Busbar (As per CPWD)
Bulbar shall be 100A,200A,300A,400A,500A,600A,800A
The Cross-section area of Bus bar shall be same as Phase Bus bar (Up to 200A) for higher Capacity Neutral Bus bar must be not less than half cross section areas of Phase Bus bar.
Bus bar shall be suitably installed with PVC sleeve/Tap.
Bus bar Chamber shall be fabricated with MS angle for Frame work and sheet steel of thickness not less than 1.5mm.
Minimum clearance between phase to earth shall be 26mm and phase to phase shall be 32mm.

Bus bar Trucking (As per CPWD)
Bus bar Trucking are generally used for interconnection between T/C over 500KVA/D.G set over 500KVA and their switch Board Panel.
Bus bar Trucking enclosure sheet steel of min 2mm thickness

Looping Box (As per CPWD)
Looping Bus shall be fabricated from MS Sheet of 1.6mm(16SWG) thickness, Min Size 250mm

X200mmX100mm for single cable entry and for 250mmX300mmX100mm for more than two cable entry

Feeder Pillar (As per CPWD)
Feeder Pillar shall be fabricated min 2mm thick MS sheet and hinged type double door at front side. If width of Pillar shall be less than 60cm than single hinged type door shall be permitted.
Min height of Pedestal of Feeder Pillar shall be not less than 45cm and 1 to 2 meter height from Road Level.
Each Feeder Pillar shall be earthed with 2 no of Earthing electrode.

Substation Area (As per CPWD)		
S/S	**TC Room Area**	**Total S.S Area(T.C,HT/LT Panel, without DG)**
2X500KVA	36 Sqmeter	130 Sqmeter
3X500KVA	54 Sqmeter	172 Sqmeter
2X800KVA	39 Sqmeter	135 Sqmeter
3X800KVA	58 Sqmeter	181 Sqmeter
2X1000KVA	39 Sqmeter	149 Sqmeter
3X1000KVA	58 Sqmeter	197 Sqmeter

Lift Car Speed (NEC(India) :2011)		
Occupancy	**No. of Floors Served**	**Car Speed m/s**
Office building	4 to 5	0.5 to 0.75 m/sec
Office building	6 to 12	0.75 to 1.5 m/sec
Shops and departmental stores	13 to 20	More than 1.5 m/sec
Passenger lifts for low and medium lodging houses	-	0.5 m/sec
Hotels	4 to 5	0.5 to 0.75 m/sec
Normal load carrying lifts	-	2.0 to 2.5 m/sec
Hospital passenger Lift	4 to 5	0.5 to 0.75 m/sec
Hospital passenger Lift	13 to 20	More than 1.5 m/sec
Hospital bed lifts (Short travel lifts insmall hospitals)	-	0.25 m/sec
Hospital bed lifts (Normal)	-	0.5 m/sec
Hospital bed lifts (Long travel lifts inGeneral hospitals)		0.6 to 1.5 m/sec

Lift Speed (Indian Army Manual)	
No of Floor	**Lift Speed**
4 to 5	0.5 to 0.7 meter/Sec
6 to 12	0.75 to 1.5 meter/Sec
3 to 20	1.5 to 2.5 meter/Sec
Above 20	Above 2.5 meter/Sec

Lift Details (CPWD-2012)						
Type of Lift	**Persons**	**Weight**	**Speed**	**Travel**	**Price**	**Add Rs /Floor**
Passenger Lift	8 Person	544 Kg	1.0 M/Sec	G+4	18 Lacs	1.25 Lacs
Passenger Lift	13 Person	844 Kg	1.5 M/Sed	G+4	22 Lacs	1.25 Lacs
Passenger Lift	16 Person	1088 Kg	1.0 M/Sec	G+4	28 Lacs	1.50 Lacs
Passenger Lift	20 Person	1360 Kg	1.5 M/Sec	G+4	30 Lacs	1.50 Lacs

LIFTS		
Model Building-Bye-laws-2016, Ministry of Urban Development, Government of India		
Head	**Clause**	**Description**
LIFTS	**7.10.a**	Provision of the lifts shall be made for all multi-storeyed building having a height of 15.0 m. and above.
	7.10. b	Grounding switch at ground floor level to enable the fire service to ground the lift car in case of emergency shall also be provided.
	7.10.c	The lift machine room shall be separate and no other machinery be installed in it.
Lift Enclosure	**7.10.1.a**	Walls of lift enclosures shall have a fire rating of two hours. Lift shafts shall have a vent at the top of area not less than 0.2 sq m.
	7.10.1.c	Landing door in lift enclosures shall have a fire resistance of not less than one hour.
	7.10.1.d	The number of lifts in one lift bank shall not exceed four. A wall of two hours fire rating shall separate individual shafts in a bank.
	7.10.1.e	Lift car door shall have a fire resistance rating of 1 hour.
	7.10.1.f	For buildings 15.0 m. and above in height, collapsible gates shall not be permitted for lifts and solid doors with fire resistance of at least one hour shall be provided.
	7.10.1.g	If the lift shaft and lobby is in the core of the building a positive pressure between 25 and 30 pa shall be maintained in the lobby and a possible pressure of 50 pa shall be maintained in the lift shaft. The mechanism for the pressurization shall act automatically with the fire alarm/sprinkler system and it shall be possible to operate this mechanically also.
	7.10.1.h	Exit from the lift lobby, if located in the core of the building, shall be through a self-closing fire smoke check door of one-hour fire resistance.
	7.10.1.i	Lift shall not normally communicate with the basement. If however, lifts are in communication, the lift lobby of the basement shall be pressurized

	7.10.1.k	Telephone/talk back communication facilities may be provided in lift cars for communication system and lifts shall be connected to the fire control room of the building.
	7.10.1.l	Suitable arrangements such as providing slope in the floor of the lift lobby shall be made to prevent water used during fire fighting, etc at any landing from entering the lift shafts.
	7.10.1.m	A sign shall be posted and maintained on every floor at or near the lift indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall also contain a plan for each floor showing the location of the stairways. Floor marking shall be done at each floor on the wall in front of the lift-landing door.
	7.10.1.n	Alternate power supply shall be provided in all the lifts.
Fire Lift	7.10.2.b	The lift shall have a floor area of not less than 1.4 sq.mt. It shall have a loading capacity of not less than 545 kg. (8 persons lift) with automatic closing doors
	7.10.2.c	The electric supply shall be on a separate service from electric supply mains in a building and the cables run in a route safe from fire, that is within a lift shaft. Lights and fans in the elevator having wooden panelling or sheet steel construction shall be operated on 24-volt supply.
	7.10.2.d	In case of failure of normal electric supply, it shall automatically switchover to the alternate supply. For apartment houses, this changeover of supply could be done through manually operated changeover switch. Alternatively, the lift should be so wired that in case of power failure, it comes down at the ground level and comes to stand still with door open.
	7.10.2.f	The words 'F1RE LIFT' shall be conspicuously displayed in fluorescent paint on the lift landing doors at each floor level.
	7.10.2.g	The speed of the fire lift shall be such that it can reach to the top floor from ground level within one minute.

Gujarat Fire Prevention and Life Safety Measures Regulations, 2023-Clause15.4 / 15.26
Elevators (Lifts) / Escalators
Building Height more than 13 Meter: Lift shall be provided. Lift shall have all the provision of fire life as specified in the National building code of India.
Building Height more than 21 Meter: **At least Two Lifts** shall be provided. From these lifts at least one of them shall be designed as fire lift as specified in National building code of India.
No of Lift: Lift shall be provided at the rate of one lift for **30 dwelling units of all the floors**, or part thereof for residential buildings and at the rate of **one lift per 1200 Sq. meters**. or part thereof of built up area for non-residential buildings.
Lift Dimensions: Minimum internal dimensions for passenger lifts shall be **1500 mm x 1500mm**. A clear landing area in front of the lift doors shall be **1800mm x 1800mm** and the clear opening width of the doors shall be of minimum **900 mm**. A handrail of 600 mm length at 1000 mm height from the floor shall be provided.
Door Clousing Speed: The time of an automatically closing door should be min 5 seconds and the closing speed should not exceed **0.25 meter/sec.**
Floor Indication: The interior of the cage shall be provided with a device that audibly indicates the floor the cage has reached and indicates that the door of the cage for entrance/exit is either open or closed.
Fire Lifts
No of Fire Lift: Each building should have at least one lift as a Fire- lift and if the building is divided into two or more parts then each part should have a Fire-lift.
No of Fire Lift: To enable fire services personnel to reach the upper floors with the minimum delay, one fire lift per 1200 Sq.Meter of floor area shall be provided and shall be available for the exclusive use of the firemen in an emergency.
Lift Speed: The speed of the fire lift shall be such that it can reach the top floor from ground level within one minute.

Lift Dimension: The life Floor area of not less than 1.4 sq. meter It shall have loaded capacity of not less than **545 KG (8 persons lift)** with automatic closing doors of minimum 0.8m width.
The electric supply shall be on a separate service from electric supply mains in a building and the cables run in a route safe from fire, that is, within the lift shaft. Lights and fans in the elevators having wooden paneling or sheet steel construction shall be operated on 24-volt supply.
Ceiling Hatch : Firefighting lift should be provided with a ceiling hatch for use in case of emergency
Standby Power Supply: In case of failure of normal electric supply, it shall automatically change over to alternate supply. For apartment houses, this changeover of supply could be done through manually operated changeover switch.
Automatic Resue Device: the lift shall be so wired that in case of power failure, it comes down at the ground level and comes to stand-still with door open.
Fire Switch : The operation of fire lift should be by a simple toggle or two -button switch situated in glass fronted box adjacent to the lift at the entrance level. When the switch is on, landing call points will become inoperative and the lift will be on car control only or on a priority control device. When the switch is off, the lift can be used by the occupants in normal times.
Lift Well Pressurization: Lift-well should have blowers to pressurize the lift-well so connected that it will automatically operate when alarm call point is operated, so that it prevents the lift well getting smoke logged.
Signages: The words 'Fire Lift' shall be conspicuously displayed in fluorescent paint on the lift landing door at each floor level
Buildings of Height more than 45 meters up to 70 meters: One fire lift for each 1200 sq. meter area of floor area on each level (Fire lift otherwise can be used as a common passenger lift).
Buildings of Height more than 45 meters up to 70 meters: All lifts of the building shall be Fire lifts and shall have a provision to ground in case of electrical failure and shall be installed with a panic button and a talk-back system. The lift shall not be installed in the centre of the building and the lift shaft shall be ventilated from the top with smoke extractors. The lift for the higher floors shall end at the ground level and not go to the basement

Number of Points for Dwelling Unit (NEC(India) :2011)					
Description	Area for the Main Dwelling Unit (m2)				
	35 mm2	45 mm2	55 mm2	85 mm2	140 mm2
Light points	7 No	8 No	10 No	12 No	17 No
Ceiling fans Pont	2 No	3 No	4 No	5 No	7 No
Ceiling fans No's	2 No	2 No	3 No	4 No	5 No
6A Socket outlets	2 No	3 No	4No	5 No	7 No
16A Socket outlets	-	1 No	2 No	3 No	4No
Call-bell (buzzer)	-	-	1 No	1 No	1 No

Recommended Schedule of Socket-Outlets (NEC(India) :2011)		
Description	Number of Socket	
	6A Socket	16A Socket
Bedroom	2	1
Living room	2	2
Kitchen	1	2
Dining room	2	1
Garage	1	1
For refrigerator	-	1
For air-conditioner	-	1 for each
Veranda	1 per 10mter2	1
Bathroom	1	1

Power requirements of the building (NEC(India) :2011)		
Part of Electrical Installation	Part of the Total Power Requirement in %	Diversity Factor
Ventilation, heating (air-conditioning)	45%	1.0
Power plant (drives)	52%	0.65
Lighting	30%	0.95
Lifts	20%	1.0
Kitchen	10%	0.6
Laundry	5%	0.6

Installation of Circuits for Residential (As per NBC)		
Type of Circuit	Wire Size	Number of Circuits
Lighting	1.0 mm2	2 or more
Socket-outlets 10 A	2.5 mm2	Any number Areas such as kitchens and laundries 3 × double socket outlets per circuit. Other areas up to 12 double socket outlets
Socket-outlets 15 or 20 A	2.5 mm2	1
Water heater 3 kW	1.5 mm2	1
Water heater 3-6 kW	2.5 mm2	1
Separate oven and/ or cook top	4.0 mm2	1
Permanently connected appliances including dishwashers, heaters, etc	2.5 mm2	1 above 10 A. Up to 10 A can be wired as part of a socket-outlet circuit
Sub mains to garage or out-building	2.5 mm2	1 for each
Mains cable	16 mm2	1

Recommended of socket-outlets in a Residential building (As per NBC)		
Location	Number of 5A Socket-Outlets	Number of 15A Socket-Outlets
Bed room	2 to 6	2
Living room	2 to 4	2
Kitchen	2 to 8	2
Dining room	2 to 4	2
Garage	1	1
For refrigerator	-	1
For air conditioner	-	1 for each

VERANDAH	1 per 10 m2	1
Bathroom	1	1

Size of Ventilation Shaft:		
Building Height	**Size of ventilation shaft**	**Minimum size of shaft**
9.0 Meter	1.5 Sq.Meter	1.0 Meter
12.5 Meter	3.0 Sq.Meter	1.2 Meter
15 Meter and above	4.0 Sq.Meter	1.5v

Cable Capacity of PVC conduits				
Nominal conductor Size mm	**16 mm**	**20 mm**	**25 mm**	**32 mm**
	Number of Cables (maximum)			
1.0	6	5	19	30
1.5	5	4	15	24
2.5	3	3	11	17
4	2	2	8	13
6	2	-	6	10
10	-	-	4	6
16	-	-	3	4
25	-	-	2	3
35	-	-	-	2

Low Voltage Cabling for Building (As per NBC)	
Low Voltage Cable	Cables/wires, such as fiber optic cable, co-axial cable, etc. These shall be laid at least at a distance of 300 mm from any power wire or cable. The distance may be reduced only by using completely closed earthed metal trucking with metal separations for various kind of cable. Special care shall be taken to ensure that the conduit runs and wiring are laid properly for low voltage signal to flow through it.
	The power cable and the signal or data cable may run together under floor and near the equipment. However, separation may be required from the insulation aspect, if the signal cable is running close to an un-insulated conductor carrying power at high voltage. All types of signal cables are required to have insulation level for withstanding 2 kV impulse voltages even if they are meant for service at low voltage.
Conduit Colour Scheme	Power conduit=Black Security conduit=Blue Fire alarm conduit=Red Low voltage conduit=Brown UPS conduit Green

Internal Electrical Works (As per CPWD)	
Circuits:	
Lighting Circuit	Per Circuit Not more than **10 Points of Lighting or Total 800Watt which is less**
Power Circuit	For Residential Per Circuit **Less than 2 No of 5A/15A Plug Socket**
	For Non-Residential Per Circuit **Less than 1 No of 5A/15A Plug Socket**
Plug Socket	In Residential wiring, wiring of Socket outlet shall be done by copper Cable only
Min Size of Wire	For Lighting Circuit **Smallest size of conductor shall be 1.5 Sq.mm**
	For Power Circuit Smallest size of conductor shall be 4 Sq.mm
Plug Socket	**5A/6A or 15A/16A Socket shall be installed at following heights:**
	For Non Residential building 23cm above Floor
	For Kitchen 23cm above Platform,
	For Bathroom not Socket is provided in bathroom MCB/IC will be 2.1 meter from fixed appliance and at least 1 meter away from Shower
Switch Board / D.B	
Operating Rod	Operating Rod/Handle of Distribution Board at the height of min 2 meter
	Clear Distance in front of Switch Board/D.B shall be min 1 meter.
	If there may be bare connection at back of Switch Board than space behind S/W shall be either less than 20cm or more than 75cm

	No fuse Body shall be mounted within 2.5 com edge of D.B or Panel
	Clearance between 2.5 cm is maintained between opposite polarity
Switch Box	Switch Box or Regular Box shall be mounted normally 1.25 meter from floor level.
Fan Hook	
Fan Hook	For Fan Hook in concrete roof 12mm dia MS Rod in 'U' Shape, horizontally Leg at Top at least 19 cm on either side.
Connection between adjustment Building (Out House, Garages)	
Safety Clearance	If the distance with adjustment building is less than 3 meter and there is no any Road interval than GI pipe of suitable size shall be installed. This pipe shall be exposed on wall at height of not less than 2.5 meter.
Safety Clearance	If the distance with adjustment building is more than 3 meter and there is any Road interval than GI pipe of suitable size shall be installed. This pipe shall be exposed on wall at height of not less than 4 meter.
Conduit	
Metallic Conduit	Shall be used for Industrial wiring, Heavy mechanical Stress, shall be ISI marked, The Thickness shall not be less than 1.6mm(16SWG) for conduits up to 32mm Dia and not less than 2mm (14SWG) for conduit above 32mm Dia.
	No steel conduit less than 20 mm Diameter shall be used.
	For rigid Conduit IS:2509/IS:3419 and For Flexible Conduit IS:6946.
	All Metallic conduit accessories shall be threaded type (Not pin grip, clamp grip)
	Saddle for surface conduit work on wall shall not less than 0.55mm(24 gauge) for conduit up to 25mm Dia not less than 0.9mm (20 gauge) for larger Dia
Metallic Outlets	Fore Cast Boxes: Wall thickness shall be at least 3mm
	For Welded mild Steel Box: Wall thickness shall not be less than 1.2mm (18 gauge) for Boxes up to size 20cmX30cm. Above This size 1.6mm(16guage)thick MS Boxes shall be used.
	Clear depth of Out less Box shall not be less than 60mm.
	This will be increased as per mounting of Fan regulator
Bends in Conduits	Bending radius not less than 7.5 cm
Fixiting Conduits on Surface	Conduits shall be fixed by saddles not less than 1meter interval but in case of coupler/Bends in either side of saddles, The saddle shall be fitted 30 cm from fitting.
Non Metallic Outlet (PVC Box)	PVC Box IS:5133(PartII) thickness not less than 2mm,Clear depth of PVC Boxes not less than 60mm.
Non Metallic Surface Conduit	Conduits shall be fixed by saddles not less than 60cm interval but in case of coupler/Bends in either side of saddles, The saddle shall be fitted 15 cm from fitting.
Junction Box	
Junction Box	Depth of Junction Box shall be min 65mm as per IS: 2667.
Fish Wire	
Fish Wire	GI fish wire of 1.6mm/1.2mm (16SWG) shall be used.

Indian Electricty (IE) Rules	
Cut-out on consumer's premises	The supplier shall provide a suitable cut-out in each conductor of every service-line other than an earthed or earthed neutral conductor or the earthed external conductor of a concentric cable within a consumer's premises, in an accessible position. Such cut-out shall be contained within an adequately enclosed fireproof receptacle.
	Where more than one consumer is supplied through a common service-line, each such consumer shall be provided with an independent cut-out at the point of junction to the common service
	Every electric supply line other than the earth or earthed neutral conductor of any system or the earthed external conductor of a concentric cable shall be protected by a suitable cut-out by its owner
	No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two wire-system or in

	any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:(a) A link for testing purposes, or (b) A switch for use in controlling a generator or transformer.
Danger Notices:	The owner of every medium, high and extra-high voltage installation shall affix permanently in a conspicuous position a danger notice in Hindi or English and the local language of the district, with a sign of skull and Bones on
	(a) Every motor, generator, transformer and other electrical plant and equipment together with apparatus used for controlling or regulating the same
	(b) All supports of high and extra-high voltage overhead lines which can be easily climb-upon without the aid of ladder or special appliances.
Cables:	Flexible cables shall not be used for portable or transportable motors, generators, transformer rectifiers, electric drills, electric sprayers, welding sets or any other portable or transportable apparatus unless they are heavily insulated and adequately protected from mechanical injury.
	Where the protection is by means of metallic covering, the covering shall be in metallic connection with the frame of any such apparatus and earth.
	The cables shall be three core type and four-core type for portable and transportable apparatus working on single phase and three phases supply respectively and the wire meant to be used for ground connection shall be easily Identifiable
	Where A.C. and D.C. circuits are installed on the same support they shall be so arranged and protected that they shall not come into contact with each other when live.
Safety:	Two or more gas masks shall be provided conspicuously and installed and maintained at accessible places in every generating station with capacity of 5 MW and above and enclosed sub-station with transformation capacity of 5 MVA and above for use in the event of fire or smoke.
	Provide that where more than one generator with capacity of 5 MW and above is installed in a power station, each generator would be provided with at least two separate gas masks in accessible and conspicuous position.
High Voltage Equipments installations	High Voltage equipments shall have the IR value as the Indian Standard.
	At a pressure of 1000 V applied between each live conductor and earth for a period of one minute the insulation resistance of HV installations shall be at least 1 Mega ohm Medium and Low Voltage Installations- At a pressure of 500 V applied between each live conductor and earth for a period of one minute, the insulation resistance of medium and low voltage installations shall be at least 1 Mega ohm
switchboard	A clear space of not less than 1 meter in width shall be provided in front of the switchboard;
	If there are any attachments or bare connections at the back of the switchboard, the space (if any) behind the switchboard shall be either less than 20 centimetres or more than 75 centimetres in width, measured from the farthest outstanding part of any attachment or conductor;
	If the space behind the switchboard exceeds 75 centimetres in width, there shall be a passage-way from either end of the switchboard clear to a height of 1.8 meters.
Declared voltage	In the case of low or medium voltage, by more than 6 per cent, or In the case of high voltage, by more than 6 per cent on the higher side or by more than 9 per cent on the lower side, or In the case of extra-high voltage, by more than 10 per cent on the higher side or by more than 12.5 per cent on the lower side
Declared frequency	Except with the written consent of the consumer or with the previous sanction of the State Government a supplier shall not permit the frequency of an alternating current supply to vary from the declared frequency by more than 3 per cent
Meters, maximum demand indicators and other apparatus on consumer's premises	Any meter or maximum demand indicator or other apparatus placed upon a consumer's premises in accordance with section 26 shall be of appropriate capacity and shall be deemed to be correct if its limits of error are within the limits specified in the relevant Indian Standard Specification and where no such specification exists, the limits of error do not exceed 3 per cent above or below absolute accuracy at all loads in excess of one tenth of full load and up to full load Connection with earth Neutral conductor of a phase, 4 wire system and the middle conductor of a 2 phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes of such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the sub-station. The earth electrodes so provided, may be interconnected to reduce earth resistance. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises
	In the case of a system comprising electric supply lines having concentric cables, the

	external conductor of such cables shall be earthed by two separate and distinct connections with earth.
	The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.
	All metal castings or metallic coverings containing or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connection throughout their whole length.
Transformer:	Where transformer or transformers are used, suitable provision shall be made, either by connecting with earth a point of the circuit at the lower voltage or otherwise, to guard against danger by reason of the said circuit becoming Accidentally charged above its normal voltage by leakage from or contact with the circuit at the higher voltage
	A sub-station or a switch station with apparatus having more than 2000 litres of oil shall not be located in the basement where proper oil draining arrangement cannot be provided.
	Where a sub-station or a switch station with apparatus having more than 2000 litres of oil is installed, whether indoor or out-doors, the following measures shall be taken, namely: The baffle walls 4[of 4 hour fire rating] shall be provided between the apparatus in the following cases: -
	(1) Single phase banks in the switch-yards of generating stations and substations, (2) On the consumer premises, (3) Where adequate clearance between the units is not available.
	Provisions shall be made for suitable oil soakpit and where use of more than 9000 litres of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tanks receptacles or chambers containing the same.
	The transformer shall be protected by an automatic high velocity water spray system or by carbon dioxide or BCF (Bromo chlorodi feuromethane) or BTM (Bromo tri flurometh ane) fixed installation system; and
	Oil filled transformers installed indoors shall not be on any floor above the ground or below the first basement.
	Isolators and the corresponding earthing switches shall be interlocked so that no earthing switch can be closed unless and until the corresponding isolator is in open position.
	When two or more transformers are operated in parallel, the system shall be so arranged as to trip the secondary breaker of a transformer in case the primary breaker of that transformer trips.
	Where two or more generators operate in parallel and neutral switching is adopted, inter-lock shall be provided to ensure that generator breaker cannot be closed unless one of the neutrals is connected to the earthing system.
	Provisions shall be made for suitable oil soakpit and where use of more than 9000 litres of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tanks receptacles or chambers containing the same.
	The transformer shall be protected by an automatic high velocity water spray system or by carbon dioxide or BCF (Bromo chlorodi feuromethane) or BTM (Bromo tri flurometh ane) fixed installation system; and
	Oil filled transformers installed indoors shall not be on any floor above the ground or below the first basement.
	Isolators and the corresponding earthing switches shall be interlocked so that no earthing switch can be closed unless and until the corresponding isolator is in open position.
	When two or more transformers are operated in parallel, the system shall be so arranged as to trip the secondary breaker of a transformer in case the primary breaker of that transformer trips.
	Where two or more generators operate in parallel and neutral switching is adopted, inter-lock shall be provided to ensure that generator breaker cannot be closed unless one of the neutrals is connected to the earthing system.
	Gas pressure type protection to given alarm and tripping shall be provided on all transformers of ratings 1000 KVA and above.
	Transformers of capacity 10 MVA and above shall be protected against incipient faults by differential protection; and All generators with rating of 100 KVA and above shall be protected against earth fault/leakage. All generators of rating 1000KVA and above shall

	be protected against faults within the generator winding using restricted earth fault protection or differential protection or by both
Connection with earth	In case of the delta connected system the neutral point shall be obtained by the insertion of a grounding transformer and current limiting resistance or impedance wherever considered necessary at the commencement of a system.
	Where the earthing lead and earth connection are used only in connection with earthing guards erected under high or extra-high voltage overhead lines where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage relays of a type and setting approved by the Inspector, the resistance shall not exceed 25 ohms.
Clearance above ground of the lowest conductor	No conductor of an overhead line, including service lines, erected across a street shall at any part thereof be at a height of less than: For low and medium voltage lines 5.8 meters (b) For high voltage lines 6.1 metres No conductor of an overhead line, including service lines, erected along any street shall at any part thereof be at a height less than: For low and medium voltage lines 5.5 metres For high voltage lines 5.8 metres No conductor of in overhead line including service lines, erected elsewhere than along or across any street shall be at a height less than: For low, medium and high voltages lines=4.6 meters. For low, medium and high voltage=4.0 meters. For high voltage lines above 11,000 volts=5.2 meters. For extra-high voltage lines the clearance above ground shall not be less than 5.2 metres plus 0.3 meter for every 33,000 volts or part thereof by which the voltage of the line exceeds 33,000 volts.

Model Building-Bye-laws-2016, Urban Development, Government of India		
Head	**Clause**	**Description**
SERVICE DUCTS	**7.13.a**	Service duct shall be enclosed by walls and door, if any, of 2 hours fire rating. If ducts are larger than 10 sq m. the floor should seal them, but provide suitable opening for the pipes to pass through, with the gaps sealed.
	7.13.b	A vent opening at the top of the service shaft shall be provided between one-fourth and one-half of the area of the shaft
ELECTRICAL SERVICES	**7.14.a**	The electric distribution cables/wiring shall be laid in a separate duct shall be sealed at every floor with non-combustible material having the same fire resistance as that of the duct. Low and medium voltage wiring running in shaft and in false ceiling shall run in separate conduits.
	7.14.b	Water mains, telephone wires, inter-com lines, gas pipes or any other service lines shall not be laid in ducts for electric cables.
	7.14.c	Separate conduits for water pumps, lifts, staircases and corridor lighting and blowers for pressuring system shall be directly from the main switch panel and these circuits shall be laid in separate conduit pipes, so that fire in one circuit will not affect the others. Master switches controlling essential service circuits shall be clearly labelled.
	7.14.d	The inspection panel doors and any other opening in the shaft shall be provided with airtight fire doors having fire resistance of not less then 1 hour.
	7.14.e	Medium and low voltage wiring running in shafts, and within false ceiling shall run in metal conduits. Any 230 voltage wiring for lighting or other services, above false ceiling should have 660V grade insulation. The false ceiling including all fixtures used for its suspension shall be of non-combustible material.
	7.14.f	An independent and well-ventilated service room shall be provided on the ground floor with direct access from outside or from the corridor for the purpose of termination of electrical supply from the licenses service and alternative supply cables. The doors provided for the service room shall have fire resistance of not less than 1 hour
STAIRCASE AND CORRIDOR LIGHTS	**7.15**	The staircase and corridor lighting shall be on separate circuits and shall be independently connected so that it could be operated by one switch installation on the ground floor easily accessible to fire fighting staff at any time irrespective of the position of the individual control of the light points, if any.

	7.15.a	Staircase and corridor lighting shall also be connected to alternate source of power supply.
	7.15.b	Emergency lights shall be provided in the staircase and corridor.

Model Building-Bye-laws-2016, Urban Development, Government of India		
Head	**Clause**	**Description**
AIR-CONDITIONING	**7.16.b**	Air -Conditioning systems circulating air to more than one floor area should be provided with dampers designed to close automatically in case of fire and thereby prevent spread of fire or smoke. Such a system should also be provided with automatic controls to stop fans in case of fire,
	7.16.c	Air- conditioning system serving large places of assembly (over one thousand persons), large departmental stores, or hostels with over 100 rooms in a single block should be provided with effective means for preventing circulation of smoke through the system in the case of fire in air filters or from other sources drawn into the system even though there is insufficient heat to actuate heat smoke sensitive devices controlling fans or dampers. Such means shall consist of approved effective smoke sensitive controls.
	7.16.1.a	Escape routes like staircase, common corridors, lift lobbies; etc should not be used as return air passage.
	7.16.1.b	The ducting should be constructed of metal in accordance with BIS 655:1963
	7.16.1.c	c) Wherever the ducts pass through fire walls or floor, the opening around the ducts should be sealed with fire resisting material of same rating as of walls / floors.
	7.16.1.d	d) Metallic ducts should be used even for the return air instead of space above the false ceiling.
	7.16.1.e	e) The material used for insulating the duct system (inside or outside) should be of flame resistant (IS 4355: 1977) and non- conductor of heat.
	7.16.1.f	Area more than 750 sq m. on individual floor should be segregated by a firewall and automatic fire dampers for isolation should be provided.
	7.16.1.h	In case of buildings more than 24 m. in height, in non-ventilated lobbies, corridors, smoke extraction shaft should be provided.

Acceptable Indoor Noise Levels (As per NBC)	
Location	**Noise Level dB(A)**
Auditoria and concert halls	20-25
Radio and TV studios	20-25
Cinemas	25-30
Music rooms	25-30
Hospitals and cinema theatres	35-40
Apartments, hotels and homes	35-40
Conference rooms, small offices and libraries	35-40
Court rooms and class rooms	40-45
Large public offices, banks and stores	40-45
Restaurants	50-55

CABLE- IS 694	
Cable Sheath (Up to 1.1KV)	The color of the sheath shall be black or any other color as agreed to between the purchaser and the supplier. For weatherproof cables, the color of sheath shall be black only.
	The difference between maximum and minimum measured values of overall diameter of sheathed circular cables shall not exceed 15 percent of the maximum measured value at the same cross-section.
Cable Construction (Up to 1.1KV)	Copper Cable up to 6mm2 =Solid/Stranded ,
	Copper Cable up to 10mm2 =Solid/Stranded
	Copper Cable above 6mm2 =Stranded ,
	Copper Cable above 10mm2 =Stranded
Cable-Testing (Up to 1.1KV)	The core(s) shall be carefully removed from a sample approximately 3 m long from the finished cable. They shall be so immersed in a water-bath at 60±3ºC that their ends protrude at least 200 mm above the water-level. After 24 hours, a voltage of 3 kV (rms) shall be applied between conductors and water. This voltage shall be raised to 6 kV (rms) within 10 seconds and held constant at this value for 5 minutes. If the sample fails in this test, one more sample shall be subjected to this test, which should pass.
	The cores which have passed the preliminary test given in 16.2.1 shall be subsequently tested with a dc voltage of 1.2 kV in the same water-bath at the same temperature. The conductors shall be connected to the negative pole and water to the positive pole of dc supply by means of a copper electrode.
	The core shall withstand this dc voltage test for 240 hours without breakdown.
	The voltage shall be applied continuously, but if there are any unavoidable interruptions during the 4 hours period, that period shall be increased by the time of interruptions. The total of such interruptions shall not exceed 1 hour otherwise the test shall be started again.
	The cables and cords shall withstand without breakdown an ac voltage of 3 kV (rms) or a dc voltage of 7.2 kV applied for a period of 5 min for each test connection
	Single-core cables shall be immersed in water at ambient temperature one hour before the testing and the test voltage shall be applied between conductor and water for the specified period.

CABLE- IS 1554	
Insulation Color (up to 11 KV)	For reduced neutral conductors, the insulation color shall be black
Arrangement of Marking (up to 11 KV)	For cables having more than 5 cores, the core identification may be done by numbers. In that case, the insulation of cores shall be of the same color and numbered sequentially, starting with number 1 for the inner layer. The numbers shall be printed in Hindu-Arabic numerals on the outer surface of the cores. All the numbers shall be of the same color which shall contrast with the color of the insulation. The numerals shall be legible.
	When the number is a single numeral, a dash shall be placed underneath it. If the number consists of two numerals, these shall be disposed one below the other and a dash placed below the lower numeral. The spacing between consecutive numbers shall not exceed 50 mm.
Type of Armor (up to 11 KV)	Where the calculated diameter below armoring does not exceed 13 mm, the armor shall consist of galvanized round steel wires. Where the calculateddiameter below armoring is greater than 13 mm, the armor shall consist of either galvanized round steel wires or galvanized steel strips.
Cable Identification/ Marking (up to 11 KV)	Type of Cable Legend: (i) Improved fire performance or Category C1 FR (Cables in constrained areas, Does not propagate fire even when installed in groups in vertical ducts),(ii) Improved fire performance for Category C2 FR—LSH (Cables in constrained areas with limited human activity and/or presence of sophisticated systems)
	Aluminum conductor= A, PVC insulation=Y, Steel round wire armor= W,

	Steel strip armor= F, Steel double round wire armor= WW, Steel double strip armor =FF, PVC outer sheath= Y
Insulating Rubber Mat	Four classes of mats, covered under this standard nd differing in electrical characteristics for different use voltages are designated
Insulating Rubber Mat	**Class** **AC (Rms)KV** **DC(V)** **Thickness(mm)** A 3.3 240 2.0 B 11 240 2.5 C 33 240 3.0 D 66 240 3.5
Insulating Rubber Mat	Most of all classes hall be resistant to acid and oil and low temperagre and shall be identified by the respective class symbol. However a category with special property of resistance to extreme 'low' ternperature will be identified by a subscript's 'to, the 'respective "c" Class symbol
Insulating Rubber Mat	Roll of Mat shall be in multiple Length of of 5000mm and ion width of 1000mm.Standard Shape in length of 1000, 2000, 3000mm.
Insulating Rubber Mat	Leakage current for all Class of Mat shall not be more than 10 Micro Amp.

CABLE- IS:11892
Maximum external Diameter of Cable (dc)=kc X d
where d= Nominal dis of conductor standards.
For solid cable Kc=1
For stranded cable kc=3 (up to 7 stranded).
More than 7 stranded kc=1.16 X sq.root(n1),
n1=Number of stranded

Installation of Cable- IS :1255	
Cable Route Indicator (Up to 33KV)	Power cable route indicators should be provided at an interval not exceeding 200 M and also at turning points of the power cable route wherever practicable
Cable Corrosion (Up to 33KV)	Electrolytic corrosion: Where the possibility of electrolytic corrosion exists, for example, adjacent to dc traction system, the potential gradient along the pipe-line and the cable sheath should be specified.
Neutral (Up to 33KV)	The neutral point is earthed in such a manner that during a line-to-earth fault the highest rms voltage to earth of a sound phase(s) expressed as a percentage of the highest line-to-line voltage, does not exceed 80 percent, irrespective of the fault location,
Earthing (Up to 33KV)	The neutral point is not earthed but a device is installed which automatically and instantly cuts out any part of the system which becomes accidentally earthed,
Earthing (Up to 33KV)	In case of ac systems only, the neutral point is earthed through an arc suppression coil with arrangement for isolation within one hour for the non-radial field cables and within 8 hours for radial field cables, of occurrence of the fault provided that the total of such periods in a year does not exceed 125 hours.
Cable Tensile Strength (Up to 33KV)	PVC and XLPE insulated armored power cables P = 9 D2 ,P=Pulling Strength(N),D=Outer Dia of Cable(mm)
Cable Tensile Strength (Up to 33KV)	PVC and XLPE insulated unarmored power cables P = 5 D2
Cable Tensile Strength (Up to 33KV)	Paper insulated armoured power cables P = 5 D3
Cable Pulling (Up to 33KV)	For Cables Pulled by Pulling Eye : If the cables are pulled by gripping the conductor directly with pulling eye, the maximum permissible tensile stress depends on the material of the conductor and on their cross-section as given below: For aluminum conductors 30 N/mm2 and For copper conductors 50 N/mm2
Cable Pulling (Up to 33KV)	**Expected Pulling Force When Pulling Cables by Winch :** The following values of pulling force are expected = (approximately percentage of cable weight): In trenches without large bends 15-20 % In trenches with 1 or 2 bends of 90° each 20-40 % In trenches with 3 bends of 90° each (assuming the use of easy-running support

	and corner rollers) 50-60 % In ducts with bends totalling 360° Up to 100 %
Cable Laying Direct in Ground (Up to 33KV)	This method involves digging a trench in the ground and laying cable(s) on a bedding of minimum 75 mm riddled soil or sand at the bottom of the trench, and covering it with additional riddled soil or sand of minimum 75 mm and protecting it by means of tiles, bricks
Cable Laying Direct in Ground (Up to 33KV)	Depth : The desired minimum depth of laying from ground surface to the top of cable is as follows: High voltage cables, 3.3 kV to 11 kV rating =0.9 m High voltage cables, 22 kV, 33 kV rating= 1.05 m Low voltage and control cables = 0.75 m Cables at road crossings = 1.00 m Cables at railway level crossings (measured from bottom of sleepers to the top of pipe)=1.00m
Cable Clearance (Up to 33KV)	**Clearances :The desired minimum clearances are as follows:** Power cable to power cable = Clearance not necessary; however, larger the clearance, better would be current carrying capacity Power cable to control cables = 0.2 m Power cable to communication cable = 0.3 m Power cable to gas/water main = 0.3 m Inductive influence on sensitive control cable on account of nearby power cables should be checked
Cable Clearance (Up to 33KV)	The power cable should not be laid above the telecommunication cable, to avoid danger to life of the person, digging to attend to the fault in the Telecommunication cable.
Crossing (Up to 33KV)	Cables Laid Across Roads, Railway Tracks and Water Pipe Lines: Steel, cast iron, plastics, cement or earthenware ducts, or cable ducting blocks should be used where cables cross roads and railway tracks. Spare ducts for future extensions should be provided. Spare duct runs should be sealed off. Buried ducts or ducting blocks should project into footpath or up to the edge of road, where there is no footpath, to permit smooth entry of cable without undue bending
Diameter of Pipe (Up to 33KV)	The diameter of the cable conduit or pipe or duct should be at least 1.5 times the outer diameter of cable. The ducts/pipes should be mechanically strong to withstand forces due to heavy traffic when they are laid across road/railway tracks.
Bending Radius (Up to 33KV)	The bending radius of steel or plastics ducts should not be less than 1.5 m.
Cable on Over Bridge (Up to 33KV)	Cable Over Bridges : On bridges, the cables are generally supported on steel cable hooks or clamped on steel supports at regular intervals. While designing a cable layout on a bridge; expansion of bridge due to changes in atmospheric temperature should be taken into account. On most of the rail-cum-road bridges, the cables are subjected to vibrations. For such conditions, round wire armoured and lead alloy 'B' sheathed cables are preferred. Cables can be laid on bridges duly suspended from catenary wire at regular intervals
Cable on Railway Crossing (Up to 33KV)	Cables Below Railway Crossing : When the cables are laid under railway tracks the cables should be laid in reinforced spun concrete or cast iron or steel pipes at such depths as may be specified by the railway authorities but not less than 1 m measured from the bottom of sleepers to the top of the pipe.
Cable on Duct (Up to 33KV)	On long run ducts, it is desirable to apply lubrication to the lead or serving/outer sheath as it enters the duct. Petroleum jelly or graphite powder or a combination of both is effective for this purpose and through lubrication will reduce the pulling tension by about 40 percent.
Laying on Racks in Air (Up to 33KV)	Lying on Racks in Air-The vertical distance between the two racks should be minimum 0.3 m and the clearance between the first cable and the wall (if racks are mounted on wall) should be 25 mm. The width of the rack should not exceed 0.75 m in order to facilitate installation of cables.
Laying on Racks in Air (Up to 33KV)	Ungalvanized steel work of cable racking/trays should be painted with a coat of primer and thereafter finished with suitable anti-corrosive paint.
Laying on Racks in Air (Up to 33KV)	Only single-core cables laid on horizontal racks need be clamped at suitable intervals. Multi-core cables need not be clamped. The distance between the vertical clamps should not be more than 2 m.
Laying Cables on Racks Inside a Tunnel(Up to	Laying Cables on Racks Inside a Tunnel: Horizontal distance between Two cable is min Diameter of Cable and vertical distance between two cable row is 30cm.In

33KV)	cable tunnel, the head room should not be less than 2 m and width sufficient to leave a free passage of at least 600 to 800 mm either from one side or in the middle.
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	With temperatures below 3°C, the cables should be warmed before the laying out, since otherwise the bending would damage the insulation and protective coverings of cables. The cable laying must be carried out swiftly, so that the cable does not cool down too much
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	Identification strips/tags of metal or plastics should be attached to the cables, particularly if several are laid in parallel, 8 to 10 m apart. Identification tags should also be attached at every entry point into the buildings and at the cable end termination
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	The spacing between three cables laid in one plane should be not less than the cable diameter.
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	When the cable run is several kilometres long, the cables should be transposed at one-third and at two-thirds of the total lengths.
Trefoil arrangement in ducts (Up to 33KV)	If several single-core cables are laid per phase, these should be arranged as follows to ensure balanced current distribution in Horizontal direction : R-Y-B-Distance-B-Y-R, (Distance=2 X Diameter of Cable) , vertical distance shall be 6 X Diameter of Cable

Requirements for Physical Protection of Underground Cables (As per NBC)	
Protective Element	**Specifications**
Bricks	(a) 100 mm minimum width
	(b) 25 mm thick
	(c) sand cushioning 100 mm and sand cover 100 mm
Concrete slabs	At least 50 mm thick
Plastic slabs (polymeric cover strips) Fiber reinforced plastic	depending on properties and has to be matched with the protective cushioning and cover
PVC conduit or PVC pipe or stoneware pipe or Hume pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe
Galvanized pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe
The trench shall be backfilled to cover the cable initially by 200 mm of sand fill; and then a plastic marker strip hall be put over the full length of cable in the trench.	
The marker signs shall be provided where any cable enters or leaves a building. This will identify that there is a cable located underground near the building.	
The trench shall then be completely filled. If the cables rise above ground to enter a building or other structure, a mechanical protection such as a GI pipe or PVC pipe for the cable from the trench depth to a height of 2.0 m above ground shall be provided.	

Cable trench (As per CPWD)
For single cable: For below 11KV, Min length of Trench shall be 35cm and depth shall be min 75cm (with sand cushioning of 8cm at bottom +Cable+ protective covering/Sand cushioning of 17cm above Cable) and without Cushioning Depth shall be 75cm+25cm.
For single cable: For above 11KV, Min length of Trench shall be 35cm and depth shall be min 1.2meter (with sand cushioning and protective covering).
For multi cable in horizontal level: Min distance between two cable shall be 20cm and min distance between cable and edge of trench on both side shall be 15cm
For multi cable in Vertical level: Min distance between two cable shall be 30cm.(min Sand cushioning at bottom of trench shall be 8cm +Cable+min Sand cushioning of 30cm+Cable+protective covering/Sand cushioning of 17cm above Cable)
For LV/MV cable cushioning is not required where there is no possibility of mechanical damages.
Extra loop of cable at end shall be 3meter for cable termination/Joints.

Cable crossing (As per CPWD)	
Cable crossing	The horizontal and vertical distance between Power and Communication cable shall not be less than 60cm.
Railway crossing	After taking approval of railway authority, Cable under railway track shall be min 1meter from bottom of sleeper under RCC or cast-Iron Pipe.
	Cable in parallel to Railway track shall be min 3meter far away from centre of nearest Track.
Cable Laying in Pipe	For Single Conductor Shall be min 10cm Dia and more than Two Cable shall be min 15cm Dia.
Cable in Road Crossing	In Road Crossing Cable shall be laid min 1 meter below Road in Pipe.

Cable Tray (Perforated) (As per CPWD)
Cable Tray may be fabricated by two angle irons of 50mmX50mmX6mm as two longitudinal members with cross bracing between them 50mmX5mm welded/Bolted at angle and 1 meter spacing of 2mm thick MS sheet.
Cable Route Marker (As per CPWD)
Cable Route Marker shall be min 0.5meter away from cable trench at the interval not exceeding 100meter parallel.
Plate Type Cable Route Marker shall be made of 100mmX5mm GI/Aluminum Plate welded/Bolted on 35mmX35mmX6mm Iron angle of 60cm Long.
Cement Concrete (C.C) type marker shall be made in formation of 1:2:4.

Cable Bending Radius (As per CPWD)			
Voltage	**Single Core**	**Unarmoured (Multi core)**	**Armoured (Multi core)**
11KV	20D	15D	12D
22KV	20D	20D	15D
33KV	20D	25D	20D

Standard Size of Transformer (IEEE/ANSI 57.120):			
Single Phase Transformer		Three Phase Transformer	
5KVA	1.25MVA	3KVA	1MVA
10KVA	1.66 MVA	5KVA	1.5 MVA
15KVA	2.5 MVA	9KVA	2 MVA
25KVA	3.33 MVA	15KVA	2.5 MVA
37.5KVA	5.0 MVA	30 KVA	3.7 MVA
50KVA	6.6 MVA	45 KVA	5 MVA
75KVA	8.3 MVA	75 KVA	7.5 MVA
100KVA	10 MVA	112.5 KVA	10 MVA
167KVA	12.5 MVA	150 KVA	12 MVA
250KVA	16.6 MVA	225 KVA	15 MVA
333KVA	20.8 MVA	300 KVA	20 MVA
500KVA	25 MVA	500 KVA	60 MVA
833KVA	33.33 MVA	750 KVA	75 MVA
			100 MVA

Standard Size of Transformer:	
Standard Size of Transformer	KVA
Power Transformer (Urban)	3,6,8,10,16
Power Transformer (Rural)	1,1.6,3.15,5
Distribution Transformer	25,50,63,100,250,315,400,500,630

Impedance of Transformer (As per IS 2026):	
MVA	% Impedance
< 1 MVA	5%
1 MVA to 2.5 MVA	6%
2.5 MVA to 5 MVA	7%
5 MVA to 7 MVA	8%
7 MVA to 12 MVA	9%
12 MVA to 30 MVA	10%
> 30 MVA	12.5%

% Impedance for Transformer (As per IS 2026)			
33KV Transformer		66KV Transformer	
MVA	%Impedance	MVA	%Impedance
1MVA	5%	6.3MVA	8.35%
1.6MVA	6.25%	8MVA	8.35%
3.15MVA	6.25%	10MVA	8.35%
4MVA	7.15%	12.5MVA	8.35%
5MVA	7.15%	20MVA	10%
6.3MVA	7.15%	16MVA	10%
8MVA	8.35%	25MVA	10%
10MVA	8.35%	31.5MVA	12.5%

% Impedance for Transformer	
MVA	%impedance
Less Than 1MVA	5%
1MVA To 2.5MVA	6%
2.5MVA To 5MVA	7%
5MVA To 7MVA	8%
7MVA To 12MVA	9%
12MVA To 30MVA	10%
More Than 30MVA	12.5%

Losses in 11 KV Transformer at 75c (As per CBIP):			
Transformer	No Load Loss(kw)	Load Loss (kw)	% Impedance
3.15MVA	2.9	20	6.25

4MVA	3.2	27	7.15
5.3MVA	3.9	31	7.15
6.3MVA	4.5	37	7.15

Losses in 66 kV Transformer at 75c (As per CBIP):

Transformer	No Load Loss(kw)	Load Loss (kw)	% Impedance
6.3MVA	6	40	8.35
8MVA	7.1	48	8.35
10MVA	8.4	57	8.35
12.5MVA	9.7	70	8.35
20MVA	13	102	10.0

Standard Rating of 66KV Transformer (As per CBIP)

Transformer	KV	Type of Cooling
6.3MVA	66KV/11KV	ONAN
8MVA	66KV/11KV	ONAN
10MVA	66KV/11KV	ONAN
12.5MVA	66KV/11KV	ONAN / ONAF
20MVA	66KV/11KV	ONAN / ONAF

Area for Transformer Room: (NBC-2005):

Transformer Size	Min. Transformer Room Area (M2)	Min. Total Sub Station Area(Incoming HV,LV Panel, T.C Roof) (M2)	Min. Space Width (Meter)
1X160	14	90	9
2X160	28	118	13.5
1X250	15	91	9
2X250	30	121	13.5
1X400	16.5	93	9
2X400	33	125	13.5
3X400	49.5	167	18
2X500	36	130	14.5
3X500	54	172	19
2X630	36	132	14.5
3X630	54	176	19
2X800	39	135	14.5
3X800	58	181	14
2X1000	39	149	14.5
3X1000	58	197	19

Transformer Mounting arrangements:

Size of Transformer	Mounting Type
Up to 25KVA	Mounted direct on Pole.
From 25KVA to 250KVA	either on “H” Frame of Plinth
Above 250KVA	Can be mounted Plinth only.
Above 100MVA	Shall be protected by Drop out Fuse or Circuit Breaker.

Requirement of Insulating Oil

400KVA to 1600KVA	1.0 Litter / KVA
1600KVA to 8000KVA	0.6 Litter / KVA
Above 80000KVA	0.5 Litter / KVA

: Transformer Cooling Arrangement Code:

Code	Description
A	Air Cooling
N	Natural Cooling by Convection
B	Cooling by Air Blast Fans
O	Oil (mineral) immersed cooling
W	Water Cooled
F	Forced Oil Circulation by Oil Pumps
S	Synthetic Liquid used instead of Oil

G	Gas Cooled (SF6 or N2)
D	Forced (Oil directed)
ONAF	Oil immersed Transformer with natural oil circulation and forced air external cooling
ONAN	Oil Immersed Natural cooled
ONAF	Oil Immersed Air Blast
ONWN	Oil Immersed Water Cooled
OFAF	Forced Oil Air Blast Cooled
OFAN	Forced Oil Natural Air Cooled
OFWF	Forced Oil Water Cooled
ODAF	Forced Directed Oil and Forced Air Cooling

Cable Size for Transformer (NPC Limited)

Transformer Size	Cable
630kVA transformers	2 no x 1C x 630 Sq mm, Al, XLPE Cable
400kVA transformers	1 no x 1C x 630 Sq mm, Al, XLPE
250kVA transformers	3 ½ C x 400 Sq mm, Al, XLPE
160kVA transformers	3 ½ C x 300 Sq mm, Al, XLPE
100kVA transformers	3 ½ C x 150 Sq mm, Al, XLPE

Size of Cable on Secondary Side of Transformer (11KV/433V) (KSEI Handbook)

Rating of T/C (KVA)	Primary current (Amp)	Secondary Current (Amp)	Min. Size of Neutral Earthing Conductor (mm2)	Minimum Size of Cable (mm2)
63	3.3	84	25X3	50mm2
100	5.25	133.3	25X3	95mm2 or (2x50 mm2)
160	8.4	213.3	25X3	185mm2 or (2x95 mm2)
200	10.49	266.6	25X3	300mm2 or (2x120 mm2)
250	13.12	333	25X3	2x185 mm2
315	16.53	420	31X3 or 25X4	(2x300 mm2) or (3x185 mm2)
400	21.80	533	38X3	(3x300 mm2) or (2x400 mm2)
500	26.20	666.5	25X6	(3x400 mm2) or (4x240 mm2)
630	33	840	31X6	4x400 mm2
750	39.36	1000	50X4	Bus Bar Trucking (min. Isc 50KA)
1000	52.50	1333	210mm2	Bus Bar Trucking (min. Isc 50KA)
1250	65.50	1667	290mm2	Bus Bar Trucking (min. Isc 50KA)
1600	83.98	2133	380mm2	Bus Bar Trucking (min. Isc 50KA)
2000	105.00	2666	450mm2	Bus Bar Trucking (min. Isc 50KA)

Corona Ring Size:

Voltage	Size
<170 KV	160mm Ring put at HV end
>170 KV	350mm Ring put at HV end
>275 KV	450mm Ring put at HV end & 350 mm Ring put at Earth end

HT Fuse on Primary Side of Transformer (11KV/433V)

Rating of T/C (KVA)	Primary current (Amp)	Secondary Current (Amp)	HT Fuse	
			Min (Amp)	Max(Amp)
63	3.3	84	10	16
100	5.25	133.3	16	25
160	8.4	213.3	16	40
200	10.49	266.6	25	40
250	13.12	333	32	40
315	16.53	420	40	63
400	21.80	533	40	63
500	26.20	666.5	50	100
630	33	840	63	100
750	39.36	1000	75	160
1000	52.50	1333	100	160
1250	65.50	1667	100	200
1600	83.98	2133	160	250

2000	105.00	2666	200	250

Loss in Watt in Different STAR Rating of T/C

Transformer Rating (KVA)	1 STAR		2 STAR		3 STAR		4 STAR		5 STAR	
	50%	100%	50%	100%	50%	100%	50%	100%	50%	100%
16	200	555	165	520	150	480	135	440	120	400
25	290	785	235	740	210	695	190	635	175	595
63	400	1415	430	1335	380	1250	340	1140	300	1050
100	700	2020	610	1910	520	1800	475	1650	435	1500
160	1000	2800	880	2550	770	2200	670	1950	570	1700
230	1130	3300	1010	3000	890	2700	780	2300	670	2100

Dimension of Transformer

Transformer Rating (KVA)	Length (mm)	Width (mm)	Height (mm)	Wheel Mounting C1 (mm)	Wheel Mounting C2 (mm)
30	755	655	945	400	400
50	825	665	985	400	400
63	840	675	1000	400	400
80	855	680	1045	400	400
100	890	690	1095	550	550
125	925	700	1155	550	550
160	960	715	1180	550	550
200	1005	800	1215	550	550
250	1330	755	1240	550	550
315	1370	770	1310	660	660
400	1425	810	1340	660	660
500	1445	815	1405	660	660
630	1600	915	1470	820	820
800	1645	935	1585	820	820
1000	1855	1125	1590	820	820
1250	1910	1130	1650	820	820
1600	2010	1220	1740	820	820
2000	2120	1280	1780	820	820

Transformer for Voltage System 1100-400 V

Power KVA	Dimensions(mm)			Oil (Ltrs)	Weight (Kgs)	Lossess (WATTS)		% Impedance
	L (mm)	W (mm)	H (mm)			No-load loss (W)	Load loss (W)	
25	960	770	1540	210	600	75	460	4
50	1010	780	1450	230	630	120	750	4
100	1030	830	1600	330	860	220	1210	4
150	1210	930	1685	470	1410	295	1675	4
200	1520	970	1730	430	1250	365	210	4
250	1740	780	1760	500	1450	455	2550	4
300	1690	840	1820	530	1600	550	3000	4
400	1700	880	1810	550	1850	745	4025	4
500	1850	890	1950	650	2100	960	5150	4
630	2120	1190	2060	860	2890	1200	6800	4
800	2150	1070	2070	960	3080	1300	11000	5
1000	2250	1160	2080	1030	3550	1500	13000	5
1250	2230	1120	2260	1230	415	1600	14500	5
1600	2350	1130	2420	1430	4910	2000	17000	6.25
2000	2490	1260	2490	1640	5910	2600	20000	6.25

2500	2780	1400	2500	2040	7040	3000	24000	6.25
3000	2900	1530	2560	2230	7820	3500	28500	6.25

Transformer for Voltage System 6KV,10KV,11KV / 440V

Capacity (kVA)	Dimensions(mm)			Weight (Kgs)	Losses		% Impedance
	L (mm)	W (mm)	H (mm)		No-load loss (W)	Load loss (W)	
30	730	605	925	350	100	600	4
50	745	650	975	450	130	870	4
63	775	665	1000	500	150	1040	4
80	820	695	1050	560	180	1250	4
100	820	665	1095	640	200	1500	4
125	1005	630	1095	770	240	1800	4
160	1045	665	1150	740	280	2200	4
200	1090	680	1175	980	340	2600	4
250	1160	730	1225	1150	400	3050	4
315	1210	770	1260	1265	480	3650	4
400	1265	790	1355	1560	570	4300	4
500	1325	845	1385	1760	680	5100	4
630	1440	905	1435	2150	810	6200	4.5
800	1501	960	1530	2580	980	7500	4.5
1000	1690	1160	1565	2870	1160	10300	4.5
1250	1800	1235	1640	3330	1360	12000	4.5
1600	1860	1300	1705	4020	1640	14500	4.5
2000	1835	1330	1845	4980	1940	18500	5.5
2500	1950	1390	1980	5890	2300	20500	5.5

Hermetically Sealed Fully with Mineral oil type Transformer

1-1. 22kV - 400/230V & 24kV - 416/240V

Capacity (kVA)	Dimensions(mm)			Oil (Ltrs)	Weight (Kgs)	Losses		% Impedance
	L (mm)	W (mm)	H (mm)			No-load loss (W)	Load loss (W)	
50	1100	1000	700	135	500	160	950	4
100	1250	1050	750	200	750	250	1550	4
160	1300	1150	750	250	990	360	2100	4
250	1350	1200	750	300	1300	500	2950	4
315	1400	1400	800	350	1300	800	3900	4
400	1400	1500	850	380	1550	960	4600	4
500	1500	1550	900	430	1750	1150	5500	4
630	1550	1600	850	450	2150	1350	6500	4
800	1600	1800	1100	650	2500	1600	11000	6
1000	1750	1900	1100	700	3200	1950	13500	6
1250	1850	2000	1150	850	4000	2300	16400	6
1500	1950	2100	1250	1150	4150	2800	19800	6
2000	2050	2250	1350	1450	5650	3250	24000	6
2500	2150	2450	1450	1750	6450	3500	28500	6

Open Type with Conservator Tank 22kV – 400/230V & 24kV - 416/240V

Capacity (kVA)	Dimensions(mm)			Oil (Ltrs)	Weight (Kgs)	Losses		% Impedance
	L (mm)	W (mm)	H (mm)			No-load loss (W)	Load loss (W)	
50	1250	1300	850	150	650	160	950	4
100	1350	1300	850	200	750	250	1550	4

160	1450	1400	850	250	950	360	2100	4
250	1550	1500	850	320	1200	500	2950	4
315	1600	1550	850	350	1250	800	3900	4
400	1650	1600	900	380	1550	960	4600	4
500	1700	1700	950	450	1800	1150	5500	4
630	1750	1800	950	600	2100	1350	6500	4
800	1850	1900	1050	650	2650	1600	11000	6
1000	2050	2050	1150	700	3200	1950	13500	6
1250	2100	2250	1200	900	4000	2300	16400	6
1500	2250	2250	1350	1100	4200	2800	19800	6
2000	2350	2300	1400	1200	5500	3250	24000	6
2500	2500	2500	1550	1800	6500	3500	28500	6

Loss in Watt in Different STAR Rating of T/C										
Transformer Rating (KVA)	**1 STAR**		**2 STARS**		**3 STARS**		**4 STARS**		**5 STARS**	
	50%	**100%**	**50%**	**100%**	**50%**	**100%**	**50%**	**100%**	**50%**	**100%**
16	200	555	165	520	150	480	135	440	120	400
25	290	785	235	740	210	695	190	635	175	595
63	400	1415	430	1335	380	1250	340	1140	300	1050
100	700	2020	610	1910	520	1800	475	1650	435	1500
160	1000	2800	880	2550	770	2200	670	1950	570	1700
230	1130	3300	1010	3000	890	2700	780	2300	670	2100

Application of Transformer according to Vector Group	
Star-Delta (Dyn11,Dyn 1,YNd1, YNd11)	Common for distribution transformers.
	Normally Dyn11 vector group using at distribution system. Because Generating Transformer are YNd1 for neutralizing the load angle between 11 and 1.
	We can use Dyn1 at distribution system, when we are using Generator Transformer are YNd11.
	In some industries 6 pulse electric drives are using due to this 5thharmonics will generate if we use Dyn1 it will be suppress the 5th harmonics.
	Star point facilitates mixed loading of three phase and single phase consumer connections.
	The delta winding carry third harmonics and stabilizes star point potential.
	A delta-Star connection is used for step-up generating stations. If HV winding is star connected there will be saving in cost of insulation.
	But delta connected HV winding is common in distribution network, for feeding motors and lighting loads from LV side.
Star-Star (Yy0 or Yy6)	Mainly used for large system tie-up Transformer.
	Most economical connection in HV power system to interconnect between two delta systems and to provide neutral for grounding both of them.
	Tertiary winding stabilizes the neutral conditions. In star connected transformers, load can be connected between line and neutral, only if
	(a) the source side transformers is delta connected or
	(b) the source side is star connected with neutral connected back to the source neutral.
	Insulation cost is highly reduced. Neutral wire can permit mixed loading.
	Triple harmonics are absent in the lines. These triple harmonic currents cannot flow, unless there is a neutral wire. This connection produces oscillating neutral.
	Three phase shell type units have large triple harmonic phase voltage. However three phase core type transformers work satisfactorily.
	A tertiary mesh connected winding may be required to stabilize the oscillating neutral due to third harmonics in three phase banks.
Delta- Delta (Dd 0 or Dd 6)	This is an economical connection for large low voltage transformers.
	Large unbalance of load can be met without difficulty.
	Delta permits a circulating path for triple harmonics thus attenuates the same.

	It is possible to operate with one transformer removed in open delta or" V" connection meeting 58 percent of the balanced load.
	Three phase units cannot have this facility. Mixed single phase loading is not possible due to the absence of neutral.
Star-Zig-zag or Delta-Zig-zag (Yz or Dz)	These connections are employed where delta connections are weak. Interconnection of phases in zigzag winding effects a reduction of third harmonic voltages and at the same time permits unbalanced loading.
	This connection may be used with either delta connected or star connected winding either for step-up or step-down transformers. In either case, the zigzag winding produces the same angular displacement as a delta winding, and at the same time provides a neutral for earthing purposes.
	The amount of copper required from a zigzag winding in 15% more than a corresponding star or delta winding. This is extensively used for earthing transformer.
	Due to **zigzag** connection (interconnection between phases), third harmonic voltages are reduced.
	It also allows unbalanced loading. The zigzag connection is employed for LV winding. For a given total voltage per phase, the zigzag side requires 15% more turns as compared to normal phase connection. In cases where delta connections are weak due to large number of turns and small cross sections, then zigzag star connection is preferred. It is also used in rectifiers.
Zig- zag/ star (ZY1 or Zy11)	Zigzag connection is obtained by inter connection of phases.4-wire system is possible on both sides. Unbalanced loading is also possible. Oscillating neutral problem is absent in this connection.
	This connection requires 15% more turns for the same voltage on the zigzag side and hence costs more. Hence a bank of three single phase transformers cost about 15% more than their 3-phase counterpart. Also, they occupy more space. But the spare capacity cost will be less and single phase units are easier to transport.
	Unbalanced operation of the transformer with large zero sequence fundamental mmf content also does not affect its performance. Even with Yy type of poly phase connection without neutral connection the oscillating neutral does not occur with these cores. Finally, three phase cores themselves cost less than three single phase units due to compactness.
Yd5	Mainly used for machine and main Transformer in large Power Station and Transmission Substation.
	The Neutral point can be loaded with rated Current.
Yz-5	For Distribution Transformer up to 250MVA for local distribution system.
	The Neutral point can be loaded with rated Current.

Application of Transformer according to Uses	
Step up Transformer	It should be Yd1 or Yd11.
Step down Transformer	It should be Dy1 or Dy11.
Grounding purpose Transformer	It should be Yz1 or Dz11.
Distribution Transformer:	We can consider vector group of Dzn0 which reduce the 75% of harmonics in secondary side.
Power Transformer	Vector group is deepen on application for Example: Generating Transformer:Dyn1 , Furnace Transformer: Ynyn0.

Convert One Group of T/C to Other Group by Channing External Connection	
Group I:	**Example: Dd0 (no phase displacement between HV and LV).** =The conventional method is to connect the red phase on A/a, Yellow phase on B/b, and the Blue phase on C/c. =Other phase displacements are possible with unconventional connections (for instance red on b, yellow on c and blue on a) By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd0 transformer can be changed either to a Dd4(-120°) or Dd8(+120°) connection. The same is true for internal connected Dd4 or Dd8 transformers
Group II:	**Example: Dd6 (180° displacement between HV and LV).** By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd6 transformer can be changed either to a Dd2(-60°) or Dd10(+60°) connection
Group III:	**Example: Dyn1 (-30° displacement between HV and LV).** =By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn1 transformer can be changed either to a Dyn5(-150°) or Dyn9(+90°) connection.

Group IV:	**Example: Dyn11 (+30° displacement between HV and LV).** =By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn11 transformer can be changed either to a Dyn7(+150°) or Dyn3(-90°) connection.

Point to be remembered

For Group-III & Group-IV: By doing some unconventional connections externally on both sides of the Transformer, an internal connected Group-III or Group-IV transformer can be changed to any of these two groups. Thus by doing external changes on both sides of the Transformer an internal connected Dyn1 transformer can be changed to either a: Dyn3, Dyn5, Dyn7, Dyn9 or Dyn11 transformer, This is just true for star/delta or delta/star connections.

For Group-I & Group-II: Changes for delta/delta or star/star transformers between Group-I and Group-III can just be done internally.

Group and Transformer Connections

Group	O'clock	TC
Group I	0 o'clock, 0°	delta/delta, star/star
Group II	6 o'clock, 180°	delta/delta, star/star
Group III	1 o'clock, -30°	star/delta, delta/star
Group IV	11 o'clock, +30°	star/delta, delta/star
Minus indicates LV lagging HV, plus indicates LV leading HV		

Phase Shift and Connections

Phase Shift (Deg)	Connection		
0	Yy0	Dd0	Dz0
30 lag	Yd1	Dy1	Yz1
60 lag		Dd2	Dz2
120 lag		Dd4	Dz4
150 lag	Yd5	Dy5	Yz5
180 lag	Yy6	Dd6	Dz6
150 lead	Yd7	Dy7	Yz7
120 lead		Dd8	Dz8
60 lead		Dd10	Dz10
30 lead	Yd11	Dy11	Yz11

Operative Parallel Operation

Sr.No	Transformer-1	Transformer-2
1	ΔΔ	ΔΔ or Yy
2	Yy	Yy or ΔΔ
3	Δy	Δy or YΔ
4	YΔ	YΔ or Δy

In operative Parallel Operation

Sr.No	Transformer-1	Transformer-2
1	ΔΔ	Δy
2	Δy	ΔΔ
3	YΔ	Yy
4	Yy	YΔ

Transformer (IS:11171)

	Part	Type of Insulation	Degree (Centigrade)
Transformer Temperature Rise Limit	Part=Winding	Type of Insulation=A	50 Centigrade
	Part=Winding	Type of Insulation=E	65 Centigrade
	Part=Winding	Type of Insulation=B	70 Centigrade
	Part=Winding	Type of Insulation=F	90 Centigrade
	Part=Winding	Type of Insulation=H	115 Centigrade
	Part=Winding	Type of Insulation=G	140 Centigrade
	Part= Core, MetallicPart	Type of Insulation=-	Not rise to damage core or metallic part
Transformer Cooling	Type of cooling Medium: A=Air		
	First Letter= Type of Cooling Medium (Contact with Winding)		

Method indication	Second Letter = Kind of Circulation(Contact with Winding)
	Third Letter= Type of Cooling Medium (Contact with external cooling System)
	Forth Letter = Kind of Circulation (Contact with external cooling System)
Transformer Reduce Temperature Rise Limit	TRANSFORMER designed for operation at an altitude greater than 1 000 m but tested at normal altitudes the limits of temperature rise are reduced by the following amounts for each 500 m by which the intended working altitude exceeds 1000Meter
	(a) Natural-air-cooled Transformers 2.5 % (b) Forced-air-cooled Transformers %
Transformer Parallel operation Condition	(1)Rated power (kVA);
	(2) Rated voltage ratio;
	(3) Voltage ratios corresponding to tappings other than the principal tapping.
	(4) Rated power (kVA); Rated voltage ratio; Voltage ratios corresponding to tapings other than the principal tapping.
	(5) Load loss at rated current on the principal tapping, corrected to the appropriate reference temperature.
	(6) Impedance voltage at rated current (on the principal tapping).
	(7) Short-circuit impedances, at least on the extreme tappings, if the tapping. Range of the tapped winding exceeds + or – 5 %.

Accuracy Class Letter of CT:	
Metering Class CT	
Accuracy Class	**Applications**
B	Metering Purpose
Protection Class CT	
C	CT has low leakage flux.
T	CT can have significant leakage flux.
H	CT accuracy is applicable within the entire range of secondary currents from 5 to 20 times the nominal CT rating. (Typically wound CTs.)
L	CT accuracy applies at the maximum rated secondary burden at 20 time rated only. The ratio accuracy can be up to four times greater than the listed value, depending on connected burden and fault current. (Typically window, busing, or bar-type CTs.)

Accuracy Class of Metering CT:	
Metering Class CT	
Class	**Applications**
0.1 To 0.2	Precision measurements
0.5	High grade kilowatt hour meters for commercial grade kilowatt hour meters
3	General industrial measurements
3 OR 5	Approximate measurements
0.15	High Accuracy Metering
0.15S	Special High Accuracy Metering
0.3	Revenue Metering
1.2	Indicating Instruments

Accuracy Class of Protection CT	
Class	**Applications**
10P5	Instantaneous over current relays & trip coils: 2.5VA
10P10	Thermal inverse time relays: 7.5VA
10P10	Low consumption Relay: 2.5VA
10P10/5	Inverse definite min. time relays (IDMT) over current
10P10	IDMT Earth fault relays with approximate time grading:15VA
5P10	IDMT Earth fault relays with phase fault stability or accurate time grading: 15VA

Protection CT			
Protective System	**CT Secondary**	**VA**	**Class**
Per current for phase & earth fault	1A	2.5	10P20 Or 5P20
	5A	7.5	10P20 Or 5P20
Unrestricted earth fault	1A	2.5	10P20 Or 5P20
	5A	7.5	10P20 Or 5P20
Sensitive earth fault	1A or 5A		Class PX use relay manufacturers formula
Distance protection	1A or 5A		Class PX use relay manufacturers formula
Differential protection	1A or 5A		Class PX use relay manufacturers formula
High impedance differential impedance	1A or 5A		Class PX use relay manufacturers formula
High speed feeder protection	1A or 5A		Class PX use relay manufacturers formula
Motor protection	1A or 5A	5	5P10

Burden of CT:	
VA	**Applications**
1 To 2 VA	Moving iron ammeter
1 To 2.5VA	Moving coil rectifier ammeter
2.5 To 5VA	Electrodynamics instrument
3 To 5VA	Maximum demand ammeter
1 To 2.5VA	Recording ammeter or transducer

Nomenclature of CT:	
Nomenclature of CT:	Ratio, VA Burden, Accuracy Class, Accuracy Limit Factor.
Ratio:	Input / output current ratio
Burden (VA):	Total burden including pilot wires. (2.5, 5, 10, 15 and 30VA.)
Class:	Accuracy required for operation (Metering: 0.2, 0.5, 1 or 3, Protection: 5, 10, 15, 20, 30).
Accuracy Limit Factor:	5, 10, 15, 20 and 30.
Dimensions:	maximum & minimum limits
Example:	**1600/5, 15VA 5P10** (Ratio: 1600/5, Burden: 15VA, Accuracy Class: 5P, ALF: 10)
As per IEEE Metering CT:	0.3B0.1 rated Metering CT is accurate to 0.3 percent if the connected secondary burden if impedance does not exceed 0.1 ohms
As per IEEE Relaying (Protection) CT:	2.5C100 Relaying CT is accurate within 2.5 percent if the secondary burden is less than 1.0 ohm (100 volts/100A).

Sizing of CT for Building:

- **New construction**: size the CT to handle about 80% of the circuit breaker capacity. If the building is served by a 2000 amp breaker, use 1600 amp (2000 x 0.8) CT's.
- **Older buildings:** the peak demand can generally be determined from the power company or from past billings. In this case add 20 to 30% to the peak demand and size the CT's for this load. If the peak demand was 500 kW, the peak current on a 480/3/60 system would be **500,000 / (480 x 1.73 x 0.9 pf) = 669 amps.** This assumes a 0.9 power factor. (Peak current would be higher with a lower power Factor.) Use CT's about 20% larger. 800:5 CT's would be a good selection.
- For older buildings with no demand history, size the **CT's** the same as for new construction. Where possible, use multi-tap **CT's** so that the ratio can be reduced if the maximum load is much less than 80% of the breaker size.
- CT's that are used to monitor motor loads can be sized from the nameplate full load motor amps.

Chapter: 15 Working Space for Electrical Room Reference

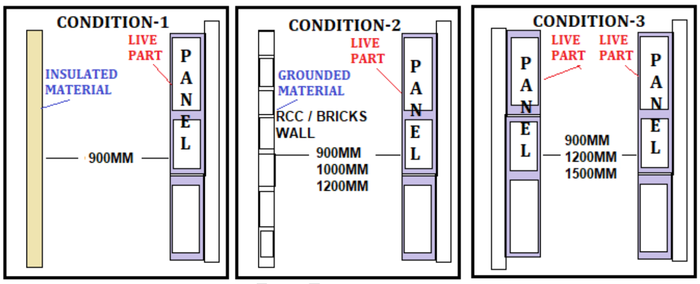
Electrical Equipment Space (As per NEC 110.26)

(A) Working Space:

- Equipment that may need examination, adjustment, servicing, or maintenance while energized must have working space which is measured from the enclosure front, must not be less than the distances contained in Table 110.26(A)(1).

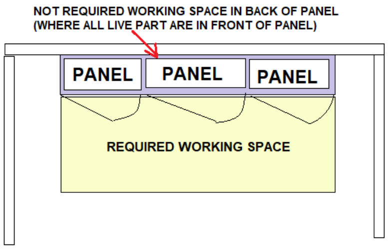
(1) Depth of Working Space.

Table 110.26(A)(1) Working Space			
Voltage-to-Ground	**One side of working Space having Panel Exposed live parts and other side of Working Space having no live or grounded parts (including concrete, brick, or tile walls)**	**One side of working Space having Panel Exposed live parts and other side of Working Space having live or grounded parts (including concrete, brick, or tile walls)**	**Exposed live parts on both sides of the working space.**
0 To 150V	3 Foot (900MM)	3 Foot (900MM)	3 Foot (900MM)
151V To 600V	3 Foot (900MM)	3.5 Foot (1000MM)	4 Foot (1200MM)
601V TO 1000V	3 Foot (900MM)	4 Foot (1200MM)	5 Foot (1500MM)



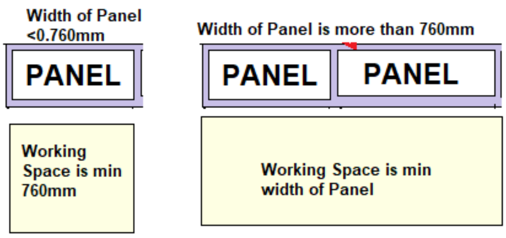
Rear and Sides.

- Working space isn't required for the back or sides of assemblies where all connections and all renewable or adjustable parts are accessible from the front.



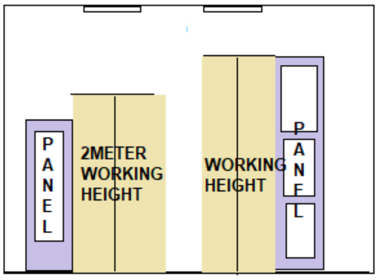
(2) Width of Working Space.

- **The width of the working space must be a minimum of 760MM (30 in) but in no case less than the width of the equipment.**
- The width of the working space can be measured from left-to-right, from right-to-left, or simply centred on the equipment, and the working space can overlap the working space for other electrical equipment.
- In all cases, the working space must be of sufficient width, depth, and height to permit all equipment doors to open 90 degrees.



(3) Height of Working Space (Headroom).

- **The height of the working space in front of equipment must not be less than 2 Meter (6½ ft) measured from the grade, floor, platform, or the equipment height, whichever is greater.**
- Equipment such as raceways, cables, wireways, cabinets, panels, and so on, can be located above or below electrical equipment, but must not extend more than 6 in. into the equipment's working space.

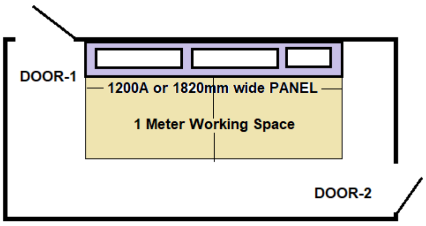


(4) Limited Access

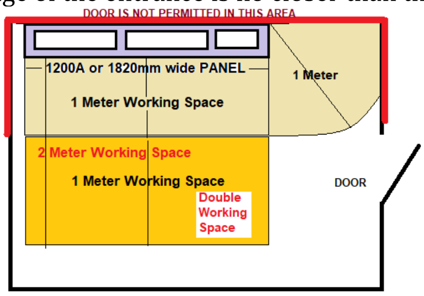
- Where equipment is installed above a lay-in ceiling, there shall be an opening not smaller than 559 mm × 559 mm (22 in. × 22 in.), or in a crawl space, there shall be an accessible opening not smaller than 559 mm × 762 mm (22 in. × 30 in.).
- The width of the working space shall be the width of the equipment enclosure or a minimum of 762 mm (30 in.) whichever is greater.
- All enclosure doors or hinged panels shall be capable of opening a minimum of 90 degrees.
- The space in front of the enclosure shall comply with the depth requirements of Table 110.26(A)(1).
- The maximum height of the working space shall be the height necessary to install the equipment in the limited space. A horizontal ceiling structural member or access panel shall be permitted in this space.

(5) Entrance to and Egress from Working Space.

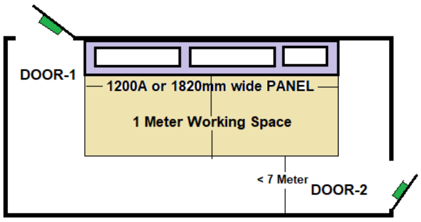
- **Minimum Required:**
- At least one entrance of sufficient area must provide access to and egress from the working space.
- **Large Equipment:**
- An entrance to and egress from each end of the working space of for electrical equipment rated 1,200A or more and over 6 ft wide is required an entrance of Not Less than 600MM Wide and 1800MM Height at each end of Working Place.



- A single entrance to and egress from the required working space is permitted where either of the following conditions is met:
- (a) Unobstructed Egress. Only one entrance is required where the location permits a continuous and unobstructed way of egress travel.
- (b) Double Workspace. Only one entrance is required where the required working space depth is doubled, and the equipment is located so the edge of the entrance is no closer than the required working space distance.



- **Personnel Doors:**
- If equipment with overcurrent or switching devices rated 1,200A or more is installed, personnel door(s) for entrance to and egress from the working space located less than **25** ft from the nearest edge of the working space must have the door(s) open in the direction of egress and be equipped with panic hardware or other devices that open under simple pressure



(6) Illumination:

- Service equipment, switchboards, panel boards, as well as motor control centres located in indoors must have illumination and controlled by automatic means only.

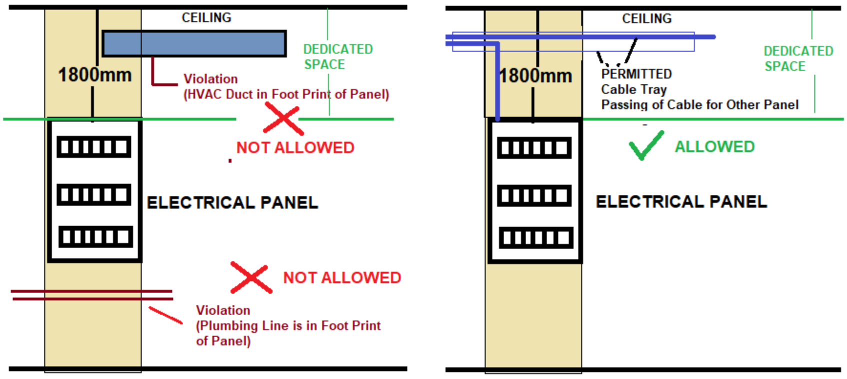
(7) Dedicated Equipment Space:

- Switchboards, panel boards, and motor control centres must have dedicated equipment space as follows:

(B) Indoors (110.26 (E))

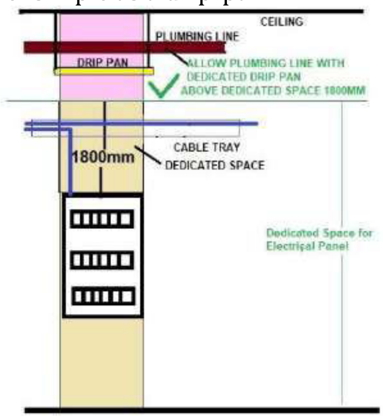
Dedicated Electrical Space:

- a dedicated electrical space is defined as the space equal to the width and the depth of the equipment extending from the floor to a **height of 1.8 m above the equipment or the structural ceiling, whichever is lower.**
- No piping, ducts, or other foreign equipment can be installed in this dedicated Electrical footprint space.
- Busways, conduits, raceways, and cables are permitted to enter through this Dedicated Electrical Space / zone.



Foreign Systems:

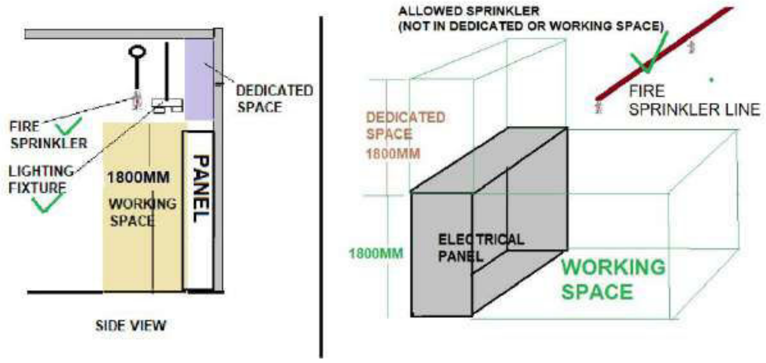
- Foreign systems can be located above the dedicated space if proper protection is installed to prevent damage to the electrical equipment from condensation, leaks, or breaks in the foreign systems,
- This can be achieved by installation of simple as a drip-pan.



Sprinkler Protection (110.26(E)):

- Sprinkler protection shall be permitted in the area above the dedicated electrical space if the electrical equipment is properly protected against Water leaks or breaks in the Sprinkler system.
- Sprinkler System shall not be permitted in Working Space of Electrical Equipment.
- **Hence the sprinkler piping can run above the dedicated electrical space 1.8 m above equipment** as long as the Electrical equipment below is protected from leaks, condensation, and even breaks by using dedicated Drip Pan.

- But drip pans which may create an obstruction to sprinkler system discharge. **So, it is always advisable to avoid locating sprinklers and sprinkler piping directly above electrical equipment and sprinklers and sprinkler piping are not permitted to be located directly within the working space for the equipment as shown in the figure**.



- Where all of the following conditions are met, sprinklers shall not be required in electrical rooms
- (1) The room is dedicated to electrical equipment only.
- (2) Only dry-type or liquid-type with listed K-class fluid electrical equipment is used.
- (3) Equipment is installed in a 2-hour fire-rated enclosure including protection for penetrations.
- (4) Storage is not permitted in the room.

Suspended Ceilings:

- A dropped, Suspended or other similar hanging ceiling that does not add strength to the building structure is permitted to be located directly in the dedicated space, because they are not considered structural ceilings. Building structural members are also permitted in this space.

(C) Outdoor.

- Outdoor Electrical installations must comply with the following:

Installation Requirements:

- Switchboards, switchgear, panel boards installed outdoors must be Installed in identified enclosures
- Protected from accidental contact by unauthorized personnel, or by vehicular traffic.
- Protected by accidental spillage or leakage from piping systems

Work Space.

- The working clearance space shall include the zone described in 110.26(A). No architectural appurtenance or other equipment shall be located in this zone.
- Exception: Structural overhangs or roof extensions shall be permitted in this zone.

Dedicated Equipment Space Outdoor.

- The footprint space (width and depth of the equipment) extending from grade to a height of 6 ft above the equipment must be dedicated for the electrical installation.
- No piping, ducts, or other equipment foreign to the electrical installation can be installed in this dedicated footprint space.

Locked Electrical Equipment Rooms or Enclosures.

- Electrical equipment rooms and enclosures housing electrical equipment can be controlled by locks because they are still considered to be accessible to qualified persons who require access.

(D) Enclosure for Electrical Installations (110.31).

- Electrical installations in an Electrical Room, or closed area surrounded by a wall, screen, or fence shall be access or controlled by a lock(s) or other approved manners.
- Electrical Installation Area (Indoor and Outdoor) shall be accessible to qualified persons only.
- The type of enclosure used shall be designed and constructed according to the nature and degree of the hazard(s) associated with the installation.
- For Outdoor Type Electrical installations shall be covered by Fence.

Fence:

- A fence shall not be less than 2.1 m (7 ft) in height or a combination of 1.8 m (6 ft) or more of fence fabric and a 300 mm (1 ft) or more extension utilizing three or more strands of barbed wire or equivalent.
- The distance from the fence to live parts shall be not less than given in Table 110.31.

Min. Distance from Fence to Live Part Table 110.31	
Nominal Voltage	Min. Distance from Live Part (Meter)
601 V To 13799 V	3.05 Meter
13800 V To 230000 V	4.57 Meter
Above 230000 V	5.49 Meter

(E) Electrical Room.

- Where an electrical vault is required or specified for conductors and equipment 110.31(A)(1) to (A)(5) shall apply.

Walls and Roof.

- The walls and roof shall be constructed of a minimum fire rating of 3 hours. For the purpose of this section, studs and wallboard construction shall not be permitted.

Floors.

- The floors of vaults in contact with the earth shall be of concrete that is not less than 102 mm (4 in.) thick, but where the vault is constructed with a vacant space or other stories below it, the floor shall have adequate structural strength for the load imposed on it and a minimum fire resistance of 3 hours.

Doors.

- Each doorway leading into a vault from the building interior shall be provided with a tight-fitting door that has a minimum fire rating of 3 hours.

Locks.

- Doors shall be equipped with locks, and doors shall be kept locked, with access allowed only to qualified persons. Personnel doors shall swing out and be equipped with panic bars, pressure plates, or other devices that are normally latched but that open under simple pressure.

(F) Enclosed Equipment Accessible to Unqualified Persons.

- Ventilating or similar openings in equipment shall be designed such that foreign objects inserted through these openings are deflected from energized parts.
- Where exposed to physical damage from vehicular traffic, suitable guards shall be provided.
- Non-metallic or metal-enclosed equipment located outdoors and accessible to the general public shall be designed such that exposed nuts or bolts cannot be readily removed, permitting access to live parts.
- Where non-metallic or metal-enclosed equipment is accessible to the general public and **the bottom of the enclosure is less than 2.5 m (8 ft) above the floor or grade level, the enclosure door or hinged cover shall be kept locked.** Doors and covers of enclosures used solely as pull boxes, splice boxes, or junction boxes shall be locked, bolted, or screwed on. Underground box covers that weigh over 45.4 kg (100 lb) shall be considered as meeting this requirement.

Size of Capacitor for P.F Correction:	
For Motor	
Size of Capacitor = 1/3 Hp of Motor OR (0.12x KW of Motor)	
For Transformer	
< 315 KVA	5% of KVA Rating
315 KVA to 1000 KVA	6% of KVA Rating
>1000 KVA	8% of KVA Rating
Capacitor Bank should be automatic Type	>= 5MVA Substation

Size of Capacitor Bank	
System Voltage	Minimum rating of capacitor bank
3.3 KV , 6.6KV	75 Kvar
11 KV	200 Kvar
22 KV	400 Kvar
33 KV	600 Kvar

Capacitor Bank for Non Linear Load	
% Non Liner Load	**Type of Capacitor**
<=10%	Standard Duty
Up to 15%	Heavy Duty
Up to 20%	Super Heavy Duty
Up to 25%	Capacitor +Reactor (Detuned)
Above 30%	

Selection of capacitor for transformer no-load compensation	
KVA Rating of the Transformer	**Kvar Required for compensation**
Up to and including 315 KVA	5% of KVA Transformer Rating
315 to 1000 KVA	6% of KVA Transformer Rating
Above 1000 KVA	8% of KVA Transformer Rating

Capacitor Bank for Transformer	
Transformer	**Required Capacitor (Kvar)**
<= 315 KVA T.C	5% of KVA
315kVA To 1000 kVA	6% of KVA
>= 1000 kVA	8% of KVA

Capacitor Bank for Power Supply Voltage	
System Voltage	**Minimum rating of capacitor bank**
3.3 KV , 6.6KV	75 Kvar
11 KV	200 Kvar
22 KV	400 Kvar
33 KV	600 Kvar

Fuse for Capacitor Bank		
KVAr	**HRC Fuse**	**Cable Amps**
5	12 Amps	12 Amps
7.5	25 Amps	25 Amps
10	32 Amps	32 Amps
12.5	32 Amps	32 Amps
15	50 Amps	50 Amps
20	50 Amps	50 Amps
25	63 Amps	63 Amps
50	125 Amps	125 Amps
75	200 Amps	200 Amps
100	200 Amps	250 Amps

Capacitor Ratings at Rated Voltage (NEC)

Motor Rating(Kw)	Capacitor Rating in KVAR for Motor Speed					
	3 000 rev/min	1 500 rev/min	1 000 rev/min	750 rev/min	600 rev/min	500 rev/min
2.25	1	1	1.5	2	2.5	2.5
3.7	2	2	2.5	3.5	4	4
5.7	2	3	3.5	4.5	5	5.5
7.5	3	4	4.5	5.5	6	6.5
11.2	4	5	6	7.5	8.5	9
15	5	6	7	9	11	12
18.7	6	7	9	10.5	13	14.5
22.5	7	8	10	12	15	17
37	11	12.5	16	18	23	25
57	16	17	21	23	29	32
75	21	23	26	28	35	40
102	31	33	36	38	45	55
150	40	42	45	47	60	67
187	46	50	53	55	68	76

Capacitor Ratings	
System	**KVAR Rating**
216 Volt	5, 7.5, 131/3, 20, 25
240 Volt	2.5, 5, 7.5,10, 25, 20, 25, 50
480 Volt	5, 10, 15, 20 25, 35, 50, 60, 100
600 Volt	5, 10, 15, 20 25, 35, 50, 60, 100
2400 Volt	50, 100, 150, 200
2770 Volt	50, 100, 150, 200
7200 Volt	50, 100, 150, 200,300,400
12470 Volt	50, 100, 150, 200,300,400
13800 Volt	50, 100, 150, 200,300,400

Calculation for Required Capacitor:

- Suppose Actual P.F is 0.8, Required P.F is 0.98 and Total Load is 516KVA.
- Power factor = KW / KVA
- **KW = KVA x Power Factor**
- KW = 516 x 0.8 = 412.8
- **Required capacitor = kW x Multiplying Factor**
- Required capacitor= (0.8 x 516) x Multiplying Factor
- Required capacitor = 412.8 x 0.547 (See Table to find Value according to P.F 0.8 to P.F of 0.98)
- **Required capacitor = 225.80 KVAR**

Multiplying factor for calculating KVAR											
Target PF											
0.6	**0.9**	**0.91**	**0.92**	**0.93**	**0.94**	**0.95**	**0.96**	**0.97**	**0.98**	**0.99**	**1**
0.6	0.849	0.878	0.907	0.938	0.970	1.005	1.042	1.083	1.130	1.191	1.333
0.61	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.157	1.299
0.62	0.781	0.810	0.839	0.870	0.903	0.937	0.974	1.015	1.062	1.123	1.265
0.63	0.748	0.777	0.807	0.837	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.716	0.745	0.775	0.805	0.838	0.872	0.909	0.950	0.998	1.058	1.201
0.65	0.685	0.714	0.743	0.774	0.806	0.840	0.877	0.919	0.966	1.027	1.169
0.66	0.654	0.683	0.712	0.743	0.775	0.810	0.847	0.888	0.935	0.996	1.138
0.67	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.966	1.108
0.68	0.594	0.623	0.652	0.683	0.715	0.750	0.787	0.828	0.875	0.936	1.078
0.69	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.907	1.049
0.7	0.536	0.565	0.594	0.625	0.657	0.692	0.729	0.770	0.817	0.878	1.020
0.71	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.452	0.481	0.510	0.541	0.573	0.608	0.645	0.686	0.733	0.794	0.936
0.74	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.371	0.400	0.429	0.460	0.492	0.526	0.563	0.605	0.652	0.713	0.855
0.77	0.344	0.373	0.403	0.433	0.466	0.500	0.537	0.578	0.626	0.686	0.829
0.78	0.318	0.347	0.376	0.407	0.439	0.474	0.511	0.552	0.599	0.660	0.802
0.79	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.634	0.776
0.8	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.608	0.750
0.81	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.556	0.698
0.83	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.530	0.672
0.84	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85	0.135	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86	0.109	0.138	0.167	0.198	0.230	0.265	0.302	0.343	0.390	0.451	0.593
0.87	0.082	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88	0.055	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89	0.028	0.057	0.086	0.117	0.149	0.184	0.221	0.262	0.309	0.370	0.512
0.9		0.029	0.058	0.089	0.121	0.156	0.193	0.234	0.281	0.342	0.484
0.91			0.030	0.060	0.093	0.127	0.164	0.205	0.253	0.313	0.456
0.92				0.031	0.063	0.097	0.134	0.175	0.223	0.284	0.426
0.93					0.032	0.067	0.104	0.145	0.192	0.253	0.395
0.94						0.034	0.071	0.112	0.160	0.220	0.363
0.95							0.037	0.078	0.126	0.186	0.329

Standard Size of The DG sets				
KVA	KVA	KVA	KVA	KVA
7.5 KVA	20KVA	35 KVA	62.5 KVA	100 KVA
10 KVA	25 KVA	40 KVA	75 KVA	125 KVA
15 KVA	30 KVA	50 KVA	82.5 KVA	200 KVA

Steel Bar Size for D.G Foundation	
Rating of D.G set	Size of Bar
Up to 82.5 KVA	10MM
100 KVA To 200 KVA	12MM
250 KVA to 500KVA	16MM

Minimum Capacity of Daily Fuel Service Tank (AS per CPWD)	
Capacity of DG set	Minimum Fuel Tank Capacity
Up to 25 KVA	100 Litres
Above 25 to 62.5 KVA	120 Litres
Above 62.5 KVA to 125 KVA	225 Litres
Above 125 KVA to 200 KVA	285 Litres
Above 200 KVA to 380 KVA	500 Litres
Above 380 KVA to 500 KVA	700 Litres
Above 500 KVA to 750 KVA	900 Litres

Battery Size for D.G Set (AS per CPWD)			
DG Set Capacity	Battery Capacity	Cu Cable Size	Electrical System
Up to 25 KVA	88 AH	35 Sq.mm	12 Volts
Above 25 KVA up to 62.5 KVA	120 AH	50 Sq.mm	12 Volts
Above 62.5 KVA up to 82.5 KVA	150 AH	50 Sq.mm	12 Volts
Above 82.5.KVA up to 125 KVA	180 AH	50 Sq.mm	12 Volts
Above 125 KVA up to 500 KVA	180 AH	70 Sq.mm	12 Volts
Above 500 KVA	360 AH	70 Sq.mm	24 Volts

Depths of PCC (Plain Cement Concrete) for DG Set (As per CPWD)	
DG Set Capacity (KVA)	Typical Depth of PCC Foundation (For soil bearing capacity 5000 kg/sqm)
750-2000	600 mm
625	400 mm
320-500	400 mm
200-320	400 mm
82.5 -200	400 mm
Up to 82.5	200 mm

Area Required For Generator in Electrical Sub Station (As per NBC)		
Capacity kVA	Area m2	Clear Height below the Soffit of the Beam m
25	56	3.6
48	56	3.6
100	65	3.6
150	72	3.6
248	100	4.2
350	100	4.2
480	100	4.2
600	110	4.6
800	120	4.6
1010	120	6.5
1250	120	6.5
1600	150	6.5
2000	150	6.5

Starting Current for D.G set	
Type of Load	**Starting Current**
Motors over 50 HP	6 X motor rated current
Variable frequency drive motors	2 X motor rated current
Uninterruptible power supply (UPS) loads	1.5 X UPS rated current
Battery charger loads	2.5 X Charger rated current
Non-Linear Load	1.5 to 2.5 X rated current
Medical imaging loads	1.1 X Rated current
Soft Starter Motor	1.2 X motor rated current
DOL Starter	4 X motor rated current
Star-Delta Starter	3 X motor rated current
Auto Transformer Starter	1.5 X motor rated current
Most generators are capable of delivering 300% of the rated current for 10 seconds	

Stand by D.G Permission As per PSEB		
D.G Set Capacity	**Permission**	**Remarks**
Up to 10 KW(11 KVA)	No permission is required. Also prior sanction of CEI is not required.	
10 KW (11 KVA) to 250 KVA		
250 KVA to 1 MVA		
1 MVA to 2.5 MVA	Permission is required. Also prior sanction of CEI is required	The capacity of D.G Set should not exceed 1.2 times of the sanctioned Load.
2.5 MVA to 5 MVA		
Exceeding 5 MVA		

Electricity Act, 2003 (Act No. 36 of 2003) & Central Electricity Authority Regulations, regulation 32, 2010	
Inspection of D.G by Electrical Inspector	All the apparatus of capacity above 100 KVA of the generating units including generating units producing electricity from renewable sources of energy shall be inspected by the Electrical Inspector before commissioning.

Sound Level of Diesel Generator (ANSI 89.2&NEMA 51.20):	
KVA	**Max. Sound Level**
<9 KVA	40 DB
10 KVA to 50 KVA	45 DB
51 KVA to 150 KVA	50 DB
151 KVA to 300 KVA	55 DB
301 KVA to 500 KVA	60 DB

Exhaust Stack Height	
Up to 1000KVA D.G	**Total Height of stack (Meter)** = (Height of Building Where D.G Installed +0.2) X √D.G Capacity in KVA
More than 1000KVA D.G	30 Meter height or more than 3 meter height of building which is higher.

Height of stack (Meter)	
Generator Sets	**Total Height of Stack in Meters.**
000 to 050 KVA	Height of Building + 1.5 Meter
050 to 100 KVA	Height of Building + 2.0 Meter.
100 to 150 KVA	Height of Building + 2.5 Meter
150 to 200 KVA	Height of Building + 3.0 Meter
200 to 250 KVA	Height of Building + 3.5 Meter
250 to 300 KVA	Height of Building + 4.0 Meter.

D.G Room Air Requirement	
D.G Set	**Air Requirement**
275 KVA	605 Cu. Meter / Min
320 KVA	625 Cu. Meter / Min
400 KVA	854 Cu. Meter / Min
500 KVA	1065 Cu. Meter / Min
600 KVA	1286 Cu. Meter / Min

Noise Limit of D.G Set As per CPWD, India
Up to 1000 KVA (manufactured after 2005) =75 dB(A) at 1 meter from the enclosure surface
The acoustic enclosure or acoustic treatment of the room shall be designed for minimum 25 dB(A) insertion loss or for meeting the ambient noise standards, whichever is on the higher side.
The measurement for insertion loss may be done at different points at 0.5 m from the acoustic enclosure / room, and then averaged.
The DG set shall be provided with proper exhaust muffler with insertion loss of minimum 25 dB(A).

Foundation & Earthing for D.G Set (As Per CPWD)	
Item	**Descriptions**
D.G set inside Room	A PCC foundation (1:2:4, M-20 grade) of approximate depth 150 mm above the finished Genset Room Floor level
	The length and breadth of foundation should be at least 250 mm more on all sides than the size of the enclosure.
D.G set in Open Room	A PCC (1:2:4, M-20 grade) foundation of weight 2.5 times the operating weight of the Genset with enclosure or as recommended by the Genset manufacturer, whichever is higher
	300 mm of this foundation height should be above the ground level. The length and breadth of foundation should be at least 250 mm more on all sides than the size of enclosure.
Earthing	Copper plate earthing (Neutral Grounding) shall be provided for DG Sets of capacity 500 KVA or above
	whereas G.I. plate earthing (Neutral Grounding) shall be provided for DG Sets below 500 KVA capacity. The body earthing shall generally be of G.I
Numbers of earthing for each DG Sets	2No's earthing sets for Genset/ control panel body.
	2No's earthing sets for neutral.
	In case there are more than one DG Set in one location, independent two nos. neutral earthing shall be provided for each DG set. However, two nos. earthing sets shall be common for the body earthing of DG Sets
	DG Set of 500 KVA capacity or above:- Copper strip
	DG Set below 500 KVA capacity:- GI strip

D.G Spacing Guidance			
Description	**DG set with Acoustic Enclosure**		**Open DG set in room.**
	in Open Area	**in Closed Area**	
Free space on both sides	Min. 1.5 m	Min. 1.5 m	Min. 2 m
Free space at front side (Radiator Hot air outlet at Front)	Min. 3 m	Min. 3 m	N/A
Free space at front side (Radiator Hot air outlet at Top)	Min. 1.0 m	Min. 1.5 m	N/A
Free space at rear side (Alternator)	Min. 2 m	Min. 2 m	Min. 2 m
Fresh air inlet opening area	N/A	N/A	Min 1.5 times of the Radiator area.
Hot air discharge opening area	N/A	N/A	Min 2.5 times of the Radiator area.
Distance between two sets	Min 1.5m between two canopies	Min 1.5m between two canopies	Min 1.5m between two foundations.

D.G Detail according to Size					
D.G Size (KVA)	**L x W x H (Canopy) mm**	**Approx Weight (Kg)**	**Fuel Tank (Ltrs)**	**Fuel Consumption (Ltr/hr)**	**Oil Consumption (Ltr/hr)**
12.5	2040 x 1230 x 1450	1050	60	2.3	0.02
15	2040 x 1230 x 1450	1050	65	2.3	0.02
20	2240 x 1230 x 1450	1300	65	3.7	0.03
30	2510 x 1130 x 1450	1300	65	6.3	0.03
40	3350 x 1180 x 1650	1500	100	7.8	0.03
50	3350 x 1180 x 1650	1500	100	8.3	0.03
62.5	3350 x 1180 x 1650	1930	150	10.5	0.03

75	3605 x 1405 x 1600	1950	150	13	0.03
100	3940 x 1700 x 1850	2500	300	15.7	0.05
125	3950 x 1700 x 1850	2700	300	19	0.05
140	4600 x 1850 x 1950	3580	300	22.6	0.06
160	4600 x 1850 x 1950	3720	450	25.9	0.14
180	4970 x 1730 x 2045	3870	450	27.7	0.14
200	4970 x 1730 x 2045	3950	450	29.8	0.14
250	4970 x 1730 x 2050	4660	450	37.7	0.15
275	5700 x 2030 x 2515	5860	450	50	0.15
320	5700 x 2030 x 2515	5860	450	57	0.3
400	5905 x 2030 x 2520	6180	990	65.1	0.3
500	6205 x 2030 x 2550	6990	990	81.3	0.3

FUEL CONSUMPTION FOR DGSET:	
Generator KVA	Diesel consumption Liter per hour
5	1.25
15	2.91
20	4.78
25	4.78
30	6.55
40	8.11
50	10.19
62.5	10.92
75	13.52
82.5	13.52
125	19.76
140	23.4
200	30.99

Approximate Fuel Consumption for Diesel Generator Set				
Generator Size (KVA) @0.8 PF	1/4 Load (Liter/Hr)	1/2 Load (Liter/Hr)	3/4 Load (Liter/Hr)	Full Load (Liter/Hr)
25	2.27	3.41	4.92	6.06
38	4.92	6.82	9.09	10.98
50	6.06	8.71	12.12	15.15
75	6.82	10.98	14.39	18.18
94	9.09	12.88	17.42	23.11
125	9.85	15.53	21.97	28.03
156	11.74	18.94	26.89	34.47
169	12.50	20.45	28.79	37.12
188	13.64	22.35	31.82	41.29
219	15.53	25.76	36.74	48.11
250	17.80	29.17	41.67	54.55
288	20.08	33.33	47.35	62.88
313	21.59	35.98	51.52	68.18
375	25.76	42.80	60.98	81.44
438	29.92	49.62	70.83	95.08
500	33.71	56.44	80.68	108.33
625	41.67	70.08	100.00	135.23
750	50.00	83.33	119.32	162.12
938	61.74	103.79	148.86	202.27
1250	81.82	137.88	197.35	269.32
1563	101.89	171.59	246.21	336.36
1875	121.97	205.68	294.70	403.41
2188	142.05	239.39	343.56	470.45
2500	162.12	273.48	392.05	537.50
2813	182.20	307.20	440.91	604.55

Approximate Current Rating of Diesel Generator Set @ 0.8 PF										
KVA	kW	220V	240V	400V	440V	450V	480V	600V	2400V	3300V

8	**6.3**	16.5	15.2	9.1	8.3	8.1	7.6	6.1		
9.4	**7.5**	24.7	22.6	13.6	12.3	12	11.3	9.1		
12.5	**10**	33	30.1	18.2	16.6	16.2	15.1	12		
18.7	**15**	49.5	45	27.3	24.9	24.4	22.5	18		
25	**20**	66	60.2	36.4	33.2	30.1	24	6	4.4	3.5
31.3	**25**	82.5	75.5	45.5	41.5	40.5	37.8	30	7.5	5.5
37.5	**30**	99	90.3	54.6	49.8	48.7	45.2	36	9.1	6.6
50	**40**	132	120	73	66.5	65	60	48	12.1	8.8
62.5	**50**	165	152	91	83	81	76	61	15.1	10.9
75	**60**	198	181	109	99.6	97.5	91	72	18.1	13.1
93.8	**75**	247	226	136	123	120	113	90	22.6	16.4
100	**80**	264	240	146	133	130	120	96	21.1	17.6
125	**100**	330	301	182	166	162	150	120	30	21.8
156	**125**	413	375	228	208	204	188	150	38	27.3
187	**150**	495	450	273	249	244	225	180	45	33
219	**175**	577	527	318	289	283	264	211	53	38
250	**200**	660	601	364	332	324	301	241	60	44
312	**250**	825	751	455	415	405	376	300	75	55
375	**300**	990	903	546	498	487	451	361	90	66
438	**350**	1155	1053	637	581	568	527	422	105	77
500	**400**	1320	1203	730	665	650	602	481	120	88
625	**500**	1650	1504	910	830	810	752	602	150	109
750	**600**	1980	1803	1090	996	975	902	721	180	131
875	**700**	2310	2104	1274	1162	1136	1052	842	210	153
1000	**800**	2640	2405	1460	1330	1300	1203	962	241	176
1125	**900**	2970	2709	1640	1495	1460	1354	1082	271	197
1250	**1000**	3300	3009	1820	1660	1620	1504	1202	301	218
1563	**1250**	4130	3765	2280	2080	2040	1885	1503	376	273
1875	**1500**	4950	4520	2730	2490	2440	2260	1805	452	327
2188	**1750**		5280	3180	2890	2830	2640	2106	528	380
2500	**2000**		6020	3640	3320	3240	3015	2405	602	436
2812	**2250**		6780	4095	3735	3645	3400	2710	678	491

Approximate Fuel Consumption of D.G Set As per Bureau of Energy Efficiency

D.G Set (Kw)	Average Load as % of De rated Capacity	Specific Fuel Cons. Lit/kWh	Specific Lube Oil Cons. Lit/kWh
480	89	0.335	0.007
480	110	0.334	0.024
292	84	0.356	0.006
200	89	0.325	0.003
200	106	0.338	0.003
292	79	0.339	0.006
292	81	0.362	0.005
292	94	0.342	0.003
292	88	0.335	0.006
292	76	0.335	0.005
292	69	0.353	0.006
400	75	0.334	0.004
400	65	0.349	0.004
880	85	0.318	0.007
400	70	0.335	0.004
400	80	0.337	0.004
880	78	0.345	0.007
800	74	0.324	0.002
800	91	0.290	0.002
880	96	0.307	0.002
920	77	0.297	0.002

Guideline for Generator (Government of Kerala-Department of Electrical Inspectorate)

SR. NO	Capacity of Generator	Category

1	Up to 10KVA	Portable Generator
2	10KVA to 100KVA	Small Generators
3	100KVA to 1000KVA	Medium Generators
4	Above 1000KVA	Large Generators

Guideline for Change Over Switch of Portable Generator (Government of Kerala-Department of Electrical Inspectorate)		
Capacity of single-Phase Generator	**Change over switch rating**	**Minimum copper area of conductors used for linking the poles**
Up to 3 kVA	32 A	20 sq.mm
3 to 6 kVA	63 A	40 sq.mm
6 to 10 kVA	100A	60 sq.mm

D.G SET CABLE SIZE				
DG SIZE	**AMP**	**CABLE SIZE X NO OF CABLE**		
2000 KVA	2782 A	500 x 10		
1800 KVA	2504 A	400 x 10		
1500 KVA	2087 A	400 x 8	300 x 9	240 x 10
1250 KVA	1739 A	400 x 7	300 x 8	240 x 9
1000 KVA	1391 A	300 x 6	225 x 7	
750 KVA	1043 A	400 x 4	240 x 5	185 x 6
650 KVA	904 A	300 x 4	225 x 5	150 x 6
625 KVA	870 A	300 x 4	185 x 5	120 x 6
600 KVA	835 A	240 x 4	185 x 5	120 x 6
500 KVA	696 A	300 x 3	185 x 4	120 x 5
450 KVA	626 A	240 x 3	150 x 4	95 x 5
380 KVA	529 A	400 x 2	185 x 3	120 x 4
320 KVA	445 A	300 x 2	150 x 3	95 x 4
285 KVA	396 A	225 x 2	120 x 3	70 x 4
250 KVA	348 A	400 x 1	185 x 2	95 x 3
225 KVA	313 A	400 x 1	150 x 2	
200 KVA	278 A	300 x 1		
180 KVA	250 A	240 x 1		
160 KVA	223 A	185 x 1		
140 KVA	195 A	150 x 1		
125 KVA	174 A	120 x 1		
100 KVA	139 A	95 x 1		
82.5 KVA	115 A	70 x 1		
75 KVA	104 A	50 x 1		
62.5 KVA	87 A	35 x 1		
50 KVA	70 A	25 x 1		
30 KVA	42 A	16 x 1		
25 KVA	40 A	10 x 4		
20 KVA	40 A	10 x 4		
15 KVA	32 A	6 x 4		

Diesel Generator Details			
Diesel Generator Size	**Typical Room Size (LXWXH)**	**Lubrication System Capacity**	**Coolant Capacity (H for HE, R for Radiator)**
2000 KVA	12.5 x 7.5 x 6.5	400Liter	550 (H) 750 (R)
1800 KVA	12.5 x 7.5 x 6.5	400Liter	550 (H) 750 (R)
1500 KVA	12.5 x 7.5 x 6.5	177Liter	320 (H) 555 (R)
1250 KVA	12.5 x 7.5 x 6.5	177Liter	310 (H) 440 (R)
1000 KVA	11.0 x 7.0 x 6.5	145Liter	199 (H) 260 (R)
750 KVA	9. 0 x 6.0 x 5.0	118Liter	230 (H) 300 (R)
650 KVA	8.5 x 6.0 x 5.0	95Liter	212 (H) 250 (R)
625 KVA	8.5 x 6.0 x 5.0	95Liter	210 (H) 240 (R)
600 KVA	8.5 x 6.0 x 5.0	95Liter	210 (H) 240 (R)
500 KVA	8.5 x 6.0 x 5.0	55Liter	125 (H) 175 (R)

450 KVA	8.5 x 6.0 x 5.0	55Liter	125 (H) 175 (R)
380 KVA	8.0 x 5.5 x 5.0	55Liter	80 (H) 115 (R)
320 KVA	7.5 x 5.0 x 5.0	39Liter	45 (H) 76 (R)
285 KVA	7.5 x 5.0 x 5.0	39Liter	40 (H) 95 (R)
250 KVA	7.5 x 5.0 x 5.0	39Liter	47 (H) 80 (R)
225 KVA	7.5 x 5.0 x 5.0	39Liter	47 (H) 80 (R)
200 KVA	6.5 x 4.5 x 3.5	24Liter	28 (R)
180 KVA	6.5 x 4.5 x 3.5	24Liter	27 (R)
160 KVA	6.5 x 4.5 x 3.5	24Liter	27 (R)
140 KVA	6.5 x 4.5 x 3.5	24Liter	27 (R)
125 KVA	6.0 x 4.0 x 3.5	14.3Liter	25 (R)
100 KVA	6.0 x 4.0 x 3.5	14.3Liter	22 (R)
82.5 KVA	6.0 x 4.0 x 3.5	14.3Liter	22 (R)
75 KVA	6.0 x 4.0 x 3.5	9Liter	13 (R)
62.5 KVA	6.0 x 3.5 x 3.0	9Liter	11 (R)
50 KVA	6.0 x 3.5 x 3.0	9Liter	11 (R)
30 KVA	6.0 x 3.5 x 3.0	9Liter	11 (R)
25 KVA	4.0 x 1.5 x 2.0	6.5Liter	7.5 (R)
20 KVA	4.0 x 1.5 x 2.0	6.5Liter	7.5 (R)
15 KVA	4.0 x 1.5 x 2.0	5Liter	6 (R)

Size of Cables, Earthing conductors and protection of Generators

Generator Capacity	Full load Current rating	Cable size AYFY	Earth conductor size (mm2/SWG)	Protection	Panel Meters
5 KVA	7 A	4 mm2	8.3/10	MCB/MCCB	
7.5 KVA	10.5 A	4 mm2	8.3/10	MCB/MCCB	
10 KVA	14 A	4.8 mm2	8.3/10	MCB/MCCB	
12.5 KVA	17.5 A	6 mm2	8.3/10	MCB/MCCB	AM,VM, FM&EM
15 KVA	21 A	10 mm2	8.3/10	MCB/MCCB	
20 KVA	28 A	10 mm2	8.3/10	MCB/MCCB	
25 KVA	35 A	16 mm2	18.6/6	MCB/MCCB	
30 KVA	42 A	16 mm2	18.6/6	MCB/MCCB	
35 KVA	49 A	25 mm2	18.6/6	MCB/MCCB	
40 KVA	56 A	35 mm2	27.27/4	MCB/MCCB	
45 KVA	63 A	35 mm2	27.27/4	MCB/MCCB	
50 KVA	70 A	35 mm2	27.27/4	MCB/MCCB	
63 KVA	88 A	50 mm2	27.27/4	MCB/MCCB	
75 KVA	105 A	95 mm2	25x3	MCB/MCCB	
82.5 KVA	115 A	95 mm2	25x3	MCB/MCCB	
100 KVA	140 A	120 mm2	25x3	MCCB + standby low set earth fault relay using CT in neutral earthing conductor	
125 KVA	175 A	150 mm2	25x3		
160 KVA	224 A	185 mm2	25x3		
180 KVA	252 A	185 mm2	25x3		
200 KVA	280 A	2x120 mm2	25x3		
225 KVA	315 A	2x120 mm2	25x3		
250 KVA	350 A	2x185 mm2	25x3		
320 KVA	448 A	2x300 mm2	25x3		
400 KVA	560 A	2x400 mm2	25x3		
500 KVA	700 A	3x400 mm2	25x3	ACB with overload and E/F release and stand by low set earth fault relay using CT in neutral earthing conductor	AM,VM, FM, EM, PFM, KVAM or KVM
625 KVA	875 A	4x400 mm2	25x3		
750 KVA	1050 A	4 x400 Al XLPE cable or Bus Trunking.	25x3		

1000 kVA and above,	ACB with thermal O/L, voltage-controlled O/C relay, over voltage, under voltage, negative sequence, low set stand by earth fault relays and REF/Differential relay with fuel shut off facilities. Over speed protection shall be provided for the engine

Guideline for Portable Generator (Government of Kerala-Department of Electrical Inspectorate)	
Size	Generators up to 10kVA rating shall be treated as portable generators
ELCB Size	ELCB having an operating time of 20ms at a residual current of 30mA shall be provided.
Neutral	For 1phase generators one terminal shall be connected to earth and designated as the neutral.
	3phase generators shall have their windings connected in star, with the star connection made available and connected to earth.
Single Phase DG use for Three Phase Supply	The supply from a single-phase generator shall be feed to a three-phase supply system through a 4-pole change over switch subject to the following conditions:
	(a) The neutral conductors of the load side and generator side shall be of adequate capacity to carry the total current in the neutral.
	(b) The 3 poles in the 4 pole change over switch shall be linked by using rigid conductors of adequate short circuit and continuous current rating capacity
Location	Portable generators shall be kept at a place, sufficiently ventilated so as to avoid possible hazards due to the accumulation of smoke and pollution.

Guideline for Medium Voltage Generator (Government of Kerala-Department of Electrical Inspectorate)	
APPROVAL FROM ELECTRICAL INSPECTOR	**NOT Required:** For generators of 10kVA to 30kVA rating completion report and SLD shall be submitted with a certification by the owner and the contractor stating that the electrical installation work is carried out by using change over switch, cable, MCB, etc. of standard make and with ISI mark for issuing the sanction for energization.
	Required: For generators above 30kVA prior scheme approval shall be obtained
Meters	Watt-hour meter and ammeters in each phase shall also be provided in GCP. For generators of 500 kVA and above, kVA/KW meter and P.F. meter shall also be provided
Exhaust Pipe	Exhaust pipe of DG sets shall maintain a minimum height of 1.8 m clearance from floor level and shall be extended to a height of at least 1m above the building.
Clearance	Minimum 1m clearances shall be provided on three sides of a generator set. When two generator sets are installed side-by-side, minimum 2.0 m clearance shall be provided between them
Location	The generator sets should not be allowed to be installed above the ground floor or below first basement level of the building. There shall be provision of separate direct escape and entry into these areas from outside in case of fire.
Generators Running in Parallel	Double frequency meter and double voltmeter, P.F Meter shall be provided in synchronizing panel / Control Panel.
	For generators of 1MVA and above synchro check relay , kVA and kVAr meters, Reverse Reactive Power relays shall provide in synchronizing panel / Control Panel.
	Neutral switching facility shall be provided. Interlock shall be provided to ensure that the generator breaker cannot be closed unless one of the neutral is connected to the earthing system
	Neutral of largest capacity generator shall only be earthed. Neutrals of other generators, running in parallel, shall be in floating condition.
	Also ensure that generator breakers can be made 'ON' only if functional neutral is earthed and closed.

General Development Control Regulations, Gujarat – 2017	
	No construction shall be permissible in the Common Plot except Electric substation, Transformer room, Auxiliary power generator, Box-type transformer, section feeder pillar, meter room, over and underground water tank and pump room, security cabin, Community/ Society common amenities shall be allowed to be constructed in the Common Plot subject
22.14	**Emergency Power Supply for Buildings height more than 45Meter and Special Buildings**

1	For every building having height more than 45mts, a stand-by electric generator shall be installed to supply power to staircase and corridor lighting circuits, fire lifts, the stand-by fire pump, pressurization fans and blowers, smoke extraction and damper systems in case of failure of normal electric supply.
2	The generator shall be capable of taking starting current of all the machines and circuits stated above simultaneously. If the stand-by pump is driven by diesel engine, the generator supply need not be connected to the main electrical pump. Where parallel HT/LT supply from a separate sub-station is provided with appropriate transformer for emergency, the provision of generator may be waived in consultation with Authority
22.15	**Electric Supply and Installation for Buildings with height more than 25mts and Special Buildings**
1	Electric supply to the High pressure Fire pump, Fire Lift and Sprinkler pump shall be supplied parallel to the building supply and should not get cut-off if the supply to the building is switched off.
2	All the electric wiring used shall be of 900 volt grading and connected to each enclosure through a MCB for a particular load.
3	Electric cable/wires used shall be of 700 volt grading with Mechanical circuit breaker and earth Leak Circuit Breaker (MCB and ELCB).

Government of Kerala-Department of Electrical Inspectorate	
Location of DG sets	The DG sets shall be installed at Ground level or First Basement Floor level, installation of DG sets at combined two upper basement floors with access from ground level is allowed

Diesel generator NBC -2016 (3.4.6.4 / 3.4.6.2)	
Installation	**Diesel generator set(s)shall not be installed at any floor other than ground / first basement.** If the same are installed indoors, proper ventilation and exhaust shall be planned. The DG set room shall be separated by 120 min fire resistance rated walls and doors.
Fuel Tank	The oil tank for the DG sets (if not in the base of the DG) shall be provided with a enclosure having a volumetric capacity of at least 10 percent more than the volume of the oil tank. The enclosure shall be filled with sand for a height of 300 mm.
D.G Power Supply for Building	Emergency power supplying distribution system for critical requirement for functioning of fire and life safety system and equipment shall be planned for efficient and reliable power and control supply to the following systems and equipment where provided:
	(a) Fire pumps.
	(b) Pressurization and smoke venting; including its ancillary systems such as dampers and actuators.
	(c) Fireman's lifts (including all lifts).
	(d) Exit signage lighting.
	(e) Emergency lighting.
	(f) Fire alarm system.
	(g) Public address (PA) system (relating to emergency voice evacuation and annunciation).
	(h) Magnetic door hold open devices.
	(j) Lighting in fire command centre and security room.
	Power supply to these systems and equipment shall be from normal and emergency (standby generator) power sources with changeover facility.
	If power supply, is from HV source and HV generation, the transformer should be planned in standby capacity to ensure continuity of power to such systems.
	Wherever transformers are installed at higher levels in buildings and backup DG sets are of higher voltage rating, then dual redundant cables shall be taken to all transformers. The generator shall be capable of taking starting current of all the fire and life safety systems and equipment as above.
	Where parallel HV/LV supply from a separate substation fed from different grid is provided with appropriate transformer for emergency, the provision of generator may be waived in consultation with the Authority

General Guideline for Diesel Generator Set	
Foundation	DG set's location area / foundation should be capable to bear the STATIC load and DYNAMIC Load which is typically **2.5 times the static load during running**.
	The length and breadth of foundation should be **minimum 150 mm (6") more** than acoustic enclosure size / base rails size
	It is recommended to have foundation elevation 150 mm above finish ground level. It helps to maintain cleanliness of DG Set. For areas having heavy rainfall, a higher platform/ rain shed (not mandatory) may be required to prevent water entry and it also helps in operator's safety
	DG Set foundation level to be checked with water level tube at frame mounting area and should be within +/- 5mm for 750 kVA and above DG Set. For DG sets below 750 kVA +/- 2.5mm to be maintained. Metal shims to be provided between DG frame and civil foundation to load DG Set uniformly.
Fuel Tank	For DG sets of rating up to 700 kVA the fuel tank is in sub-base type part of DG Set skid. For DG sets above 750 kVA, 990Liter capacity day tank is supplied loose, which needs to be installed at floor level or 300 mm above the DG floor level to maintain positive suction head on fuel pump inlet.
	The height of the day tank should be sufficient to put a positive head on the engine fuel pump. (Minimum level in tank not less than 6 inches [150 mm] above engine fuel inlet.)
	The maximum height of fuel in the day tank should not be sufficient to put a positive head on the engine fuel return lines. Please ensure that all diesel lines are leak proof and should prevent air seepage even if the DG sets is not run for a long time.
Control Panel	The control panel of the generator should be located away from the generator, but in the same room. The clearance between the generator and the control panel should be more than 1 meter, for small sets up to and including 5OO KVA. For larger sets, more separation for proper cooling is the deciding factor
Two D.G sets side by Side	When two generators are erected side by side, a minimum clearance of 1500 mm should be provided between the generators.
Protection	Up to and inclusive of 100 KVA: Switch fuse, Fuse Switch or Circuit Breaker. Above 100 KVA: Circuit Breaker.
	All generators with rating of 100 KVA and above shall be protected against earth fault leakage. Protected against faults within the generator winding using restricted earth fault protection or differential protection or by both

Insulation Resistance (IR) Values

(1) IR Tester Voltage Selection:

Selection of IR Testers (Megger):	
Insulation testers with test voltage of 500, 1000, 2500 and 5000 V are available	
Voltage Level	**IR Tester**
650V	500V DC
1.1KV	1KV DC
3.3KV	2.5KV DC
66Kv and Above	5KV DC

Measurement Range of Megger:	
Test voltage	**Measurement Range**
250V DC	0MΩ to 250GΩ
500V DC	0MΩ to 500GΩ
1KV DC	0MΩ to 1TΩ
2.5KV DC	0MΩ to 2.5TΩ
5KV DC	0MΩ to 5TΩ

Test Voltage for Meggering:	
AC Voltage is used, Rule of Thumb is **Test Voltage (A.C) = (2X Name Plate Voltage) +1000**	
DC Voltage is used (Most used in All Megger), **Test Voltage (D.C) = (2X Name Plate Voltage)**	
Equipment / Cable Rating	**DC Test Voltage**
24V To 50V	50V To 100V
50V To 100V	100V To 250V
100V To 240V	250V To 500V
440V To 550V	500V To 1000V
2400V	1000V To 2500V
4100V	1000V To 5000V

(2) IR Value for Panel Bus:

- **IR Value for Panel = 2 x KV rating of the panel.**
- Example, for a 5 KV panel, the minimum insulation is 2 x 5 = 10 MΩ.

(3) IR Test Values Electrical Apparatus and Systems:

IR Value (PEARL Standard / NETA MTS-1997 Table 10.1)		
Max. Voltage Rating of Equipment	**Megger Size**	**Min.IR Value**
250 Volts	500 Volts	25 MΩ
600 Volts	1,000 Volts	100 MΩ
5 KV	2,500 Volts	1,000 MΩ
8 KV	2,500 Volts	2,000 MΩ
15 KV	2,500 Volts	5,000 MΩ
25 KV	5,000 Volts	20,000 MΩ
35 KV	15,000 Volts	100,000 MΩ
46 KV	15,000 Volts	100,000 MΩ
69 KV	15,000 Volts	100,000 MΩ

IR Value for Equipment (One Meg ohm Rule):	
Equipment Rating	**IR Value**
<1KV	**= 1 MΩ minimum**
>1KV	**1 MΩ per KV**

IR Value for Equipment (As per IE Rules-1956):	
Equipment Rating	**IR Value**
Medium and Low Voltage Installations	At a pressure of 500 V applied between each live conductor and earth for a period of one minute, the insulation resistance of medium and low voltage

	installations shall be at least **1 MΩ** or as specified by the Bureau of Indian Standards] from time to time.
HV installations	At a pressure of 1000 V applied between each live conductor and earth for a period of one minute the insulation resistance of HV installations shall be at least **1 MΩ** or as specified by the Bureau of Indian Standards

IR Value (As per CBIP):
Acceptable IR value= 2 MΩ per KV

(4) IR Value for Transmission / Distribution Line:

Typical IR Value of Lines		
Equipment.	**Megger Size**	**Min IR Value**
S/S .Equipments	5 KV	5000MΩ
EHV Lines.	5 KV	10MΩ
H.T.Lines.	1 KV	5MΩ
LT / Service Lines.	0.5 KV	5MΩ

(5) IR Value for Substation Equipment:

Typical IR Value of S/S Equipment			
Equipment		**Megger Size**	**IR Value(Min)**
Circuit Breaker	(Phase-Earth)	5KV,10 KV	1000 MΩ
	(Phase-Phase)	5KV,10 KV	1000 MΩ
	Control Circuit	0.5KV	50 MΩ
CT/PT	(Pri-Earth)	5KV,10 KV	1000 MΩ
	(Sec-Phase)	5KV,10 KV	50 MΩ
	Control Circuit	0.5KV	50 MΩ
Isolator	(Phase-Earth)	5KV,10 KV	1000 MΩ
	(Phase-Phase)	5KV,10 KV	1000 MΩ
	Control Circuit	0.5KV	50 MΩ
L.A	(Phase-Earth)	5KV,10 KV	1000 MΩ
Electrical Motor	(Phase-Earth)	0.5KV	50 MΩ
LT Switchgear	(Phase-Earth)	0.5KV	100 MΩ
LT Transformer	(Phase-Earth)	0.5KV	100 MΩ

IR Value of S/S Equipment As per DEP Standard			
Equipment	**Meggering**	**IR Value at Commissioning Time (MΩ)**	**IR Value at Maintenance Time(MΩ)**
Switchgear	HV Bus	200 MΩ	100 MΩ
	LV Bus	20 MΩ	10 MΩ
	LV wiring	5 MΩ	0.5 MΩ
Cable(min 100 Meter)	HV & LV	(10XKV) / KM	(KV) / KM
Motor & Generator	Phase-Earth	10(KV+1)	2(KV+1)
Transformer Oil immersed	HV & LV	75 MΩ	30 MΩ
Transformer Dry Type	HV	100 MΩ	25 MΩ
	LV	10 MΩ	2 MΩ
Fixed Equipments/Tools	Phase-Earth	5KΩ / Volt	1KΩ / Volt
Movable Equipments	Phase-Earth	5 MΩ	1MΩ
Distribution Equipments	Phase-Earth	5 MΩ	1MΩ
Circuit Breaker	Main Circuit	2 MΩ / KV	
	Control Circuit	5MΩ	
Relay	D.C Circuit-Earth	40MΩ	
	LT Circuit-Earth	50MΩ	
	LT-D.C Circuit	40MΩ	
	LT-LT	70MΩ	

(6) IR Value for Transformer:

IR Value for Transformer (Guide to TC Maintenance by. JJ. Kelly. S.D Myer)	
Transformer	**Formula**
1 Phase Transformer	**IR Value (MΩ) = C X E / (√KVA)**
3 Phase Transformer (Star)	**IR Value (MΩ) = C X E (P-n) / (√KVA)**

3 Phase Transformer (Delta)	**IR Value (MΩ) = C X E (P-P) / (√KVA)**
Where C= 1.5 for Oil filled T/C with Oil Tank, 30 for Oil filled T/C without Oil Tank or Dry Type T/C.	

Temperature correction Factor (Base 20°C):		
^0C	^0F	Correction Factor
0	32	0.25
5	41	0.36
10	50	0.50
15	59	0.720
20	**68**	**1.00**
30	86	1.98
40	104	3.95
50	122	7.85

- Example: For 1600KVA, 20KV/400V,Three Phase Transformer
- IR Value at HV Side= (1.5 x 20000) / √ 1600 =16000 / 40 = 750 MΩ at 20^{0}C
- IR Value at LV Side = (1.5 x 400) / √ 1600= 320 / 40 = 15 MΩ at 20^{0}C
- IR Value at 300C =15X1.98= 29.7 MΩ

Insulation Resistance of Transformer Coil			
Transformer Coil Voltage	**Megger Size**	**Min.IR Value Liquid Filled T/C**	**Min.IR Value Dry Type T/C**
0 - 600 V	1KV	100 MΩ	500 MΩ
600 V To 5KV	2.5KV	1,000 MΩ	5,000 MΩ
5KV To 15KV	5KV	5,000 MΩ	25,000 MΩ
15KV To 69KV	5KV	10,000 MΩ	50,000 MΩ

IR Value of Transformers:			
Voltage	**Test Voltage (DC) LV side**	**Test Voltage (DC) HV side**	**Min IR Value**
415V	500V	2.5KV	100MΩ
Up to 6.6KV	500V	2.5KV	200MΩ
6.6KV to 11KV	500V	2.5KV	400MΩ
11KV to 33KV	1000V	5KV	500MΩ
33KV to 66KV	1000V	5KV	600MΩ
66KV to 132KV	1000V	5KV	600MΩ
132KV to 220KV	1000V	5KV	650MΩ

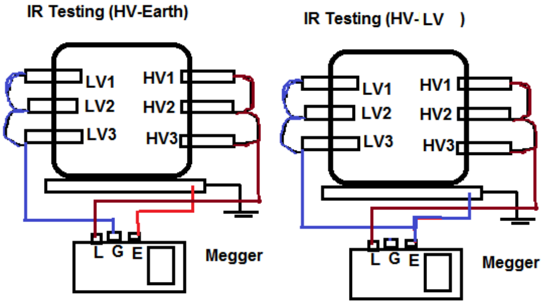
Test Connections of Transformer for IR Test (Not Less than 200 MΩ		
Type of Transformer	**Megger Connection**	
	Megger (L)	**Megger (E)**
Two winding transformers	(HV + LV)	GND
	HV	(LV + GND)
	LV	(HV + GND)
Three winding transformer	HV	(HV + TV + GND)
	LV	(HV + LV + GND)
	(HV +LV+ TV)	GND
	TV	(HV + LV + GND)
Auto transformer (two winding)	(HV + LV) - GND	GND
Auto transformer (three winding)	HV + LV)	(TV + GND)
	(HV + LV + TV)	GND
	TV	(HV + LV + GND)

For any installation, the insulation resistance shall not be less than:

=HV to Earth 200 M Ω
=LV to Earth 100 M Ω
=HV to LV 200 M Ω

- Insulation resistance tests are made to determine insulation resistance from individual windings to ground or between individual windings. Insulation resistance tests are commonly measured directly in megohms or may be calculated from measurements of applied voltage and leakage current.

- The recommended practice in measuring insulation resistance is to always ground the tank (and the core). Short circuit each winding of the transformer at the bushing terminals. Resistance measurements are then made between each winding and all other windings grounded.



a) Windings are never left floating for insulation resistance measurements. Solidly grounded winding must have the ground removed in order to measure the insulation resistance of the winding grounded. If the ground cannot be removed, as in the case of some windings with solidly grounded neutrals, the insulation resistance of the winding cannot be measured. Treat it as part of the grounded section of the circuit.

b) We need to test winding to winding and winding to ground (E).For three phase transformers, We need to test winding (L1,L2,L3) with substitute Earthing for Delta transformer or winding (L1,L2,L3) with earthing (E) and neutral (N) for wye transformers.

Steps for measuring the IR of Transformer:

- Shut down the transformer and disconnect the jumpers and lightning arrestors.
- Discharge the winding capacitance.
- Thoroughly clean all bushings
- Short circuit the windings.
- Guard the terminals to eliminate surface leakage over terminal bushings.
- Record the temperature.
- Connect the test leads (avoid joints).
- Apply the test voltage and note the reading. The IR. Value at 60 seconds after application of the test voltage is referred to as the Insulation Resistance of the transformer at the test temperature.
- The transformer Neutral bushing is to be disconnected from earth during the test.
- All LV surge diverter earth connections are to be disconnected during the test.
- Due to the inductive characteristics of transformers, the insulation resistance reading shall not be taken until the test current stabilizes.
- Avoid meggering when the transformer is under vacuum.

Factors affecting on IR value of Transformer

The IR value of transformers are influenced by

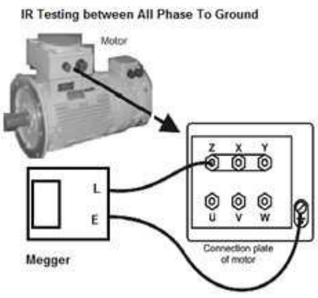
- surface condition of the terminal bushing
- quality of oil
- quality of winding insulation
- temperature of oil
- duration of application and value of test voltage

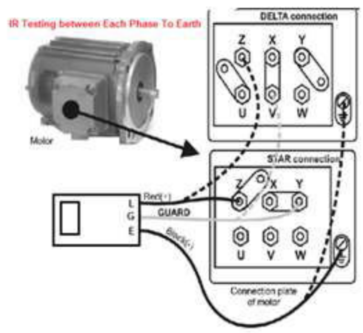
IR Value for Tap Changer (Off-circuit/On-load tap changer)

- IR between HV and LV as well as windings to earth.
- Minimum IR value for Tap changer is **1000 ohm per volt service voltage**

(7) IR Value for Electric motor

- For electric motor, we used a insulation tester to measure the resistance of motor winding with earthing.
- For rated voltage below 1KV, measured with a 500VDC Megger.
- For rated voltage above 1KV, measured with a 1000VDC Megger.
- In accordance with IEEE 43, clause 9.3, the following formula should be applied.
- **Min IR Value (For Rotating Machine) =(Rated voltage (v) /1000) + 1**





As per IEEE 43 Standard 1974,2000	
IR Value in MΩ	
IR (Min) = kV+1	For most windings made before about 1970, all field windings, and others not described below
IR (Min) = 100 MΩ	For most dc armature and ac windings built after about 1970 (form wound coils)
IR (Min) = 5 MΩ	For most machines with random -wound stator coils and form-wound coils rated below 1kV

- **Example-1:** For 11KV, Three Phase Motor.
- IR Value =11+1=12 MΩ but as per IEEE43 It should be 100 MΩ
- Example-2: For 415V,Three Phase Motor
- IR Value =0.415+1=1.41 MΩ but as per IEEE43 It should be 5 MΩ.
- As per IS 732 Min IR Value of Motor=(20XVoltage(p-p/(1000+2XKW))

IR Value of Motor as per NETA ATS 2007. Section 7.15.1

Motor Name Plate (V)	Test Voltage	Min IR Value
250V	500V DC	25 MΩ
600V	1000V DC	100MΩ
1000V	1000V DC	100MΩ
2500V	1000V DC	500MΩ
5000V	2500V DC	1000MΩ
8000V	2500V DC	2000MΩ
15000V	2500V DC	5000MΩ
25000V	5000V DC	20000MΩ
34500V	15000V DC	100000MΩ

IR Value of Submersible Motor

Motor Out off Well (Without Cable)	IR Value
New Motor	20 MΩ
A used motor which can be reinstalled	10 MΩ
Motor Installed in Well (With Cable)	
New Motor	2 MΩ
A used motor which can be reinstalled	0.5 MΩ

(8) IR Value for Electrical Cable:

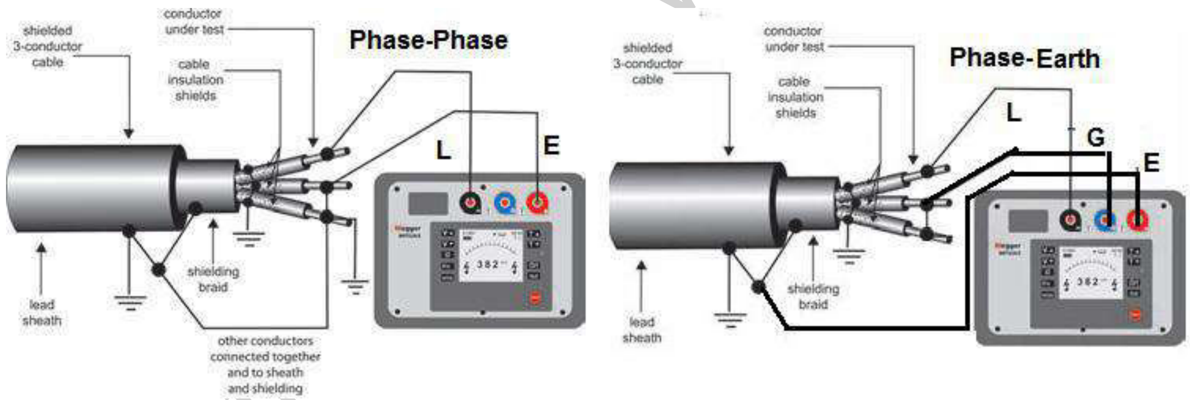
- For insulation testing, we need to disconnect from panel or equipment and keep them isolated from power supply. The wiring and cables need to test for each other (phase to phase) with a ground (E) cable. The Insulated Power Cable Engineers Association (IPCEA) provides the formula to determine minimum insulation resistance values.
- **R = K x Log 10 (D/d)**
- R =IR Value in MΩs per 1000 feet (305 meters) of cable.
- K =Insulation material constant.(Varnished Cambric=2460, Thermoplastic Polyethlene=50000,Composite Polyethylene=30000)
- D =Outside diameter of conductor insulation for single conductor wire and cable
- (D = d + 2c + 2b diameter of single conductor cable)
  d – Diameter of conductor
  c – Thickness of conductor insulation
  b – Thickness of jacket insulation

IR Value on New HT Cable		
Application	**Test Voltage**	**Criteria**
New cables – Sheath	1kV Megger 1 minute	100 meg-ohms min.
New cables – Insulation	10kV DC 15 minute	1.0 µA (micro-amps) max
New cables – Insulation	10kV DC 15 minute	1000 meg-ohms min.

IR Value of Cable		
Application	**Test Voltage**	**Criteria**
11kV new cables	5kV Megger 1 minute	100 meg-ohms.
11kV after repairs	5kV Megger 1 minute	100 meg-ohms.
33kV - no TF's connected	5kV Megger 1 minute	1000 meg-ohms.
33kV - with TF's connected	5kV Megger 1 minute	15 meg-ohms.

HV test on new XLPE cable (As per ETSA Standard)		
Application	**Test Voltage**	**Min IR Value**
New cables – Sheath	1KV DC	100 MΩ
New cables – Insulation	10KV DC	1000 MΩ
After repairs – Sheath	1KV DC	10 MΩ
After repairs - Insulation	5KV DC	1000MΩ

11kV / 33kV Cables between Cores and Earth (As per ETSA Standard)		
Application	**Test Voltage**	**Min IR Value**
11KV New cables – Sheath	5KV DC	1000 MΩ
11KV After repairs – Sheath	5KV DC	100 MΩ
33KV no TF's connected	5KV DC	1000 MΩ
33KV with TF's connected.	5KV DC	15MΩ



IR Value Measurement (Conductors to conductor (Cross Insulation))

- The first conductor for which cross insulation is being measured shall be connected to Line terminal of the megger. The remaining conductors looped together (with the help of crocodile clips) i. e. Conductor 2 and onwards, are connected to Earth terminal of megger. Conductors at the other end are left free.
- Now rotate the handle of megger or press push button of megger. The reading of meter will show the cross Insulation between conductor 1 and rest of the conductors. Insulation reading shall be recorded.
- Now connect next conductor to Line terminal of the megger & connect the remaining conductors to earth terminal of the megger and take measurements.

IR Value Measurement (Conductor to Earth Insulation)

- Connect conductor under test to the Line terminal of the megger.
- Connect earth terminal of the megger to the earth.
- Rotate the handle of megger or press push button of megger. The reading of meter will show the insulation resistance of the conductors. Insulation reading shall be recorded after applying the test voltage for about a minute till a steady reading is obtained.

IR Value Measurements:

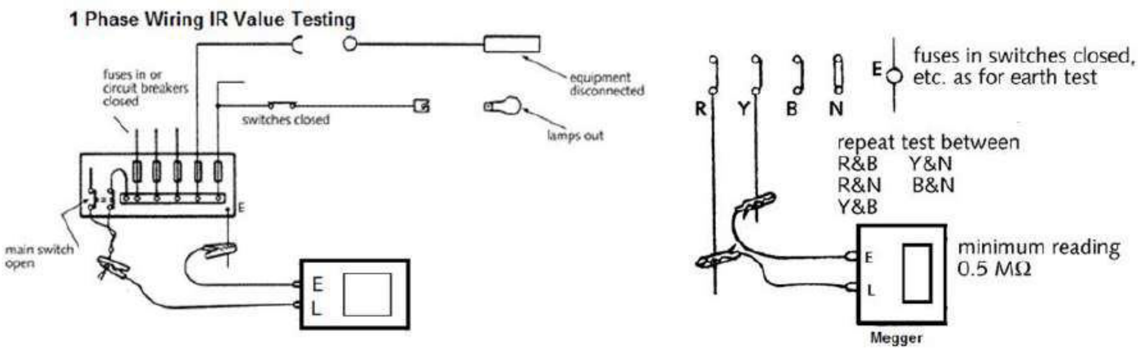
- If during periodical testing, insulation resistance of cable is found between **5 and 1 MΩ/km** at buried temperature, the subject cable should be programmed for replacement.
- If insulation resistance of the cable is found between **1000 to 100 KΩ/km**, at buried temperature, the subject cable should be replaced urgently within a year.
- If the insulation resistance of the cable is found less than **100 KΩ /km**, the subject cable must be replaced immediately on emergency basis.

(9) IR Value for Domestic /Industrial Wiring:

- A low resistance between phase and neutral conductors, or from live conductors to earth, will result in a leakage current. This cause deterioration of the insulation, as well as involving a waste of energy which would increase the running costs of the installation.
- The resistance between **Phase-Phase-Neutral-Earth must never be less than 0.5 MΩ** for the usual supply voltages.
- In addition to the leakage current due to insulation resistance, there is a further current leakage in the reactance of the insulation, because it acts as the dielectric of a capacitor. This current dissipates no energy and is not harmful, but we wish to measure the resistance of the insulation, so DC Voltage is used to prevent reactance from being included in the measurement.

1 Phase Wiring:

- The IR test between Phase-Natural to earth must be carried out on the complete installation with the main switch off, with phase and neutral connected together, with lamps and other equipment disconnected, but with fuses in, circuit breakers closed and all circuit switches closed.
- Where two-way switching is wired, only one of the two stripper wires will be tested. To test the other, both two-way switches should be operated and the system retested. If desired, the installation can be tested as a whole, when a **value of at least 0.5 MΩ** should be achieved.



3 Phase Wiring:

- In the case of a very large installation where there are many earth paths in parallel, the reading would be expected to be lower. If this happens, the installation should be subdivided and retested, when each part must meet the minimum requirement.
- The IR tests must be carried out between Phase-Phase-Neutral-Earth with a minimum acceptable **value for each test of 0.5 MΩ.**

IR Testing for Low voltage		
circuit voltage	**Test voltage**	**IR Value (Min)**
Extra Low Voltage	250V DC	0.25MΩ
Up to 500 V except for above	500 V DC	0.5MΩ
500 V To 1KV	1000 V DC	1.0MΩ

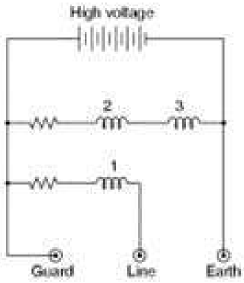
- **Min IR Value= 50MΩ / No of Electrical outlet. (All Elect. Points with fitting & Plugs).**
- **Min IR Value = 100MΩ / No of Electrical outlet. (All Elect. Points without fitting & Plugs).**

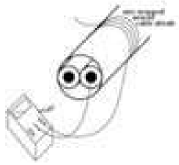
Required Precautions:

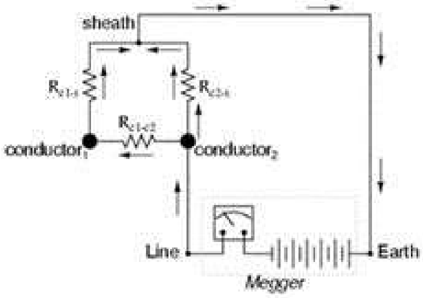
- Electronic equipment like electronic fluorescent starter switches, touch switches, dimmer switches, power controllers, delay timers could be damaged by the application of the high test voltage should be disconnected.
- Capacitors and indicator or pilot lamps must be disconnected or an inaccurate test reading will result.
- Where any equipment is disconnected for testing purposes, it must be subjected to its own insulation test, using a voltage which is not likely to result in damage. The result must conform with that specified in the British Standard concerned, or be at least 0.5 M Ohms if there is no Standard.

(10) How to use Megger:

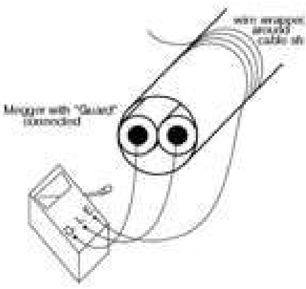
- Meggers is equipped with three connection terminals, Line Terminal (L), Earth Terminal (E) and Guard Terminal (G).

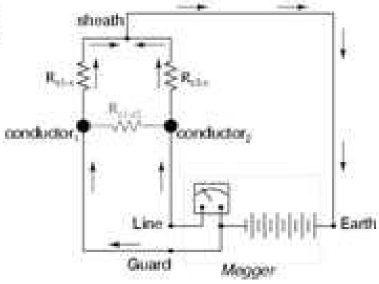




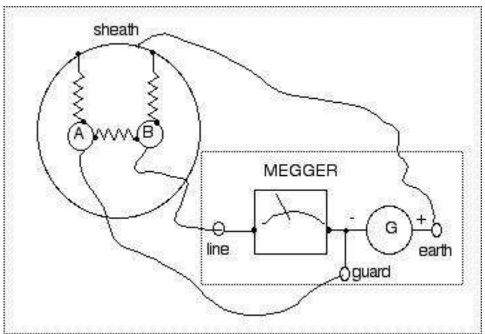


- Resistance is measured between the Line and Earth terminals, where current will travel through coil 1. The "Guard" terminal is provided for special testing situations where one resistance must be isolated from another. Let's us check one situation where the insulation resistance is to be tested in a two-wire cable.
- To measure insulation resistance from a conductor to the outside of the cable, we need to connect the "Line" lead of the megger to one of the conductors and connect the "Earth" lead of the megger to a wire wrapped around the sheath of the cable.
- In this configuration the Megger should read the resistance between one conductor and the outside sheath.
- We want to measure Resistance between Conductor- 2To Sheaths but Actually Megger measure resistance in parallel with the series combination of conductor-to-conductor resistance (Rc1-c2) and the first conductor to the sheath (Rc1-s).
- If we don't care about this fact, we can proceed with the test as configured. If we desire to measure only the resistance between the second conductor and the sheath (Rc2-s), then we need to use the megger's "Guard" terminal.





- Connecting the "Guard" terminal to the first conductor places the two conductors at almost equal potential. With little or no voltage between them, the insulation resistance is nearly infinite, and thus there will be no current between the two conductors. Consequently, the Megger's resistance indication will be based exclusively on the current through the second conductor's insulation, through the cable sheath, and to the wire wrapped around, not the current leaking through the first conductor's insulation.
- The guard terminal (if fitted) acts as a shunt to remove the connected element from the measurement. In other words, it allows you to be selective in evaluating certain specific components in a large piece of electrical equipment. For example consider a two core cable with a sheath. As the diagram below shows there are three resistances to be considered.



- If we measure between core B and sheath without a connection to the guard terminal some current will pass from B to A and from A to the sheath. Our measurement would be low. By connecting the guard terminal to A the two cable cores will be at very nearly the same potential and thus the shunting effect is eliminated.

Precaution while Meggering:

Before Meggering:

- Make sure that all connections in the test circuit are tight.
- Test the megger before use, whether it gives **INFINITY** value when not connected, and ZERO when the two terminals are connected together and the handle is rotated.

During Meggering:

- Make sure when testing for earth, that the far end of the conductor is not touching, otherwise the test will show faulty insulation when such is not actually the case.
- Make sure that the earth used when testing for earth and open circuits is a good one otherwise the test will give wrong information
- Spare conductors should not be meggered when other working conductors of the same cable are connected to the respective circuits.

After completion of cable Meggering:

- Ensure that all conductors have been reconnected properly.
- Test the functions of Points, Tracks & Signals connected through the cable for their correct response.
- In case of signals, aspect should be verified personally.
- In case of points, verify positions at site. Check whether any polarity of any feed taken through the cable has got earthed inadvertently.

Safety Requirements for Meagering:

- All equipment under test **MUST** be disconnected and isolated.
- Equipment should be discharged (shunted or shorted out) for at least as long as the test voltage was applied in order to be absolutely safe for the person conducting the test.
- Never use Megger in an explosive atmosphere.
- Make sure all switches are blocked out and cable ends marked properly for safety.
- Cable ends to be isolated shall be disconnected from the supply and protected from contact to supply, or ground, or accidental contact.
- Erection of safety barriers with warning signs, and an open communication channel between testing personnel.
- Do not megger when humidity is more than 70 %.
- **Good Insulation: Megger reading increases first then remain constant.**
- **Bad Insulation: Megger reading increases first and then decreases.**
- Expected IR value gets on Temp. 20 to 30 decree centigrade.
- If above temperature reduces by 10 degree centigrade, IR values will increased by two times.
- If above temperature increased by 70 degree centigrade IR values decreases by 700 times

Chapter: 19 Electrical Motor Reference

Types of Over Load Relay:	
Class	**Tripping Time**
Class 10	Would Trip after 10 seconds.
Class 20	Would Trip after 20 seconds.
Class 30	Would Trip after 30 seconds.
Class 10 is faster than Class 20 and Class 30 over Load Relay	
Over Load Relay should be set 115% to 130% of Motor Full Load Current	

Approximate RPM of Motor	
HP	**RPM**
< 10 HP	750 RPM
10 HP to 30 HP	600 RPM
30 HP to 125 HP	500 RPM
125 HP to 300 HP	375 RPM

Standard Size of Motor:	
1 HP	200 HP
1.5 HP	250 HP
3 HP	300 HP
5 HP	450 HP
7.5 HP	500 HP
10 HP	600 HP
15 HP	700 HP
20 HP	800 HP
30 HP	900 HP
40 HP	1000 HP
50 HP	1250 HP
60 HP	1050 HP
75 HP	1750 HP
100 HP	2000 HP
125 HP	2250 HP
150 HP	3000 HP
	3500 HP
	4000 HP

Motor Line Voltage:	
Motor (KW)	**Line Voltage**
< 250 KW	440 V (LV)
150 KW to 3000KW	2.5 KV to 4.1 KV (HV)
200 KW to 3000KW	3.3 KV to 7.2 KV (HV)
1000 KW to 1500KW	6.6 KV to 13.8 KV (HV)

Motor Starting Current:		
Supply	**Size of Motor**	**Max. Starting Current**
1 Phase	< 1 HP	6 X Motor Full Load Current
1 Phase	1 HP to 10 HP	3 X Motor Full Load Current
3 Phase	10 HP	2 X Motor Full Load Current
3 Phase	10 HP to 15 HP	2 X Motor Full Load Current
3 Phase	> 15 HP	1.5 X Motor Full Load Current

Max. Lock Rotor Amp for Single Phase 230 V Motor (NEMA)	
HP	**Amp**
1 HP	45 Amp
1.5 HP	50 Amp
2 HP	65 Amp
3 HP	90 Amp
5 HP	135 Amp
7.5 HP	200 Amp

10 HP	260 Amp

Three Phase Motor Code (NEMA)	
HP	**Code**
<1 HP	L
1.5 to 2.0 HP	L,M
3 HP	K
5 HP	J
7 to 10 HP	H
>15 HP	G

Service Factor of Motor:							
HP	**Synchronous Speed (RPM)**						
	3600 RPM	**1800 RPM**	**1200 RPM**	**900 RPM**	**720 RPM**	**600 RPM**	**514 RPM**
1 HP	1.25	1.15	1.15	1.15	1	1	1
1.5 to 1.25 HP	1.15	1.15	1.15	1.15	1.15	1.15	1.15
150 HP	1.15	1.15	1.15	1.15	1.15	1.15	1
200 HP	1.15	1.15	1.15	1.15	1.15	1	1
> 200 HP	1	1.15	1	1	1	1	1

Motor Starting Current:	
Size of Motor	**Limit of maximum starting current**
Up to 5 H.P	Direct on line starting permitted.
5 H.P to 20 H.P	2 times full load current
20 H.P to 100 H.P	1.5 times full load current
Above 100 H.P	1.25 times full load current

:Maximum Current Demand for Motor:		
Ref: NEC(India) :2011		
Nature of supply	**Size of installation**	**Maximum current demand**
Single phase or Three phase	Up to and including 0.75 kW	Six times the full load current
	Above 0.75 kW and up to 7.5 kW	Three times the full load current
	Above 7.5 kW up to and up to11 kW	Two times the full load current
	Above 11 kW	One and half times the full load current

Motor Starter:

Starter	HP or KW	Starting Current	Torque
DOL	<13 HP(11KW)	7 X Full Load Current	Good
Star-Delta	13 HP to 48 HP	3 X Full Load Current	Poor
Auto TC	> 48 HP (37 KW)	4 X Full Load Current	Good/ Average
VFD		0.5 to 1.5 X Full Load Current	Excellent
Motor > 2.2KW Should not connect direct to supply voltage if it is in Delta winding			

Type of Contactor:

Type	Application
AC1	Non Inductive Load or Slightly Inductive Load
AC2	Slip Ring Motor, Starting, Switching OFF
AC3	Squirrel Cage Motor
AC4,AC5,AC5a,AC5b,AC6a	Rapid Start & Rapid Stop
AC 5a	Auxiliary Control circuit
AC 5b	Electrical discharge Lamp
AC 6a	Electrical Incandescent Lamp
AC 6b	Transformer Switching
AC 7a	Switching of Capacitor Bank
AC 7b	Slightly Inductive Load in Household
AC 5a	Motor Load in Household
AC 8a	Hermetic refrigerant compressor motor with Manual Reset O/L Relay
AC 8b	Hermetic refrigerant compressor motor with Automatic Reset O/L Relay
AC 12	Control of Resistive Load & Solid State Load
AC 13	Control of Resistive Load & Solid State Load with Transformer Isolation
AC 14	Control of small Electro Magnetic Load (<72 VA)
AC 15	Control of Electro Magnetic Load (>72 VA)

Making and Breaking Capacity of Contactor:

Contactor	Making Capacity (Amp)	Breaking Capacity (Amp)
AC1	1.5 X motor rated current	1.5 X motor rated current
AC2	4 X motor rated current	4 X motor rated current
AC3	10 X motor rated current	8 X motor rated current
AC4	12 X motor rated current	10 X motor rated current
AC5a	3 X motor rated current	3 X motor rated current
AC5b	1.5 X motor rated current	1.5 X motor rated current
AC6a	12 X motor rated current	10 X motor rated current
AC6b	12 X motor rated current	10 X motor rated current
AC7a	1.5 X motor rated current	1.5 X motor rated current
AC7b	8 X motor rated current	8 X motor rated current
AC8a	6 X motor rated current	6 X motor rated current
AC8b	6 X motor rated current	6 X motor rated current
AC12		
AC13	10 X motor rated current	1.1 X motor rated current
AC14	6 X motor rated current	6 X motor rated current
AC15	10 X motor rated current	10 X motor rated current

Contactor Coil:

Coil Voltage	Suffix
24 Volt	T
48 Volt	W
110 to 127 Volt	A
220 to 240 Volt	B
277 Volt	H
380 to 415 Volt	L

Size of over Load Relay:

Size	Amp Capacity
S00	0.1 To 0.4
	0.4 To 0.6
	1.6 To 6
	3 To 12
S0	3 To 12
	6 To 25
S2	6 To 25
	13 To 50
S3	13 To 50
	25 To 100
S6	50 To 200
S10 & S12	55 To 250
	200 To 540
	300 To 630

Contactor Coil:

Coil Voltage (40 To 50 Hz)	Suffix
24V	T
48V	W
110V To 127V	A
220V To 240V	B
277V	H
380V To 415V	L

Contactor Status

Contactor Status	Continuity Between Pins (N/C)	Non Continuity Between Pins (N/O)
Power Not Applied	32 and 33	21 and 22
		11 and 12
		A1 and A2
		B1 and B2
Power Applied	21 and 22	32 and 33
	11 and 12	
	A1 and A2	
	B1 and B2	

Rated Current of Contactor(Thermal and Intermitted Duty)

A.C	6,10,16,25,63,100,160,200,315,400,630,800 Amp
D.C	16,20,80,160,315,1250,8000 Amp

Voltage Level

Main Circuit Voltage	A.C	240V,415V
	D.C	230V,460V,600V
Contactor's Coil Voltage	A.C	40V,220V,240V,415V
	D.C	24V(For PLC),110V,230V,460V

Locked Rotor Current

Code	Min	Max
A	1	3.14
B	3.15	3.54
C	3.55	3.99
D	4	4.49
E	4.5	4.99
F	5	2.59
G	2.6	6.29
H	6.3	7.09
I	7.1	7.99
K	8	8.99
L	9	9.99
M	10	11.19

N	11.2	12.49
P	12.5	13.99
R	14	15.99
S	16	17.99
T	18	19.99
U	20	22.39
V	22.4	

DOL STARTER

H.P	KW	FLC	Contactor Size (Amp)	Relay setting		Fuse	Cable (mm2)	
				Min	Max		Cu	Allu
0.5	0.37	1	-	0.8	1.17	4	1	1.5
0.75	0.55	1.3	9	1	1.5	4	1	1.5
1	0.74	1.9	9	1.6	2.3	6	1.5	2.5
1.5	1.11	2.6	9	2	3	6	1.5	2.5
2	1.49	3.7	9	2.5	3.7	10	1.5	2.5
3	2.2	4.8	9	4	5.9	16	1.5	2.5
5	3.73	7.8	9	6.3	9.4	20	1.5	2.5
7	5.22	11.2	12	8	11.7	25	2.5	4
10	7.46	16	16	12.5	18.7	25	4	6
12.5	9.32	19	32	16	23.4	32	4	6
15	11.19	20.8	32	16	23.4	50	6	10
20	14.92	28	32	20	30	50	6	10
25	18.65	34	38	32	37.4	63	10	16
30	22.38	40	45	32	47	80	16	25
40	29.84	53	63	50	59	100	25	35
50	37.3	65	70	57	65.5	125	25	50
60	44.76	78	85	70	88.9	125	25	50
75	55.95	96	110	85	98.2	160	50	70
100	74.6	131	140	115	168	200	70	95
125	93.25	156	170	115	168	250	120	150
150	111.9	189	205	160	234	315	150	240
180	134.28	227	250	160	234	355	185	300
215	160.39	271	300	200	299	400	-	-
270	201.42	339	400	250	374	500	-	-
335	249.91	338	475	320	468	500	-	-

Selection of Motor Starter -Contactor-Relay- Fuse -Cable

Motor Rating (3 Phase,415V)		Full Load Current (Amp	Phase Current (Amp)	Contactor Capacity (Amp)		Relay Scale (Amp)		Back up Fuse HRC (Amp)	Cable Size (Sq.mm)	
HP	KW			Main/ Delta	Star	Min	Max		Supply Side	Motor Side
3	2.25	5	2.88	12	12	1.5	4	10	1.5/2.5	1.5/2.5
5	3.75	7.5	4.32	12	12	3	6	20	1.5/2.5	1.5/2.5
7.5	5.5	11	6.34	12	12	6	10	25	2.5	1.5/2.5
10	7.5	14	8.1	16	16	6	12	25	4	1.5/2.5
12.5	9.3	18	10.02	16	16	8	12	35	4	2.5
15	11	21	12.1	16	16	11	16	50	6	2.5
20	15	28	16	30	30	14	20	63	10	4
25	18.5	35	20.2	30	30	17	25	63	16	6
30	22	40	23	30	30	17	25	100	16	6
35	26	47	27	38	30	22	32	100	25	10
40	30	55	30.3	38	30	22	32	100	25	16
45	33.5	60	34.6	70	30	25	40	125	35	16
50	37	66	35	70	70	25	40	125	35	16
60	45	80	45	70	70	38	63	125	50	25
65	28.5	87	50	70	70	38	63	160	70	35
70	52	94	54	70	70	38	63	160	70	35
75	56	100	57.5	70	70	38	63	160	70	35

90	67.5	120	69	105	70	50	90	200	95	50
100	75	135	78	105	70	50	90	200	95	50
125	90	165	95	160	70	70	110	250	120	70
150	112	200	115	170	170	90	135	250	185	70
175	132	230	133	170	170	90	135	300	225	120
200	150	275	159	300	170	140	170	350	400	150
240	175	320	184.5	400	170	140	170	400	400	185
250	187.5	323	185	400	170	140	200	400	400	185
275	204	360	206	400	170	175	250	400	500	185
300	225	385	222	400	400	210	300	500	500	225
400	300	500	390	400	400	280	400	700	625	300/400

Relay Range & Back up Fuse for DOL Starter

H.P	KW	Full Load Current (amp)	Relay Rang(Amp)	Back Up Fuse	
				Min	Max
10	7.5	13.6	13 To 20	25	50
12.5	9.3	17	13 To 20	25	50
15	11.2	20	20 To 30	35	80
20	14.9	28	20 To 30	60	80
25	18.7	35	30 To 45	60	100
30	22.4	40	30 To 45	80	100
35	26.1	47	45 To 63	80	125

Relay Range & Back up Fuse for Star / Delta Starter

H.P	KW	Full Load Current (amp)	Relay Rang(Amp)	Back Up Fuse	
				Min	Max
20	14.9	28	13 To 20	60	60
25	18.7	35	20 To 30	60	100
30	22.4	40	20 To 30	60	100
35	26.1	47	20 To 30	80	100
40	29.8	55	30 To 35	80	125
50	37.3	66	30 To 35	100	125
60	44.8	80	45 To 63	100	160
75	55.95	95	45 To 63	125	160

Circuit Breaker as per NEC 430-52

Type of Motor	Instantaneous Trip	Inverse Time
Single Phase	800%	250%
3 Phase	800%	250%
Synchronous	800%	250%
Wound Rotor	800%	150%
Direct Current	200%	150%

Selection Chart for 3Ph Induction Motor

Motor Rating,415V ,3Ph		Full Load Current (A)	CONTACTOR (A)		OVER LOAD RELAY (A)		BACK UP FUSE (A)	Cable Size			
								DOL Starter		STAR-DELTA Starter	
HP	KW		DOL	STAR-DELTA	DOL	STAR-DELTA		Alu.	Cu.	Alu.	Cu.
0.75	0.52	1.6	16		1.0 To 1.6		4	1.5	1.5		
1	0.75	2	16		1.6 To 2.5		6	1.5	1.5		
2	1.5	3.5	16		3.0 To 4.5		10	1.5	1.5		
3	2.2	5	16		4.5 To 7.0		10	1.5	1.5		
5	3.7	7.5	16		6.5 To 10		16	1.5	1.5		
7.5	5.5	11	16	16	10 To 15	4.5 To 7.0	16	2.5	1.5	2.5	1.5
10	7.5	14	16	16	13 To 20	6.5 To 10	20	2.5	2.5	2.5	2.5
12.5	9.3	18	25	16	13 To 20	10 To 15	25	4	2.5	4	2.5
15	11	21	25	16	15 To 22	13 To 20	25	6	4	6	4
20	15	28	32	18	24 To 30	13 To 20	32	10	6	10	6

25	18.5	35	40	25	25 To 30	15 To 22	50	16	10	16	10
30	22.5	40	50	25	32 To 50	24 To 30	50	16	16	16	16
35	26	47	70	32	32 To 50	25 To 30	63	25	16	25	16
50	37	66	70	40	57 To 70	32 To 50	80	35	25	35	25
60	45	80	95	50	70 To 105	32 To 50	100	50	35	50	35
75	55	100	125	70	100 To 150	40 To 57	100	70	50	70	50
90	67.5	120	140	70	100 To 150	57 To 70	160	95	70	95	70
100	75	135	140	95	100 To 150	70 To 105	160	95	70	95	70
125	90	165		125		70 To 105	160			150	95
150	110	200		125		100 To 150	200			185	150

Size of each part of Star-Delta starter:

(1) Size of Over Load Relay:

- For a star-delta starter there is a possibility to place the overload protection in two positions, in the line or in the windings.
- **Overload Relay in Line:** In the line is the same as just putting the overload before the motor as with a DOL starter.
- **The rating of Overload (In Line) = FLC of Motor.**
- Disadvantage: If the overload is set to FLC, then it is not protecting the motor while it is in delta (setting is x1.732 too high).
- **Overload Relay in Winding:** In the windings means that the overload is placed after the point where the wiring to the contactors are split into main and delta. The overload then always measures the current inside the windings.
- **The setting of Overload Relay (In Winding) =0.58XFLC (line current).**
- Disadvantage: We must use separate short circuit and overload protections.

(2) Size of Main and Delta Contractor:

- There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor.
- **Size of Main Contactor= IFL x 0.58**

(3) Size of Star Contractor:

- The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is 1/ √3= (58%) of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.
- **Size of Star Contactor= IFL x 0.33**

Calculate Size of Contactor, Fuse, C.B, O/L Relay of DOL Starter:

(1) Basic Calculation of Motor Torque & Current:

- Motor Rated Torque (Full Load Torque) =5252xHPxRPM
- Motor Rated Torque (Full Load Torque) =9500xKWxRPM
- If Motor Capacity is less than 30 KW than Motor Starting Torque is 3xMotor Full Load Current or 2X Motor Full Load Current.
- Motor Starting Torque=3xMotor Full Load Current.
- Motor Lock Rotor Current =1000xHPx figure from Chart/1.732x415
- Motor Full Load Current (Line) =KWx1000/1.732x415
- Motor Full Load Current (Phase)=Motor Full Load Current (Line)/1.732
- Motor Starting Current =6 to 7xFull Load Current.

(2) Size of Fuse:

- Maximum Size of Time Delay Fuse =300% x Full Load Line Current.
- Maximum Size of Non Time Delay Fuse =1.75% x Full Load Line Current.

(3) Size of Circuit Breaker:

- Maximum Size of Instantaneous Trip Circuit Breaker =800% x Full Load Line Current.
- Maximum Size of Inverse Trip Circuit Breaker =250% x Full Load Line Current.

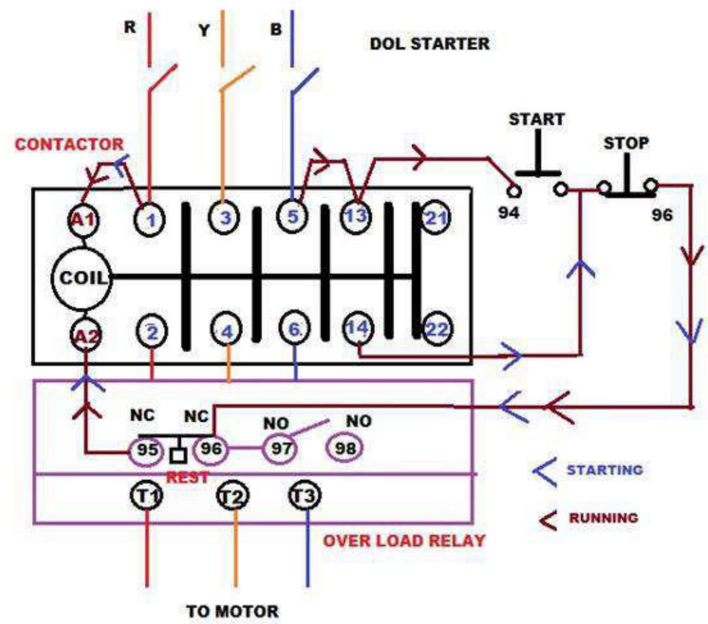
(4) Thermal over Load Relay:

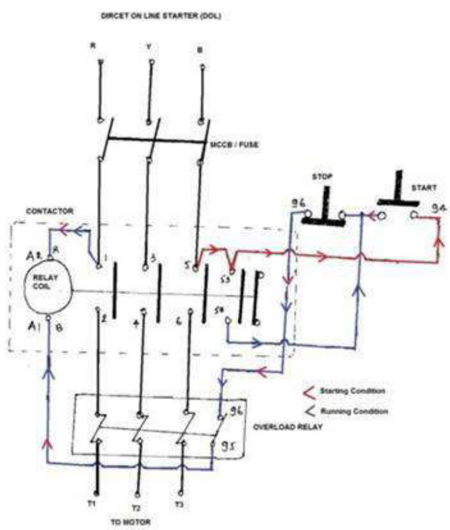
- Thermal over Load Relay (Phase):
- Min Thermal Over Load Relay setting =70%xFull Load Current(Phase)

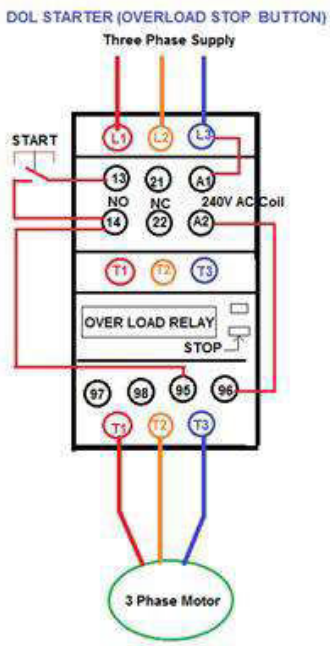
- Max Thermal Over Load Relay setting =120%xFull Load Current(Phase)
- Thermal over Load Relay (Phase):
- Thermal over Load Relay setting =100%xFull Load Current (Line).

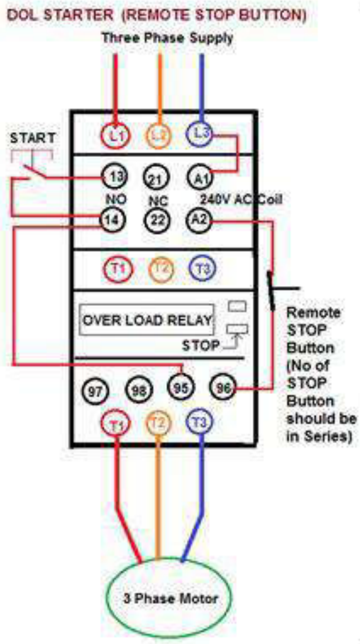
(5) Size and Type of Contactor:

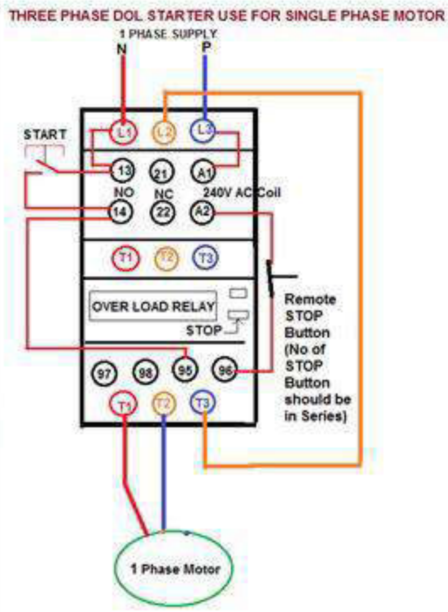
- Size of Main Contactor = 100%X Full Load Current (Line).
- Making/Breaking Capacity of Contactor= Value above Chart x Full Load Current (Line).

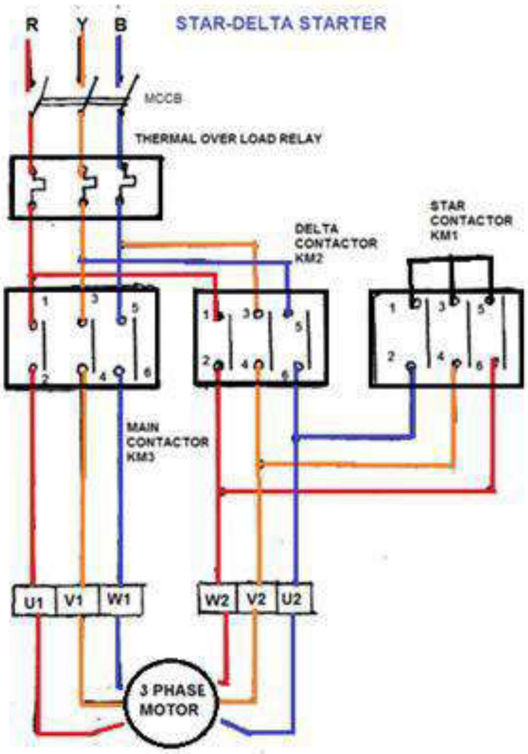




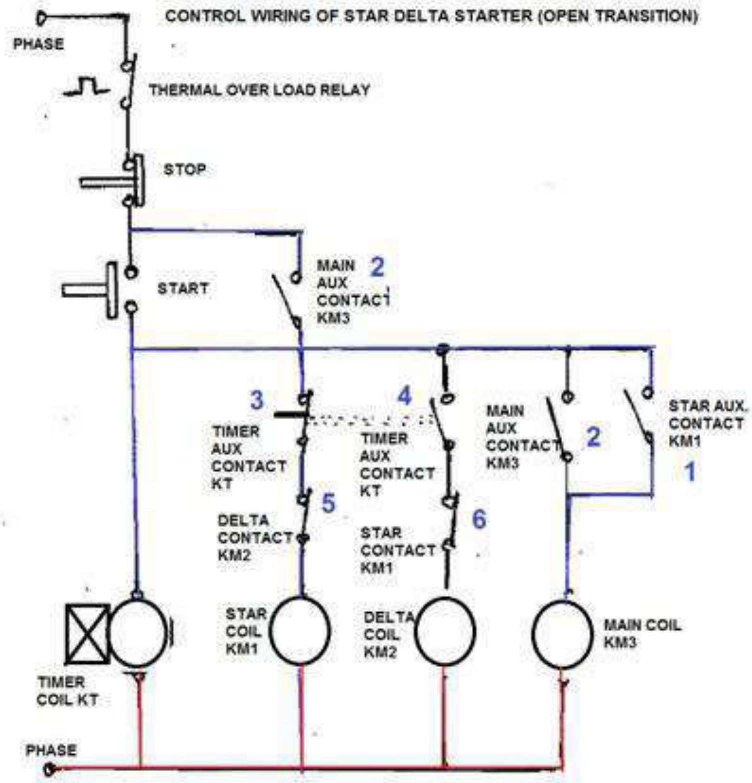




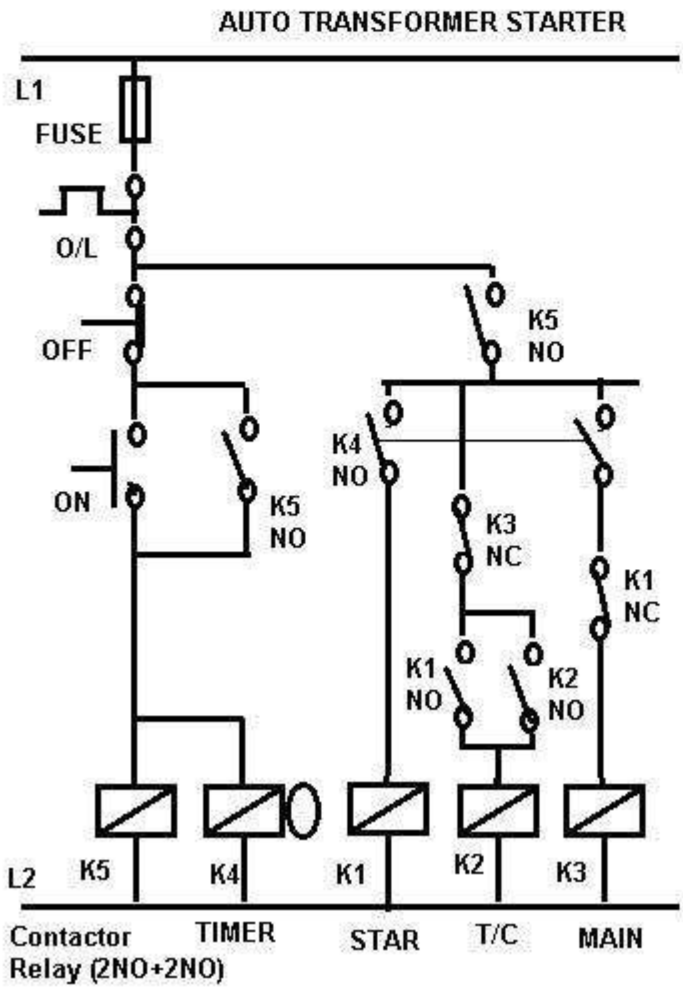




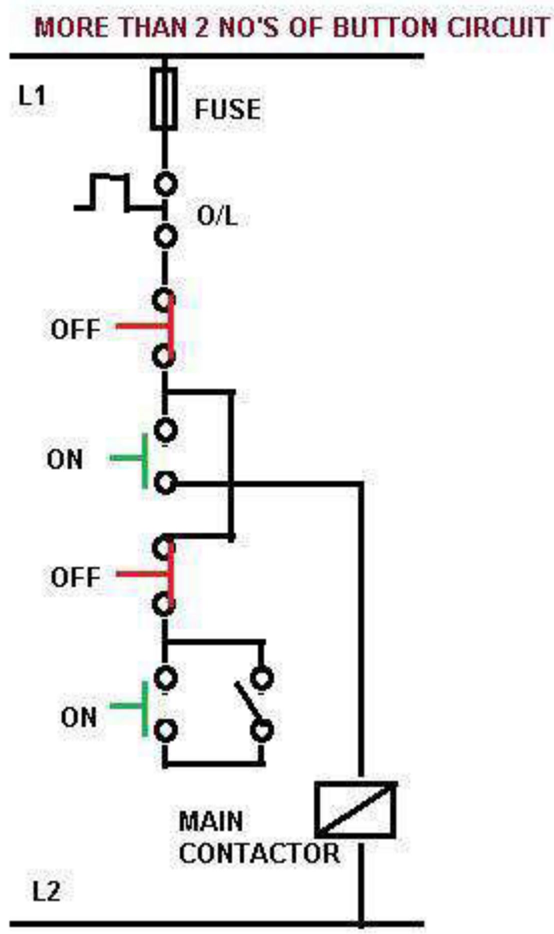
R
Y
B
STAR-DELTA STARTER
MCCB
THERMAL OVER LOAD RELAY
DELTA CONTACTOR KM2
STAR CONTACTOR KM1
MAIN CONTACTOR KM3
U1
V1
W1
W2
V2
U2
3 PHASE MOTOR



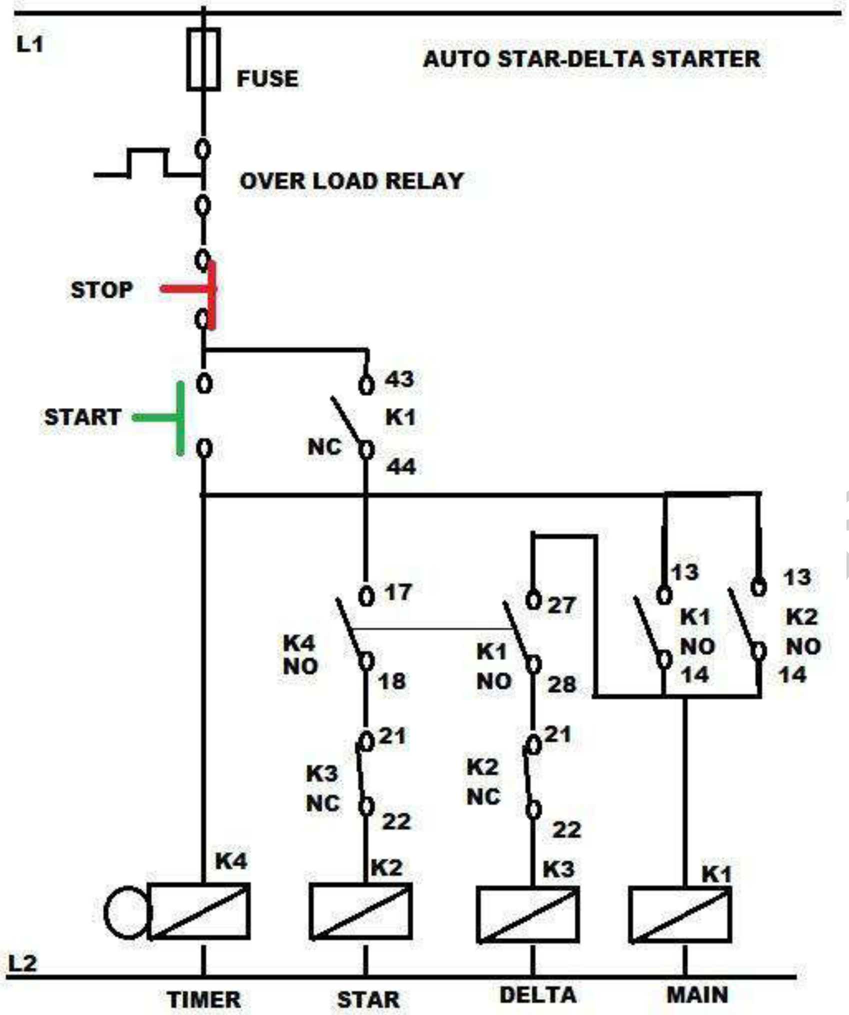
CONTROL WIRING OF STAR DELTA STARTER (OPEN TRANSITION)
PHASE
THERMAL OVER LOAD RELAY
STOP
START
MAIN AUX CONTACT KM3
TIMER AUX CONTACT KT
TIMER AUX CONTACT KT
MAIN AUX CONTACT KM3
STAR AUX. CONTACT KM1
DELTA CONTACT KM2
STAR CONTACT KM1
TIMER COIL KT
STAR COIL KM1
DELTA COIL KM2
MAIN COIL KM3
PHASE

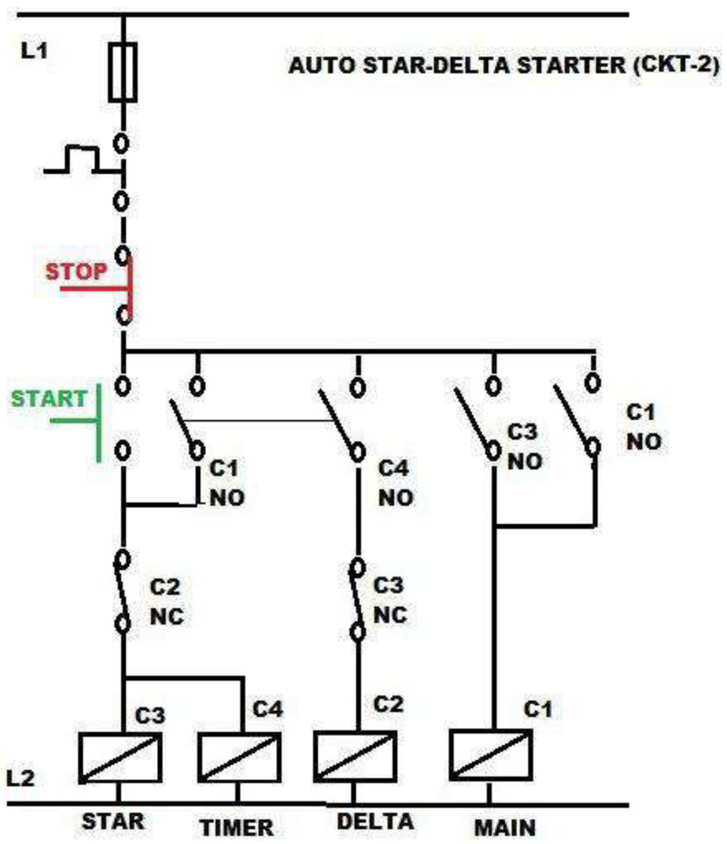


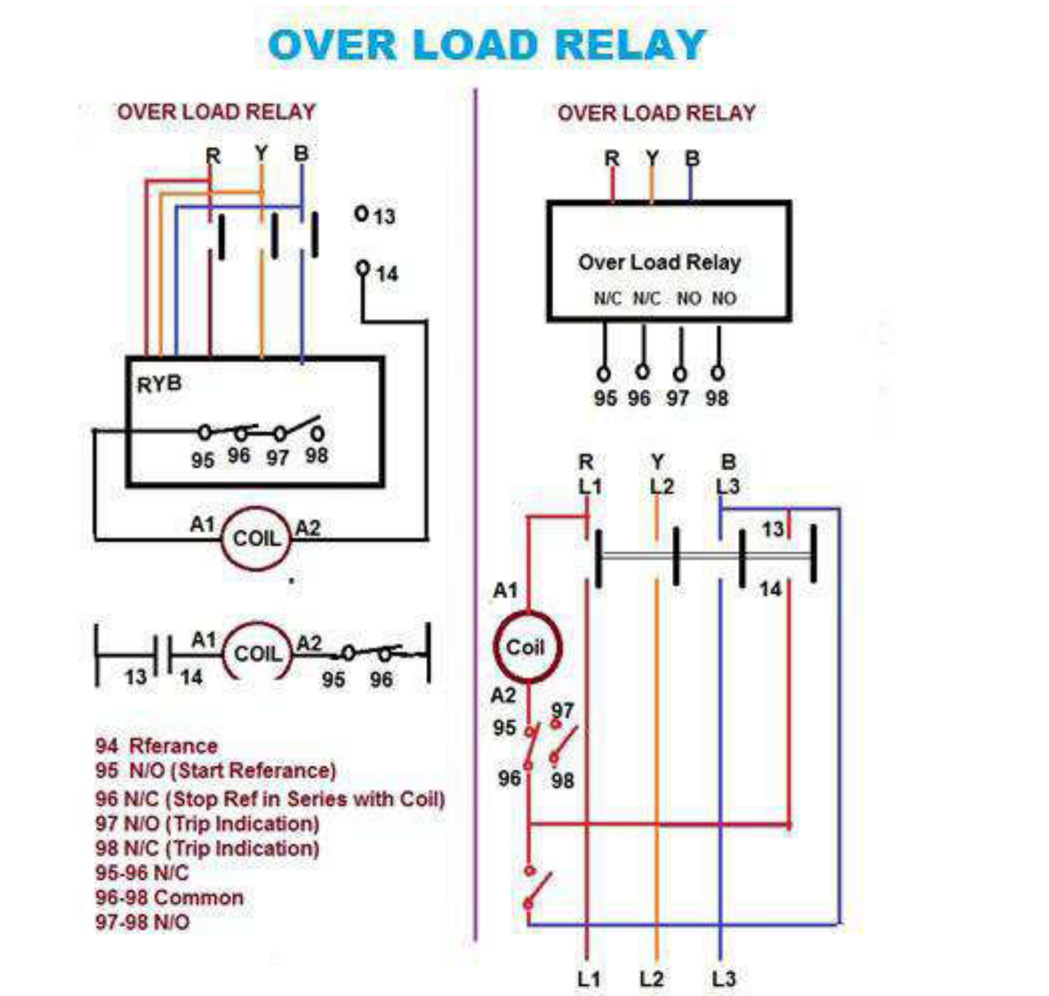
AUTO TRANSFORMER STARTER
L1
FUSE
O/L
OFF
ON
K5 NO
K5 NO
K4 NO
K3 NC
K1 NC
K1 NO
K2 NO
L2
K5
K4
K1
K2
K3
Contactor Relay (2NO+2NO)
TIMER
STAR
T/C
MAIN

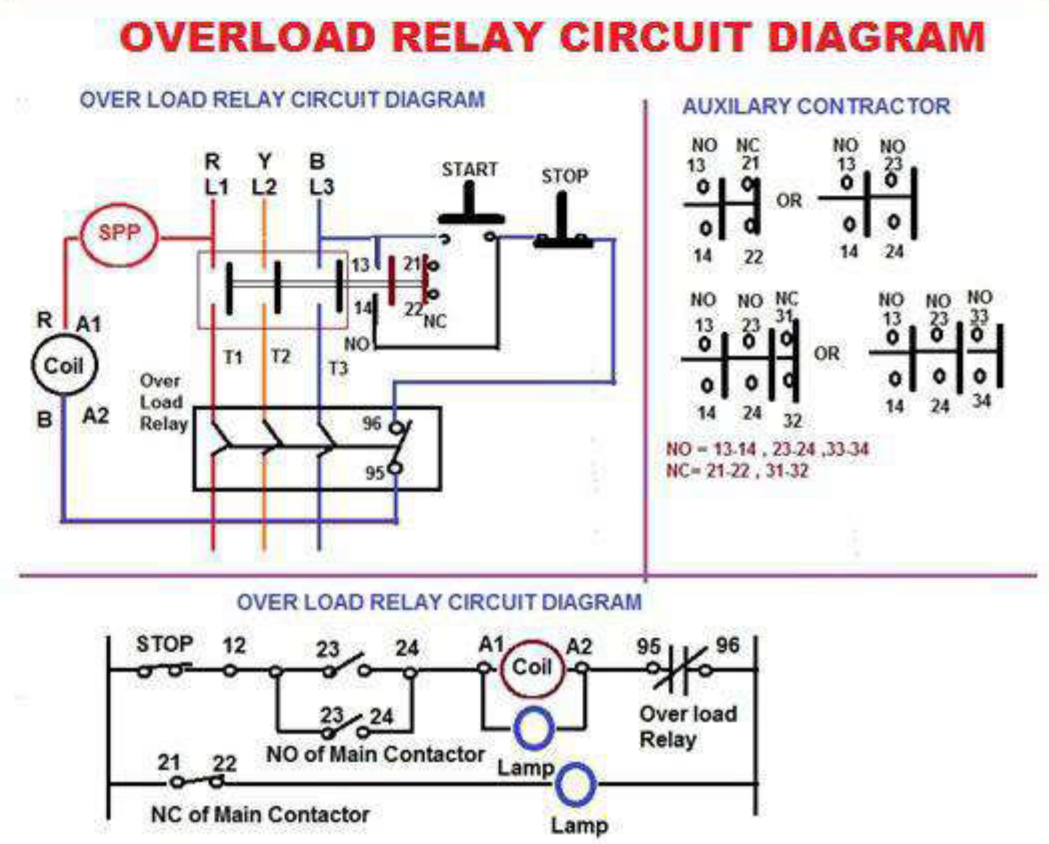


MORE THAN 2 NO'S OF BUTTON CIRCUIT
L1
FUSE
O/L
OFF
ON
OFF
ON
MAIN CONTACTOR
L2


AUTO STAR-DELTA STARTER
L1
FUSE
OVER LOAD RELAY
STOP
START
43
K1
NC
44
17
K4
NO
18
27
K1
NO
28
13
K1
NO
14
13
K2
NO
14
21
K3
NC
22
21
K2
NC
22
K4
K2
K3
K1
L2
TIMER
STAR
DELTA
MAIN


AUTO STAR-DELTA STARTER (CKT-2)
L1
STOP
START
C1
NO
C4
NO
C3
NO
C1
NO
C2
NC
C3
NC
C3
C4
C2
C1
L2
STAR
TIMER
DELTA
MAIN


OVER LOAD RELAY
OVER LOAD RELAY
R Y B
13
14
RYB
95 96 97 98
A1 COIL A2
13 14 A1 COIL A2 95 96
94 Rferance
95 N/O (Start Referance)
96 N/C (Stop Ref in Series with Coil)
97 N/O (Trip Indication)
98 N/C (Trip Indication)
95-96 N/C
96-98 Common
97-98 N/O
OVER LOAD RELAY
R Y B
Over Load Relay
N/C N/C NO NO
95 96 97 98
R Y B
L1 L2 L3
13
14
A1
Coil
A2
95 97
96 98
L1 L2 L3

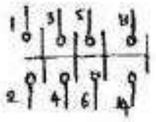

OVERLOAD RELAY CIRCUIT DIAGRAM
OVER LOAD RELAY CIRCUIT DIAGRAM
R Y B
L1 L2 L3
START
STOP
SPP
13 21
14 22
NC
NO
R A1
Coil
B A2
T1 T2 T3
Over Load Relay
96
95
AUXILARY CONTRACTOR
NO NC
13 21
14 22
OR
NO NO
13 23
14 24
NO NO NC
13 23 31
14 24 32
OR
NO NO NO
13 23 33
14 24 34
NO = 13-14 , 23-24 ,33-34
NC= 21-22 , 31-32
OVER LOAD RELAY CIRCUIT DIAGRAM
STOP 12 23 24 A1 Coil A2 95 96
23 24
NO of Main Contactor
Lamp
Over load Relay
21 22
NC of Main Contactor
Lamp

TYPE OF MAIN & AUXILIARY CONTACTOR

CONTACTOR

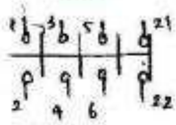
MAIN CONTACTOR: 1-2,3-4,5-6.

1 NO



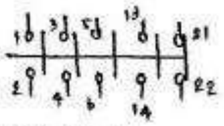
N/O = 13-14

1 NC



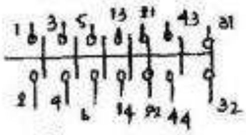
N/C = 21-22

1 NO + 1 NC



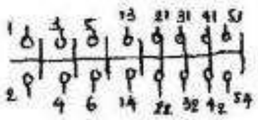
N/O = 13-14
N/C = 21-22

2 NO + 1 NC



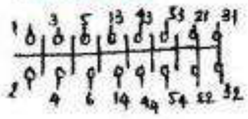
N/O = 13-14, 43-44
N/C = 21-22, 31-32

2 NO + 3 NC



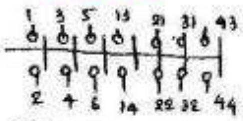
N/O = 13-14, 53-54
N/C = 21-22, 31-32, 41-42

3 NO + 2 NC



N/O = 13-14, 43-44, 53-54
N/C = 21-22, 31-32

2 NO + 2 NC



N/O = 13-14, 43-44
N/C = 21-22, 31-32.

SUMMARY OF MAIN / NO / NC CONTACTOR

MAIN CONTACTOR:= 1-2 ,3-4, 5-6.

NO CONTACTOR:= 13-14, 33-34, 43-44, 53-54, 83-84

NC CONTACTOR:= 21-22, 31-32, 41-42, 61-62, 71-72

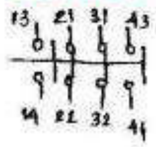
N.B: You can easily Identify whether The Contactor is NO or NC from above Summary.

AUXILIARY CONTECTOR

3 NO + 1 NC

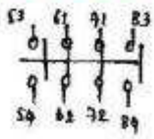
N/O : 13-14, 33-34, 43-44
N/C = 21-22

2 NO + 2 NC



N/O = 13-14, 43-44
N/C = 21-22, 31-32

2 NO + 2 NC

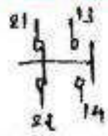


N/O = 53-54, 83-84
N/C = 61-62, 71-72

1 NO + 3 NC

N/O = 13-14
N/C = 21-22, 31-32, 41-42

1 NO + 1 NC

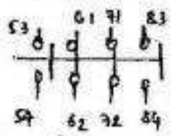


N/O = 13-14
N/C = 21-22

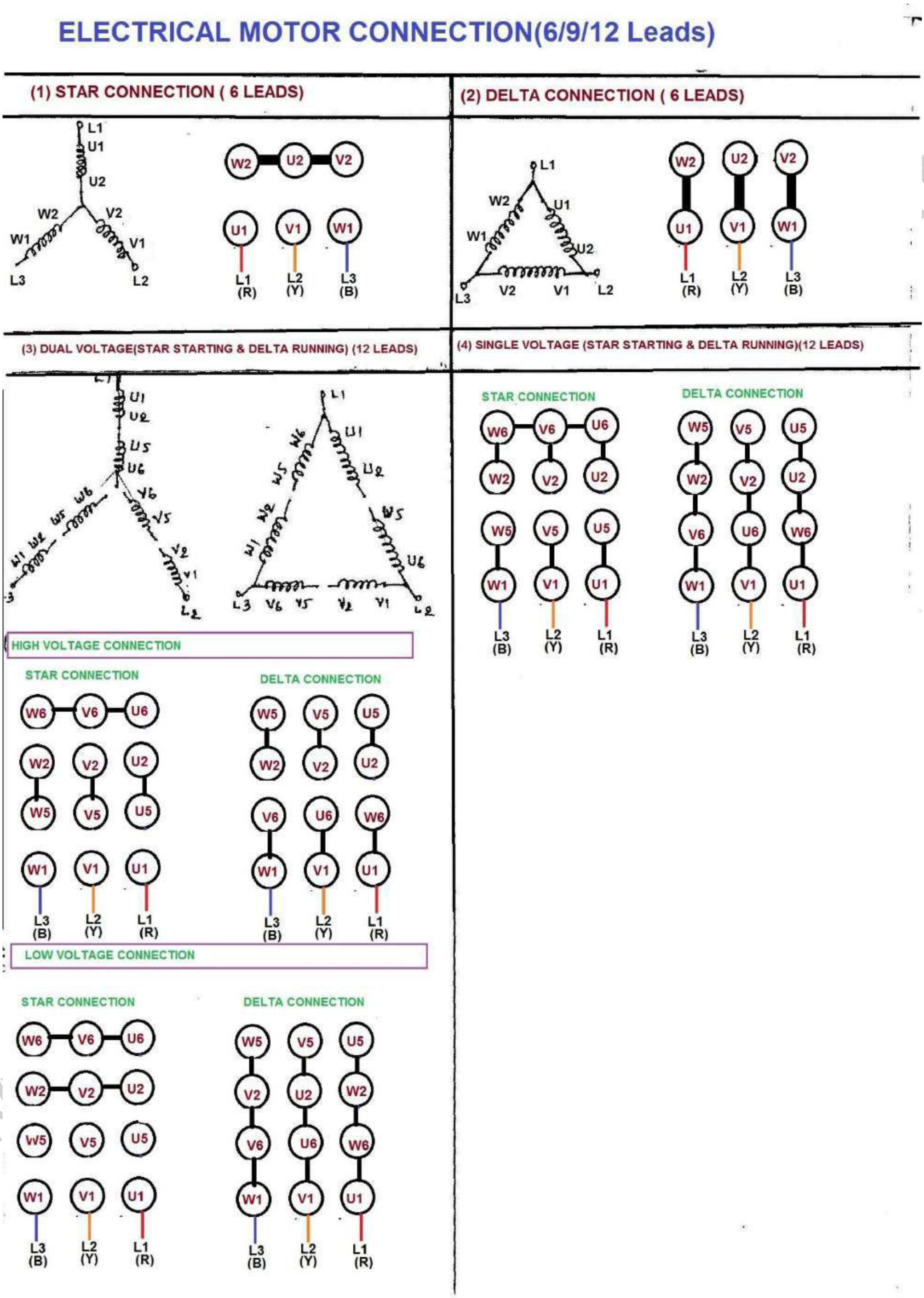
1NO + 1 NC

N/O = 43-44
N/C = 31-32

2 NO + 2 NC



N/O = 53-54, 83-84
N/C = 61-62, 71-72


ELECTRICAL MOTOR CONNECTION(6/9/12 Leads)
(1) STAR CONNECTION (6 LEADS)
(2) DELTA CONNECTION (6 LEADS)
(3) DUAL VOLTAGE(STAR STARTING & DELTA RUNNING) (12 LEADS)
(4) SINGLE VOLTAGE (STAR STARTING & DELTA RUNNING)(12 LEADS)
STAR CONNECTION
DELTA CONNECTION
HIGH VOLTAGE CONNECTION
STAR CONNECTION
DELTA CONNECTION
LOW VOLTAGE CONNECTION
STAR CONNECTION
DELTA CONNECTION
L1 (R)
L2 (Y)
L3 (B)
U1 U2 U5 U6
V1 V2 V5 V6
W1 W2 W5 W6

Change Rotation in Clockwise Direction:						
No	**Present Motor Connection:**			**Change Direction in Clockwise**		
1	R Phase Connected to	U1	W2	R Phase Connected to	U1	**V2**
	Y Phase Connected to	V1	U2	Y Phase Connected to	V1	**W2**
	B Phase Connected to	W1	V2	B Phase Connected to	W1	**U2**
2	R Phase Connected to	W1	V2	R Phase Connected to	W1	**U2**
	Y Phase Connected to	U1	W2	Y Phase Connected to	U1	**V2**
	B Phase Connected to	V1	U2	B Phase Connected to	V1	**W2**
3	R Phase Connected to	V1	U2	R Phase Connected to	V1	**W2**
	Y Phase Connected to	W1	V2	Y Phase Connected to	W1	**U2**
	B Phase Connected to	U1	W2	B Phase Connected to	U1	**V2**

Change Rotation in Anticlockwise Direction:						
No	**Present Motor Connection:**			**Change Direction in Clockwise**		
1	R Phase Connected to	U1	V2	R Phase Connected to	U1	**W2**
	Y Phase Connected to	W1	U2	Y Phase Connected to	W1	**V2**
	B Phase Connected to	V1	W2	B Phase Connected to	V1	**U2**
2	R Phase Connected to	W1	U2	R Phase Connected to	W1	**V2**
	Y Phase Connected to	V1	W2	Y Phase Connected to	V1	**U2**
	B Phase Connected to	U1	V2	B Phase Connected to	U1	**W2**
3	R Phase Connected to	V1	W2	R Phase Connected to	V1	**U2**
	Y Phase Connected to	U1	V2	Y Phase Connected to	U1	**W2**
	B Phase Connected to	W1	U2	B Phase Connected to	W1	**V2**

Thumb Rule (If Phase sequence is R-Y-B):

- Check Phase Winding Starting Phase and Connected ending Connection of That Phase winding to the one Phase after the Phase where Phase winding Starting lead is connected.
- (Example If U1 is connected to R Phase than Connect U2 to B Phase, If V1 is connected to Y Phase than V2 should be connected to R Phase)

Cable Gland Terminology		
First Letter of Gland	**Description**	**Sealing**
A1	Un armored cable	with an elastomeric or plastics outer sheath, where the function of the gland is to secure the outer sheath of the cable
A2	Un armored cable	As type AI, but with an IP66 seal between the outer sheath and gland.
A3	Un armored cable	As type AI, but with an electrical bond for the metallic inner sheath.
A4	Un armored cable	As type A2, but with an electrical bond for the metallic inner sheath.
B	Armored cable or wire braided cable, no sealing	The function of the gland is to secure the armor or metallic braid and to provide electrical continuity between such armor or braid and the threaded fixing component of the gland.
C	Armored cable or wire braided cable, sealing on outer sheath	As type B, but with an IP66 seal between outer sheath and gland.
D1	Armored cable or wire braided cable, sealing on inner sheath	As type B, but with an IP66 seal between the inner sheath and threaded fixing component.
D2	Armored cable or wire braided cable, sealing on inner sheath	As type DI, but with an electrical bond for The metallic inner sheath.
E1	Armored cable, sealing on both sheaths	An extruded elastomeric or plastics inner sheath and elastomeric or plastics outer sheath. As type B, but with IP66 seals between the outer sheath and gland and between the inner sheath and threaded fixing component
E2	Armored cable, sealing on both sheaths	As type E I, but with an electrical bond for the metallic inner sheath.
Second Letter of Gland	**Description**	**Sealing**
W	Single wire armored	
X	Wire braided	
T	Pliable wire armored flexible	
Y	Aluminium strip armored	
Z	Double steel tape armored	
Example		
Type BW	An armored clamp without a watertight seal, for single wire armored cable.	
Type CT	A gland for pliable wire armored flexible cable, with an IP66 seal between the outer sheath and gland.	
Type E2X	gland for wire braided cable with an electrical bond for the metallic inner sheath	

Gland for 600/1000V STANDARD COPPER CONDUCTORS PVC INSULATED WITH STEEL WIRE ARMOUR AND PVC SHEATHED OVERALL														
Cable Size	Numbers of Cores													
(mm2)	Neutral	1	2	3	31/2	4	5	7	10	12	19	27	37	48
1.5	-	-	16	16	-	20S	20S	20S	20	20	25	25	32	32
2.5	-	-	20S	20S	-	20S	20S	20	25	25	25	32	32	40
4	-	-	20S	20	-	20	20	25	25	25	32	40	-	-
6	-	-	20	20	-	20	-	-	-	-	-	-	-	-
10	-	-	25	25	-	25	-	-	-	-	-	-	-	-
16	-	-	25	25	-	25	-	-	-	-	-	-	-	-
25	16	-	25	32	32	32	-	-	-	-	-	-	-	-
35	16	-	32	32	32	40	-	-	-	-	-	-	-	-
50	25	25	32	32	32	40	-	-	-	-	-	-	-	-
70	35	25	32	40	40	40	-	-	-	-	-	-	-	-
95	50	25	40	40	50S	50S	-	-	-	-	-	-	-	-
120	70	32	40	50S	50	50	-	-	-	-	-	-	-	-
150	70	32	50S	50	50	63S	-	-	-	-	-	-	-	-
185	95	32	50	50	63S	63	-	-	-	-	-	-	-	-
240	120	40	50	63S	63	75S	-	-	-	-	-	-	-	-
300	150	40	63S	63	75S	75	-	-	-	-	-	-	-	-
300	185	40	63	63	75	75	-	-	-	-	-	-	-	-
400	185	50S	63	75S	75	75	-	-	-	-	-	-	-	-
500	-	50	-	-	-	-	-	-	-	-	-	-	-	-
630	-	50	-	-	-	-	-	-	-	-	-	-	-	-
800	-	63S	-	-	-	-	-	-	-	-	-	-	-	-
1000	-	63	-	-	-	-	-	-	-	-	-	-	-	-

Gland For 600 / 1000v stranded copper conductors XLPE/SWA/PVC cable and PVC sheathed overall. (BS 5467 : 1989)														
Cable Size	Numbers of Cores													
Area (mm2)	Neutral	1	2	3	31/2	4	5	7	10	12	19	27	37	48
1.5	-	-	20S	20S	-	20S	20S	20S	20	25	25	32	32	32
2.5	-	-	20S	20S	-	20S	20S	20	25	25	32	32	40	40
4	-	-	20S	20S	-	20	20	25	25	25	32	40	40	50S
6	-	-	20	20	-	20	-	-	-	-	-	-	-	-
10	-	-	20	25	-	25	-	-	-	-	-	-	-	-
16	-	-	25	25	-	25	-	-	-	-	-	-	-	-
25	16	-	25	32	32	32	-	-	-	-	-	-	-	-
35	16	-	32	32	32	32	-	-	-	-	-	-	-	-
50	25	25	25	32	32	32	-	-	-	-	-	-	-	-
70	35	25	32	32	40	40	-	-	-	-	-	-	-	-
95	50	25	32	40	50S	50S	-	-	-	-	-	-	-	-
120	70	32	40	40	50	50	-	-	-	-	-	-	-	-
150	70	32	40	50S	50	50	-	-	-	-	-	-	-	-
185	95	32	50S	50	63S	63S	-	-	-	-	-	-	-	-
240	120	40	50	63S	63	63	-	-	-	-	-	-	-	-
300	150	40	63S	63	75S	75S	-	-	-	-	-	-	-	-
300	185	40	63S	63	75S	75	-	-	-	-	-	-	-	-
400	185	50S	63S	75S	75	75	-	-	-	-	-	-	-	-
500	-	50	-	-	-	-	-	-	-	-	-	-	-	-
630	-	50	-	-	-	-	-	-	-	-	-	-	-	-
800	-	63S	-	-	-	-	-	-	-	-	-	-	-	-
1000	-	63	-	-	-	-	-	-	-	-	-	-	-	-

CABLE GLAND REFERANCE								
Conductor Size	AMP	Breaker	Gland Size					
			1 Core	2 Core	3 Core	3.5 Core	4 Core	MM

0.5 SQ.MM	14A	10A	7				20S	16MM
2.5 SQ.MM	25A	25A	7	20S	20S	20S	20S	16MM
4 SQ.MM	33A	32A	9	20S	20S	20S	20S	16MM
6 SQ.MM	42A	40A	9	20L	20L	20L	20S	19MM
10 SQ.MM	58A	50A	11. 16	20L	20L	20L	25S	22MM
16 SQ.MM	77A	63A	19	20L	20L	20L	25L	25MM
25 SQ.MM	102A	80A	21	25S	25L	32S	32S	28MM
35 SQ.MM	125A	100A	21	25L	32L	32L	32L	28MM
50 SQ.MM	150A	125A	25S	32L	32L	40S	40S	32MM
70 SQ.MM	192A	160A	25S	32L	40L	40L	40L	35MM
95 SQ.MM	230A	200A	25L	40L	40L	50S	50S	38MM
120 SQ.MM	267A	250A	32L	40L	50S	50L	50L	42MM
150 SQ.MM	290A	250A	32L	50S	50L	50L	63S	45MM
185 SQ.MM	345A	345A	32L	50L	50L	63S	63L	50MM
240 SQ.MM	400A	400A	40L	50L	63S	63L	75S	57MM
300 SQ.MM	500A	450A	40L	63S	63L	75S	75L	63MM
400 SQ.MM	670A	630A	63L			75L	90S	70MM

CABLE GLAND REFERANCE	
3 To 6 SQ.MM	PG-7
4 To 8 SQ.MM	PG-9
5 To 10 SQ.MM	PG-11
6 To 12 SQ.MM	PG-13.5
10 To 14 SQ.MM	PG-16
12 To 16 SQ.MM	PG-19

Chapter: 23 Demand Factor / Diversity Factor Reference

Demand Factor For Industrial Load (Design of Elect. Installation- Jain)	
Electrical Load	**Demand Factor**
1 No of Motor	1
Up to 10 No's of Motor	0.75
Up to 20 No's of Motor	0.65
Up to 30 No's of Motor	0.6
Up to 40 No's of Motor	0.5
Up to 50 No's of Motor	0.4

Demand Factor (Design of Elect. Installation- Jain)	
Utility	**Demand Factor**
Office ,School	0.4
Hospital	0.5
Air Port, Bank, Shops,	0.6
Restaurant, Factory,	0.7
Work Shop, Factory (24Hr Shift)	0.8
Arc Furnace	0.9
Compressor	0.5
Hand tools	0.4
Inductance Furnace	0.8

Demand Factor(Saudi Electricity Company Distribution)	
Utility	**Demand Factor**
Residential	0.6
Commercial	0.7
Flats	0.7
Hotel	0.75
Mall	0.7
Restaurant	0.7
Office	0.7
School	0.8
Common Area in building	0.8
Public Facility	0.75
Street Light	0.9
Indoor Parking	0.8
Outdoor Parking	0.9
Park / Garden	0.8
Hospital	0.8
Workshops	0.6
Ware House	0.7
Farms	0.9
Fuel Station	0.7
Factories	0.9

Demand Factor (Principal of Power System-V.K.Mehta)	
Utility	**Demand Factor**
Residence Load (<0.25 KW)	1
Residence Load (<0.5 KW)	0.6
Residence Load (>0.1 KW)	0.5
Restaurant	0.7
Theatre	0.6
Hotel	0.5
School	0.55
Small Industry	0.6
Store	0.7

Motor Load (up to 10HP)	0.75
Motor Load (10HP to 20HP)	0.65
Motor Load (20HP to 100HP)	0.55
Motor Load (Above 100HP)	0.50

Diversity Factor in distribution Network

(Standard Handbook for Electrical Engineers" by Fink and Beaty)

Elements of System	Residential	Commercial	General Power	Large Industrial
Between individual users	2.00	1.46	1.45	
Between transformers	1.30	1.30	1.35	1.05
Between feeders	1.15	1.15	1.15	1.05
Between substations	1.10	1.10	1.10	1.10
From users to transformers	2.00	1.46	1.44	
From users to feeder	2.60	1.90	1.95	1.15
From users to substation	3.00	2.18	2.24	1.32
From users to Generating station	3.29	2.40	2.46	1.45

Diversity Factor for Distribution Switchboards

Number of circuits	Diversity Factor in % (ks)
Assemblies entirely tested 2 and 3	90%
4 and 5	80%
6 to 9	70%
10 and more	60%
Assemblies partially tested in every case choose	100%

Diversity Factor as per IEC 60439

Circuits Function	Diversity Factor in % (ks)
Lighting	90%
Heating and air conditioning	80%
Socket-outlets	70%
Lifts and catering hoist	
For the most powerful motor	100%
For the second most powerful motor	75%
For all motors	80%

Diversity Factor for Apartment block

Apartment	Diversity Factor in % (ks)
2 To 4	1
5To 19	0.78
10To 14	0.63
15To 19	0.53
20To 24	0.49
25To 29	0.46
30 To 34	0.44
35 To 39	0.42
40To 40	0.41
50 To Above	0.40

Diversity Factor (Principal of Power System-V.K.Mehta)

Area	Residence Lighting	Commercial Lighting	Ind. Lighting
Between Consumer	3	1.5	1.5
Between Transformer	1.3	1.3	1.3
Between Feeder	1.2	1.2	1.2
Between S.S	1.1	1.1	1.1

Diversity Factor (NBC)

Type of Load	Type of Building

	Individual House Hold , Individual Dwelling of a Block	Small Shops, Stores, Offices & Business Premises	Small Hotels, Boarding Houses, etc
Lighting	66% of total current demand	90% of total current demand	75% of total current demand
Heating and power	100% of total current demand up to 10 A+ 50 % of any current demand in excess of 10 A	100% of full load of largest Appliance + 75% of Remaining appliances	100% of full load of largest appliance+ 80% of second largest appliance + 60% of remaining appliances
Cooking appliances	10 A +30 percent full load of connected cooking appliances in excess of 10 A + 6 A if socket-outlet incorporated in the unit	100 % of full load of largest appliance + 80% of full load of second largest appliance + 60% of full load of Remaining appliances	100 % of full load of largest appliance + 80 % of full load of second largest appliance + 60% of full load of Remaining appliances
Motors (other than lift motors which are subject to special consideration)		100% of full load of largest Motor + 80% of full load of second largest motor	100 % of full load of largest Motor + 50%of full load of remaining motors
Water heater (instantaneous)	100 % of full load of largest Appliance + 100%of full load of second largest appliance + 25 %of full load of remaining appliances	100 % of full load of largest Appliance + 100%of full load of second largest appliance + 25 %of full load of remaining appliances	100 % of full load of largest Appliance + 100%of full load of second largest appliance + 25 %of full load of remaining appliances
Water heater (thermostatically controlled)	No diversity		
Standard arrangements of final circuits in accordance with good practice	100 percent of the current demand of the largest circuit + 40 percent of the current demand of every other circuit	100 percent of the current demand of the largest circuit + 50 percent of the current demand of every other circuit	
Socket outlets other than above and stationary equipment other than those listed above	100% of the current demand of the largest point + 40%of the current demand of every other point	100% of the current demand of the largest point+ 75 % of the current demand of every other point	100%of the current demand of the largest point + 75%of the current demand of every point in main rooms (dining rooms, etc) + 40 % of the current demand of every other point
After calculating the electrical load on the above basis, an overall load factor of 70 to 90 percent is to be applied to arrive at the minimum capacity of substation.			

Diversity (The Electricians Guide 5th Edition by John Whitfield)

Type of final circuit	Type of premises		
	Households	Small shops, stores, offices	Hotels, guest houses
Lighting	66% total demand	90% total demand	75% total demand
Heating and power	100% up to 10 A + 50% balance	100%X + 75%(Y+Z)	100%X + 80%Y + 60%Z
Cookers	10 A + 30% balance + 5 A for socket	100%X + 80%Y + 60%Z	100%X + 80%Y + 60%Z
Motors (but not lifts)		100%X + 80%Y + 60%Z	100%X + 50%(Y+Z)

Instantaneous water heaters	100%X + 100%Y + 25%Z	100%X + 100%Y + 25%Z	100%X + 100%Y + 25%Z
Thermostatic water heaters	100%	100%	100%
Floor warming installations	100%	100%	100%
Thermal storage heating	100%	100%	100%
Standard circuits	100%X + 40%(Y+Z)	100%X + 50%(Y+Z)	100%X + 50%(Y+Z)
Sockets and stationary equip.	100%X + 40%(Y+Z)	100%X + 75%(Y+Z)	100%X + 75%Y + 40%Z
X = the full load current of the largest appliance or circuit			
Y = the full load current of the second largest appliance or circuit			
Z = the full load current of the remaining appliances or circuits			

Diversity factor (Horizon Power)

No of customer	Diversity factor
1	3
2	2.57
3	2.2
4	2
5	1.89
6	1.8
7	1.74
8	1.71
9	1.69
10	1.64
11	1.61
12 To 14	1.57
15 To 17	1.5
18 To 20	1.46
21 To 23	1.42
24 to 26	1.4
27 To 29	1.38
30 To 59	1.37
≥60	1

Demand Factor & Load Factor

Introduction to Power Requirement for Building - J. Paul Guyer,

Utility	Demand Factor (%)	Load Factor (%)
Communications – buildings	60-65	70-75
Telephone exchange building	55-70	20-25
Air passenger terminal building	65-80	28-32
Aircraft fire and rescue station	25-35	13-17
Aircraft line operations building	65-80	24-28
Academic instruction building	40-60	22-26
Applied instruction building	35-65	24-28
Chemistry and Toxicology Laboratory	70-80	22-28
Materials Laboratory	30-35	27-32
Physics Laboratory	70-80	22-28
Electrical and electronics laboratory	20-30	3-7
Cold storage warehouse	70-75	20-25
General warehouse	75-80	23-28
Controlled humidity warehouse	60-65	33-38
Hazardous/flammable storehouse	75-80	20-25
Disposal, salvage, scrap building	35-40	25-20
Hospital	38-42	45-50

Laboratory	32-37	20-25
7-12 schools	65-70	12-17
Churches	65-70	5-25
Post Office	75-80	20-25
Retail store	65-70	25-32
Bank	75-80	20-25
Supermarket	55-60	25-30
Restaurant	45-75	15-25
Auto repair shop	40-60	15-20
Hobby shop, art/crafts	30-40	25-30
Bowling alley	70-75	10-15
Gymnasium	70-75	20-45
Skating rink	70-75	10-15
Indoor swimming pool	55-60	25-50
Theatres	45-55	8-13
Library	75-80	30-35
Golf clubhouse	75-80	15-20
Museum	75-80	30-35

Demand Factors (As Per Table 220.42 NEC)		
Type of Occupancy	**Electrical Load**	**Demand Factor**
Dwelling units	First 3000VA	100%
	From3001 to120,000VA	35%
	Remainder over 120,000VA	25%
Hospitals	First 50,000VA or less	40%
	Remainder over 50,000VA	20%
Hotels and motels, including apartment houses without provision for cooking by tenants	First 20,000VA	50%
	20,001VA to100,000VA	40%
	Remainder over100,000VA	30%
Warehouses storage	First 12,500VA	100%
	Remainder over 12,500VA	50%
All others	Total volt-ampere	100%

Non-dwelling Lighting Loads Demand Factors (As Per 220.44 NEC)		
Type of Occupancy	**Electrical Load**	**Demand Factor**
Non-dwelling Receptacle Loads	First 10KVA	100%

Demand Factor (The Electricians Guide Fifth Edition) by John Whitfield)	
Area	**Demand Factor**
Office / School	40%
Technical Blocks / Hospital	50%
Air Port / Banks / Department Store / Shopping Center / Public Place	60%
Restaurants / Factories (for 8 Hours Shifts)	70%
Workshops / Factories (for 24 Hours Shifts)	80%
Arc Furnace	90 % TO 100%
Arc Welding	20 % TO 50%
Compressor	20 % TO 50%
Conveyor Crane	90 % TO 100%
Had tool	20 % TO 40%
Paper Mills	50 % TO 70%
Induction Furnace	80 % TO 100%

Demand Factor As per No of Appliances			
No of Appliances	**(A) Less than 3.5 KW**	**(B) 3.5 KW to 8.5 KW**	**(C) Less 12 KW**
1	80%	80%	8%
2	75%	655	11%
3	70%	55%	14%
4	66%	50%	17%
5	62%	45%	20%
6	59%	43%	21%
7	56%	36%	22%
8	53%	35%	23%
9	51%	34%	24%
10	49%	32%	25%
11	47%	32%	26%
12	45%	32%	27%
13	43%	32%	28%
14	41%	32%	29%
15	40%	32%	30%
16	39%	28%	31%
17	38%	28%	32%
18	37%	28%	33%
19	36%	28%	34%
20	35%	28%	35%
21	34%	26%	36%
22	33%	26%	37%
23	325	26%	38%
24	31%	26%	39%
25	30%	26%	40%
26 To 30	30%	24%	**15KW+1KW for Each**
31 To 40	30%	22%	
41 To 50	30%	20%	**25KW+0.75KW for Each**
51 To 60	30%	18%	
More Than 60	30%	16%	

Lighting Demand for Building (As per NBC)
Lighting demand for buildings should be considered as per type of building.
Where nothing is specified, for lighting demand of any type of building a maximum of **13 W/m2** of all built-up areas including balconies.
Covered parking areas may be considered at 3.23 W/m2 including balconies, service areas, corridors, etc, may be considered with very basic diversity of 80 % to 100 %.
Power requirements shall be considered at least 55 W/m2 with an overall diversity not exceeding 50 %. These shall be excluding defined loads such as lifts, plumbing system, fire fighting systems, ventilation requirement, etc.

Lighting Power Densities for Building Exteriors (ASHRAE 90.1-2004, Table 9.4.5)	
Tradable Surfaces	**LPD**
Uncovered Parking Areas --Parking Lots and drives	**0.15** W/ft^2
Building Grounds --Walkways less than 10 feet wide	**1.0** W/linear foot
Building Grounds --Walkways 10 feet wide or greater; Plaza areas; Special Feature Areas	**0.2** W/ft^2
Building Grounds --Stairways	**1.0** W/ft^2
Building Entrances and Exits --Main entries	**30** W/linear foot of door width
Building Entrances and Exits --Other doors	**20** W/linear foot of door width
Canopies and Overhangs --free standing and attached	**1.25** W/ft^2
Outdoor Sales --Open areas (including vehicle sales lots)	**0.5** W/ft^2
Outdoor Sales --Street frontage for vehicle sales lots in addition to "open area" allowance	**20** W/linear foot

Lighting Power Density (AS per CPWD)	
Building Area Type	**LPD (W/m2)**
Automotive Facility	9.7
Multifamily Residential	7.5
Convention Centre	12.9
Museum	11.8
Dining : Bar Lounge/ Leisure	14
Office	10.8
Dining : Cafeteria/ Fast Food	15.1
Parking Garage	3.2
Dining : Family	17.2
Performing Arts Theatre	17.2
Dormitory/ Hostel	10.8
Police/ Fire Station	10.8
Gymnasium	11.8
Post Office/ Town Hall	11.8
Health care-Clinic	10.8
Religious Building	14
Hospital/ Health Care	12.9
Retail/ Mall	16.1
Hotel	10.8
School/ University	12.9
Library	14
Sports Arena	11.8
Manufacturing Facility	14
Transportation	10.8
Motel	10.8
Motion Picture Theatre	12.9
Warehouse	8.6
Workshop	15.1

Interior Lighting Power Space Density As per Function Method (CPWD)	
Building Area Type	**LPD (W/m2)**
Office-enclosed	11.8
Office-open plan	11.8
Conference/ Meeting/ Multipurpose	14
Classroom/Lecture/ Training	15.1
Lobby	14
• For Hotel	11.8
• For Performing Arts Theatre	35.5
• For Motion Picture Theatre	11.8
Audience/ Seating Area	9.7
• For Gymnasium	4.3
• For Convention Centre	7.5

• For Religious Buildings	18.3
• For Sports Arena	4.3
• For Performing Arts Theatre	28
• For Motion Picture Theatre	12.9
• For Transportation	5.4
Atrium-first three floors	6.5
Atrium-each additional floor	2.2
Lounge/ Recreation	12.9
• For Hospital	8.6
Dining Area	9.7
• For Hotel	14
• For Motel	12.9
• For Bar Lounge/ Leisure Dining	15.1
• For Family Dining	22.6
• Food Preparation	12.9
Laboratory	15.1
Restrooms	9.7
Dressing/ Lockers/ Fitting Room	6.5
Corridor/ Transition	5.4
• For Hospital	10.8
• For Manufacturing facility	5.4
Stairs-active	6.5
Active Storage	8.6
• For Hospital	9.7
Inactive Storage	3.2
• For Museum	8.6
Electrical/ Mechanical Facility	16.1
For Indoor Field Area	15.1
Warehouse	
• For Fine Material Storage	15.1
• For Medium/ Bulky Material	
Storage	9.7
Workshop	20.5
Convention Centre - Exhibit Space	14
Library	
• For Card File & Cataloguing	11.8
• For Stacks	18.3
• For Reading Area	12.9
Hospital	
• For Emergency	29.1
• For Recovery	8.6
• For Nurse Station	10.8
• For Exam Treatment	16.1
• For Pharmacy	12.9
• For Patient Room	7.5
• For Operating Room	23.7
• For Nursery	6.5
• For Medical Supply	15.1
• For Physical Therapy	9.7
• For Radiology	4.3
• For Laundry - Washing	6.5
Automotive - Service Repair Manufacturing Facility	7.5
• For Low Bay (<8m ceiling)	12.9
• For High Bay (>8m ceiling)	18.3
• For Detailed Manufacturing	22.6
• For Equipment Room	12.9
• For Control Room	5.4
Hotel/ Motel Guest Rooms	11.8
Dormitory - Living Quarters	11.8
Museum	
• For General Exhibition	10.8

• For Restoration	18.3
Bank Office - Banking Activity Area	16.1
Retail	
• For Sales Area	18.3
• For Mall Concourse	18.3
Sports Arena	
• For Rising Sports Area	29.1
• For Court Sports Area	24.8
Parking Garage - Garage Area	2.2
Transportation	
• For Airport - Concourse	6.5
• For Air/ Train/ Bus-Baggage Area	10.8
• For Ticket Counter Terminal	16.1

Exterior Lighting Power Space Density (AS per CPWD)	
Exterior Lighting Applications	**Power Limits**
Building entrance (with canopy)	13 W/m2 of canopied area
Building entrance (without canopy)	90 W/linear meter of door width
Building exit	60 W/linear meter of door width
Building facades	2 W/m2 of vertical facade area2

Lighting Power Densities for Buildings Except Low-Rise Residential Buildings	
ANSI/ASHRAE/IES Standard 90.1-2010: Table 9.6.11	
Common Space Type	**LPD (W/ft^2)**
Conference/Meeting/Multipurpose	1.23
Corridor/Transition	0.66
Dining Area	0.65
Electrical/Mechanical	0.95
Food Preparation	0.99
Lobby	0.99
Lobby for Elevator	0.64
Lounge/Recreation	0.73
Office: Enclosed	1.11
Office: Open Plan	1.11
Restrooms	0.98
Stairway	0.69
Storage	0.63
Workshop	1.59

Lighting Power Densities Using the Building Area Method (ASHRAE-TABLE 9.5.1)	
Building Area Type	**LPD**
Automotive facility	0.82W/ft2
Convention center	1.08W/ft2
Courthouse	1.05W/ft2
Dining: bar lounge/leisure	0.99W/ft2
Dining: cafeteria/fast food	0.90W/ft2
Dining: family	0.89W/ft2
Dormitory	0.61W/ft2
Exercise center	0.88W/ft2
Fire station	0.71W/ft2
Gymnasium	1.00W/ft2
Health-care clinic	0.87W/ft2
Hospital	1.21W/ft2
Hotel	1.00W/ft2
Library	1.18W/ft2
Manufacturing facility	1.11W/ft2
Motel	0.88W/ft2
Motion picture theater	0.83W/ft2
Multifamily	0.60W/ft2
Museum	1.06W/ft2

Office	0.90W/ft2
Parking garage	0.25W/ft2
Penitentiary	0.97W/ft2
Performing arts theater	1.39W/ft2
Police station	0.96W/ft2
Post office	0.87W/ft2
Religious building	1.05W/ft2
Retail	1.40W/ft2
School/university	0.99W/ft2
Sports arena	0.78W/ft2
Town hall	0.92W/ft2
Transportation –Airport	0.77W/ft2
Warehouse	0.66W/ft2
Workshop	1.20 W/ft2

Maximum Illumination Power Densities	
Building Code of Australia (BCA)	
Lux Level of Rooms	**LPD**
< 80 Lux:	7.5 Watt/M2
80 To 160 Lux	9 Watt/M2
160 To 240 Lux	10 Watt/M2
240 To 320 Lux	11 Watt/M2
320 To 400 Lux	12 Watt/M2
400 To 480 Lux	13 Watt/M2
480 To 540 Lux	14 Watt/M2
540 To 620 Lux	15 Watt/M2

ILLUMINATION POWER DENSITY	
Building Code of Australia (BCA)	
Space	**LPD**
Auditorium, church and public hall	10 Watt/M2
Boardroom and conference room	10 Watt/M2
Carpark – general	6 Watt/M2
Carpark – entry zone (first 20m of travel)	25 Watt/M2
Common rooms, spaces and corridors in a Class 2 building	8 Watt/M2
Control room, switch room, and the like	9 Watt/M2
Corridors	8 Watt/M2
Courtroom	12 Watt/M2
Dormitory of a Class 3 building used for sleeping only	6 Watt/M2
Dormitory of a Class 3 building used for sleeping and study	9 Watt/M2
Entry lobby from outside the building	15 Watt/M2
Health-care – children's ward	10 Watt/M2
Health-care – examination room	10 Watt/M2
Health-care – patient ward	7 Watt/M2
Health-care – all patient care areas including corridors	13 Watt/M2
Kitchen and food preparation area	8 Watt/M2
Laboratory – artificially lit to an ambient level of 400 lx or more	12 Watt/M2
Library – stack and shelving area	12 Watt/M2
Library – reading room and general areas	10 Watt/M2
Lounge area for communal use in a Class 3 building or Class 9c	10 Watt/M2
Museum and gallery – circulation, cleaning and service lighting	8 Watt/M2
Office – artificially lit to an ambient level of 200 lx or more	9 Watt/M2
Office – artificially lot to an ambient level of less than 200 lx	7 Watt/M2
Plant room	5 Watt/M2
Restaurant, Cafe, bar, hotel lounge and a space for the serving of food or drinks	18 Watt/M2
Retail space including a museum and gallery whose purpose is the sale of objects	22 Watt/M2
School – general purpose learning areas and tutorial rooms	8 Watt/M2
Sole-occupancy unit of a Class 3 building	5 Watt/M2
Sole-occupancy unit of a Class 9c building	7 Watt/M2
Storage with shelving no higher than 75% of the height of the aisle lighting	8 Watt/M2
Storage with shelving higher than 75% of the height of the aisle lighting	10 Watt/M2

Service area, cleaner's room and the like	5 Watt/M2
Toilet, locker room, staff room, rest room and the like	6 Watt/M2
Wholesale storage and display area	10 Watt/M2

MAXIMUM ILLUMINATION POWER DENSITY	
Building Code of Australia (BCA)	
Illumination	**LPD (Watt/M2)**
Rooms to achieve	
<80 lux	7.5
80 – 160 lux	9
160 – 240 lux	10
240 – 320 lux	11
320 – 400 lux	12
400 – 480 lux	13
480 – 540 lux	14
540 – 620 lux	15
>620 lux	80

Recommended LPD for Buildings (ECBC-2007)			
Building Area	**LPD (Watt/M2)**	**Building Area**	**LPD (Watt/M2)**
Automotive Facility	9.7	Motel	10.8
Convention Center	12.9	Motion Picture Theater	12.9
Dining: Bar Lounge/Leisure	14	Multifamily Residential	7.5
Dining: Cafeteria/Fast Food	15.1	Museum	11.8
Dining: Family	17.2	Office	10.8
Dormitory/Hostel	10.8	Parking Garage	3.2
Gymnasium	11.8	Performing Arts Theatre	17.2
Healthcare-Clinic	10.8	Police/Fire Station	10.8
Hospital/Health Care	12.9	Post Office/Town Hall	11.8
Hotel	10.8	Religious Building	14
Library	14	Retail/Mall	16.1
Manufacturing Facility	14	School/University	12.9
Warehouse	8.6	Sports Arena	11.8
Workshop	15.1	Transportation	10.8

Lighting Power Density (BEC-Table 5.4)	
Building Area	**LPD (Watt/M2)**
Atrium / Foyer with headroom over 5m	17
Bar / Lounge	14
Banquet Room / Function Room / Ball Room	20
Canteen	11
Car Park	5
Classroom / Training Room	12
Clinic	15
Computer Room / Data Centre	15
Conference / Seminar Room	14
Corridor	8
Court Room	15
Dormitory	8
Entrance Lobby	14
Exhibition Hall / Gallery	17
Guest room in Hotel or Guesthouse	13
Gymnasium / Exercise Room	13
Kitchen	13
Laboratory	15
Lecture Theatre	13

Library – Reading Area, Stack Area or Audio Visual Centre	15
Lift Car	11
Lift Lobby	11
Loading & Unloading Area	8
Office, enclosed (Internal floor area at or below 15m2)	13
Office, open plan or with internal floor area above 15m2	12
Passenger Terminal Building	14
Arrival Hall /Departure Hall with headroom not exceeding 5m	18
Arrival Hall / Departure Hall with headroom over 5m	13
Passenger circulation area	
Patient Ward / Day Care	15
Plant Room / Machine Room / Switch Room	10
Public Circulation Area	13
Railway Station	
Concourse / Platform / Entrance / Adit / Staircase, with headroom not exceeding 5 m	14
Platform / Entrance / Adit / Staircase, with headroom over 5 m	18
Refuge Floor	11
Restaurant	17
Retail	17
School hall	14
Seating Area inside Theatre / Cinema /Auditorium / Concert Hall / Arena	10
Server Room / Hub Room	10
Sports Arena, Indoor, for recreational purpose	17
Staircase	7
Storeroom / Cleaner	9
Toilet / Washroom / Shower Room	11
Workshop	13

Lighting Power Densities (ASHRAE –TABLE- 9.6.1)	
Building Area Type LPD (W/m2)	**LPD (W/m2)**
Atrium (First 40 ft in height)	0.03
Atrium (Above 40 ft in height)	0.02
Audience/Seating Area	
Permanent For auditorium	0.79
For Performing Arts Theater	2.43
For Motion Picture Theater	1.14
Classroom/Lecture/Training	1.24
Conference/Meeting/Multipurpose	1.23
Corridor/Transition 0.66 Width<8 ft	
Dining Area	0.65
For Bar Lounge/Leisure Dining	1.31
For Family Dining	0.89
Dressing/Fitting Room for Performing Arts Theater	0.40
Electrical/Mechanical	0.95
Food Preparation	0.99
Laboratory	
For Classrooms	1.28
For Medical/Industrial/Research	1.81
Lobby	0.90
For Elevator	0.64
For Performing Arts Theater	2.00
For Motion Picture Theater	0.52
Locker Room	0.75
Lounge/Recreation	0.73
Office	
Enclosed	1.11
Open Plan	0.98
Restrooms	0.98
Sales Area	1.68
Stairway	0.69

Storage	0.63
Workshop	1.59
Automotive	
Service/Repair	0.67
Bank/Office	
Banking Activity Area	1.38
Convention Center	
Audience Seating	0.82
Exhibit Space	1.45
Courthouse/Police Station/Penitentiary	
Courtroom	1.72
Confinement Cells	1.10
Judges' Chambers	1.17
Penitentiary Audience Seating	0.43
Penitentiary Classroom	1.34
Penitentiary Dining	1.07
Dormitory	
Living Quarters	0.38
Fire Stations	
Engine Room	0.56
Sleeping Quarters	0.25
Gymnasium/Fitness Center	
Fitness Area	0.72
Gymnasium Audience Seating	0.43
Playing Area	1.20
Hospital	
Corridor/Transition Width < 8 ft	0.89
Emergency	2.26
Exam/Treatment	1.66
Laundry/Washing	0.60
Lounge/Recreation	1.07
Medical Supply	1.27
Nursery	0.88
Nurses' Station	0.87
Operating Room	1.89
Patient Room	0.62
Pharmacy	1.14
Physical Therapy	0.91
Radiology/Imaging	1.32
Recovery	1.15
Hotel/Highway Lodging	
Hotel Dining	0.82
Hotel Guest Rooms	1.11
Hotel Lobby	1.06
Highway Lodging Dining	0.88
Highway Lodging Guest Rooms	0.75
Library	
Card File and Cataloging	0.72
Reading Area	0.93
Stacks	1.71
Manufacturing	
Corridor/Transition Width < 8 ft	0.41
Detailed Manufacturing	1.29
Equipment Room	0.95
Extra High Bay (>50 ft Floor to Ceiling Height)	1.05
High Bay (25–50 ft Floor to Ceiling Height)	1.23
Low Bay (<25 ft Floor to Ceiling Height)	1.19
Museum	
General Exhibition	1.05
Restoration	1.02
Parking Garage	

Garage Area	0.19
Post Office	
Sorting Area	0.94
Religious Buildings	
Audience Seating	1.53
Fellowship Hall	0.64
Worship Pulpit, Choir	1.53
Retail	
Dressing/Fitting Room	0.87
Mall Concourse	1.10
Sales Area (for accent lighting)	1.68
Sports Arena	
Audience Seating	0.43
Court Sports Arena—Class 4	0.72
Court Sports Arena—Class 3	1.20
Court Sports Arena—Class 2	1.92
Court Sports Arena—Class 1	3.01
Transportation	
Air/Train/Bus—Baggage Area	0.76
Airport—Concourse	0.36
Audience Seating	0.54
Terminal—Ticket Counter	1.08
Warehouse	
Fine Material Storage	0.95
Medium/Bulky Material Storage	0.58

Chapter: 25 Lighting illuminations Level Reference

Illumination Requirements per Building & Fire Codes		
Walking Surface or Area	**Lighting Level (Lux) NFPA 1 & 101**	**Lighting Level (Lux) IFC/IBC / ICC**
New stairways	108	10.8
Floors & other walking surfaces (not stairs)	10.8	10.8
Assembly areas during performances	2.2	2.2

Illumination Level		
Lux Level	**Work Activity and Function**	**Example of User Area**
20 – 80	Public walking	Public parks and open-air car parks
100 – 140	Casual non-visual task	Corridors, changing rooms, office restrooms
150 – 180	Some perception of detail	Warehouses, stores, plant rooms, lift lobbies
200 – 240	Continuous occupation	Entrance halls, dining rooms
250 – 300	Very easy visual task	Public toilet, classrooms
300 – 400	Moderately easy visual task	Private office, libraries, lecture theatres
500 – 600	Moderately difficult visual task	Offices, laboratories, retail outlets
750 – 900	Difficult visual task	Supermarkets, technical drawing offices
1000 – 1300	Very difficult visual task	Operating theatres, polishing and painting plant
1500 – 1800	Extremely difficult visual task	Assembly plants, inspection plants
> 2000	Exceptionally difficult visual task	Precision assembly, fine work inspection

Illumination Level		
Australian Standard AS/NZS 1680.2.2 under Table 3.1		
Areas and Activities	**Examples**	**Illumination (lux)**
Interiors rarely visited where lighting is only required to aid movement and orientation	Pass-though corridors and walkways; cable tunnels; indoor storage tanks	**40**
Areas of intermittent use for tasks of coarse detail	Movement, orientation and tasks of coarse detail in areas such as change rooms, storage rooms, loading bays etc.	**80**
Areas that are continually used for tasks of coarse detail	Simple tasks such as occasional reading of clearly printed documents for short periods or rough bench or machine work in areas such as waiting rooms and entrance halls etc.	**160**
Continuously occupied interiors used for ordinary tasks with high contrasts or large detail	Food preparation areas; counters for transactions; school boards; medium woodworking	**240**
Areas where visual tasks are moderately difficult and include moderate detail with low contrast	Routine office tasks such as reading, typing and writing in office spaces or enquiry desks	**320**
	Medium level inspection work such as fine woodwork or car assembly	**400**
Areas where visual tasks are difficult with small detail with lower contrast	Visually difficult tasks including most inspection tasks such as proofreading, fine machine work or fine painting	**600**
Areas where visual work are very difficult and involve very small detail with very low contrast	Very difficult tasks such as fine inspection, paint retouching or fine manufacture	**800**
Areas where visual work is extremely difficult with extremely small detail with very low contrast	Extremely difficult tasks that may require visual aids such as graphic arts inspection; hand tailoring; inspection of dark goods; extra-fine bench work etc.	**1200**
Areas where visual work is exceptionally difficult with exceptionally small detail with very low contrast	Exceptionally difficult tasks where visual aids would be of advantage such as the assembly of minute mechanisms and jewellery and watch making	**1600**

Illumination Level

Illuminance	Example
Full moon overhead	1 lux
Family living room	50 lux
Hallway/toilet	80 lux
Very dark overcast day	100 lux
Sunrise or sunset on a clear day. Well lit office area	400 lux
Overcast day, typical TV studio lighting	
Full daylight (not direct sun)	10000-25000 lux
Direct sunlight	32000-130,000 lux

Illumination Level (IS 3646 (PART-1) 1992)	
Types of interior or activity	**illuminance (lux)**
GENERAL BUILDING AREAS	
Entrance	
Entrance Halls, Lobbies, Waiting Rooms	150-200-300
Inquiry desks	300-500-750
Gatehouses	150-200-300
Circulation Areas	
Lifts	50-100-150
Corridors, Passageway, stairs	50-100-150
Escalator, travellators	100-150-200
Medical and First aid Centers	
Consulting Rooms, Treatment Rooms	300-500-750
Rest Rooms	100-150-200
Medical stores	100-150-200
Staff Rooms	
Changing, locker and cleaner Rooms, Cloakrooms, lavatories	50-100-150
Rest Rooms	100-150-200
Staff Restaurant	
Canteens, cafeterias, dining rooms Mess rooms	150-200-300
Servery, vegetable preparation, washing-up area	200-300-500
Food preparation and cooking	300-500-750
Food stores, cellars	100-150-200
Communications	
Switchboard rooms	200-300-500
Telephone apparatus room	100-150-200
Telex room, post room	300-500-750
Reprographic room	200-300-500
Building Services	
Boiler houses General	50-100-150
Boiler front	100-150-200
Boiler control room	200-300-500
Control rooms	200-300-500
Mechanical plant room	100-150-200
Electrical power supply and distribution Room	100-150-200
Store rooms	50-100-150
Car Parks	
Floors	5 to 20
Ramps and Corners	30
Entrances and Exits	50-100-150
Control Booths	150-200-300
Outdoor Car Parks 5-20	5 to 20
TRANSPORT	
Airports	
Ticket counters, checking, desks And Information desks	300-500-750
Departure lounges, other waiting Areas	150-200-300
Baggage reclaim	150-200-300
Baggage handling	50-100-150
Customers and immigration halls	300-500-750
Concourse	150-200-300
Railway Stations	

Ticket office	300-500-750
Information Office	300-500-750
Parcels office, left Luggage Office General	50-100-150
Counter	150-200-300
Waiting rooms	150-200-300
Concourse	150-200-300
Time table	150-200-300
Ticket Barriers	150-200-300
Platforms (covered)	30-50-100
Platforms (open)	20
Ticket offices	300-500-750
Information offices	300-500-750
Concourse	150-200-300
Loading Areas	100-150-200
EDUCATION	
Assembly Halls	
General	200-300-500 3
Teaching Spaces	
General	200-300-500
Lecture Theatres	
General	200-300-500
Demonstration benches	300-500-750
Seminar Rooms	300-500-750
Art Rooms	300-500-750
Needlework Rooms	300-500-750
Laboratories	300-500-750
Libraries	200-300-500
Music rooms	200-300-500
Sport halls	200-300-500
Workshops	200-300-500
PLACES OF PUBLIC ASSEMBLY	
Public rooms, Village Halls, Worship Halls	200-300-500
Concert Halls, Cinemas and theatres	
Foyer	150-200-300
Booking Office	200-300-500
Auditorium	50-100-150
Dressing Rooms	200-300-500
Projection Rooms	100-150-200
Churches	
Body of church	100-150-200
Pulpit, Lectern	200-300-500
Choir Stalls	200-300-500
Alter, communion table, cancel	100-150-200
Vestries	100-150-200
Organ	200-300-500
Hospitals	
Anesthetic Rooms-General	200-300-500
Anesthetic Rooms-Local	750-1000-1500
Consulting Area- General	200-300-500
Consulting Area-Examination	750-1000-1500
Corridors-General	100-150-200
Ward corridors-Day, screened from bays	150-200-300
Ward corridors- Day, open to natural light	150-200-300
Ward corridors- Morning/evening	100-150-200
Ward corridors- Night	5 to 10
Cubicles- General	200-300-500
Cubicles-Treatment	750-1000-1500
Examination- General	200-300-500
Examination- Local inspection	750-1000-1500
Intensive therapy-Bad head	30-50
Intensive therapy- Circulation between bed ends	50-100-150

Intensive therapy- Observation	200-300-500
Intensive therapy- Local observation	750-1000-1500
Intensive therapy- Staff base(day)	200-300-500
Intensive therapy- Staff base(night)	30
Laboratories-General	200-300-500
Laboratories-Examination	300-500-750
Nurses stations- Morning/day/evening	200-300-500
Nurses stations- Night desks	30
Nurses stations-Night, medical trolleys	50-100-150
Operating theatres- General	300-500-750
Operating theatres-Local	10000 to 50000
Pathology department- General	200-300-500
Pathology department-Examination	300-500-750
Pathology department- Pharmacies	200-300-500
Pathology department-Reception/ inquiry	200-300-500
Pathology department-Recovery rooms	200-300-500
Ward circulation-Day	50-100-150
Ward circulation-Morning/evening	50-100-150
Ward circulation-Night	3 to 5
Ward bed head-Morning/Evening	30-50
Ward bed head- Reading	100-150-200
Night- Adult	0.1-1
Night-Pediatric	1 to 5
Night-Psychiatric	5
X-ray Areas-General	150-200-300
X-ray Areas-Diagnostic	150-200-300
X-ray Areas-Operative	200-300-500
X-ray Areas- Process dark room	50
Surgeries-General	200-300-500
Surgeries-Waiting rooms	100-150-200
Dental Surgeries- Chair Special lighting	Special lighting
Dental Surgeries-Laboratories	300-500-750
Consulting rooms- General	200-300-500
Consulting rooms- Desk	300-500-750
Consulting rooms-Examination	300-500-750
Consulting rooms-Ophthalmic wall & nearvision	300-500-750
Hotels	
Entrance Halls 50-100-150	
Reception, cashiers and porters Desks	200-300-500
Bars, coffee base, dinning rooms, grill, rooms, restaurants, lounges	50-200
Cloak room	50-100-150 3
Bed room	30-50-100
Bathroom	50-100-150
Libraries	
General	200-300-500 1
Counters	300-500-750
Bookshelves	100-150-200
Reading rooms	200-300-500
Reading tables	200-300-500
Catalogues- Card	100-150-200
Catalogues- Microfiche/visual display units	100-150-200
Reference libraries- General	200-300-500
Reference libraries-Counters	300-500-750
Reference libraries- Bookshelves	100-150-200
Reference libraries- Study tables, carrels	300-500-750
Reference libraries- Map room	200-300-500
Display and exhibition- Exhibits insensitive to light	200-300-500
Library workrooms- Book repair and binding	300-500-750
Library workrooms- Catalogue and sorting	300-500-750
Library workrooms- Remote book stores	100-150-200
Museums and Art Galleries- Exhibits insensitive to light	200-300-500

Museums and Art Galleries- Light sensitive exhibits, for e.g., oil and temper paints, undyed leather, bone, Ivory, wood, etc	150
Museums and Art Galleries- Extremely light sensitive exhibits ,For e.g., textiles, water colors, prints and drawing, skins, botanical specimens, etc	50
Museums and Art Galleries- Conservation studies and workshops	300-500-750
Museums and Art Galleries- Multi-purpose sports hall	300-750
AGRICULTURE AND HORICULTURE	
Inspection of farm products where Color is important	300-500-750
Other important tasks	200-300-500
Farm workshops	
General	50-100-150
Workbench or machine	200-300-500
Milk premises	50-100-150
Sick Animal Pets, Calf Nurseries	30-50-100
Other Firm and Horticulture Building	20-30-50
ELECTRICITY GENERATION TRANSMISSION AND DISTRIBUTION	
General plant	
Turbine houses (operating floor)	150-200-300
Boiler and turbine house basements	50-100-150
Boiler house, platforms, areas around Burners	50-100-150
Switch rooms, meter rooms, oil plant Rooms, HV substations (indoor)	100-150-200
Control room	200-300-500
Relay and telecommunication rooms	200-300-500
Diesel generator & compressor rooms	100-150-200
Pump houses, water treatment plant Houses	100-150-200
Battery rooms, charges, rectifiers	50-100-150
Precipitator chambers, platforms, etc	50-100-150
Cable tunnels & basements, Circulating Water culverts & screen chamber	30-50-100
Coal Plant-Conveyors, gantries, junction towers, Unloading hoppers, ash handling plants, Setting pits, dust hoppers	50-100-150
Coal Plant-Other areas where operators may be Attendance	100-150-200
Nuclear Plants-Gas circulation bays, reactor area, boiler Platform, reactor charges and discharge	100-150-200
MECHANICAL ENGINEERING	
Structural steel Fabrication-General	200-300-500
Structural steel Fabrication-Marking off	300-500-750
Sheet Metal Works- Pressing, punching, shearing, stamping, spinning, folding	300-500-750
Bench work, scribing, inspection	500-750-1000
Machine and tool shops-Rough bench and machine work	200-300-500
Machine and tool shops- Medium bench and machine work	300-500-750
Machine and tool shops-Fine bench and machine work	500-750-1000
Machine and tool shops- Gauge rooms	750-1000-1500
Die Sinking Shops-General	300-500-750
Die Sinking Shops-Fine Works	1000-1500-2000
Welding and soldering shops-Gas and arc welding, rough spot welding	200-300-500
Welding and soldering shops-Medium soldering, brazing, spot welding	300-500-750
Welding and soldering shops- Fine soldering , fine spot welding	750-1000-1500
Assembly Shops- Rough work for example, frame and heavy machine assembly	200-300-500
Medium work, for example , office Machinery assembly	300-500-750
Fine work, for example, office machinery assembly	500-750-1000
Very fine work, for example, instrument assembly	750-1000-1500
Minute work for example, watch making	1000-1500-2000
Inspection and Testing Shops	
Coarse Work, for example, using go/on go gauge, inspection of large sub-assembly	300-500-750
Medium work for example, inspection of painted surfaces	500-750-1000
Fine work, for example, using calibrated scales, inspection of precision mechanism	750-1000-1500
Very fine work, for example, inspection of small intricate parts	1000-1500-2000
Minute work, for example, inspection of very small instruments	2000
Points Shops and Spray Booths- Dipping, rough spraying 00	200-300-5
Points Shops and Spray Booths-Preparation, ordinary painting, spraying & finishing	200-500-750
Fine painting,. Spraying and finishing	500-750-1000

Inspection, retouching and matching	750-1000-1500
Plating shops-Vats and baths	200-300-500
Plating shops- Buffing, polishing burnishing	300-500-750
Plating shops- Final buffing and polishing	500-750-1000
ELECTRICAL AND ELECTRONIC ENGG.	
Electrical Equipment manufacture	
Manufacture of cables & insulated wires, winding, varnishing & immersion of coils, assembly of large machines, simple assembly work	200-300-500
Medium assembly , for example Telephones, small motors	300-500-750
Assembly of precision components for e.g., telecommunication equipment ,adjustment, inspection and calibration	750-1000-1500
Assembly of high precision parts	1000-1500-2000
Electronic Equipment Manufacture	
Printed Circuit Board	
Silk Screening	300-500-75
Hand insertion of components, soldering	500-750-1000
Inspection	750-1000-1500
Assembly of wiring harness, clearing Harness , testing and calibration	500-750-1000
Chassis assembly	750-1000-1500
Inspection and testing	
Soak test	150-200-300
Safety and functional tests	200-300-500
FOOD, DRINKS AND TOBACCO	
Slaughter houses	
General	200-300-500
Inspection	300-500-750
Canning, Preserving and Freezing	500-750-1000
Grading and sorting of raw materials Preparation	300-500-750
Canned and bottled goods Retorts	200-300-500
Automatic processes	150-200-300
Labeling and packaging	200-300-500 3
Frozen labeling	
Process area	200-300-500
Packaging and storage	200-300-500
Bottling, Brewing & Distilling	
Keg washing and handling, bottle Washing	150-200-300
Keg inspection	200-300-500
Process area	200-300-500
Bottle filling	500-750-1000
Edible oils and Fats Processing	
Refining and Blending	200-300-500
Production	300-500-750
Mills-milling, Filtering and Packing	200-300-500
Bakeries	
General	200-300-500
Hand decorating, icing	300-500-75
Chocolate and Confectionery Manufacturer	
General	200-300-500
Automatic processes	150-200-300
Hand decoration, inspection, wrapping and packing	300-500-750
Tobacco Processing	
Material preparation, making and packing	300-500-750
Hand processes	500-750-1000
LEATHER INDUSTRY	
Leather Manufacture-Cleaning, tanning and stretching, vats, cutting, fleshing, stuffing	200-300-500
Finishing, scarfing	300-500-750
Leather Work General	200-300-500
Pressing, glazing	300-500-750
Cutting, splitting, scarfing, sewing	500-750-1000
CLOTHING AND FOOTWEAR	
Clothing Manufacture	

Preparation of cloth	200-300-500
Cutting	500-750-1000
Matching	500-750-1000
Sewing	750-1000-1500
Pressing	300-500-750
Inspection	1000-1500-2000
Hand tailoring	1000-1500-2000
Hosiery and Knitwear Manufacture	
Flat bed knitting machines	300-500-750
Circular knitting machines	500-750-1000
Lock stitch and over locking machine	750-1000-1500
Linking or running on	750-1000-1500
Mending, hand finishing	1000-1500-3000
Inspection	1000-1500-2000
Glove Manufacture	
Sorting & grading	500-750-1000
Pressing, knitting, cutting	300-500-750
Sewing	500-750-1000
Inspection	1000-1500-2000
Hat Manufacture	
Stiffening, braiding, refining, forming, Sizing, pounding, ironing	200-300-500
Cleaning, flanging, finishing	300-500-750
Sewing	500-750-1000
Inspection	1000-1500-2000 -
Boot and Shoe Manufacture Leather and Synthetics	
Sorting and Grading	750-1000-1500
Clicking, closing	750-1000-1500
Preparatory Operations	750-1000-1500
Cutting tables and pressure	1000-1500-2000
Bottom stock preparation, lasting, Bottoming finishing, show rooms	750-1000-1500
Rubber	
Washing, compounding, coating, drying Varnishing, vulcanizing	200-300-500
Lining, making and finishing	300-500-750
DISTRIBUITION AND STORAGE	
Work stores	100-150-200
Unpacking, sorting	150-200-300
Large item storage	50-100-150
Small item rack storage	200-300-500
Issue counter, records, storemans desk	300-500-750
Warehouses and bulk stores	
Storage of goods where identification requires only limited preparation of details	50-100-150
Storage of goods where identification	100-150-200
Automatic high bay rack stores Gangway	20
Control station	150-200-300
Packing and dispatch	200-300-500
Loading bays	100-150-200
Cold stores	
General	200-300-500
Breakdown, make-up and dispatch	200-300-500
Loading bays	100-150-200
COMMERCE	
General Offices	300-500-750
Deep plan General offices	500-750-1000
Offices Computer Work station	300-500-750
Offices- Conference Rooms, Executive Offices	300-500-750
Computer and data preparation Rooms	300-500-750
Filling rooms	200-300-500
Drawing Offices-General	300-500-750
Drawing Offices- Drawing Board	500-750-1000
Print rooms	200-300-500
Counter, office area	300-500-750

Banks and building societies- Public area	200-300-500
SERVICES Workshop Garages	
(Garages)Interior parking areas	20-30-50
(Garages) General repairs, servicing, washing, polishing	200-300-500
(Garages) Workbench	300-500-750
(Garages) Spray Booths	300-500-750
External apron-General	30-50-100
Pump area (retail details)	200-300-500
Workshop- General	200-300-500
Workshop- Workbench	300-500-750
Workshop-Counter	200-300-500
Workshop- Stores	200-300-500
Commercial laundries- Receiving, sorting, washing, drying, Ironing, dispatch, dry-cleaning, bulk Machine work	200-300-500
Commercial laundries-Head ironing, pressing, mending, spotting, inspection	300-500-750
Commercial laundries-Launderettes	200-300-500
Commercial laundries-Walkways	30-50-100
Commercial laundries-Process areas	50-100-150
RETAILING	
Small Shops with Counters	300-500-750
Small Self Service shops with island displays	300-500-750
(Supper-Markets) , Hyper-Markets)General	300-500-750
(Supper-Markets) , Hyper-Markets)Checkout	300-500-750
(Supper-Markets) , Hyper-Markets)Showroom for large objects, for e.g. Cars, furniture	300-500-75
(Supper-Markets) , Hyper-Markets)Shopping precincts and arcades	100-150-200

Lighting levels	
Chartered Institution of Building Services Engineers (CIBSE)	
Building	**Lux**
Areas common to most buildings	
Entrance hall, lobby, waiting room	200
Enquiry desk	500
Corridor, passageway, stairs	100
Atria	50-200
Changing room, cloakroom, lavatory	100
Rest room	150
Canteen, cafeteria, dining room	200
Kitchen	300
Commercial offices	
General offices	500
Computer workstations	300-500
Conference rooms, executive offices	500
Computer and data preparation rooms	500
Filing room	300
Banks and building societies	
Counter, office area	500
Public area	300
Hotels	
Entrance halls	100
Reception, cashiers and porters' desks	300
Bars, coffee bars, dining rooms, grill rooms, restaurants, lounges	50-200
Cloakrooms, baggage, rooms	100
Bedrooms	50-100
Bathrooms	150
Kitchen	150-300
Retailing	
Small retail outlets	500
Grocery/vegetable stores	500
Showrooms	1000
Covered arcades and malls	500-700
Fashion	500-750

Supermarket	750
Restaurant	200
Bookshop, chemist, jeweler	500
Superstore	1000
Electrical/furniture store	750
Arcades and malls	50-300
Places of public assembly	
Cinema and theatre foyer	200
Booking office	300
Auditoria	100-150
Library	150-300
Museum art gallery	50-300
Lecture theatre	300
Church	100-300
School and College	
Computer Room	300
Classroom and Tuition Centre	350
Technical Drawing Room	750
Museum and Science Centre	
General Area and Corridor	150
Common Toilet and Restroom	200
Special Lighting for Paintings	300
Special Lighting for Sculptures	750
Retail Shop and Outlet	
Sales Area and Premises	400
Gift Wrap Station	450
Cash Register Counter	500
Commercial Space and Office	
Lift Lobby	200
Corridor	300
Toilet and Restroom	150
Cafeteria	350
Plant Room (AHU, Genset etc.)	150
Store Room	180
Hospital	
Lift Lobby	200
Corridor	250
Waiting Area and Lobby	300
Common Toilet and Restroom	250
Waiting rooms	200
Counseling Room	200
Breast-Feeding Room	200
Intensive Care Unit	300
High Dependency Unit	300
Isolation Room	300
Isolation Room – Ante Room	300
Delivery Suite – Labor Room	300
Simple examination room	300
Operating Theatre – Air-Lock	300
CSSD/TSSU – Sterilization Area	300
CSSD/TSSU – Packing Area	500
Patient Ward – Room	300
Patient Ward – Toilet	150
Operating theatre	1000
Conference Room	400
Catering Dept – Main Kitchen	400
Catering Dept – Beverage Kitchen	300
Catering Dept – Refuse Holding	150
Nursing Homes	
Entrance lobbies	200
Lounges (communal)	300

Kitchens	300
Bathrooms	150
Toilets	100
Corridors	100
Staircases	100
Quiet / rest rooms	100
Dining rooms	200
Stores	100
Hotel and Restaurant	
Lift Lobby	150
Corridor	150
Common Toilet and Restroom	150
Bar	150
Bedroom	200
Conference Room	400
Exhibition Hall	500
Cinema, Concert Hall and Theatre	
Entrance Foyer	200
Auditorium	150
Toilet and Restroom	200
Dress Change	300
Make-Up Room	400
Residential Buildings	
Living Room	200
Dining Room	250
Kitchen	250
Bedroom	180
Bathroom	150

Lighting Levels

Chartered Institution of Building Services Engineers (CIBSE)

Area	Illuminance (lux)
Lifts	100
Corridors and stairs	100
Toilets	100
Canteens	300
Mess rooms	150 - 300
Plant rooms	150 - 300
Store rooms	100

Recommended Lighting Levels

Singapore Standards SS 531-1 : 2006 (2013)

Type of area, task or activity	Lux
Shipyards & Docks	
Shipyard area, storage areas	**20**
Short term handling of large units	**20**
Ship hull cleaning	**50**
Ship hull painting and welding	**100**
Mounting of electrical and mechanical components	**200**
Building Sites	
Clearance, excavation and loading	**20**
Construction areas, drain pipes mounting, auxiliary and storage tasks	**50**
Framework element mounting, light reinforcement work, wooden mould and framework mounting, electric piping and cabling	**100**
Element jointing, electrical machine and pipe mountings	**200**
Very Low Risk: Storage areas with occasional traffic in industrial outdoor	**5**
Low Risk: Occasionally used platforms and stairs in petrochemical industries	**10**
Medium Risk: Pre-Fabrication yards, Vehicle storage, Fuel storage	**20**
High Risk: Areas with pits / excavations, Valves, compressors area, regularly used staircase and platforms	**50**
Office Interior	

Filing, copying	**300**
Writing, reading, Data processing	**500**
Technical drawings	**750**
CAD work stations	**500**
Conf& Meeting rooms	**500**
Reception desk	**300**

Recommended Lighting Levels	
SAUDI STANDARD-4520	
Area	**Lux**
General Area	
Entrance halls	**100**
Lounges	**200**
Circulation area and corridors	**100**
Stairs, escalators, travelators	**150**
Loading ramps/bays	**150**
Canteens	**200**
Rest rooms	**100**
Rooms for physical exercise	**300**
Cloakrooms, washrooms, bathrooms, toilets	**200**
Sick bay	**500**
Rooms for medical attention	**500**
Plant rooms, switch gear rooms	**500**
Dispatch packing handling areas	**300**
Control station	**150**
Agriculture building	
Loading and operating of goods handling equipment and machinery	**200**
Building for livestock	**50**
Sick animal pens, calving stalls	**200**
Feed preparation, dairy, utensil washing	**200**
Bakeries	
Preparation and baking	**300**
Finishing, glazing,decorating	**500**
Cement, concrete, & bricks industry	
Drying	**50**
Preparation of materials,work on kilns and mixers	**200**
General machine work	**300**
Rough forms	**300**
Ceramics and glass industry	
Drying	**50**
Preparation, general machine work	**300**
Enameling, rolling, pressing, shaping simple parts, glazing	**300**
Grinding, engraving, glass polishing, shaping precision parts, manufacture of glass instruments	**750**
Decorative work	**500**
Grinding of optical glass, crystal hand grinding and engraving, work on average goods	**750**
Precision work e.g decorative grinding, hand painting	**1000**
Manufacture of synthetic stones precious	**1500**
Chemicals, plastics and rubber industry	
Remote operated processing installations	**50**
Processing installations with limited manual intervention	**150**
Constantly manned work places in processing installations	**300**
Precision measuring rooms, laboratories	**500**
Pharmaceutical production	**500**
Tire production	**500**
Color inspection	**1000**
Cutting, finishing, inspection	**750**
Electrical industry	
Cable and wire manufacture	**300**
Wending -large coils	**300**
Wending-medium-sized coils	**500**

Wending-small Coils	**750**
Coil impregnating	**300**
Galvanizing	**300**
Assembly work-rough e.g. large transformers	**300**
Assembly work- medium e.g. switchboards	**500**
Assembly work- fine e.g. telephones	**750**
Assembly work-precision e.g. measuring equip.	**1000**
Assembly work-Electronic workshops, testing, adjusting	**1500**
Mosques	
Prayer Area, Mosques	**300**
Airports	
Arrival and departure halls, baggage claim areas	**200**
Connecting areas, escalators, travelators	**150**
Information desks, check in desks	**500**
Customs and passport control desks	**500**
Waiting areas	**200**
Luggage store rooms	**200**
Security check areas	**300**
Air traffic control tower	**500**
Air traffic rooms	**500**
Testing and repair hangars	**500**
Engine test areas	**500**
Measuring areas in hangars	**500**
Platforms and passenger subways (underpasses)	**50**
Ticket hall and concourse	**200**
Ticket and luggage offices and counters	**300**
Waiting rooms	**200**
Health care premises	
Waiting rooms	**200**
Corridors: during the day	**200**
Corridors: during the night	**50**
Day rooms	**200**
Staff office	**500**
Staff rooms	**300**
Wards-General lighting	**100**
Wards-Reading lighting	**300**
Wards-Simple examination	**300**
Examination and treatment	**1000**
Night lighting, observation lighting	**5**
Bathrooms and toilets for patients	**200**
Examination room general	**500**
Ear and eye examination	**1000**
Reading and Color vision test with vision charts	**500**
Scanners with image enhancers and television systems	**50**
Dialysis rooms	**500**
Dermatology rooms	**500**
Endoscopy rooms	**300**
Plaster rooms	**500**
Medical baths	**300**
Massage and radiotherapy	**300**
Pre-operation and recovery rooms	**500**
Operating theatre	**1000**
Intensive care- General lighting	**100**
Intensive care- Simple examinations	**300**
Intensive care-Examination and treatment	**1000**
Intensive care-- Night watch	**20**
Dentists- General lighting	**500**
Dentists- At the patient	**1000**
Dentists- Operating cavity	**5000**
Dentists- White teeth matching	**5000**
Color inspection (laboratories)	**1000**

Sterilization rooms	**300**
Disinfection rooms	**300**
Autopsy rooms and mortuaries	**500**
Autopsy table and dissecting table	**5000**
Educational buildings	
Play school room	**300**
Nursery class	**300**
Nursery craft room	**300**
Classrooms, tutorial rooms	**300**
Classroom for evening classes and adults education	**500**
Lecture hall	**500**
Black board	**500**
Demonstration table	**500**
Art and craft rooms	**500**
Art rooms in art schools	**750**
Technical drawing rooms	**750**
Practical rooms and laboratories	**500**
Teaching workshop	**500**
Music practice rooms	**300**
Computer practice rooms	**500**
Language laboratory	**300**
Preparation rooms and workshops	**500**
Student common rooms and assembly halls	**200**
Teachers rooms	**300**
Sports halls, gymnasiums and swimming pools	**300**
Public car parks (indoor)	
In/out ramps	**300**
In/out ramps (at night)	**75**
Traffic lanes	**75**
Parking areas	**75**
Ticket office	**300**
Libraries	
Bookshelves	**200**
Reading area	**500**
Counters	**500**
Places of entertainment	
Theatres & concert halls	**200**
Multipurpose halls	**300**
Practice rooms, dressing rooms	**300**
Museums (general)	**300**
Restaurants and hotels	
Reception/cashier desk, porters desk	**300**
Kitchen	**500**
Restaurant, dining room, function room	**200**
Self-service restaurant	**200**
Buffet	**300**
Conference rooms	**500**
Corridors	**100**
Retailing	
Sales area small	**300**
Sales area large	**500**
Till area	**500**
Wrapper table	**500**

illuminance values (As per IES)	
Area Type	**Lux**
CIRCULATION AREA	
Corridors, Passageway	**100**
Lift	**150**
Stairs	**150**
Escalator	**150**

External Covered Ways	**30**
ENTRANCES	
Entrance halls, lobbies, waiting rooms	**150**
Enquiry desk	**500**
Gate houses	**300**
KITCHENS	
Foods stores	**150**
General	**500**
OUTDOOR	
Controlled entrance halls or exit gate	**150**
Entrance and exit car park	**30**
Stores, stockyards	**30**
Industrial covered ways	**50**
STAFF RESTAURANTS	
Centre cafeterias, dining room	**300**
MEDICAL AND FIRST AIDS CENTRES	
Consultant room, treatment areas	**500**
Medical stores	**100**
Rest room	**150**
STAFF ROOM	
Changing locker and cleaner's room, cloakrooms lavatories	**150**
Rest rooms	**150**
STORE AND STOCK ROOMS	**150**
Telecommunication board,switchboard rooms	**500**
Cordless switchboard	**300**
Apparatus rooms	**150**
Teteprinter rooms	**500**
AIRCRAFT MAINTENANCE HANGERS	
Aircraft engine testing	**750**
Inspection and repairs (hanger)	**500**
GARAGES	
External apron general	**50**
Pumps	**300**
Parking areas (interior) general repairs servicing	**30**
Greasing, pits washing, polishing	**500**
GAS WORKS	
Exterior walkways and platforms	**50**
Exterior stairs and ladders	**100**
Retort house, oil gas plants, watergas plant purifier, indoor coke	**100**
Booster and exhauster houses	**150**
GAUGE TOOLS ROOMS	
General	**1000**
INSPECTION & TESTING SHOP	
Rough work e.g. counting rough Checking of stock parts	**300**
sub-assemblies	**500**
Fine work e.g. radio and telecommunication equipment, calibrated scales, precision mechanism, instruments	**1000**
Very fine work e.g. gauging and inspections of small intricate parts	**1500**
Minute work e.g. very small instruments	**3000**
HOMES	
Living rooms general	**50**
Casual reading	**150**
Sewing darningsrudies desk and protuged	**300**
Bedroom general	**50**
Bed lead kitchen	**150**
Bathrooms	**100**
Halls and landings	**150**
Stairs	**100**
Workshops	**300**
Garages	**50**
INDOOR SPORTS AND RECREATIONAL BUILDING	

MULTIPURPOSE SPORTS HALLS	
Athletics, basketball, bowls, judo	**300**
Hockey	**700**
BADMINTON COURTS	**300**
BILLIARD ROOMS	
General Table special lighting	**100**
CARD ROOMS	**300**
GYMNASIA GENERAL	**500**
SWIMMING POOL	
Top pool	**500**
Spectator areas	**150**
Club recreational	**300**
Changing rooms showers, lookers rooms	**150**
TABLE TENNIS	
Club	**300**
Recreational	**200**
HOSPITAL	
Ward unit bed heads general	**30**
General	**150**
Nurse station evening	**300**
Pharmacies dispensing bench	**500**
Shelves	**150**
Reception general	**300**
Enquiry desk	**500**
Laboratories	**500**
Operating theatre suits general	**400**
Operating area	**30-50**
X-ray department radio diagnostic and rooms fluoroscopy	**500**
TRANSPORTS TERMINAL BUILDING	
Airport coach and railway station	
Reception areas (desk),customs and immigration halls	**500**
Railway stations booking offices	**500**
Railway station parcel and left luggage offices counters	**300**
Circulation area	**150**
Waiting area	**300**
SCHOOL	
Assembly halls general	**300**
Teaching spaces general	**300**
Teaching spaces general	**300**
General where also used for further education	**500**
Chalkboard	**500**
Beedlework rooms	**500**
Laboratories	**500**
Workshop	**300**
Gymnasium	**300**
Music practice rooms	**300**
MUSEUM AND ART GALLERIES GENERAL	
Exhibits insensitive to light	**300**
Light sensitive exhibits	**150**
Specially light sensitive exhibit	**50**
LIBRARIES	
Shelves, book stack	**150**
Reading table	**300**
Reading rooms, newspaper and magazines	**300**
Reference libraries	**500**
Counters	**500**
Cataloging and sorting	**500**
Binding	**500**
Closed book store	**100**
PUBLIC BUILDING ASSEMBLY AND CONCERT HALLS	
Theatre and concert halls	**100**

Cinemas	50
Multipurpose	500
SHOP	
Conventional with counters	500
Conventional with wall display	500
Conventional with wall display	500
SHOP	
Self service	500
Supermarkets	500
Hypermarkets	500
General	500
OFFICES AND SHOPS	
Executive office	500
Computer rooms	500
Punch card rooms	750
Drawing offices drawing boards	750
Reference table and general	500
Print room	300
OFFICE	
General office with mainly clerical task and typing office	500
Deep plan general offices	750
Business machine and typing	750
Filling room	300
Conference rooms	750
Aircraft Industry	
Maintenance area	750
Inspection area	1000
Paint Shop	1000
Testing area	750
Instruments assembly	1500
Electrical assembly	1500
Explosives Manufacturing	
Furnaces, Boiling Tanks, Driers	200
Mechanical furnaces, mechanical driers, generators	500
Paint Shop	
Simple spraying	200
Fine finishing	500
Extra fine finishing	2000
Paint Manufacturing	
Processing	200-500
Mix comparison	1000-2000
Electricity generating station	
Boilers area	50
Cooling towers	50
Fuel handling	50
Storage tanks	10
Transformer yards	50
Turbine areas	50
Petroleum, Chemical and Petrochemical Industry	
Process areas	
General process units	
Pump rows, valves, manifolds	50
Heat exchangers	30
Maintenance platforms	10
Operating platforms	50
Cooling towers (equipment areas)	50
Furnaces	30
Ladders and stairs (inactive)	10
Ladders and stairs (active)	50
Gauge glassed	50
Instruments (on process units)	50

Compressor house	**200**
Separators	**50**
General area	**10**
Control rooms and houses	
Ordinary control house	**300**
Instrument panel	**300**
Console	**300**
Back of panel	**100**
Central control house	**500**
Instrument panel	**500**
Console	**500**
Back of panel	**100**
Specialty process units	
Electrolytic cell room	**50**
Electric furnace	**50**
Conveyors	**20**
Conveyor transfer points Change house	**50**
Locker room, shower	**100**
Lavatory	**100**
Clock house and entrance gatehouse Card rack and clock area	**100**
Entrance gate, inspection	**150**
General	**50**
Cafeteria	
Eating	**300**
Serving area	**300**
Food preparation	**300**
General, halls, etc.	**100**
Garage and firehouse	
Storage and minor repairs	**100**
First aid room	**700**
Iron and Steel Industry	
Open hearth	
Stock yard	**100**
Charging floor, Pouring side , Slag pits	**200**
Control platforms	**300**
Mold yard	**50**
Kilns (operating area)	**50**
Extruders and mixers	**200**
Non process areas	
Loading, unloading, and cooling	
water pump houses	
Pump area	**50**
General control area	**150**
Control panel	**200**
Boiler and air compressor plants	
Indoor equipments	**200**
Outdoor equipments	**50**
Tank fields (where lighting is required)	
Ladders and stairs	**5**
Gauging area	**10**
Manifold area	**5**
Loading racks	
General area	**50**
Tank car	**100**
Tank trucks, loading point	**100**
Electrical substations and switch yards	
Outdoor switch yards	**20**
General substation outdoor	**20**
Substation operating aisles	**150**
General substation indoor	**50**
Switch racks	**50**

Plant road lighting (where lighting is Required)	
Frequent use (trucking)	**4**
Infrequent use	**2**
Plant parking lots Aircraft obstruction lighting	**1**
Buildings	
Laboratories Qualitative, quantitative and physical test	**500**
Research, experimental	**500**
Pilot plant, process and specialty	**300**
ASTM equipment knock test	**300**
Glassware, washrooms	**300**
Fume hoods	**300**
Stock rooms	**150**
Warehouse and stock rooms	
Indoor bulk storage	**50**
Outdoor bulk storage	**5**
Large bin storage	**50**
Small bin storage	**100**
Small parts storage	**200**
Counter tops	**300**
Repair shop	
Large fabrication	**200**
Bench and machine work	**500**
Craneway, aisles	**150**
Small machine	**300**
Sheet metal	**200**
Electrical	**200**
Instrument	**300**
Hot top	**300**
Hot top storage	**100**
Checker cellar	**100**
Buggy and door repair	**300**
Stripping yard	**200**
Scrap stockyard	**100**
Mixer building	**300**
Calcining building	**100**
Skull cracker	**100**
Rolling mills	
Blooming, scabbing, hot strip Hot sheet	**300**
Cold strip, plate	**300**
Pipe, rod, tube, wire drawing	**500**
Merchant and sheared plate	**300**
Tin plate mills Tinning and galvanizing	**500**
Cold strip rolling	**500**
Motor room, machine room Inspection	**1000**
Black plate, bloom and billet chipping Tin plate and other bright surfaces	**2000**

Recommended Lighting Levels	
IESNA Lighting Handbook	
Type of activity	**Lighting**
Public spaces with dark surroundings	**30 Lux**
Simple orientation for short temporary visits	**50 Lux**
Working spaces where visual tasks are only occasionally performed	**100 Lux**
Performance of visual tasks of high contrast or large scale	**300 Lux**
Performance of visual tasks of medium contrast or small size	**500 Lux**
Performance of visual tasks of low contrast or very small size	**1000 Lux**
Performance of visual tasks near threshold of person's ability to recognize an image	**3000-10000 Lux**

Industries Recommended Levels of Illumination	
Area And Task	**Lux Level**
Paper Manufacturing	
Beaters, grinding	**30**

Finishing, cutting	**50**
Hand Counting	**70**
Paper machine reel, inspection	**100**
Rewinder	**150**
Warehousing, Storage	
Inactive	**5**
Active:	
Rough Bulky	**10**
Medium	**20**
Fine	**50**
Clothing Manufacture	
Receiving, storing, shipping, winding, measuring	**30**
Pattern making, trimming	**50**
Shops, making	**100**
Textile Mills - Cotton	
Opening, mixing, picking	**30**
Carding and drawing	**50**
Slubbing, roving, spinning, spooling	**50**
Beaming and splashing on combo Gray goods	**50**
Denims	**150**
Inspection	
Gray goods (hand tuning)	**150**
Denims (rapid moving)	**500**
Automatic tying-in	**150**
Weaving	**100**
Drawing-in by hand	**200**
Machine Shops	
Rough bench and machine work	**50**
Medium bench and machine work, ordinary automatic machines, rough grinding medium buffing and polishing	**100**
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing	**500**
Extra-Fine bench and machine work, grinding fine work	**1000**

Recommended Lighting Levels	
International Standard Serial Number ISSN: 2278-6252	
Area/task/ process	**Illuminance (lux)**
Exterior circulating, walkways, stores, main entrances and exit roads, car parking, internal factory roads etc.	**20-50**
Boiler house, transformer yards, furnace rooms, entrances, corridors, stairs etc.	**70-100**
Circulation areas in industry, stores and stock rooms, canteen	**100-150**
Coarse work	**200-300**
Medium work	**300-500**
Fine work	**500-1500**
Very fine minute and precise work	**1500-3000**
Bale breaking, washing , Stock dyeing, tinting, Mixing, Blowing	**200-300**
Carding, drawing, roving	**300-500**
Spinning, doubling, reeling, winding	**300-750**
Warping	**300-400**
Sizing	**400-500**
Heading (drawing in)	**750-1000**
Weaving (plain gray fabrics)	**200-300**
Weaving (light colored)	**300-750**
Weaving (dark colored)	**500-1000**
Knitting	**300-750**
Dyeing	**200- 450**
Calendaring, chemical treatment	**300-750**
Grey cloth inspection	**700-1000**
Final inspection	**1000-2000**

Recommended lighting levels	
IESNA Lighting Handbook	
Type of activity	**Lighting (Lux)**
Public spaces with dark surroundings	30
Simple orientation for short temporary visits	50
Working spaces where visual tasks are only occasionally performed	100
Performance of visual tasks of high contrast or large scale	300
Performance of visual tasks of medium contrast or small size	500
Performance of visual tasks of low contrast or very small size	1000
Performance of visual tasks near threshold of person's ability to recognize an image	3000-10000

Illuminance Values for Indoor Activities (TABLE 10.4 IES)		
ACTIVITY	**CATEGORY**	**LUX**
Public spaces with dark surroundings	large area (lobby space)	20-30-50
Simple orientation for short temporary visits	large area (lobby space)	50-75-100
Working spaces where visual tasks are only occasionally performed	large area (lobby space)	100-150-200
Performance of visual tasks of high contrast or large size	localized tasks	200-300-500
Performance of visual tasks of medium contrast or small size	localized tasks	500-750-1000
Performance of visual tasks of low contrast or very small size	localized tasks	1000-1500-2000
Performance of visual tasks of low contrast or very small size over a prolonged period	extremely difficult visual tasks	2000-3000-5000
Performance of very prolonged and exacting visual tasks	extremely difficult visual tasks	5000-7500-10000
Performance of very special visual tasks of extremely low contrast	extremely difficult visual tasks	10000-15000-20000

Lighting levels-Sports	
Sports	**Illumination**
Football/Rugby	
National/ international	500 Lux
Regional/Local	200 Lux
Local/Training	75 Lux
Tennis	
National/ international	500 Lux
Regional/Local	300 Lux
Local/Training	200 Lux
Equestrian	
National/ international	500 Lux
Regional/Local	200 Lux
Local/Training	100 Lux
Badminton	
National/ international	750 Lux
Regional/Local	500 Lux
Local/Training	300 Lux
Court lighting	
Social Play	310 Lux
Club Competition	435 Lux
International	1250 Lux
Swimming	
National/Internal	750 Lux
Regional/Local	500 Lux
Local/Training	200 Lux

Lighting levels-Sports	
Australian Standard AS 2560.2.6 – 1994	
Sport	**Illumination Level**
Baseball	

Baseball (International & National)	1500 lux
Baseball (AAA Standard)	750 lux
Baseball (Club Competition)	250 lux
Football	
Recreational Level	50 lux
Amateur Level (Training)	50 lux
Amateur Level (Competition)	100 lux
Semi-Professional level (Training)	50 lux
Semi-Professional (match Practice)	100 lux
Semi-Professional (Competition)	200 lux
Professional level (Training)	100 lux
Professional level (Match practice)	200 lux
Professional level (Competition)	500 lux
For all sports the minimum for TV coverage.	**1500 lux**

Recommended Lighting Levels For Sports Areas

Area Type	Lux
Archery, indoor	
General Area	**25**
Shooting Zone	**50**
Target (Vertical)	**100**
Badminton	
Recreational	**300**
Supervised Training	**400**
Club & County	**400**
National & International	**500**
Bowls, indoor	
Practice	**300**
Club & County	**400**
National & International	**500**
Boxing	
Club & Supervised Training	**500**
Regional	**750**
National	**1000**
International	**2000**
Special Events	**2000**
Cricket, indoor	
Recreational & Supervised Training	**400**
Club & County	**500**
Cycle Racing	
Training	**300**
Club	**500**
National & International	**750**
Equestrian, indoor	
Practice & Training, show jumping	**400**
Practice & Training, Dressage	**300**
Competition Show Jumping	**700**
Competition Dressage)	**500**
Five-A-Side Football, indoor	
Recreational & Supervised Training	**300**
Club & County	**400**
National & International	**500**
Handball, indoor	
Recreational & Supervised Training	**300**
Club	**400**
County & National	**500**
International	**750**
Hockey, indoor	
Recreational & Supervised Training	**300**
Club	**400**
County & National	**500**

International	**750**
Ice Rinks, Indoor	
Hockey & Figure Skating Training	**200**
Hockey & Figure Skating Competition	**750**
Skating, Recreational	**100**
Lawn Tennis, indoor	
Recreational	**300**
Practice & Club	**400**
County	**500**
National & International	**750**
Lawn Tennis, outdoor	
Recreational	**200**
Club	**300**
County	**400**
National & International	**500**
Martial Arts, indoor	
Supervised Training	**300**
Club	**400**
National	**500**
Netball, indoor	
Recreational & Supervised Training	**300**
Club & County	**400**
National & International	**500**
Shooting, indoor	
Target (Vertical)	**1000**
Shooting Zone	**300**
Snooker & Billiards	
Recreational & Club	**750**
National & International	**1000**
Squash	
Recreational & Supervised Training	**300**
Club & County	**400**
indoor National	**500**
International	**750**
Swimming, indoors	
Recreational	**200**
Club & County	**300**
National	**500**
International	**10000**
Table Tennis	
Recreational	**200**
Club & County	**300**
National	**500**
International	**750**
Volleyball	
Recreational	**200**
Training, Club & County	**300**
National	**500**
International	**750**
Weight Training	
Supervised Training	**400**
Sports Halls	
Recreational	**300**
Club & County	**400-500**
National & International	**500-750**
Televised (vertical/normal to camera)	**1000-2000**
Indoor Arenas	
Maintenance of Area	**100**
General Lighting & Training	**300**
Competition	**500**
Spectator Viewed Events	**900**

Televised (vertical/normal to camera)	**1000-2000**

Recommended Lighting Levels For Sports Areas				
TYPE OF SPORTS	**PRACTIVE LEVEL**	**MINOR LEAGUE**	**MAJOR LEAGUE**	**PROV LEVEL**
Bowls	20 lux	50 lux	100 lux	150 lux
Tennis	50 lux	100 lux	150 lux	250 lux
Football	50 lux	100 lux	250 lux	450 lux
Cricket Outfield	50 lux	100 lux	250 lux	450 lux
Cricket Pitch	100 lux	200 lux	400 lux	600 lux
Hockey	50 lux	100 lux	250 lux	350 lux
Swimming	50 lux	100 lux	150 lux	250 lux

Industrial & Office Applications Lux Level		
WORK AREAS	**WORK TYPE**	**LUX**
General Engineering	Rough Work	**160 lux**
General Engineering	Medium Work	**400 lux**
General Engineering	Fine Work	**800 lux**
General Engineering	Very Fine Work	**1600 lux**
Inspection Areas	Rough Work	**160 lux**
Inspection Areas	Medium Work	**320 lux**
Inspection Areas	Sub Assemblies	**400 lux**
Inspection Areas	Fine Work, electric & high precision mechanical	**800 lux**
Offices	Entrance halls and receptions areas	**160 lux**
Offices	Conference facilities, general offices, typing and filing	**500 lux**
Offices	Computer and business machine operation	**630 lux**
Offices	Drawing Offices	**800 lux**
Outdoor Areas	Mechanical loading	**10 lux**
Outdoor Areas	Manual loading	**10 lux**
Outdoor Areas	Service station forecourts	**160 lux**
Warehousing	Inactive storage	**20 lux**
Warehousing	Loading bays and large materials storage	**100 lux**
Warehousing	Small material storage, packing and dispatch	**200 lux**

Recommended Lighting Levels		
Characteristics of Activity	**Representative Activity**	**Illuminance (lux)**
Interiors rarely used for visual tasks (no perception of detail)	Cable tunnels, nighttime sidewalk, parking lots	**50**
Interiors with minimal demand for visual acuity (limited perception of detail)	Corridors, changing rooms, loading bay	**100 - 150**
Interiors with low demand for visual acuity (some perception of detail)	Foyers and entrances, dining rooms, warehouses, restrooms	**200**
Interior with some demand for visual acuity (frequently occupied spaces)	Libraries, sports and assembly halls, teaching spaces, lecture theaters	**300**
Interior with moderate demand for visual acuity (some low contrast, color judgment tasks)	Computer work, reading & writing, general offices, retail shops, kitchens	**500**
Interior with demand for good visual acuity (good color judgment, inviting interior)	Drawing offices, chain stores, general electronics work	**750**
Interior with demand for superior visual acuity (accurate color judgment & low contrast)	Detailed electronics assembly, drafting, cabinet making, supermarkets	**1000**
Interior with demand for maximum visual acuity (low contrast, optical aids & local lighting will be of advantage)	Hand tailoring, precision assembly, detailed drafting, assembly of minute mechanisms	**1500 -2000+**

Interior Light Levels	
Environment	**Required Light Level**
Storage Area / Plant Room (minimal movement of people)	150 - 200 Lux
Construction Areas & Loading Bays (minimal perception of detail)	300 - 500 Lux
Factories & Kitchens (higher perception of detail)	500 - 750 Lux

Inspection, Welding, And Machinery (demanding work)	750 - 1000 Lux
Electronics & Textile Production (repetitive detail)	1000 - 1500 Lux
Technical Offices (accurate detail)	1500 - 3000 Lux
Jewelers & Goldsmiths (precision detail)	3000 + Lux

Outdoor Light Levels	
Environment	**Required Light Level**
Very Bright Summer Day	Up To 100,000 Lux
Overcast Summer Day	30,000 - 40,000 Lux
Floodlit Football Match	700 - 16,000 Lux
Shady Room In Daylight	250 - 300 Lux
Night Light On A Building	60 Lux
Night-Time Urban Street	10 Lux
Night-Time Car Park	1 Lux
Security Floodlights	700-1300 Lux
Shed Lights	150-300 Lux
Lamp Posts	120-180 Lux
Landscape Spotlights	120 Lux
Outdoor Path Lighting	100 Lux
Path lighting.	100 Lux
Landscape Lights	100-300 Lux
Garden lights	20 Lux

Illumination Level		
Light levels as per IS 1944		
Classification of Road	**Type of road**	**illumination (lux)**
Group A1	Important traffic routes carrying fast traffic	30
Group A2	Other main roads carrying mixed traffic, like main city streets, arterial roads, throughways etc	15
Group B1	Secondary roads with considerable traffic like principal local traffic routes, shopping streets etc	8
Group B2	Secondary roads with light traffic Important traffic routes carrying fast traffic	4

Illumination Level			
Roadway Classification	**Average Maintained Illuminance**		
	High lux	**Medium lux**	**Low lux**
Major/Major	34	26	18
Major/Collector	29	22	15
Collector/Collector	24	18	12
Collector/Local	21	16	10
Local/Local	18	14	8

Interior Lighting Level		
Chartered Institute of Building Services Engineers CIBSE Part 2 (2002)		
Illuminance (lux)	**Activity**	**Area**
100	Casual seeing	Corridors, changing rooms, stores
150	Some perception of detail	Loading bays, switch rooms, plant rooms
200	Continuously occupied	Foyers, entrance halls, dining rooms
300	Visual tasks moderately easy	Libraries, sports halls, lecture theatres.
500	Visual tasks moderately difficult	General offices, kitchens, laboratories, retail shops.
750	Visual tasks difficult	Drawing offices, meat inspection, chain stores.
1000	Visual tasks very difficult	General inspection, electronic assembly, paintwork, supermarkets.
1500	Visual tasks extremely difficult	Fine work and inspection, precision assembly.
2000	Visual tasks exceptionally difficult	Assembly of minute items, finished fabric inspection.

Illumination levels of Switch Yard	
AS/NZS 1158.3.1	
Switchyard area lighting targets	**Illuminance (lx)**
HV areas including any overhead line road crossings and any access path zone type infrastructure	10
Non-HV areas and general open areas	5
Isolated areas such as back of buildings, corners of switchyards away from HV Equipment	2

Sub Station Light Levels	
WEST BENGAL STATE ELECTRICITY TRANSMISSION COMPANY LIMITED	
Environment	**Required Light Level**
CONTROL ROOM / Switch gear Room	300
Battery Room	150
Communication Room	300
Offices/Engineers' Room/Other Office Room	300
Toilet	100
Outdoor Switchyard area including road	30
Stairs	100
Corridor	100
Road within campus including colony area	30
Maintenance room	150
Any other spot where high level of illumination required	150
Dormitory & 'C' type quarters	150
Auxiliary Buildings like Pump room and other houses	150
ACDB- DCDB room/Store / Store Office	150
Conference room	300
Tiffin room/Kitchen	150
GIS Hall	150

Sub Station Light Levels			
ODISHA POWER TRANSMISSION CORPORATION LIMITED			
Environment	**Required Light Level**	**Environment**	**Required Light Level**
Control Room	**350**	Corridor and landing	**150**
PLCC Room	**300**	Conference and display	**300**
LT Room	**150**	Rest Room	**250**
Charger Room	**150**	AHU Room	**100**
Cable Gallery	**150**	DG Set Building	**150**
Heating Plant	**100**	Fire Fighting Pump House	**150**
Battery Room	**100**	Switchyard - Main equipment	**50**
Computer Room	**300**	Switchyard - general equipment	**30**
Entrance lobby	**150**	Street/Road	**30**

Illumination Level			
Area	**Lux Level**	**Area**	**Lux Level**
Very Bright Summer Day (Max)	Up to 100000 Lux	Machine shop	700 Lux
Very Bright Summer Day (Min)	20000 Lux	Canteens	300 Lux
Nighttime Car Park	1 Lux	Waiting Rooms	80 Lux
Nighttime Urban Street	10 Lux	Foyers	200 Lux
Night Light on a Building	60 Lux	Entrance halls	160 Lux
Machine shop	400 Lux	Stairs	40 Lux
Offices	500 Lux	Warehouses	80 Lux
Kitchens (food preparation area)	400 Lux	Passageways	80 Lux
Counters	240 Lux	Corridors	40 Lux

Illumination Level (NEC(India) :2011)			
Location	**Illumination Level (Lux)**	**Location**	**Illumination Level (Lux)**
Residence		**Hospital Building**	
Entrance / Hallways	100	Reception & Waiting	150
Living room	300	General ward	100
Dining Room	150	Bed Side	150
Bed Room (General)	300	Toilet	70
Bed Room (Dressing , Bed Heads)	200	Stairs	100
Kitchen	200	Operation Theatre (General)	300
Kitchen sink	300	Operation Theatre (Operation Table)	Special
Bathroom	100	Laboratories	300
Sewing	700	Radiology	100
Workshop	200	Causality	150
Staircase	100	Dispensaries	300
Garage	70	Laundry	200
Study Room	300	Dry Cleaning	200
Assembly & Concert Halls		Ironing	300
Foyers	100 to 150	General Office	450
Auditoria	100 to 150	Kitchen	200
Platform	450	**School / College Building**	
Corridors	70	**Assembly Halls**	
Stairs	100	General	150
Cinema Halls		Examination center	300
Foyers	150	Platform	300
Auditoria	50	**Classes**	
Corridors	70	Desktop	300
Stairs	100	Blackboard	200 to 300
Theatres		**Libraries**	
Foyers	150	Shelves	70 to 150
Auditoria	70	Reading Room	150 to 300
Corridors	70	Reading Table	300 to 700
Stairs	100	Cataloguing	150 to 300
Office Building		**General**	
Entrance hall / Reception	150	Office	300
Conference Room / Executive Office	300	Staff Room	150
General Office Space	300	Corridors	70
Business Machinery Operation	450	Stairs	100
Drawing Office	450		
Corridors	70		
Stairs	100		
Lift landing	150		

Lamp's Lumen Data					
Rating (Watt)	**Life (Hours)**	**Initial Lumens**	**Rating (Watt)**	**Life (Hours)**	**Initial Lumens**
Incandescent Lamp			**Fluorescent Lamp**		
60	1000	870	18	7000	1120
100	750	1750	20	7000	1020
150	2000	1740	36	7000	2800

200	2000	2300	40	7000	2700
500	2000	6500	2X40	7000	4000
Compact Fluorescent Lamp			**High Pressure Sodium Vapour Lamps**		
5	10000	220	35	16000	2250
7	7000	380	50	24000	4000
11	7000	560	70	24000	5800
13	7000	680	100	24000	9500
15	7000	810	150	24000	16000
18	7000	1050	250	24000	27500
23	7000	1500	400	24000	47500
26	7000	1800	1000	24000	140000
32	7000	2400	**Pulse Start Metal Halide Lamp**		
Metal Halide Lamp			50	15000	3400
50	15000	3400	70	15000	5600
70	15000	5600	100	15000	9000
100	15000	9000	150	15000	15000
150	10000	13500	175	15000	17500
175	10000	15000	200	15000	21000
250	10000	20500	250	15000	26300
400	20000	36000	320	20000	34000
1000	12000	110000	400	20000	44000
Mercury Vapour Lamp			450	20000	50000
100	18000	3700			
175	24000	8600			
250	24000	12100			
400	24000	22500			
1000	24000	57000			

Illuminance for Various Roadway Types (ANSI/IES RP-8)	
Road Type	**Illuminace Lux**
Urban Freeway	10
Freeway Interchange	14
Commercial Arterial	20
Residential Collector	8
Local	6

Light levels as per IS 1944				
Classification of road	**Type of road**	**Average level of illumination (lux)**	**Min:Avg**	**Min:Max (%)**
Group A1	Important traffic routes carrying fast traffic	30	0.4	33
Group A2	Other main roads carrying mixed traffic, like main city streets, arterial roads, throughways etc	15	0.4	33
Group B1	Secondary roads with considerable traffic like principal local traffic routes, shopping streets etc	8	0.3	20
Group B2	Secondary roads with light traffic. important traffic routes carrying fast traffic	4	0.3	20

Lighting Levels				
Category	**Eave (LUX)**	**Emin LUX)**	**Uniformity ratios**	
			Emax : Emin	**Eave : Emin**

Express & Main street	30	15	3:01	2.5:1
Suburban shopping street	25	10	5:01	3:01
Subsidiary street	15	10	5:01	3:01
Other streets	15	5	10:01	5:01

Lux Level			
Road Classification	**Area Classification**	**Average Lux**	**Uniformity Ratio (Aver./Min.)**
Arterial (Minor & Major)	Commercial	12	3 to 1
	Intermediate	9	
	Residential	6	
Collector (Minor & Major)	Commercial	8	
	Intermediate	6	4 to 1
	Residential	4	
Local	Commercial	6	
	Intermediate	5	6 to 1
	Residential	3	
Alleys	Commercial	4	
	Intermediate	3	6 to 1
	Residential	2	
Sidewalks (Roadside)	Commercial	3	3 to 1
	Intermediate	6	4 to 1
	Residential	2	6 to 1
Pedestrian Ways		15	3 to 1

Illumination for Intersections				
Functional Classification	**Average Maintained Illumination at Pavement by Pedestrian Area Classification in Lumen**			**Uniformity Eavg/Emin**
	High	**Medium**	**Low**	
Major/Major	37	28	19	32
Major/Collector	31	24	16	32
Major/Local	28	22	14	32
Collector/Collector	26	19	16	43
Collector/Local	23	17	11	43
Local/Local	19	15	9	65

Illumination for Pedestrian Areas				
Maintained Illuminance Values for Walkways				
Area Classification	**Description**	**E Avg (Lux)**	**EV Min (Lux)**	**E Avg/Emin**
High Pedestrian Conflict Areas	Mixed Vehicle and Pedestrian	22	11	43
	Pedestrian Only	11	5	43
Medium Pedestrian Conflict Areas	Pedestrian Areas	5	2	43
Low Pedestrian Conflict Areas	Rural/Semi-Rural Areas	2	1	108
	Low Density Residential (2 or fewer dwelling units per acre)	3	1	65
	Medium Density Residential (2.1 to 6.0 dwelling units per acre)	4	1	43
Pedestrian Portion of Pedestrian /Vehicular Underpasses	Day	108	54	43
	Night	43	22	32

Minimum Level of illumination in Lux			
Road	**Residential**	**Industrial**	**Commercial**
Arterial Roads	10.0	13.0	17

Collector Road	6.0	10.0	13.0
Local Roads	4.0	7.0	9.0
Walkways & Pathways	4.0		
Lanes	4.0	2.0	2.0

Recommended Levels of Illumination (BIS, 1981)Table 6			
Road Characteristics	**Avg Illumination (Lux)**	**Min / Avg Illumination (Lux)**	**Type of Luminaries Preferred**
Important traffic routes carrying fast traffic	30	0.4	Cutoff
Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	15	0.4	Cutoff
Secondary roads with considerable traffic like local traffic routes, shopping streets	8	0.3	Cutoff or semi-cutoff
Secondary roads with light traffic	4	0.3	Cutoff or semi-cutoff

Recommended Average Horizontal Illumination level in Lux				
Pedestrian Traffic	**Vehicular traffic Classification**			
	Very light	**Light**	**Medium**	**Heavy to Heaviest**
Heavy	9.68	12.91	16.14	12.52
Medium	6.46	8.61	10.26	12.91
Light	2.15	4.30	6.46	9.68

Table 4: Road Classes as per SP 72 (Part 8), IS 1944 (Part 1) and IS 1970	
Class A1	Important routes with rapid and dense traffic where safety, traffic speed, and driving comfort are the main considerations
Class A2	Main Roads with considerable volume of mixed traffic, such as main city streets, arterial roads and thoroughfares.
Class B1	Secondary roads with considerable traffic such as main local traffic routes, shopping streets
Class B2	Secondary roads, with light traffic
Class C	Lighting for residential and unclassified roads not included in previous groups
Class D	Lighting for bridges and flyovers
Class E	Lighting for town and city centers
Class F	Lighting for roads with special requirement such as roads near air fields, railways and docks

TYPE OF ROAD

TYPE OF ROAD	DENSITY OF TRAFFIC	TYPE	EXAMPLE
A	Heavy and high speed motorized traffic	Road with fixed separators, No crossings for very long distance	National highways or state highways or called interstate highways, express ways or motor ways
B	Slightly lower density and lower speed traffic termed	Road which is made for vehicular traffic with adjoining streets for slow traffic and pedestrians as we find in metros	Trunk road or major road in a city
C	Heavy and moderate speed traffic	Important urban roads or rural roads. they do not interfere with the local traffic within the town	Ring roads
D	Slow traffic, pedestrians	Linking to shopping areas and invariably the pedestrians, approach road	Shopping street, trunk road
E	Limited speed. Slow or mixed traffic predominantly pedestrians,		Local streets, collectors road

Set Back (BS 5489)

Design Speed	Pole Set Back
50 Km/Hr	0.8 Meter
80 Km/Hr	1 Meter
100 Km/Hr	1.5 Meter
120 Km/Hr	1.5 Meter

Tilt Angle

Pole Height	Arm Length	Arm Tile Angle
6 Meter	0.5 Meter	5°,10°,15°
8 Meter	1 Meter	5°,10°,15°
10 Meter	1.5 Meter	5°,10°,15°
>=12 Meter	2 Meter	5°,10°,15°

	Pole Height
Height of Pole	**Application**
<6 Meter	For streets ,alleys, public gardens and parking lots
8 Meter	Urban traffic route, multiplicity of road junctions,
	Narrow roads such as local access roads in residential areas in which a mounting height between 10 M or 12 M and 5 M or 6 M is required.
10 Meter	Urban traffic route, For wide heavily used routes where a large number of intersection,

	bends can lead to a short spacing making the use of 12 M mounting height uneconomical.
12 Meter	Wide or heavily used routes where advantage can be taken of a longer spacing of luminaries.
18 Meter and above	High mast lighting poles shall be installed at large-scale area such as airports, dockyards, large industrial areas, sports areas and road intersections

Relationship between Mounting Height and Spacing of Fixtures

Pole Arrangement	**Cut-off type**		**Semi cutoff type**	
	Height	**Spacing**	**Height**	**Spacing**
Single side	>=0.7 X Width of Road	<=3 X Fixture Mounting Height	>=0.8 X Width of Road	<=3.5 X Fixture Mounting Height
Both Side Staggered	>=1.5 X Width of Road	<=3.5 X Fixture Mounting Height	>=1.7 X Width of Road	<=4 X Fixture Mounting Height
Both Side Opposite	>=0.5 X Width of Road	<=3 X Fixture Mounting Height	>=0.6 X Width of Road	<=3.5 X Fixture Mounting Height
Twin central	>=0.7 X Width of Road	<=3.5 X Fixture Mounting Height	>=0.8 X Width of Road	<=4 X Fixture Mounting Height

Lighting Pole details as per Road

Road	**Road Width (Meter)**	**Pole Arrangement**	**Lamp (Watts)**	**Pole to Pole Spacing (Meters)**	**Mounting Height, (Meters)**	**Arm Length, (Meters)**
Expressway	10	Twin Central	250	25 To 35	12	1.5
	15		250	20 To 35	12	3
	20	Opposite	250	20 To 45	12	1.5
	25		250	20 To 40	12	1.5
	30		250	20 To 30	12	1.5
	36		250	20 To 25	12	1.5
	40		250	20 To 22	12	1.5
Major	10	One-side	250	10 To 40	10	1.5
	15		250	10 To 45	12	3
	10	Twin Central	150	20 To 37	10	1.5
	15		250	20 To 43	12	3
	20	Opposite	150	20 To 40	10	3
	25		250	20 To 45	10	1.5
	30		250	20 To 45	10	1.5
	36		250	20 To 45	12	3
	40		250	20 To 45	2	3
Collector	10	One-side	150	10 To 40	10	1.5
	15		250	10 To 50	12	3
	10	Twin Central	150	20 To 40	10	1.5
	15		150	20 To 37	12	3
	20	Opposite	150	20 To 47	10	1.5
	25		250	20 To 48	10	1.5
Rural	8	One-side	150	10 To 38	8	1.5
Highway	10		150	10 To 37	8	3
	15		150	15 To 38	10	3
	10	Twin Central	150	20 To 45	10	3
	15		150	20 To 39	12	3
	20					1.5
Minor	4	One-side	70	10 To 40	8	1.5
	6		70	10 To 40	8	1.5
	8		70	10 To 40	8	1.5
	10		70	10 To 39	8	1.5
	10	Twin Central	70	20 To 35	8	1.5
	15	Staggered	70	10 To 20	8	1.5

	15	Opposite	70	20 To 40	8	1.5

Illumination Level		
Classification	**Average Illumination (lux)**	**Ratio Minimum to average illumination**
Class A1	30	0.4
Class A2	15	0.4
Class B1	8	0.3
Class B2	4	0.3

Lux Vs Mounting Height	
Fixtures (Lux)	**Mounting Height**
3000 to 10000 Lux	6 to 7 Meter
10000 to 20000 Lux	7 to 9 Meter
More than 20000 Lux	More than 9 Meter

Pole to Pole Distance vs Lux Level				
Pole Height	**Lamp**	**Pole to Pole Distance**	**Max. Illumination (Lux)**	**Average (Lux)**
4 Meter	15 watt	12 to 18 Meter	25	18
5 Meter	18 watt	14 to 20 Meter	30	18
6 Meter	30 watt	18 to 24 Meter	32	20
7 Meter	50 watt	21 to 28 Meter	32	20
8 Meter	100 watt	24 to 32 Meter	40	22
9 Meter	110 watt	27 to 35 Meter	34	20
10 Meter	140 watt	30 to 40 Meter	35	22
12 Meter	180 watt	30 to 40 Meter	33	23
14 Meter	200 watt	30 to 40 Meter	30	21

Road – Pole Detials											
Road	**Road Type**	**Type of Pole positions**	**Individual Carriageway Width (Meter)**	**Central Verge (Meter)**	**Pole Height above Ground (Meter)**	**Maximum Pole to Pole Spacing (Meter)**	**Clearance from Road Edge (Meter)**	**Bracket Length (Meter)**	**Tilt Angle**	**Lighting Specifications**	**Lamp (Watt)**
A1	Dual Carriage	Central Verge	10	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Dual Carriage	Central Verge	11	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Dual Carriage	Central Verge	12	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Dual Carriage	Central Verge	14	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Dual Carriage	Central Verge	16	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Single Carriage	Opposite	12	0	12	35	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 250W

A1	Single Carriage	Opposite	14.5	0	12	35	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 250W
A1	Single Carriage	Opposite	16	0	12	40	0.6	Around one meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Single Carriage	Opposite	18	0	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Single Carriage	Opposite	21	0	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
	Single Carriage	Opposite	25	0	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400W
A1	Single Carriage	Opposite	31	0	12	40	0.6	1 meter	10°	35 lux/ 0.4/ 0.33	HP SV 400W
A2	Single Carriage	Single Sided	10		11	30	0.6	< 1.0 meter	10°	25 lux /0.4/ 0.33	HP SV 250W
A2	Single Carriage	Single Sided	9		11	30	0.6	< 0.5 meter	10°	25 lux /0.4/ 0.33	HP SV 250W
A2	Single Carriage	Single Sided	7		11	30	0.6	< 0.5 meter	10°	25 lux /0.4/ 0.33	HP SV 250W
A2	Single Carriage	Single Sided	7		11	30	0.6	< 0.5 meter	10°	25lux /0.4/ 0.33	HP SV 250W
A3	Single Carriage	Single Sided	7		8	20	0.6	< 0.5 meter	10°	20lux /0.4	HP SV 150W
Pedestrian Path way	Single Carriage	Single Sided	3m-6m		7.5	20-25	0.6	<0.5 meter	10°	20 lux /0.4	HP SV 150W

Pole Data						
Poles (Meter)	**Top Dia (mm)**	**Bottom Dia (mm)**	**Thickness (mm)**	**Base plate (mm)**	**Single Arm Bracket (mm)**	**Double Arm Bracket (mm)**
3	70	130	3	200x200x12	1000	NA
3	70	130	3	200x200x12	NA	1000
4	70	130	3	200x200x12	1000	NA
4	70	130	3	200x200x12	NA	1000
4	70	130	3	200x200x12	1000	NA
5	70	130	3	200x200x12	NA	1000
5	70	130	3	200x200x12	1000	NA
6	70	130	3	200x200x12	NA	1000
6	70	130	3	200x200x12	1000	NA
7	70	135	3	225x225x16	1000	NA
7	70	135	3	225x225x16	NA	1000
8	70	135	3	225x225x16	1000	NA
8	70	135	3	225x225x16	NA	1000
9	70	155	3	260x260x16	1000	NA
9	70	155	3	260x260x16	NA	1000
9	70	175	3	275x275x16	1000	NA
9	70	175	3	275x275x16	NA	1000
10	70	175	3	275x275x16	1000	NA
10	70	175	3	275x275x16	NA	1000
10	70	200	3	290x290x16	1000	NA

10	70	200	3	290x290x16	NA	1000
11	70	210	3	320x320x20	1000	NA
11	70	210	3	320x320x20	NA	1000
12	70	230	3	325x325x20	1000	NA
12	70	230	3	325x325x20	NA	1000

Recommended Levels of Illumination (BIS 1981) (IS 1944)

Type of Road	Road Characteristics	Road Width (Meter)	Average Level of Illumination on Road Surface in Lux	Ratio of Minimum/Average Illumination	Ratio of Minimum/Max Illumination	Type of Luminaire Preferred	Luminas Mounting Height
A-1	Important traffic routes carrying fast traffic	>10.5,12,14,16,18,20, 30	30	0.4	33	Cutoff	9 To 10 Meter
A-2	Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	> 7 m up to 10 m	15	0.4	33	Cutoff	9 To 10 Meter
B-1	Secondary roads with considerable traffic like local traffic routes, shopping streets	< 7m Colony Roads	8	0.3	20	Cutoff or semi-cutoff	7.5 To 9 Meter
B-2	Secondary roads with light traffic	4m,5m, 6m	4	0.3	20	Cutoff or semi-cutoff	7.5 To 9 Meter

Type of Classification

AREA CLASSIFICATION	CUTOFF TYPE
Commercial	Full Cutoff or Semi Cutoff
Intermediate	Full Cutoff or Semi Cutoff
Residential	Full Cutoff

THE SELECTION OF LUMINAIRE MOUNTING HEIGHTS

Lamp Lumens	Mounting Height
≤20,000 Lumen	≤35 Foot
20,000 To 45,000 Lumen	35 To 45 Foot
45,000 To 90,000 Lumen	45 To 60 Foot

GUIDE FOR LUMINAIRE LIGHT TYPE AND PLACEMENT

Pole Arrangement	Road Width	Type of Distribution
One Side or Staggered	up to 1.5 x Mounting Height	Types II-III-IV
Staggered or Opposite	Beyond 1.5 x Mounting Height	Types III & IV
Center of the Roadway Mounting	up to 2 x Mounting Height	Type I

Road-Mounting Height-Illumination

Type of LED Luminaries	Type of Road	Lamp mounting height from the floor level (Meters)	Minimum Illumination Level (Lux) at centre of road	Color of Illumination
250-260W		Above 18	(20 To 22)	5000K-6500K
190W	A1	Between 11 To 15	(20 To 22)	5000K-6500K
140-170W	A1	Between 9 To 15	(18 To 20)	5000K-6500K

90-120W	A2/B1	07 To 11	(15 To 18)	4300K-5600K
70-120W	A2/B1	07- To 11	(15 To 18)	4300K-5600K
70-120W	B1/B2	06 To 09	(15 To 18)	4300K-5600K
70-50W	B1/B2/C1	7 To 9	(12 To 15)	4300K-5600K
45-50W	B1/B2/C1	5 To 7	(12 To 15)	4300K-5600K
25-30W	B1/B2/C1	5 To 7	(10 To 12)	4300K-5600K

Relationship between Mounting Height and Spacing

Mounting Height	Width of road	6 Meter to 7 Meter		9 Meter to 10.5 Meter		12 Meter to 14 Meter	
	Pole arrangement	Cut-off Type	Semi Cutoff Type	Cut-off Type	Semi Cutoff Type	Cut-off Type	Semi Cutoff Type
8 Meter	Single side	24	28	-	-	-	-
	Staggered	24	28	-	-	-	-
	Opposite	-	-	28	28	-	-
10 Meter	Single side	30	30	-	-	-	-
	Staggered	35	35	30	35	-	-
	Opposite	-	-	35	40	30	35
12 Meter	Single side	42	48	36	42	-	-
	Staggered	-	-	36	42	36	42
	Opposite	-	-	42	48	42	48

Luminare Type and Placement Arrangement

SIDE OF THE ROADWAY MOUNTING			CENTER OF THE ROADWAY MOUNTING		
One Side or Staggered	**Staggered or Opposite**	**Local Street Intersection**	**Single Roadway**	**Twin Roadways (Median Mounting)**	**Local Street Intersections**
Road Width up to 1.5 x Mounting Height	Road Width beyond1.5 x Mounting Height	Road Width up to 1.5x Mounting Height	Road Width up to 2x Mounting Height	Road Width up to 1.5x Mounting Height (each pavement)	Width up to 2.0x Mounting Height
Types	Types	Type	Type	Types	Types
II, III, IV	III & IV	II (4-way)	I	II & III	I (4-way) & V

Pole Maintenance Factor

Maintenance Factor	Max. Spacing of Pole (Meter)
0.95	43
0.9	40.5
0.85	38
0.8	36

Various Factors

Type	Luminaries Dirt Depreciation	Luminaire Lumen Depreciation	Total Light Loss Factor
LED	0.9	0.85	0.765
HPS	0.9	0.9	0.81
LPS	0.9	0.85 (0.7 for 180W)	0.765 (0.63 for 180W)

Light Loss Factors

Type of Lamp	Laminar Dirt description	Light Loss Factor
HPS	0.88	0.74
Induction	0.88	0.62
LED	0.88	0.72

Maintenance Factors for 36 month cleaning interval						
Factors	IP5X			IP6X		
	Pollution category			Pollution category		
	Low	Medium	High	Low	Medium	High
LMF	0.88	0.82	0.76	0.9	0.87	0.83
LLMF	0.89	0.89	0.89	0.89	0.89	0.89
MF	**0.78**	**0.73**	**0.68**	**0.80**	**0.77**	**0.74**

Effective Road Lighting	
Features	**Benefits**
Proper pole height & spacing	Provide uniform light distribution
Proper Luminaire aesthetics	Blends in with the surroundings
Good maintenance	Reduce problems in lightning
High lamp efficiency	Minimize energy cost
Life of Luminaire	Reduce lamp replacement cost
Good color rendering	Helps object appear more natural
Proper light distribution	Provide required light on roads
Cost effectiveness	Lowers operating cost
Minimizing light pollution & glare	Reduce energy use

Effective Energy-efficient Street Lighting Systems (NYSERDA, 2002)	
Features	**Benefits**
Proper pole height and spacing	Provides uniform light distribution, which improves appearance for safety and security Meets recommended light levels Minimizes the number of poles, reducing energy and maintenance costs
Proper luminaire aesthetics	Blends in with the surroundings
High lamp efficacy and Luminaire efficiency	Minimizes Energy cost
Life of the luminaire and other components	Reduces lamp replacement costs
Cost effectiveness	Lowers operating cost
High Lumen Maintenance	Reduces lamp replacement costs
Good color rendering	Helps object appear more natural and pleasing to the public Allows better recognition of the environment, improves security
Short lamp Re strike	Allows the lamp to quickly come back after a power interruption
Proper light distribution	Provides required light on the roads and walkways
Proper Cutoff	Provides adequate optical control to minimize light pollution
Minimizing light pollution and Glare	Reduces energy use
Automatic Shutoff	Saves energy and maintenance costs by turning lamps off when not needed

Minimum Value of Street Light Designing	
Descriptions	**Min Value**
Watt	400
Lumens Per Watt	80 To 140
Voltage	230Volt
Frequency	50 To 60Hz
Power Factor	More than 95
THD	< 20%
Life Hours	70,000 hours
Color Temperature	4000K To 5000K
CRI	More than 75
Beam Angle / Beam Pattern	Type 2,3,4,5
Operating Temperature	(-)25°C To (+)50°C
Working Humidity	10% To 90% RH
IP Rating	IP67
Dimmable	0-10V

Optic Lens Material	High Polycarbonate (PMMA)
Forward Current	>600mA
Housing	IP65 - Aluminum Alloy and PC Lens
Weight	15.30 lbs - 34.39 lbs
Warranty	10 Years

Classification Roadway Traffic

Classification Number	Number of Vehicles per Hour	
	Maximum Night Hour	Both Direction
Very light traffic	Under	150
Light traffic	150	500
Medium traffic	500	1200
Heavy traffic	1200	2400
Very heavy traffic	2400	4000
Heavy traffic	Over	4000

Classification of Pedestrian Traffic

Light or No Traffic	Residential, warehouse areas on express / elevated depressed roadways
Medium Traffic	Secondary business streets and some industrial roads
Heavy Traffic	Business streets.

Illuminance Levels for different Areas of Activity

	Illuminance level (lux)	Examples of Area of Activity
General Lighting for rooms and areas used either infrequently and/or casual or simple visual tasks	20	Minimum service illuminance in exterior circulating areas, outdoor stores , stockyards
	50	Exterior walkways & platforms.
	70	Boiler house.
	100	Transformer yards, furnace rooms etc.
	150	Circulation areas in industry, stores
General lighting for interiors	200	Minimum service illuminance on the task
	300	Medium bench & machine work, general process in chemical and food industries, casual reading and filing activities.
	450	Hangers, inspection, drawing offices, fine bench and machine assembly, color work, critical drawing tasks.
	1500	Very fine bench and machine work, instrument & small precision mechanism assembly; electronic components, gauging & inspection of small intricate parts (may be partly provided by local task lighting)
Additional localized lighting for visually exacting tasks	3000	Minutely detailed and precise work, e.g. very small parts of instruments, watch making, engraving

Chapter: 27 Various Illumination Parameters

Illumination Unit Comparisons		
Term	**English**	**Metric (SI)**
Length	Feet	Meter
Area	Square foot	Square meter
Luminance Flux	Lumens	Lumens
Illumination Flux Density	Foot candles	Lux
Luminance	Foot lamberts	Lambert or Milli-Lamberts

Coefficient of Utilization	
Fixture Description	**cu**
Efficient fixture, large unit colored room	0.45
Average fixture, medium size room	0.35
Inefficient fixture, small or dark room	0.25

Maintenance Factor	
Enclosed fixture, clean room	0.8
Average conditions	0.7
Open Fixture or dirty room	0.6

Various Beam Angle as per Applications			
(MR Type) Flood Light	**(PAR Type) Spot Light**	**Descriptions**	**Applications**
<7°	<15°	Very Narrow Spot	Highlight a small statue or figure on display in a museum or in a jewelry store to make diamonds "pop."
5° to 15°	15° to 30°	Narrow spot	Special or sale item or in landscape bullets illuminating a sign or garden feature.
16° to 22°	30° to 60°	spot	Used in stores to highlight a special or sale area or outdoors to illuminate an architectural feature.
23° to 32°	60° to 90°	Narrow flood	highlight a display table, while homes might use this bulb in recessed eyeball lights to illuminate a painting
32° to 45°	90° to 120°	flood	Pendant lights in coffee shops to recessed lights in living rooms.
45° to 60°	120° to 160°	Wide flood	Common in many general illumination applications from motion-sensing lights above garage doors to recessed cans in auditoriums and movie theaters.
>60°	>160°	Very wide flood	used to illuminate without highlighting any particular object or area. They're good options for outdoor flood lighting and low-ceiling recessed lights.

Beam Spread Diameter at various Beam angle				
Beam Angle	**At 5 Feet**	**At 10 Feet**	**At 15 Feet**	**At 20 Feet**
10°	0.9 feet	1.8 feet	2.7 feet	3.6 feet
15°	1.35 feet	2.7 feet	4.05 feet	5.4 feet
20°	1.8 feet	3.6 feet	5.4 feet	7.2 feet
25°	2.25 feet	4.5 feet	6.75 feet	9 feet
40°	3.6 feet	7.2 feet	10.8 feet	14.4 feet
60°	5.4 feet	10.8 feet	16.2 feet	21.6 feet
90°	8.1 feet	16.2 feet	24.3 feet	32.4 feet
120°	10.8 feet	21.6 feet	32.4 feet	43.2 feet

Various Beam Angle as per Applications			
(MR Type) Flood Light	**(PAR Type) Spot Light**	**Descriptions**	**Applications**
<7°	<15°	Very Narrow Spot	Highlight a small statue or figure on display in

			a museum or in a jewelry store to make diamonds "pop."
5° to 15°	15° to 30°	Narrow spot	Special or sale item or in landscape bullets illuminating a sign or garden feature.
16° to 22°	30° to 60°	spot	Used in stores to highlight a special or sale area or outdoors to illuminate an architectural feature.
23° to 32°	60° to 90°	Narrow flood	highlight a display table, while homes might use this bulb in recessed eyeball lights to illuminate a painting
32° to 45°	90° to 120°	flood	Pendant lights in coffee shops to recessed lights in living rooms.
45° to 60°	120° to 160°	Wide flood	Common in many general illumination applications from motion-sensing lights above garage doors to recessed cans in auditoriums and movie theaters.
>60°	>160°	Very wide flood	Used to illuminate without highlighting any particular object or area. They're good options for outdoor flood lighting and low-ceiling recessed lights.

Ceiling Height and Beam angle	
Ceiling Height	**Beam Angle**
2.5 to 3.5 meters	60° beam angle
3.5 to 4.5 meters	38° or 40° beam angle
5 meters	24° to 30° beam angle

Beam Angle	
Beam Angle	**Ceiling Height**
140°	Up to 4 meter
120°	4 to 6 meter
90°	6 to 8 meter
60°	8 to12 meter

Beam Angle & Applications	
Beam Angle	**Applications**
10°	Spot Lights Stadium Lights
25°	Spot Lights Stadium Lights
40°	Residential and Architectural Lighting
60°	Commercial and Industrial Lighting
90°	Commercial and Industrial Lighting
120°	Low Ceiling Gas Stations and Public Spaces
150°	Industrial Lighting Parking Garages

Beam Angle & Fitting Type	
Beam Angle	**Type of Fitting**
4° To 9°	Spot Light
20° To 35°	Flood Light
36° To 49°	Wide Flood Light
More than 60°	Very Wide Flood Light

Spacing between lights	
Height	**Spacing**
15 feet	12 feet to 15 feet
20 feet	15 feet to 18 feet
30 feet	20 feet to 25 feet

Mounting Height and lumens

Mounting Height	Lumens
10 to 15 feet	10,000 to 15,000 lumens
15 to 20 feet	16,000 to 20,000 lumens
25 to 30 feet	33,000 lumens

Low Bay / High Bay Lighting Fixtures

Watt	Installation height	Distance Fixture To Fixture
50 Watt	3 Meter	3 To 6 Meter
90 Watt	4 Meter	6 Meter
120 To 150 Watt	5 Meter	6 To 8 Meter
200 Watt	7 Meter	9 To 10 Meter
300 Watt	8 Meter	More than 10 Meter

LED Vs Metal Halide

LED Watt	Metal Halide Watt
20W to 50W	75W
30W to 75W	100W
40W to 125W	150W
50W to 175W	225W
60W to 225W	250W
80W to 250W	300W
100W to 350W	350W
120W to 400W	400W
150W to 500W	500W

Table 1.7 Typical Reflectance Factors

Color	Refelextion (%)
White	80% To 85%
Light gray	45% To 70%
Dark gray	20% To 25%
Ivory white	70% To 85%
Ivory	60% To 70%
Pearl gray	70% To 75%
Buff	40% To 70%
Tan	30% To 50%
Brown	20% To 40%
Green	25% To 50%
Olive	20% To 30%
Azure blue	35% To 40%
Sky blue	35% To 40%
Pink	50% To 70%
Cardinal red	20% To 25%
Red	20% To 40%

SPACING AND MOUNTING HEIGHT RATIO

Direct Concentrating	0.40
Direct Spreading	1.20
Direct Indirect Diffusing	1.30
Semi-direct-Indirect	1.50

Utilization factor

Room Reflectance			Room Index								
Ceiling	Wall	Floor	0.75	1	1.25	1.5	2	2.5	3	4	5
0.7	0.5	0.2	0.43	0.49	0.55	0.6	**0.66**	0.71	0.75	0.8	0.83
0.7	0.3	0.2	0.35	0.41	0.47	0.52	0.59	0.65	0.69	0.75	0.78
0.7	0.1	0.2	0.29	0.35	0.41	0.46	0.53	0.59	0.63	0.7	0.74

0.5	0.5	0.2	0.38	0.44	0.49	0.53	0.59	0.63	0.66	0.7	0.73
0.5	0.3	0.2	0.31	0.37	0.42	0.46	0.53	0.58	0.61	0.66	0.7
0.5	0.1	0.2	0.27	0.32	0.37	0.41	0.48	0.53	0.57	0.62	0.66
0.3	0.5	0.2	0.3	0.37	0.41	0.45	0.52	0.57	0.6	0.65	0.69
0.3	0.3	0.2	0.28	0.33	0.38	0.41	0.47	0.51	0.54	0.59	0.62
0.3	0.1	0.2	0.24	0.29	0.34	0.37	0.43	0.48	0.51	0.56	0.59
0	0	0	0.19	0.23	0.27	0.3	0.35	0.39	0.42	0.46	0.48

Quick Consideration of Maintenance factor

Room Classification	Lamp Maintenance Factor	Maintenance Factor for dirty lamp	Total Maintenance Factor
Very clean	0.09	0.85	0.9
Clean	0.9	0.9	0.8
Average	0.9	0.8	0.7
Dirty	0.9	0.7	0.6

Environment Activity or Task Area

Very Clean	Clean rooms, semiconductor plants, hospital clinical areas, computer centers
Clean	Offices, schools, hospital wards
Normal dirty Dirty	Shops, laboratories, restaurants, warehouses, assembly areas, workshops Steelworks, chemical works, foundries, welding, polishing, woodwork

Quick Consideration of Maintenance Factor

Enclosed fixture, clean room	0.80
Average conditions	0.70
Open fixture or dirty room	0.60

Room Surface Maintenance Factor (Annual Clean) – RSMF

Type of Room	1 Year Room Clean		3 Year Room Clean	
	Direct Luminaires	Direct /Indirect Luminaires	Direct Luminaires	Direct /Indirect Luminaires
Very Clean	0.97	0.96	0.97	0.95
Clean	**0.95**	0.91	0.94	0.91
Normal	0.91	0.84	0.9	0.83
Dirty	0.86	0.75	0.86	0.75

Lamp Lumen Maintenance Factors (LLMF)

Lamp Type	Operating Hours				
	4000 Hr.	6000 Hr.	8000 Hr.	10000 Hr.	12000 Hr.
High Pressure Sodium	0.98	0.97	0.94	0.91	0.9
Metal Halide	0.82	0.78	0.76	0.74	0.73
High Pressure Mercury	0.87	0.83	0.8	0.78	0.76
Low Pressure Sodium	0.98	0.96	0.93	0.9	0.87
Tubular Fluorescent	0.95	0.94	0.93	0.92	0.91
Compact Fluorescent	**0.91**	0.88	0.86	0.85	0.84

Luminar Maintenance Factor (LMF)

IP Category	Environment Condition	Expose Time				
		1 Year	1.5 Year	2 Year	2.5 Year	3 Year
IP2X	Dirty	0.53	0.48	0.45	0.43	0.42
	Normal	0.62	0.58	0.56	0.54	0.53
	Clean	0.82	0.8	0.79	0.78	0.78
IP5X	Dirty	0.89	0.87	0.84	0.8	0.76
	Normal	0.9	0.88	0.86	0.84	0.82
	Clean	0.92	0.91	0.9	0.89	0.88
IP6X	Dirty	0.91	0.9	0.88	0.85	0.83
	Normal	0.92	0.91	0.89	0.88	0.87

	Clean	0.93	0.92	0.91	0.9	0.9

Luminar Maintenance Factor (LMF)

Type of Distribution	Environment Condition	Expose Time					
		1 Year	2 Year	3 Year	4 Year	5 Year	6 Year
Open Distribution	Very Clean	0.96	0.94	0.92	0.9	0.88	0.87
	Clean	0.93	0.89	0.85	0.82	0.79	0.77
	Normal	0.89	0.84	0.79	0.75	0.7	0.67
	Dirty	0.83	0.78	0.73	0.69	0.65	0.62
Direct Distribution	Very Clean	0.95	0.92	0.89	0.86	0.84	0.82
	Clean	**0.9**	0.84	0.79	0.74	0.7	0.67
	Normal	0.86	0.8	0.74	0.69	0.64	0.6
	Dirty	0.83	0.75	0.68	0.62	0.57	0.53
Closed Distribution	Very Clean	0.94	0.91	0.89	0.87	0.86	0.85
	Clean	0.88	0.83	0.79	0.75	0.72	0.7
	Normal	0.82	0.77	0.73	0.69	0.65	0.62
	Dirty	0.77	0.71	0.66	0.61	0.57	0.53
Indirect-Distribution	Very Clean	0.93	0.88	0.85	0.82	0.79	0.77
	Clean	0.86	0.77	0.7	0.64	0.59	0.55
	Normal	0.81	0.66	0.55	0.48	0.43	0.4
	Dirty	0.74	0.57	0.45	0.38	0.33	0.3

Lamp Survival Factors (LSF)

Lamp Type	Operating Hours				
	4000 Hr	6000 Hr	8000 Hr	10000 Hr	12000 Hr
High Pressure Sodium	0.98	0.96	0.94	0.92	0.89
Metal Halide	0.98	0.97	0.94	0.92	0.88
High Pressure Mercury	0.93	0.91	0.87	0.82	0.76
Low Pressure Sodium	0.92	0.86	0.8	0.74	0.62
Tubular Fluorescent	0.99	0.99	0.99	0.98	0.96
Compact Fluorescent	**0.98**	0.94	0.9	0.78	0.5

Advantage & Disadvantage of Luminar

Type of Lamp	Advantage	Disadvantage
High Pressure Sodium Vapor Lamp (HPSV)	Long lamp life,	High initial cost. Poorcolor rendering, cycles on and off at end of life, not dimmable, cannot use electronic ballast
	Highestlamp output.	
High Pressure Metal Halide Lamp (HPMH)	Moderately long lamp life. High light output.	High initial cost.
	Makes colors look close to natural.	
High Pressure Mercury Vapor Lamp (HPMV)	Long lamp life, High light output.	High initial cost.
Low Pressure Sodium Vapor Lamp (LPSV)		Completely monochromatic,
		lends no color perception,
		shorter life than HPS,
		optical control difficult
Florescent	Long lamp life, High light output. Low brightness.	High initial cost.
		Frequent switching cuts life,
		needs ballast,
		Runs poorly in cold temperatures
LED	Long life, very efficient, can be dimmable,	Very high initial cost,
	can offer excellent color quality (w/ less efficiency)	very sensitive to overheating, requires large heat sinks,
		variable color and quality

Bulbs and Application			
Type	**Application**	**Advantage**	**Disadvantage**
Standard Incandescent bulbs	Domestic use	Direct connection without intermediate switchgear	Low luminous efficiency and high electricity consumption
	Decorative lighting	Reasonable purchase price	Significant heat dissipation
		Compact size	Short service life
		Instantaneous lighting	
		Good colour rendering	
Halogen Incandescent bulbs	Spot lighting	Direct connection	Average luminous efficiency
	Intense lighting	Instantaneous efficiency	
		Excellent colour rendering	
Fluorescent tube	Shops	High luminous efficiency	Low light intensity of single unit
	Office		
	Workshops		Sensitive to extreme temperatures
	Outdoors	Average colour rendering	
HP mercury vapour	Workshops	Good luminous efficiency	
	Halls	Acceptable colour rendering	
	Hangars.	Compact size	
	Factory floors	Long service life	
High-pressure sodium	Outdoors	Very good luminous efficiency	Lighting and relighting timeof a few minutes
	Large halls		
Low-pressure sodium	Outdoors	Good visibility in foggy weather	Long lighting time (5 min.)
	Emergency lighting	Economical to use	Mediocre colour rendering
Metal halide	Large areas	Good luminous efficiency	Lighting and relighting timeof a few minutes
	Halls with High ceilings	Good color rendering	
		Long service life	
LED	Signalling (3-color traffic lights, “exit” signs and emergency lighting)	Insensitive to the number of switching operations	Limited number of colours
		Low energy consumption	Low brightness of single Unit
		Low temperature	

amp Comparison Chart (Bureau of Energy Efficiency, Delhi)					
Lamp Type	**Lamp (Watts)**	**Efficacy (Lumens/ Watt)**	**Color Render**	**Lamp Life (Hr)**	**Remarks**
Incandescent (GLF) Lamps:					
(Incandescent bulbs)	15,25,40,60,75,100,150,200, 300,500 (no ballast)	8 to 17	100	1000	
Tungsten Halogen	75,100,150,500,1000,2000 (no ballast)	13 to 25	100	2000	
Fluorescent Tube lights (Argon filled)	20,40,65, (32,51,79)	31 to 58	67 to 77	5000	
Fluorescent Tubular Lamp (T5)	18,20,36,40,58,65	100 to 120	Very Good	15,000 to 20,000	Energy-efficient, long lamp life, only available in low wattages
Compact Fluorescent Lamps (CFLs)	5,7,9,11,18,24,36	26 to 64	85	8000	
HID Lamps:					
High Pressure Mercury	80,125,250,400,1000,2000	25 to 60	45 (Fair)	16,000 to 24,000	High energy use, Poor lamp life

Vapor (HPMV)					
High Pressure Metal Halide Lamps (HPMH)	70,150,250, 400,1000,2000	62 to 72	70 (Excellent)	8000 to 12000	High luminous efficacy, Poor lamp life
High Pressure Sodium Vapor Lamps (HPSV)	70,150,250,400,1000	69 to 108	25 to 60 (Fair)	15000 to 24000	Energy-efficient, poor color rendering
Low Pressure Sodium Vapor Lamps (LPSV)	35,55,135	90 to 133	Very Poor	18000 to 24000	Energy-efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamps (T8 & T12)	35,55,135	30 to 90	Good	5000 to 10000	Poor lamp life, Medium energy use, only available in low wattages
LED Lamps					
Light Emitting Diode (LED)		70 to 160	Good	40,000 to 90,000	High energy savings, low maintenance, long life, no mercury. High investment cost

Savings by Use of More Efficient Lamps (Bureau of Energy Efficiency)

Existing Lamp	Replace by	Energy Savings
GLS (Incandescent)	Compact Fluorescent Lamp (CFL)	35 to 60 %
	High Pressure Mercury Vapor (HPMV)	40 to 50 %
	Metal Halide	65 %
	High Pressure Sodium Vapor (HPSV)	65 to 75%
Tungsten Halogen	High Pressure Mercury Vapor (HPMV)	50 to 60 %
	Metal Halide	40 to 70 %
	High Pressure Sodium Vapor (HPSV)	40 to 80 %
High Pressure Mercury Vapor (HPMV)	Metal Halide	35 %
	High Pressure Sodium Vapor (HPSV)	35 to 60 %
	Low Pressure Sodium Vapor (HPSV)	60 %
Metal Halide	High Pressure Sodium Vapor (HPSV)	30 %
	Low Pressure Sodium Vapor (HPSV)	40 %
High Pressure Sodium Vapor (HPSV)	Low Pressure Sodium Vapor (HPSV)	40 %

Variation in Light Output and Power Consumption (BEE, India)

Type of Lamp	10% lower voltage		10% Higher voltage	
	Light Out Put	Power Out Put	Light Out Put	Power Out Put
Fluorescent lamps	Decreased 9%	Decreased 15%	Increased 9%	Increased 15%
HPMV lamps	Decreased 20%	Decreased 16%	Increased 20%	Increased 17%
Mercury Blended lamps	Decreased 24%	Decreased 20%	Increased 30%	Increased 20%
Metal Halide lamps	Decreased 30%	Decreased 20%	Increased 30%	Increased 20%
HPSV lamps	Decreased 28%	Decreased 20%	Increased 30%	Increased 26%
LPSV lamps	Decreased 4%	Decreased 8%	Increased 2%	Increased 3%

Watts & Light Brightness

Incandescent Watts	CFL Watts	LED Watts	Lumens (Brightness)
40	8 to 12	6 to 9	400 to 500
60	13 to 18	8 to 12.5	650 to 900
75 to 100	18 to 22	13 to 15	1100 to 1750
100	23 to 30	16 to 20	1800 to 2779
150	30 to 55	25 to 28	2780

Minimum Lumens

Incandescent (Watt)	CFL , Halozan , LED (Minimum Lumen)
25 Watt	200
40 Watt	450
60 Watt	800
75 Watt	1100
100 Watt	1600
150 Watt	2700

Approximate Lumen

Watt	Approximate Lumens
25 Watt	230 to 270
35 Watt	250 to 410
40 Watt	440 to 460
50 Watt	330 to 450
60 Watt	800 to 850
75 Watt	1000 to 1100
100 Watt	1500 to 1600

Watt Vs Brightness

Incandescent	CFL	LED	Lumens
40 Watt	8 To 12 Watt	4 To 5 Watt	450 Lumen
60 Watt	13 To 18 Watt	6 To 8 Watt	750 To 900 Lumen
75 To 100 Watt	18 To 22 Watt	9 To 13 Watt	1100 To 1300 Lumen
100 Watt	23 To 30 Watt	16 To 20 Watt	1600 To 1800 Lumen
150 Watt	30 To 55 Watt	25 To 28 Watt	2600 To 2800 Lumen

Wattage Comparison Chart

Incandescent / Halogens (Watt)	Mercury Vapor (Watt)	Metal Halide (Watt)	High Pressure Sodium (Watt)	Compact Fluorescent (CFLs) (Watt)	Light Emitting Diodes (LEDs) (Watt)
40 to 60	15 to 25	5 to 15	5 to 15	12 to 15	5 to 8
60 to 75	25 to 35	15 to 25	15 to 25	15 to 18	7 to 10
75 to 100	35 to 45	20 to 35	20 to 35	18 to 23	10 to 15
100 to 150	50 to 60	25 to 40	25 to 40	23 to 35	15 to 20
150 to 200	70 to 85	35 to 45	35 to 45	30 to 45	20 to 25
200 to 250	90 to 110	40 to 55	40 to 55	45 to 60	25 to 30

Luminous efficacy

Light type	Typical luminous efficacy (lumens/watt)
Tungsten incandescent light bulb	12.5 to17.5 lm/W
Halogen lamp	16 to 24 lm/W
Fluorescent lamp	45 to 75 lm/W
LED lamp	30 to 90 lm/W
Metal halide lamp	75 to 100 lm/W
High pressure sodium vapor lamp	85 to 150 lm/W
Low pressure sodium vapor lamp	100 to 200 lm/W
Mercury vapor lamp	35 to 65 lm/W

Selection parameter of LED Bulbs

Parameter	Average	Good	Best
Lumens/Watt	75	90	100
Power Factor	0.7	0.8	0.9
CRI	60	70	80
LED Life in Hours	15000	25000	50000

Available CRI of Various Lighting Sources

Source	CRI
Incandescent / Halogens	>95
T8 Linear Fluorescent	75 to 85
Cool White Linear Fluorescent	62

Compact Fluorescent	82
Metal Halide	65
High Pressure Sodium (HPS)	22
LED	80 to 98

Color Accuracy - CRI Chart

CRI	Rating
>90	Great
80 to 90	Very Good
70 to 80	Good
60 to 70	Good
40 to 60	Poor

Color Temperature & CRI Chart

Kelvin	Light Effect	CCT	CRI
< 3600K	Incandescent Fluorescent (IF)	2750	89
< 3600K	Deluxe warm white (WWX)	2900	82
< 3600K	Warm white (WW)	3000	52
3200K to 4000K	White (W)	3450	57
3200K to 4000K	Natural white (N)	3600	86
Above 4000 K	Light white (LW)	4150	48
Above 4000 K	Cool white (CW)	4200	62
Above 4000 K	Daylight (D)	6300	76
Above 4000 K	Deluxe Daylight (DX)	6500	88
Above 4000 K	Sky white	8000	88

Color Temperature & CRI

Lighting source	Color Temperature	Color Rendering Index
High Pressure Sodium Lamp	2100K	25
Incandescent Lamp	2700K	100
Tungsten Halogen Lamp	3200K	95
Tungsten Halogen Lamp	3200K	62
Clear Metal Halide Lamp	5500K	60
Natural Sun Light	5000K to 6000K	100
Day Light Bulb	6400K	80

Lighting Source CCT

Source	Color temperature in Kelvin
Skylight (blue sky)	12,000 - 20,000
Average summer shade	8000
Light summer shade	7100
Typical summer light (sun + sky)	6500
Daylight fluorescent	6300
Xenon short-arc	6400
Overcast sky	6000
Clear mercury lamp	5900
Sunlight (noon, summer, mid-latitudes)	5400
Design white fluorescent	5200
Special fluorescents used for color evaluation	5000
Daylight photoflood	4800 - 5000
Sunlight (early morning and late afternoon)	4300
Bright White Deluxe Mercury lamp	4000
Sunlight (1 hour after dawn)	3500
Cool white fluorescent	3400
Photoflood	3400
Professional tungsten photographic lights	3200
100-watt tungsten halogen	3000
Deluxe Warm White fluorescent	2950
100-watt incandescent	2870
40-watt incandescent	2500

High-pressure sodium light	2100
Sunlight (sunrise or sunset)	2000
Candle flame	1850 – 1900
Match flame	1700
Skylight (blue sky)	12,000 - 20,000
Average summer shade	8000
Light summer shade	7100
Typical summer light (sun + sky)	6500
Daylight fluorescent	6300
Xenon short-arc	6400
Overcast sky	6000
Clear mercury lamp	5900
Sunlight (noon, summer, mid-latitudes)	5400
Design white fluorescent	5200
Special fluorescents used for color evaluation	5000
Daylight photoflood	4800 - 5000
Sunlight (early morning and late afternoon)	4300
Bright White Deluxe Mercury lamp	4000
Sunlight (1 hour after dawn)	3500
Cool white fluorescent	3400
Photoflood	3400
Professional tungsten photographic lights	3200
100-watt tungsten halogen	3000
Deluxe Warm White fluorescent	2950
100-watt incandescent	2870
40-watt incandescent	2500
High-pressure sodium light	2100
Sunlight (sunrise or sunset)	2000
Candle flame	1850 – 1900
Match flame	1700

CCT – Correlated Color Temperature			
Kelvin	**Associated Effects**	**Type of Bulbs**	**Appropriate Applications**
2700°	Warm White, Very Warm White	Incandescent bulbs	Homes, Libraries, Restaurants
3000°	Warm White	mostly halogen lamps, Slightly whiter than ordinary incandescent lamps	Homes, Hotel rooms and Lobbies, Restaurants, retail Stores
3500°	White	Fluorescent or CFL	Executive offices, public reception areas, supermarkets
4100°	Cool White		Office, classrooms, mass merchandisers, showrooms
5000°	Daylight	Fluorescent or CFL	Graphic industry, hospitals
6500°	Cool Daylight	Extremely white‘	Jewelry stores, beauty salons, galleries, museums, printing

Average Life Cycle	
Source	**Average Life**
Incandescent / Halogens	1,000 to 4,000 hours
CFL	6,000 hours
LED	15,000 to 50,000 hrs

Lamp Properties				
Option	**Life (hrs)**	**Efficacy (lpw)**	**CRI**	**Color of light**
LED	35,000-50,000	30-300	≥70	White
High Pressure Sodium	20,000-24,000	50-110	≤40	Orange
Metal Halide	6,000-15,000	72-76	75-90	White
Mercury Vapor	16,000-24,000	30-50	40-60	Blue-White
Fluorescent	10,000-24,000	40-140	20-80	White

Illuminance Levels for Signage Lighting		
Light Intensity	**Foot candles**	**Lux**
Low	10 to 20	100 to 200
Medium	20 to 40	200 to 400
High	40 to 80	400 to 800

Types of Lamp Technologies				
Type of Lamp	**Luminous Efficacy (lm/W)**	**Color Rendering Properties**	**Lamp life in Hrs.**	**Lamp life in Hrs.**
High Pressure Mercury Vapor (MV)	35-36 lm/W	Fair	10000-15000	High energy use, poor lamp life
Metal Halide (MH)	70-130 lm/W	Excellent	8000-12000	High luminous efficacy, poor lamp life
High Pressure Sodium Vapor (HPSV)	50-150 lm/W	Fair	15000-24000	Energy-Efficient, poor color rendering
Low Pressure Sodium Vapor (LPSV)	100-190 lm/W	Very Poor	18000-24000	Energy-Efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamp (T12 & T8)	30-90 lm/W	Good	5000-10000	Poor lamp life, medium energy use, only available in low wattages
EE Fluorescent Tubular Lamp (T5)	100-120 lm/W	Very Good	15000-20000	long lamp life, only available in low wattages
Light Emitting Diode (LED)	70-160 lm/W	Good	40000-90000	High energy savings, low O&M, long life, no mercury, high

Luminous Efficacy, Life, Lumen Maintenance and Color Rendition (Table-8) NBC					
Light Source	**Wattage**	**Efficacy (lm/W)**	**Average Life**	**Maintenance**	**Color Rendition**
Incandescent lamps	15 to 200	12 to 20	500 to 1000	Fair to good	Very good
Tungsten halogen	300 to 1500	20 to 27	200 to 2000	Good to very good	Very good
Standard fluorescent lamps	20 to 80	55 to 65	5000	Fair to good	Good
Compact fluorescent lamps (CFL)	5 to 40	60 to 70	7500	Good	Good to very good
Slim line fluorescent	18 to 58	57 to 67	5000	Fair to good	Good
High pressure mercury vapor lamps	60 to 1000	50 to 65	5000	Very low to fair	Federate
Blended - light lamps	160 to 250	20 to 30	5000	Low to fair	Federate
High pressure sodium vapor lamps	50 to 1000	90 to 125	10000 to 15000	Fair to good	Low to good
Metal halide lamps	35 to 2000	80 to 95	4000 to 10000	Very low	Very good
Low pressure sodium	10 to 180	100 to 200	10000 to 20000	Good to very good	Poor
LED	0.5 to 2.0	60 to 100	10000	Very good	Good for white LED

Comparison of Lamp Technology

Technology	Mercury Vapor	High Pressure Sodium Vapor	Induction	New Ceramic	Induction New Ceramic LED
Description	Older Very Common white light HID light source	Most common HID light source used in street lighting	White light electrode less light source with long operating life	White light HID technology	White-light, solid-state light source
Pros	Low initial cost	Low initial cost	maintenance-free	White light	Small size
	Longer lamp life	Longer lamp life	High efficacy	Longer lamp life	Very long time life
	White light	High lamp efficacy (70-150) lumens/watt)	Excellent color rendering index	High lamp efficacy (115) lumens/watt)	Switching has no effect on life
	Sudden failure are uncommon		Instant start and restrike operations	High fixture efficiency	Contains no mercury
			No flickering, strobing or noise		low ambient temperature operations
			Low temperature operations		High lumens efficacy
					No flickering, strobing or noise
					Instant start and restrike operations
Cons	Poor lamp efficacy (34-58) lumens/watt)	Low CRI	High initial cost	High price	High price
	Low fixture efficiency	Contains mercury	Low lamp efficacy (36-64 lumens/watt)	Lower luminaire efficacy	Low luminous flux
	Contains mercury		Contains mercury	Higher electricity consumption	CRI can be low
				Contains mercury	Risk of glare

Restrick Rate of Bulbs

HID lamp type	Time to reach 80% light output	Time to Restrike
Mercury	5-7 min	3-6 min
Metal halide	2-4 min	10-15 min
High-pressure sodium	3-4 min	1 min

Mounting Height of Light according to Types of Bulbs

HID lamp type	Watt	Mounting Height
Mercury	100 Watt	8 Meter
	175 Watt	10 Meter
	250 Watt	15 Meter
	400 Watt	23 Meter
	1000 Watt	30 Meter
Metal halide	70 Watt	7 Meter
	100 Watt	10 Meter
	175 Watt	16 Meter
	250 Watt	20 Meter
	400 Watt	25 Meter
	1000 Watt	35 Meter

High-pressure sodium	35 Watt	6 Meter
	50 Watt	7 Meter
	70 Watt	8 Meter
	100 Watt	12 Meter
	175 Watt	18 Meter
	250 Watt	25 Meter
	400 Watt	30 Meter
	1000 Watt	38 Meter

LAMP Comparison

CPWD

Lamp type	Range	Luminous LUX	Efficacy (lm/W)	Average Life (hr)	Color Rendering (Ra)
CFL	18W-36W	1200-2900	60-80	15000	75-85
Fluorescent-T5	28W-54W	2900-4850	90-104	24000	80-90
Fluorescent-T8	18W-36W	750-3250	50-90	20000	80-85
Fluorescent-T12	20W-40W	950-2450	48-61	12000	50-75
Halogen	50W	1200	24	2000	75-90
Metal halide	70W-250W	5300-25000	76-100	12000	70-90
High pressure sodium vapor	70W-1000W	5600-130000	80-130	20000	20-65
Low pressure sodium vapor	55W-135W	8100-32000	100-230	20000	20-65
Induction lamp	70W-150W	6500-12000	80-95	100000	65-90
LED	3W-120W	750-14000	80-100	80000	65-90

Lamp Comparison As per CPWD

Lamp type	LED (Warm White)	LED (Cool White)	T5 Lamp	CFL Lamp	HPSV Lamp	Metal Lamp Halide
CRI	80-85	75	85	85	22	60-90
Efficiency in lm/w	80	132	90	70	95-110	65-70
Usable lm/w	55-65	>100	75-85	50-60	55-65	35-40
Life (Hrs.)	50k+	50k+	30k	8-10k	24k	10k-20K

Road and Type of Luminar

Type of Road	Pole	Pole Height	Laminar Watt	Type of Laminar
Rural	Aluminum or Steel Pole	10 to 16 Meter	250W to 400W	HPS
Urban	Aluminum	10 to 13 Meter	250W to 400W	HPS (Cut off or Semi Cut off)

Watt / Efficiency / Life (Hr)

Lamp	Power (watt)	Efficiency (lm/w)	Life (Hr)	CRI	CRI Status
Inductance	100 to 150	100	100000	60 to 70	Good
HPSV	50 to 400	39 to 140	24000	20 to 30	Poor
HPMH	35 to 400	70 to 90	60000	60 to 70	Good
HPMV	50 to 400	35 to 90	100000	40 to 60	O.K
LPSV	18 to 180	100 to 160	200000	Less than 20	Very Poor
Florescent	18 to 57	50 to 80	90000	40 to 90	Good
LED	112	55	500000	20 to 95	Good

Color Rendering Index

Light source	CRI
clear mercury	17
white deluxe mercury	45
warm white fluorescent tube	55
cool white fluorescent tube	65
deluxe warm white fluorescent	73
daylight fluorescent	79
metal halide 4200K	85
deluxe cool white fluorescent	86
metal halide 5400K	93

low pressure sodium	0-18
high pressure sodium	25
100-watt incandescent	100

Color Temperature & CRI		
Lighting source	**Color Temperature**	**Color Rendering Index**
High Pressure Sodium Lamp	2100K	25
Incandescent Lamp	2700K	100
Tungsten Halogen Lamp	3200K	95
Tungsten Halogen Lamp	3200K	62
Clear Metal Halide Lamp	5500K	60
Natural Sun Light	5000K to 6000K	100
Day Light Bulb	6400K	80

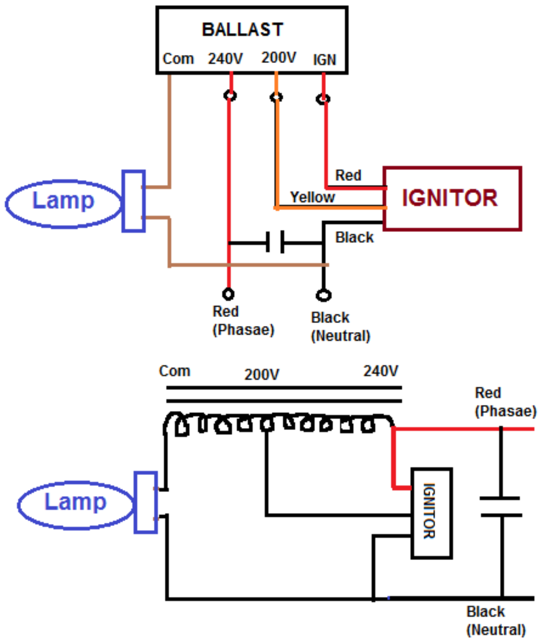
Color Temperature & CRI			
Kelvin	**Light Effect**	**CCT**	**CRI**
Below 3600K	Incandescent Fluorescent (IF)	2750	89
Below 3600K	Deluxe warm white (WWX)	2900	82
Below 3600K	Warm white (WW)	3000	52
3200K to 4000K	White (W)	3450	57
3200K to 4000K	Natural white (N)	3600	86
Above 4000 K	Light white (LW)	4150	48
Above 4000 K	Cool white (CW)	4200	62
Above 4000 K	Daylight (D)	6300	76
Above 4000 K	Deluxe Daylight (DX)	6500	88
Above 4000 K	Sky white	8000	88

Parameter of LED Bulbs			
Parameter	**Average**	**Good**	**Best**
Lumens/Watt	75	90	100
Power Factor	0.7	0.8	0.9
CRI	60	70	80
LED Life in Hours	15000	25000	50000

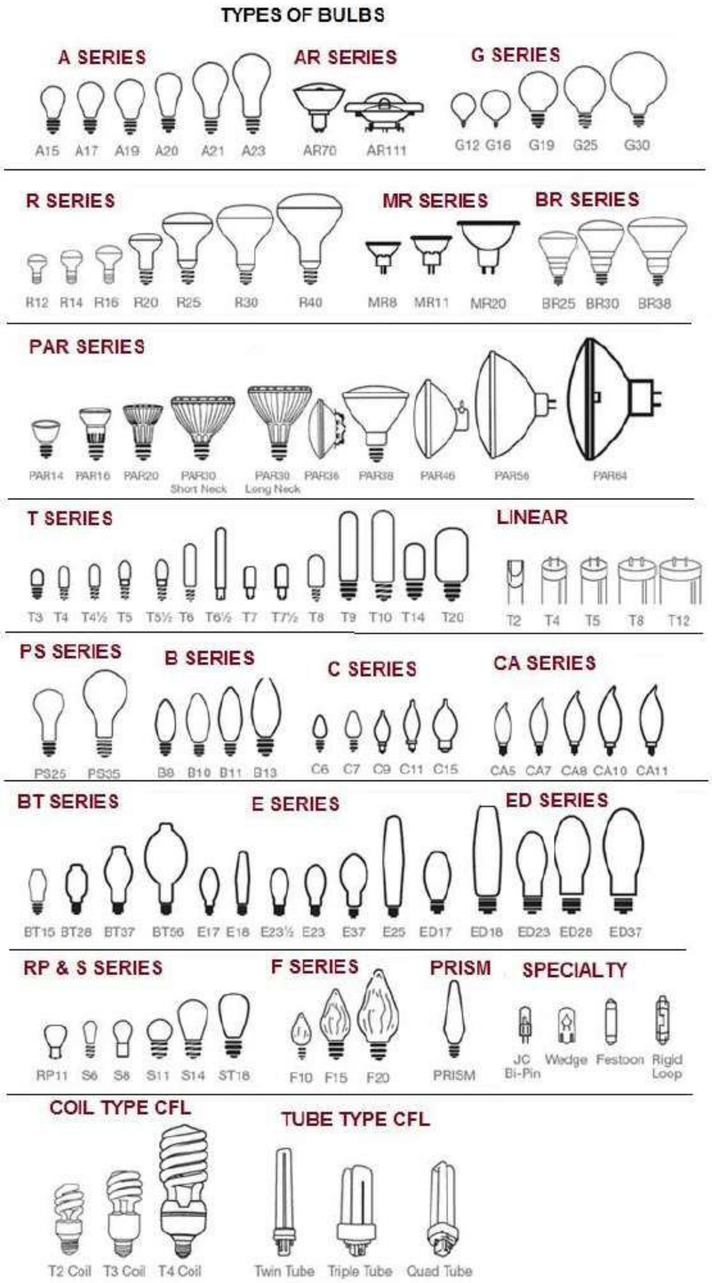
Bulb Shapes and Applications			
Code	**Bulb Shape Designations**	**Type of Bulbs**	**Applications**
A	Arbitrary	Incandescent ,CFL ,LED, Metal Halide, High Pressure Sodium ,Mercury vapor,	In household light.
			Table lamps.
			Wall Light, Ceiling lights.
AR	Arbitrary with Reflector	Incandescent ,CFL ,LED, Metal Halide, High Pressure Sodium ,Mercury vapor,	In household light.
			Table lamps.
			Wall Light, Ceiling lights.
B	Bulged	Incandescent ,CFL ,HID,LED	In various light fixtures,
			Decorative Lights.
BT	Blown Tubular	Incandescent ,CFL ,HID,LED	Less in general used,
			In various light fixtures.
			Table Lamp.
BR	Bulged Reflector	Incandescent ,CFL ,HID,LED	In Track lighting (spot lights)
			In recessed lighting.
MR	Mirror Reflector	LED	In Track lighting
C	Candle	Incandescent ,CFL ,HID,LED	Widely used in ceiling and table chandeliers and decorative light fixtures.
			In small appliances and indicator lamps
			They have a smaller base.
CA	Candle Angular	Incandescent ,CFL ,HID,LED	Like Candle bulbs, used in chandeliers and similar light fixtures.
			They also often have a smaller base.

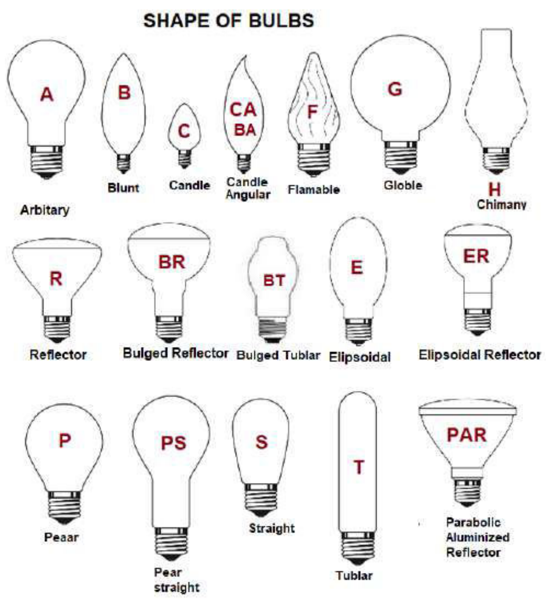
CW	Candle Twisted	Incandescent ,CFL ,HID,LED	These are used in chandeliers and have smaller bases.
CP	Crystalline Pear	Incandescent ,CFL ,HID,LED	Used in various decorative light fixtures in wall lights, ceiling lights and table lamps. To create interesting reflective effects.
E	Ellipsoidal	Incandescent ,CFL ,HID,LED	Widely used in various light fixtures.
ER	Extended Reflector	Incandescent ,CFL ,HID,LED	in track lighting and other fixtures for spot lights.
F	Flambeau	Incandescent ,CFL ,HID,LED	in chandeliers and similar decorative interior lighting fixtures.
G	Globe	Incandescent ,CFL ,HID,LED	Widely used in ceiling and table lamps. in Bathrooms. In ornamental lighting and some floodlights
GA	Decorator	Incandescent ,CFL ,LED	Used in ceiling lamps, table lamps and other decorative fixtures.
HX	Hexagonal Candle	Incandescent ,CFL ,LED	Used in chandeliers and other decorative light fixtures to create beautiful reflective light effects.
P	Pear	Incandescent ,CFL ,LED	Used in various light fixtures. In standard for streetcar and locomotive headlights
PAR	Parabolic Aluminum Reflector	Incandescent ,CFL ,LED	Widely used in track lighting and spot light fixtures. used in floodlights
PC	Ogive	Incandescent ,CFL ,LED	Used in decorative light fixtures.
PS	Pear Straight	Incandescent ,CFL ,LED	Used in various light fixtures.
R	Reflector	Incandescent ,CFL ,LED	Widely used in Recessed cans and track lighting, spot light fixtures.
S	Straight Sided	Incandescent ,CFL ,LED	Used in various light fixtures. lower wattage lamp as sign and decorative
ST	Straight Tubular	Incandescent ,CFL ,LED	Used in various light fixtures.
T	Tubular	Incandescent ,CFL ,LED	Used in various light fixtures according to functional rather than decorative purposes. Showcase and appliance lighting In closets/garages.
TA	Tubular Angular	Incandescent ,CFL ,LED	Used in various light fixtures, often for decorative effect.

Circuit for Ballast-Ignitor-Capacitor-Lamp



Chapter: 28 Types of Electrical Lamp & Holder





Incandescent Bulb Shapes

Compact Fluorescent Bulb Shapes

Halogen Bulb Shapes

HID Bulb Shpes

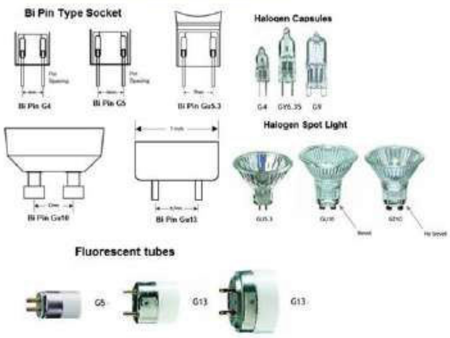
Halogen Bulb Shapes

HID Bulb Shpes

(1) Bayonet Cap (B / BC / SBC):

(2) Edison Screw Cap (E / ES):

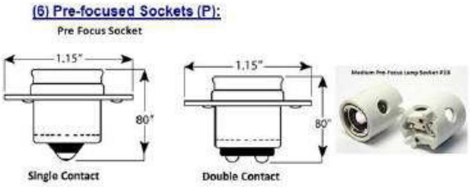
(3) Bi Pin or Multiple Pin Type Base (G):



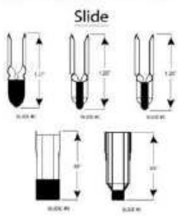
(4) Single Pin Type Base (F):

(5) Cable connected Socket (K):

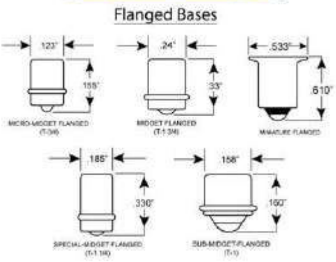
(6) Pre-focused Sockets (P):

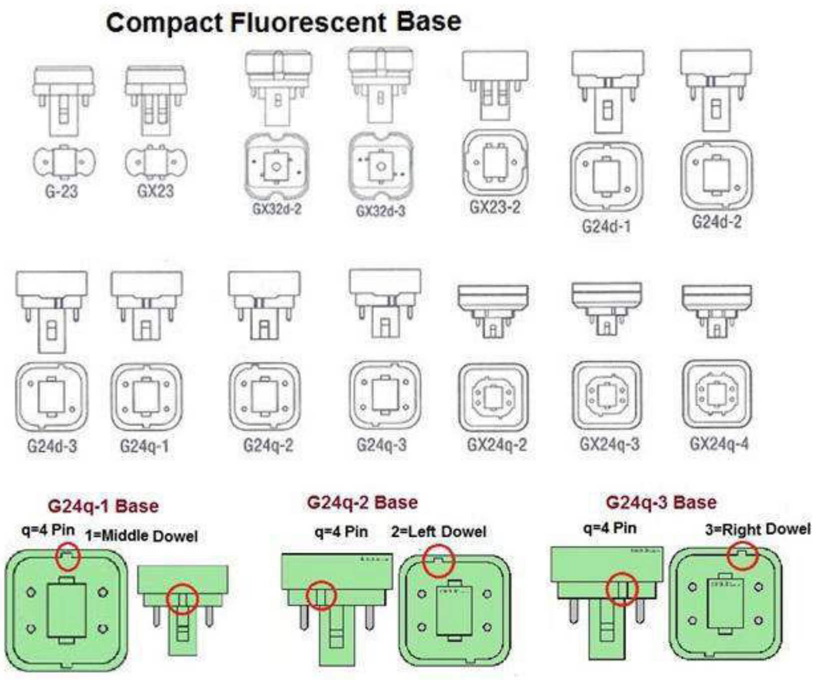


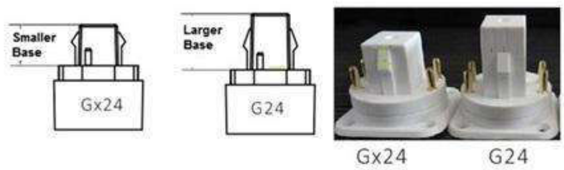
(9) Slide base Sockets (S):



(8) Flange base Sockets (F or T):







Bulb Shapes and Applications			
Code	**Bulb Shape**	**Type of Bulbs**	**Applications**
A	Arbitrary	Incandescent ,CFL ,LED	In household light.
		Metal Halide, High Pressure Sodium	Table lamps.
		Mercury vapor	Wall Light, Ceiling lights
AR	Arbitrary with Reflector	Incandescent ,CFL ,LED	In household light
		Metal Halide, High Pressure Sodium	Table lamps.
		Mercury vapor	Wall Light, Ceiling lights.
B	Bulged	Incandescent ,CFL ,HID,LED	In various light fixtures,
			Decorative Lights.
BT	Blown Tubular	Incandescent ,CFL ,HID,LED	Less in general used,light fixtures.Table Lamp.
BR	Bulged Reflector	Incandescent, CFL ,HID,LED	In Track lighting (spot lights)
			In recessed lighting.
MR	Mirror Reflector	LED	In Track lighting
C	Candle	Incandescent ,CFL ,HID,LED	Ceiling and table chandeliers and decorative light fixtures.
			In small appliances and indicator lamps
			They have a smaller base.
CA	Candle Angular	Incandescent ,CFL ,HID,LED	Like Candle bulbs, used in chandeliers and similar light fixtures.
			They also often have a smaller base.
CW	Candle Twisted	Incandescent ,CFL ,HID,LED	These are used in chandeliers and have smaller bases.
CP	Crystalline Pear	Incandescent ,CFL ,HID,LED	Used in various decorative light fixtures
			in wall lights, ceiling lights and table lamps.
			To create interesting reflective effects.

E	Ellipsoidal	Incandescent ,CFL ,HID,LED	Widely used in various light fixtures.
ER	Extended Reflector	Incandescent ,CFL ,HID,LED	in track lighting and other fixtures for spot lights.
F	Flambeau	Incandescent ,CFL ,HID,LED	in chandeliers and similar decorative interior lighting fixtures.
G	Globe	Incandescent ,CFL ,HID,LED	Widely used in ceiling and table lamps. in Bathrooms. In ornamental lighting and some floodlights
GA	Decorator	Incandescent ,CFL ,LED	Used in ceiling lamps, table lamps and other decorative fixtures.
HX	Hexagonal Candle	Incandescent ,CFL ,LED	Used in chandeliers and other decorative light fixtures to create beautiful reflective light effects.
P	Pear	Incandescent, CFL ,LED	Used in various light fixtures. In standard for streetcar and locomotive headlights
PAR	Parabolic Aluminum Reflector	Incandescent ,CFL ,LED	Widely used in track lighting and spot light fixtures. used in floodlights
PC	Ogive	Incandescent ,CFL ,LED	Used in decorative light fixtures.
PS	Pear Straight	Incandescent ,CFL ,LED	Used in various light fixtures.
R	Reflector	Incandescent ,CFL ,LED	Widely used in Recessed cans and track lighting ,spot light fixtures.
S	Straight Sided	Incandescent ,CFL ,LED	Used in various light fixtures. lower wattage lamp as sign and decorative
ST	Straight Tubular	Incandescent ,CFL ,LED	Used in various light fixtures.
T	Tubular	Incandescent ,CFL ,LED	Used in various light fixtures according to functional rather than decorative purposes. Showcase and appliance lighting,In closets/garages.
TA	Tubular Angular	Incandescent ,CFL ,LED	Used in various light fixtures, often for decorative effect.

Chapter: 29 Electrical Costing per Square Meter

Load in Multi-storied Building (Madhyanchal Vidyut Vitran Nigam)		
Type of Load	**Calculation**	**Diversity**
Domestic (Without Common Area)	50 watt / sq. meters	0.5
Commercial (Without Common Area)	150 watt / sq. meters	0.75
Lift, Water Pump, Streetlight ,Campus Lighting ,Common Facilities,	Actual load shall be calculated	0.75

Load in Multi-storied Building (Noida Power Company Limited)		
Type of Load	**Calculation**	**Diversity**
Domestic (Constructed area)	15 watt / sq. Foot	0.4
Commercial(Constructed area)	30 watt / sq. Foot	0.8
Industrial (Constructed area)	100 watt/ 1 sq. Foot	0.5
Lift, Water Pump, Streetlight ,Campus Lighting ,Common Facilities,	0.5Kw / Flat	
Voltage Drop:	2% Voltage drop from Transformer to Consumer end.	
T&D Losses:	2% T&D Losses from Transformer to Consumer end.	

Approximate % Cost or Sq.Foot Cost		
Project Item	**% of Total Project Cost**	**Rs per Sq.Foot**
Articheture (Consultancy)	0.7%	13.1 Rs / Sq.Foot
Structural (Consultancy)	1.2%	21.8 Rs / Sq.Foot
Service Design (Consultancy)	0.4%	7.2 Rs / Sq.Foot
Fire Fighting Work	1.3%	23 Rs / Sq.Foot
Electrical Work	4.1%	76 Rs / Sq.Foot
Lift Work	4.4%	82 Rs / Sq.Foot

Street Light Cost (CPWD-2012)	
Fluorescent Lamp	95 Rs/Sq.Meter
With HPMV Lamp	130 Rs/Sq.Meter
With HPSV Lamp	165 Rs/Sq.Meter
Electrical Signage	85 Rs/Sq.Meter

Solar / HVAC Cost	
Solar Light	10 Watt/Sq.Foot
Solar Power Installation	1.5 Lacs Rs/1Kw
HVAC	18 Watt/Sq.Foot

Rate Analysis Rs per Sq. Meter (CPWD-2012)				
Work	**Office/College/Hospital**	**School**	**Hostel**	**Residence**
Fire Fighting (with Wet Riser)	500	500	500	500
Fire Fighting (with Sprinkler)	750	750	750	750
Fire Alarm (Manually)	-	-	-	300
Fire Alarm (Automatic)	500	500	500	500
Pressurized Ventilation	650	650	650	650

Rate Analysis % of Total Project Cost (CPWD-2012)				
Work	**Office/College/Hospital**	**School**	**Hostel**	**Residence**
Internal Water Supply & Sanitary	4%	10%	5%	12%
Internal Electrical Installation	12.5%	12.5%	12.5%	12.5%

Approximate Load as per Sq.ft Area (As per DHBVN)	
Sq.ft Area	**Required Load (Connected)**
< 900 Sq.ft	8 KW
901 Sq.ft to 1600 Sq.ft	16 KW
1601 Sq.ft to 2500 Sq.ft	20 KW
> 2500 Sq.ft	24 KW

For Flats :	100 Sq.foot / 1 KW
For Flats USS /TC:	100 Sq.foot / 23 KVA

Contracted Load in case of High-rise Building:	
For Domestic Load	500 watt per 100 Sq. foot of the constructed area.
For Commercial	1500 watt per 100 Sq. foot of the constructed area
Other Common Load	For lift, water lifting pump, streetlight if any, corridor/campus lighting and other common facilities, actual load shall be calculated
Staircase Light	11 Watt/Flat Ex: 200Flat=200x11=2.2KW
Sanctioned Load for Building	
Up to 50 kW	The L.T. existing mains shall be strengthened.
50 kW to 450 kW (500 kVA)	11 kV existing feeders shall be extended if spare capacity is available otherwise, new 11 kV feeders shall be constructed.
450 kW to 2550 kW (3000 kVA)	11 kV feeder shall be constructed from the nearest 33 kV or 110 kV substation
2550 kW to 8500 kW (10,000 kVA)	33kV feeder from 33 kV or 110 kV sub station
8500 kW (10,000 kVA)	110 kV feeder from nearest 110 kV or 220 kV sub-station

Approximate Load as per Sq.Foot Area:		
Type of Load	**Load/Sq.Ft**	**Diversity Factor**
Industrial	1000 Watt/Sq.Ft	0.5
Commercial	30 Watt/Sq.Ft	0.8
Domestic	15 Watt/Sq.Ft	0.4
Lighting	15 Watt/Sq.Ft	0.8

Lighting Load Thumb Rules as per Area	
A. Bell Jr. PE (McGraw-Hill)	
Area	**Watts / Sq.Ft**
General	1.5–3.0 Watts/Sq.Ft.
Private	2.0–5.0 Watts/Sq.Ft.
Conference, Meeting Rooms	2.0–6.0 Watts/Sq.Ft.
Banks, Court Houses, Municipal Buildings, Town Halls	2.0–5.0 Watts/Sq.Ft.
Police Stations, Fire Stations, Post Offices	2.0–3.0 Watts/Sq.Ft.
Precision Manufacturing	3.0–10.0 Watts/Sq.Ft.
Computer Rooms	1.5–5.0 Watts/Sq.Ft.
Restaurants	1.5–3.0 Watts/Sq.Ft.
Kitchens	1.5–2.5 Watts/Sq.Ft.
Cocktail Lounges, Bars, Taverns, Clubhouses,Nightclubs	1.5–2.0 Watts/Sq.Ft.
Hospital Patient Rooms, Nursing Home Patient Rooms	1.0–2.0 Watts/Sq.Ft.
Hospital General Areas	1.5–2.5 Watts/Sq.Ft.
Medical/Dental Centers, Clinics, and Offices	1.5–2.5 Watts/Sq.Ft.
Residential	1.0–4.0 Watts/Sq.Ft.
Apartments (Eff., 1 Room, 2 Room)	1.0–4.0 Watts/Sq.Ft.
Motel and Hotel Public Spaces	1.0–3.0 Watts/Sq.Ft.
Motel and Hotel Guest Rooms, Dormitories	1.0–3.0 Watts/Sq.Ft.
School Classrooms	2.0–6.0 Watts/Sq.Ft.
Dining Halls, Lunch Rooms, Cafeterias, Luncheonettes	1.5–2.5 Watts/Sq.Ft.
Libraries, Museums	1.0–3.0 Watts/Sq.Ft.
Retail, Department Stores	2.0–6.0 Watts/Sq.Ft.
Drug, Shoe, Dress, Jewelry, Beauty, Barber,and Other Shops	1.0–3.0 Watts/Sq.Ft.
Supermarkets	1.0–3.0 Watts/Sq.Ft.
Malls, Shopping Centers	1.0–2.5 Watts/Sq.Ft.
Jails	1.0–2.5 Watts/Sq.Ft.
Auditoriums, Theaters	1.0–3.0 Watts/Sq.Ft.
Churches	1.0–3.0 Watts/Sq.Ft.
Bowling Alleys	1.0–2.5 Watts/Sq.Ft.

Heat Generation by Electrical Equipment	
A. Bell Jr. PE (McGraw-Hill)	
Area	**Watts / Sq.Ft**

Computer Rooms, Data Centers, and Internet Host Facilities	2.0–300.0 Watts/Sq.Ft.
Telecommunication Rooms	50.0–120.0 Watts/Sq.Ft.
50 KVA and Smaller	50 Watts/KVA
151–500 KVA	30 Watts/KVA
501–1000 KVA	25 Watts/KVA
1001–2500 KVA	20 Watts/KVA
Larger than 2500 KVA	15 Watts/KVA
MCB 0–40 Amps	10 Watts
MCB 50–100 Amps	20 Watts
MCB 225 Amps	60 Watts
MCB 400 Amps	100 Watts
MCB 600 Amps	130 Watts
MCB 800 Amps	170 Watts
MCB 1,600 Amps	460 Watts
MCB 2,000 Amps	600 Watts
MCB 3,000 Amps	1,100 Watts
MCB 4,000 Amps	1,500 Watts
MCCB 600 Amps	1,000 Watts
MCCB 1,200 Amps	1,500 Watts
MCCB 2,000 Amps	2,000 Watts
MCCB 2,500 Amps	2,500 Watts
Panel boards:	2 Watts per circuit
Low Voltage Starters Size	50-650 Watts
Medium Voltage Starters Size 200 Amp	400 Watts
Medium Voltage Starters Size 400 Amp	1,300 Watts
Medium Voltage Starters Size 700 Amp	1,700 Watts
Variable Frequency Drives:	2 to 6% of the KVA
Bus Duct	0.015 Watts/Ft/Amp
Capacitors	2 Watts/KVAR
Motors 0 to 2 Hp	190 Watts/Hp
Motors 3–20 Hp	110 Watts/Hp
Motors 25–200 Hp	75 Watts/Hp
Motors 250 Hp and Larger	60 Watts/Hp

Chapter: 30 Electrical Safety Clearance

Standard: Indian Electricity Rules/ Central Electricity Authority:

Right of Way Clearance (As per GETCO Standard):

KV	Minimum Right of Way ROW
66 KV	18 Meter
132 KV	27 Meter
220 KV	35 Meter
400KV	52 Meter (Single Circuit)
400 KV	48 Meter (Double Circuit)

Minimum clearances between Electrical Lines crossing each other:

Voltage	66 KV	132 KV	220 KV	400 KV
66 KV	2.4 Meter	3 Meter	4.5 Meter	5.4 Meter
132 KV	3 Meter	3 Meter	4.5 Meter	5.4 Meter
220 KV	4.5 Meter	4.5 Meter	4.5 Meter	5.4 Meter
400 KV	4.5 Meter	5.4 Meter	5.4 Meter	5.4 Meter

Permissible Min ground Clearance of Electrical Line:

KV	Ground Clearance	Over National Highway
66 KV	6.1 Meter	8.0 Meter
132 KV	6.1 Meter	8.6 Meter
220 KV	7.0 Meter	9.8 Meter
400KV	8.8 Meter	10.8 Meter

Clearance for Telephone line Crossings Power Line:

KV	Clearance (Min)
66 KV	2.4 Meter
132 KV	2.7 Meter
220 KV	3.0 Meter

Vertical Clearance between Electrical Line and railway tracks

KV	Clearance (Min)
66 KV	14 Meter
132 KV	14.6 Meter
220 KV	15.4 Meter
400 KV	17.9 Meter

Clearance from Buildings to low, medium & high voltage lines:

Voltage	Description	Distance
Low & Medium Voltage	Flat roof, open balcony, verandah roof ,When the line passes above the building a vertical clearance from the highest point	2.5 Meter
Low & Medium Voltage	Line passes adjacent to the building a horizontal clearance from the nearest point	1.2 Meter
Low & Medium Voltage	Line passes above the building a vertical clearance	2.5 Meter
Low & Medium Voltage	Line passes adjacent the building a Horizontal clearance	1.2 Meter
11 KV to 33 KV	Line passes above or adjacent to any building or part of a building	3.7 Meter
Above 33 KV	Line passes above or adjacent to any building or part of a building	3.7+(0.3 for every additional 33 KV)
Up to 11 KV	The horizontal clearance between the nearer conductor and any part of such building	1.2 Meter
11 KV to 33 KV	The horizontal clearance between the nearer conductor and any part of such building	2.0 Meter
Above 33 KV	The horizontal clearance between the nearer conductor and any part of such building	2.0 + (0.3 for every additional 33 KV)

Clearance above ground at the lowest conductor		
Voltage	**Description**	**Distance**
Low & Medium Voltage	Across a street	5.8 Meter
High Voltage	Across a street	6.1 Meter
Low & Medium Voltage	Along a street	5.5 Meter
High Voltage	Along a street	5.8 Meter
Low & Medium Voltage	Elsewhere than along or across any street	4.0 Meter
High Voltage	Elsewhere than along or across any street	5.2 Meter
33 KV & EHV	Clearance above ground (Add 0.3 Meter for every 33 KV Volts in 5.2 Meter)	Min 6.1 Meter

Vertical Clearance at Middle of Span:	
Span	**Vertical Clearance (At Middle of Span)**
200 Meter	4.0 Meter
300 Meter	5.5 Meter
400 Meter	7.0 Meter
500 Meter	8.5 Meter

Safety Clearance from Live Part in Outdoor Substation:	
KV	**Safety Working Clearance**
12 KV	2.6 Meter
36 KV	2.8 Meter
72.5 KV	3.1 Meter
145 KV	3.7 Meter
220 KV	4.3 Meter
400KV	6.4 Meter
800 KV	10.3 Meter

Lying of Telecommunication Cables with Power Cables (>33 kV)	
Cable	**Min. Distance**
Power cable of voltage exceeding 33 kV shall be laid	Min 1.2 Meter depth
Underground telecommunication cable shall be with underground power cable of voltage exceeding 33 kV.	Min 0.6 Meter Separate from Power Cable

Safe approach limits for people:						
Voltage	**214V to 415 KV**	**11KV**	**33KV**	**66KV**	**132KV**	**275KV**
Person using manually operated tool	1.3 Meter	2.0 Meter	3.0 Meter	4.0 Meter	5.0 Meter	6.0 Meter
Person using power operated tool	3.0 Meter	3.0 Meter	3.0 Meter	4.0 Meter	5.0 Meter	6.0 Meter

Minimum Ground Clearance As Per IE-1956(Rule 77)	
Voltage in KV	**To ground in mm**
132	6.10
220	7.00
400	8.84
800	12.40

Minimum Height above Railway As Per IE-1957	
Voltage	**Broad Meter & Narrow Gauges**
Above 66KV up to 132KV	14.60 Meter
Above 132KV up to 220KV	15.40 Meter
Above 220KV up to 400KV	17.90 Meter
Above 400KV up to 500KV	19.30 Meter
Above 500KV up to 800KV	23.40 Meter

Clearances from Buildings of HT and EHT voltage lines IE Rule 80	
Vertical Distance	
High voltage lines up to 33KV	3.7 Meter

Extra High Voltage	3.7 Meter + Add 0.3 meter for every additional 33KV
Horizontal clearance between the conductor and Building	
High Voltage Up to 11 KV	1.2 Meter
11KV To 33KV	2.0 Meter
Extra High Voltage	2.0 Meter + Add 0.3 meter for every additional 33KV

Minimum Clearance between Lines Crossing Each Other (IE-1957)

System Voltage	132KV	220KV	400KV	800KV
Low & Medium	3.05	4.58	5.49	7.94
11-66KV	3.05	4.58	5.49	7.94
132KV	3.05	4.58	5.49	7.94
220KV	4.58	4.58	5.49	7.94
400KV	5.49	5.49	5.49	7.94
800KV	7.94	7.94	7.94	7.94

Various Air clearances to be provided as per IE rule 64

Voltage KV	33KV	66KV	110KV	220KV	400KV
BIL (Kvp)	170	325	550	1050	1425
P-E (cm)	30	63	115	240	350
P-P(cm)	40	75	135	210	410
P-G (Meter)	3.7	4.0	4.6	5.5	8.0
Section Clearance(Mt)	2.8	3.0	3.5	4.3	6.5

Clearance above ground of the lowest conductor As per IE Rule 77

Over head Line Across Street	
Low and Medium Voltage	5.8 Meter
High Voltage	6.1 Meter
Over head Line Along Street (Parallel to Street)	
Low and Medium Voltage	5.5 Meter
High Voltage	5.8 Meter
Over head Line Without Across or Along Street	
Low/Medium /HT line up to 11KV If Bare Conductor	4.6 Meter
Low/Medium /HT line up to 11KV If Insulated Conductor	4.0 Meter
Above 11 KV Line	5.2 Meter
Above 33KV Line	5.8 Meter + 0.3 meter for every additional 33KV

Clearance between conductors and Trolley / Tram wires (IE Rule 78)

Low and Medium Voltage	1.2 Meter
High Voltage Line Up to 11KV	1.8 Meter
High Voltage Line Above to 11KV	2.5 Meter
Extra High Voltage Line	3.0 Meter

Clearances from Buildings of low & medium voltage lines (IE Rule 79)

For Flat roof, Open Balcony, Verandah Roof and lean to Roof	
Line Passes Over Building Vertical Clearance	2.5 Meter
Line Passes Adjustment of Building Horizontal Clearance	1.2 Meter
For pitched Roof	
Line Passes Over Building Vertical Clearance	2.5 Meter
Line Passes Adjustment of Building Horizontal Clearance	1.2 Meter

Electrical Clearance As per IE Rules

Voltage	Ground clearance	Sectional clearance
11KV	2.75 Meter	2.6 Meter
33KV	3.7 Meter	2.8 Meter
66KV	4.0 Meter	3.0 Meter
132KV	4.6 Meter	3.5 Meter
220KV	5.5 Meter	4.3 Meter
400KV	8.0 Meter	6.5 Meter

Phase-Phase-Neutral Conductor Clearance (As per IS:5613)

Voltage	Description	Distance

Up to 650V	Horizontal "V" Shape Cross arm: (P-P(Street Light)-Neutral)	Phase to Neutral=750mm , Phase to Phase(Streetlight at Top of Pole)=325mm, Last Phase-Cross Arm end=80mm
650V to 11KV	Horizontal Cross arm: (P-P(Street Light)-N)	Phase-Phase=300mm, Phase-Phase(Street Ltg)=300mm, Phase-Neutral=300mm, Last Phase-Cross Arm end=80mm
Low and Medium Voltage Line	(Horizontal Configuration):	Less than 75cm Sag(P-P) =30 cm 76cm to 120 cm Sag (P-P)=45 cm 121cm to 145 cm Sag (P-P)=60 cm
Low and Medium Voltage Line	(Vertical Configuration):	Less than 70cm Sag(P-P) =20 cm 71cm to 100 cm Sag (P-P)=30 cm
High Voltage Line	(Horizontal Configuration):	Up to 120cm Sag(P-P) =40 cm 140cm to 225cm Sag (P-P)=65 cm Double Circuit on Same Pole at Different Level: Distance between two Circuit=120 cm

Min Overhead conductor Clearance (Up to 11KV) (As per IS:5613)

Type of Crossing	Clearance
Across any street (Low Medium Voltage)	5.8 Meter
Across any street (High Voltage)	6.1 Meter
Along with street (Low Medium Voltage)	5.5 Meter
Along with street (High Voltage)	5.8 Meter
Line(Bare) erected elsewhere(Low &Medium Voltage)	4.6 Meter
Line(Bare) erected elsewhere(High Voltage)	4.6 Meter
Line(Insulated) erected elsewhere(Low &Medium Voltage)	4.0 Meter
Line(Insulated) erected elsewhere(High Voltage)	4.0 Meter
Line conductor from buildings(Low &Medium Voltage)	2.5 Meter
Line conductor from buildings(High Voltage)	3.7 Meter

Clearance (11KV to 220KV) (As per IS:5613)

Voltage	Number Of Circuit	P-P Vertical Clearance	P-P Horizontal Clearance
33KV	Single	1.5 Meter	1.5 Meter
33KV	Single/Double	1.5 Meter	1.5 Meter
66KV	Single/Double	2.0 Meter	3.5 Meter
110KV	Single/Double	3.2 Meter	5.5 Meter
220KV	Single/Double	4.9 Meter	8.4 Meter

Phase to Earth wire Clearance (As per IS:5613)

Line Voltage(KV)	Spacing between P-E
33 KV	1.5 Meter
66 KV	3.0 Meter
110 KV	4.5 Meter
132 KV	6.1 Meter
220 KV	8.5 Meter

Span of Overhead Conductor (As per IS:5613)

System Voltage	Number Of Circuit	Span
33 KV (over Pole)	Single	90 Meter to 135 Meter
33 KV	Single	180 Meter to 305 Meter
33 KV	Double	180 Meter to 305 Meter
66 KV	Single	204 Meter to 305 Meter
66 KV	Double	240 Meter to 320 Meter
220 KV	Single	320 Meter to 380 Meter
220 KV	Double	320 Meter to 380 Meter

Overhead LineConductor Clearance(min) (As per CPWD)

Same Support	**For LV/MV Line on Same Support Vertical distance:**	Between Phase to Earth shall be min 30cm and Between Phase to Phase min 20cm

	For LV/MV Line on Same Support Horizontal distance:	Between Live wire on either side of support shall be 45cm.
	For LV/MV Line on Same Support Horizontal distance:	Between Live wire on same side of support shall be 30cm.
	For LV/MV Line on Same Support Horizontal distance:	Between central of pin insulator to end of cross Arm shall be 05cm.
	For HV Line in Triangular Configuration for 11KV/33KV Line	shall be min 1.5meter.
Different Voltage	When Two conductor of different Voltage are erected on same support min clearance between LV/MV and 11KV shall be min 1meter.	
	A Clearance not less than height of tallest support may be maintained between parallel overhead line on Different support.	
	When Two overhead line cross each other vertical clearance between LV/MV and 11KV shall not be less than 1.25meter and for LV/MV and 33KV line shall be not less than 2meter.	
Across Road	**Min Conductor Clearance across Road:**	For LV/MV Line is 5.8 meter and for HV Line 6.1 meter
Along Road	**Min Conductor Clearance along Road:**	For LV/MV Line is 5.5meter and for HV Line 5.8meter
Along/Across	**Min Conductor Clearance along/across Road:**	For LV/MV/HV up to 11Kv (Bare Cond) Line is 4.6meter.
	Min Conductor Clearance along/across Road:	For LV/MV/HV up to 11Kv (Insulated Cond) Line is 4.0meter.
	Min Conductor Clearance along/across Road:	For HV (11Kv To 33Kv) Line is 5.2meter.
	Min Conductor Clearance along/across Road:	For EHV (above 33Kv) is 5.2meter + 0.3 meter for every 33KV(Not Less than 6.1).
From Building	**Min Conductor Vertical Clearance above Building:**	For LV/MV Line is 2.5meter from highest Point.
	Min Conductor Horizontal Clearance near Building:	For LV/MV Line is 1.5meter from nearest Point.
	Min Conductor Vertical Clearance above Building:	For MV/EHV(up to 33KV) Line is 3.7meter from highest Point.
		For MV/EHV(above 33KV) Line is 3.7meter + 0.3meter for every 33KV Min Conductor Horizontal Clearance above Building:
	Min Conductor Horizontal Clearance above Building:	For MV/EHV(Up to 11KV) Line is 1.2meter.
		For EHV(Up to 33KV) Line is 02meter.
		For EHV(above 33KV) Line is 2meter + 0.3meter for every 33KV

Standard: Qatar General Electricity and Water Corporation:

Minimum Safety Clearance of Pipeline from Electrical Tower:		
Description	**Voltage**	
	33KV/66KV/132KV	**220KV/400KV**
The right of way (ROW) (widths on either side of the centre line of overhead transmission lines)	25 Meter	50 Meter
Other than the roadways and boundary fences of security establishments any temporary or permanent structures / buildings, parapet walls,	Not within 25 Meter	Not within 50 Meter
With All Underground services crossing the way leave (from the nearest tower foundation)	35 Meter (Min)	50 Meter (Min)
The nearest side of the road reservation to the nearest tower foundation	25 Meter	35 Meter,50 Meter
The pipelines (water, oil/gas etc.) crossing (respectively away from the nearest base of tower leg). Pipe-lines shall not be laid parallel to the overhead line within the limits of a way leave (ROW).	25 Meter (Min)	35 Meter(Min) ,50 Meter(Min)
Cables crossing the transmission lines way leave (ROW) respectively away from the nearest base of tower leg.	25 Meter	35 Meter,50 Meter

Foundations and civil structures (Temporary or permanent) will not be permitted in the close proximity to the cable circuit. A minimum horizontal distance from such structures to the nearest edge of the cable trench shall be observed	Min 1.5 Meter	Min 1.5 Meter

Clearance among Electrical Line, Telephone, Water, Sewerage & Gas Services	
Service	**Vertical Clearance(Min)**
Water Line (to cross below EHV cable level)	0.5 Meter
Sewerage Mains (to cross below EHV cable level)	1.0 Meter
Drainage Mains (to cross below EHV cable level)	0.5 Meter
Gas pipes	0.6 Meter
Telephone lines	0.5 Meter
LV / 11kV cables	0.5 Meter

Excavation:	
Type of Excavation	**Distance**
Use of heavy mechanical excavators (other than hand operated pneumatic jack hammers) or driving sheet piles	Not less than 3 Meter from the edge of cable, cover, cable joint
Heavy machinery engaged in the civil construction or road works	operating load/thrust/ weight will not be applied directly on the cable installation
Trench excavations parallel to the cable installations	Minimum separation of 1 Meter to the nearest edge of cable tile
Laying of metal pipes over a long distance parallel to cable	Not permitted unless the Step and Touch Potentials at any point of the pipe line do not exceed 65 Volts.

(A)Inside Towns

Distance between Tower's foundation to Pipeline in parallel and intersections	
Voltage	**Min Distance**
380/220V	0.5 Meter
20KV	2 Meter
63KV	7 Meter
132KV	10 Meter
230KV and Above	20 Meter

Distance between underground power cables to wall of gas pipelines in parallel		
Voltage	**Min Horizontal Distance**	**Min Vertical Distance**
380/220V	1 Meter	0.5 Meter
20KV	2 Meter	1 Meter
63KV	3 Meter	1.5 Meter

(B)Outside of Towns:

Distance between Tower's foundation to Pipeline in parallel and intersections		
KV	**Min Distance in Parallel Route (Up to 5 Km)**	**Min Distance in Parallel Route (Above 5 Km)**
20KV	20 Meter	30 Meter
63KV	30 Meter	40 Meter
132KV	40 Meter	50 Meter
230KV	50 Meter	60 Meter
400KV	60 Meter	60 Meter

Distance between overhead lines to gas pipelines at intersections	
KV	**Min Distance**
20KV	8 Meter
63KV	9 Meter
132KV	10 Meter
230KV	11 Meter
400KV	12 Meter

Distance between Tower's foundations to gas pipelines at intersections

KV	Min Distance
20KV	20 Meter
63KV and Higher	30 Meter

Right Of Way (R.O.W) From Roads:	
Highway	**Distance**
High Way : (38 meter from one side of Central Line of Highway)	76 Meter
First Class State Road :(22.5 meter from one side of Central Line of Highway)	45 Meter
Second Class State Road:(17.5 meter from one side of Central Line of Highway)	35 Meter
Third Class State Road :(12.5 meter from one side of Central Line of Highway)	25 Meter
Forth Class State Road:(7.5 meter from one side of Central Line of Highway)	15 Meter

General Clearance		
KV	**Description**	**Distance**
Up to 11 KV	At points where the lines cross roads or railways	Min 6 Meter Height
Up to 11 KV	parallel to roads the	Min 5.5 Meter Height
Up to 11 KV	lines cross totally desert regions where no traffic is possible	Min 5.5 Meter Height
20 KV to 66 KV	All Location	Min 6 Meter Height
Up to 11 KV	Conductor Joint	No joint shall be closer than 3 meters to a point of support
33 KV & 66 KV	Conductor Joint	No tension joints shall be used unless specially approved.

Standard: Northern Ireland Electricity (NIE), 6/025 ENA

Clearances to Ground and Roads						
Description of Clearance	**0.4 KV**	**11 KV**	**33KV**	**110KV**	**220 KV**	**400KV**
Line conductor to any point not over road	5.2 Mt	6.1 Mt	6.4 Mt	6.4 Mt	7.0 Mt	7.0 Mt
Line conductor to road surface	5.8 Mt	6.1 Mt	6.4 Mt	6.4 Mt	7.4 Mt	8.1 Mt
Line conductor to road surface of high load routes	6.9 Mt	6.9 Mt	6.9 Mt	7.2 Mt	8.5 Mt	9.2 Mt
Bare live metalwork (transformer terminals, jumper connections, etc)	4.6 Mt	4.6 Mt	4.6 Mt	-	-	-

Electrical Clearances to Objects:					
Description of Clearance	**<11 KV**	**33 KV**	**110KV**	**220KV**	**400 KV**
Line conductor or bare live metalwork to any object that is normally accessible (including permanently mounted ladders and access platforms) or to any surface of a building	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
Line conductor or bare live metalwork to any object to which access is not required AND on which a person cannot stand or lean a ladder	0.8 Meter	0.8 Meter	1.2 Meter	2.4 Meter	3.1 Meter
Line conductors to irrigators, slurry guns and high-pressure hoses	30 Meter	30 Meter	30 Meter	30 Meter	30 Meter
Line conductors to playing fields	8.5 Meter	8.5 Meter	8.5 Meter	8.5 Meter	8.5 Meter
Line conductors to Caravan Sites	9.0 Meter	9.0 Meter	9.0 Meter	9.0 Meter	9.0 Meter
Horizontal clearances to wells	15.0 Meter	15Meter	15Meter	15Meter	15 Meter

Clearances to Trees and Hedges:					
Description of Clearance	**<11 KV**	**33 KV**	**110KV**	**220KV**	**400 KV**
Line conductor or bare live metalwork to trees or hedges unable to support a ladder or being climbed.	0.8 Meter	0.8 Meter	1.2 Meter	2.4 Meter	3.1 Meter
Line conductor or bare live metalwork to trees or hedges capable of supporting a ladder or being climbed.	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
Line conductor or bare live metalwork to	0.8 Meter	0.8 Meter	1.2 Meter	2.4 Meter	3.1 Meter

trees falling towards the overhead line with the line conductors hanging vertically.					
Line conductors to trees in Orchards	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Mt

Clearances to Street Lighting:

Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Line conductor to Lantern on same pole	1.0 Meter	-	-	-	-	-
Bare line conductor to lantern or column below	1.5 Meter	-	-	-	-	-
Insulated line conductor to column	0.3 Meter	-	-	-	-	-
Insulated line conductor to lantern	1.0 Meter	-	-	-	-	-
Column to nearest LV pole	1.5 Meter	-	-	-	-	-
Line conductor to street lighting column with						
(i) Column in normal upright position.	-	1.7 Mt	1.7 Mt	2.3 Mt	3.3 Mt	4.0 Mt
(ii) Column falling towards line with line conductor hanging vertically only	-	1.7 Mt	1.7 Mt	2.3 Mt	3.3 Mt	4.0 Mt
(iii)Column falling towards line	-	0.4 Mt	0.4 Mt	0.8 Mt	1.4 Mt	1.9 Mt

Clearances to Waterways:

Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Navigable Waters: Lower bank to conductor or earth wire	10.5 Meter	10.5 Meter	10.5 Meter	10.5 Meter	10.5 Meter	10.5 Meter
Minor Watercourses : Lower bank to conductor or earth wire	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter

Clearances to Railways:

Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Line conductor to ground level	6.1 Mt	6.1 Mt	6.1 Mt	6.7 Mt	7.0 Mt	7.6 Mt
Line conductor to ground level on or across vehicle parks	7.6 Mt	8.5 Mt	8.5 Mt	9.1 Mt	9.4 Mt	10.1 Mt
Line conductor to ground level at roads and yards, where road mobile cranes are likely to be employed	10.7 Mt	10.7 Mt	10.7 Mt	11.2 Mt	11.5 Mt	12.2 Mt
Line conductor to Rail level	7.3 Mt	7.3 Mt	7.3 Mt r	8.0 Mt	8.2 Mt	8.8 Mt
Line conductor to the level of buildings, gantries or other structures (including those carrying traction wires) on which a man may be	3.0 Mt	3.0 Mt	3.0 Mt	3.7 Mt	4.6 Mt	6.1 Mt
Line conductor to poles and other projections.	2.4 Mt	2.7 Mt	2.7 Mt	3.0 Mt	3.7 Mt	5.5 Mt
Line conductor to any other wire other than traction wires.	1.8 Mt	1.8 Mt	1.8 Mt	2.4 Meter	3.0 Mt	3.7 Mt

Clearances to Fuel Tanks:

Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Horizontal clearance from line conductors to petrol tanks and vents	15 Meter	15 Meter	15 Meter	15 Meter	15 Meter	15 Meter
Horizontal clearance from line conductors to liquid gas tanks						
(1) 459 to 2273 litre capacity	3.0 Meter	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
(2) 2274 to 9092 litre capacity	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter
(3) More than 9093 litre.	15Meter	15Meter	15 Meter	15Meter	15Meter	15Meter
Vertical clearance from line conductors to fuel oil tanks	Please refer Clearances to Objects					

Clearances to other Power Lines:

Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Lowest line conductor or earth wire of upper line to highest line conductor of lower line.	1.0 Meter	1.8 Meter	2.0 Meter	2.5 Meter	3.7 Meter	4.4 Meter
Lowest line conductor or earth wire of upper line to earth wire of lower line where erected.	0.7 Meter	1.4 Meter	1.6 Meter	2.5 Meter	3.7 Meter	4.4 Meter
Lowest line conductor or earth wire of upper line to any point on a support of the lower line on which a person may stand.	2.7 Meter	2.8 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
Support of upper line and any conductor of lower line.	7.5 Meter	7.5 Meter	7.5 Meter	15 Meter	15 Meter	15 Meter

Vertical Passing Clearance (sites where vehicles will pass below the lines):

Description of Clearance	<33 KV	110KV	220KV	400 KV
Passing clearance: fixed height loads	0.8 Meter	1.4 Meter	2.4 Meter	3.1 Meter
Passing Clearance: variable height loads.	2.3 Meter	3.2 Meter	4.1 Meter	5.0 Meter

Horizontal Clearance (where there will be no work / passage of plant under lines

Description of Clearance	<33 KV	110KV	220KV	400 KV
Minimum horizontal distances to safety barriers	6.0 Meter	9.0 Meter	12.0 Meter	14.0 Meter

Distance between Conductors of Same/Different Circuit (On Same Support):

Higher Voltage of either Circuit	Lower Voltage of either Circuit	Distance between Circuits
< 33 KV	< 1 KV	1.0 Meter
< 33 KV	> 1 KV	1.2 Meter
33 KV to 110 KV	< 1 KV	1.5Meter
33 KV to 110 KV	> 1 KV	2.0 Meter
Above 110 KV	All	2.5 Meter

Vertical Distance between Conductors of different Circuit (On Different Support):

Higher Voltage of either Circuit	Distance between Circuits
< 1 KV	0.6 Meter
1 KV to 33 KV	1.2 Meter
33 KV to 66 KV	1.8 Meter
110 KV	2.4 Meter
220 KV	2.8 Meter

Distance between Conductors (down from Pole to other Support, on Transformer)

Voltage	Distance between Circuits
11 KV & LV Line	0.60 Meter
22 KV & LV Line	0.75 Meter
33 KV & LV Line	0.90 Meter

Horizontal Distance of Telecommunication Line & Overhead Line:

Description of Clearance	Distance
Telecommunication Line(Not insulated) to HV Line	Min 1.6 Meter
Telecommunication Line (Bare) to LV (Bare) Line	Min 1.2 Meter
Telecommunication Line (Covered) to LV (Bare) Line	Min 0.6 Meter
Telecommunication Line (Bare) to Stay (Bare) Wire	Min 0.3 Meter

Passage Way for Metal clad Switchgear:

Description of Clearance	Distance
Clean &unobstructed Passages at the front of any Low/High Voltage Switchgear.	1.0 Meter wide & 2.5 Meter high
Clean &unobstructed Passages at side or under any earthed enclosure containing Bare Conductor	0.8 Meter wide & 2.2 Meter high

Safe approach distance for Person from Exposed Live Parts:

Circuit Voltage	Distance
< 1 KV	0.5 Meter
11 KV	1.5 Meter
22 KV	2.0 Meter
33 KV	2.5 Meter
66 KV	3.0 Meter
110 KV	4.0 Meter
>220 KV	6.0 Meter

Standard: ETSA Utilities

Vertical Clearances between Services:		
Service	**LV Cable**	**HV Cable**
Common Pipe	0.100 Meter	0.100 Meter
Gas Pipe	0.200 Meter	0.200 Meter
Sewer Pipe	0.300 Meter	0.300 Meter
Water Pipe	0.600 Meter	0.600 Meter

Horizontal Clearances between Services:		
Service	**LV Cable**	**HV Cable**
Common Pipe	0.100 Meter	0.100 Meter
Gas Pipe	0.200 Meter	0.200 Meter
Sewer Pipe	1.0 Meter	1.0 Meter
Water Pipe	0.600 Meter	0.600 Meter

Minimum Electrical Clearance as per BS: 162.

INDOOR		
Voltage in KV	**Phase to earth in mm**	**Phase to phase in mm**
0.415	15.8	19.05
0.600	19.05	19.05
3.3	50.8	50.8
6.6	63.5	88.9
11	76.2	127.0
15	101.6	165.1
22	139.7	241.3
33	222.25	355.6
OUTDOOR		
Voltage in KV	**Phase to earth in mm**	**Phase to phase in mm**
6.6	139.7	177.8
11	177.8	228.6
22	279.4	330.2
33	381	431.8
66	685.8	787.4
110	863.6	990.6
132	1066.8	1219.2
220	1778	2057.4

Minimum working Clearance : OUTDOOR Switchyard		
Voltage in KV	**To ground in mm**	**Between section(mm)**
11	2750	2500
33	3700	2800
66	4000	3000
132	4600	3500
220	5500	4500

Standard: UK Power Networks - EI 02-0019

Cable Installation Depths:		
Voltage	**Area**	**Depth (min)**
Low Voltage	Footways, grass verges or private property	0.450 Meter
	Carriageways (including road crossings)	0.600 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter

	Agricultural land subject to deep ploughing	1.2 Meter
11 KV to 20 KV	Footways, grass verges or private property	0.600 Meter
	Carriageways (including road crossings)	0.750 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter
	Agricultural land subject to deep ploughing	1.2 Meter
33 KV to 132 KV	Footways, grass verges or private property	0.900 Meter
	Carriageways (including road crossings)	0.900 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter
	Agricultural land subject to deep ploughing	1.2 Meter
Auxiliary Multi-core & Multi-pair Cables	Footways, grass verges or private property	0.450 Meter
	Carriageways (including road crossings)	0.600 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter
	Agricultural land subject to deep ploughing	1.2 Meter
On Cable Ladder for LV to HV	The Horizontal clearance between cables on cable ladders	2X Dia of Cable of Largest Cable or min 150 mm
	The clearance from a supporting wall	20 mm
	The vertical clearance between cables is greater	150 mm
	If the number of cables > 4, they are to be installed in a horizontal	

Minimum Approach Distance of Crane or Moving Part from Live Conductor:

Voltage	Without Safety Observation		For ordinary Person
	Un insulated portions	Insulated portions	
Upto1KV	2 Meter	1.0 Meter	3.0 Meter
11 KV	2 Meter	1.4 Meter	3.0 Meter
22 KV	2.4 Meter	2 Meter	3.0 Meter
33 KV	2.4 Meter	2 Meter	3.0 Meter
66 KV	2.8 Meter	2 Meter	3.0 Meter
132 KV	3.0 Meter	3.0 Meter	3.0 Meter
220 KV	4.8 Meter	4.8 Meter	6.0 Meter
330 KV	6.0 Meter	6.0 Meter	6.0 Meter
500 KV	8.0 Meter	8.0 Meter	8.0 Meter

Minimum Fixed Clearances for Electrical Apparatus (Isolation Points):

Voltage	Fixed Clearance
Up to 11Kv	0.320 Meter
11KV to 33KV	0.320 Meter
33KV to 66KV	0.630 Meter
66KV to 132KV	1.1 Meter

Standard: New Zealand Electrical Code:

Min Safe Distance between Buildings and Overhead Line:

Voltage	Pole	Tower
11 kV to 33 kV	2 Meter	2 Meter
33 kV to 66 kV	6 Meter	6 Meter
66 kV and Above	8 Meter	8 Meter

Min Safe Distance for excavation near Overhead Line:

Description of Clearance	From Pole (Min)	From Tower (min)
Excavation in land more than 750mm depth	8 Meter	12 Meter
Excavation in land up to750mm depth	2.2 to 5 Meter	6 to12 Meter
Excavation in land up to300mm depth	2.2 Meter	6 Meter
Construction near 11KV to 33KV Line	2.2 Meter	6 Meter
Construction near 33KV to 66KV Line	6 Meter	9 Meter
Construction near 66KV and more	8 Meter	12 Meter
Wire Fence near 1KV to 66KV Line	2.2 Meter	2.2 Meter
Wire Fence near 66KV and more	5 Meter	5 Meter

Min Safe Distance for Tower Crain near Electrical Tower:

Description of Clearance	Distance (Min)

Mobile Crain movement	4.0 Meter
Tower Crain movement	4.0 Meter
Crain movement	4.0 Meter
Moving Activity above height of Tower	4.0 Meter
Hedge Cutter movement	4.0 Meter

Min Safe Vertical Distance above Railway Track:

Description of Clearance	Distance (Min)
Earthed conductors	5.5 Meter
Stay wires	5.5 Meter
Conductors up to 33 kV	6.5 Meter
Conductors above 33 kV to 220 kV	7.5 Meter
Conductors above 220 kV.	8 Meter

Min Distance between two Conductors on Same Supports:

High Voltage Circuit	High Voltage Circuit	Distance between circuits(min)
Up to 33 KV	Up to 1KV	1.0 Meter
Up to 33 KV	More than 1KV	1.2 Meter
33 KV to 110 KV	Up to 1KV	1.5 Meter
33 KV to 110 KV	More than 1KV	2.0 Meter
More than 110 KV	All	2.5 Meter

Min Distance between two Conductors on Different Supports:

High Voltage Circuit	Distance (min)
Up to 1 KV	0.6 Meter
1 KV to 33 KV	1.2 Meter
33 KV to 66 KV	1.8 Meter
110 KV	2.4 Meter
More than 220 KV	2.8 Meter

Min Safety Distance from Electrical Apparatuses:

Description of Clearance	Distance (min)
Passage In front of Metal Clad Switchgear (UP to HV)	1.0 Meter wide 2.5 Height
Passage In rear or side of Metal Clad Switchgear (UP to HV)	1.0 Meter wide 2.2 Height
Passage at any side of Metal Clad Switch gear containing Bare conductor (UP to HV)	0.8 Meter wide 2.2 Height

Min Approach Distance for Non-Competent Person near exposed Live Parts:

Voltage	Distance (min)
Below 110 kV	4.0 Meter
220 kV and above	6.0 Meter

Min Approach Distance for Competent Person near exposed Live Parts:

Voltage	Distance (min)
Below 1 kV	0.5 Meter
11 kV	1.5 Meter
22 kV	2.0 Meter
33 kV	2.5 Meter
66 kV	3.0 Meter
110 kV	4.0 Meter
220 kV and above	6.0 Meter

Standard: Western Power Company.

Water Safely Clearance on Electrical Fires:

Voltage	Minimum distances between a nozzle producing a fog stream of fresh water and a live conductor
Up to 750 V	1.5 Meter
750 V to 15 KV	4.0 Meter
15 KV to 230 KV	5.0 Meter

Minimum Approach Distance for Authorized Person:	
Voltage	**Distance (min)**
Up to 1 KV	0.7 Meter
1 V to 6.6 KV	0.7 Meter
6.6 KV to 11 KV	0.7 Meter
11 KV to 22 KV	0.7 Meter
22 KV to 33 KV	1.0 Meter
33 KV to 66 KV	1.0 Meter
66 KV to 132 KV	1.2 Meter
132 KV to 220 KV	1.8 Meter
220 KV to 330 KV	3.0 Meter

Minimum Approach Distance for Ordinary Person:	
Voltage	**Distance (min)**
Up to 1 KV	3.0 Meter
1 V to 6.6 KV	3.0 Meter
6.6 KV to 11 KV	3.0 Meter
11 KV to 22 KV	3.0 Meter
22 KV to 33 KV	3.0 Meter
33 KV to 66 KV	3.0 Meter
66 KV to 132 KV	3.0 Meter
132 KV to 220 KV	4.5 Meter
220 KV to 330 KV	6.0 Meter

Minimum Approach Distance for Vehicle & Plant for Ordinary Person:		
Voltage	**Distance (min)**	
	Mobile Plant	**Vehicle**
Up to 1 KV	3.0 Meter	0.6 Meter
1 V to 6.6 KV	3.0 Meter	0.9Meter
6.6 KV to 11 KV	3.0 Meter	0.9Meter
11 KV to 22 KV	3.0 Meter	0.9Meter
22 KV to 33 KV	3.0 Meter	0.9Meter
33 KV to 66 KV	3.0 Meter	2.1 Meter
66 KV to 132 KV	3.0 Meter	2.1 Meter
132 KV to 220 KV	3.0 Meter	2.9 Meter
220 KV to 330 KV	6.0 Meter	3.4 Meter

Chapter: 31 Safety Clearance for Electrical Panel

Working Space around Indoor Panel/Circuit Board (NES 312.2):			
Voltage	**Exposed live parts to Not live parts(or grounded parts)**	**Exposed live parts to Grounded parts (concrete, brick, and walls).**	**Exposed live parts on both sides**
Up to 150 V	0.914 Meter (3 Ft)	0.914 Meter (3 Ft)	0.914 Meter (3 Ft)
150 V to 600 V	0.914 Meter (3 Ft)	1.07 Meter (3'6")	1.22 Meter (4 Ft)

Clearance around an Indoor electrical panel (NES 110.26)	
Description of Clearance	**Distance (min)**
Left to Right the minimum clearance	0.9 Meter (3 Ft)
Distance between Panel and wall	1.0 Meter
Distance between Panel and Ceiling	0.9 Meter
Clear Height in front of Panel>480V	2.0 Meter
Clear Height in front of Panel <480V	0.9 Meter (3 Ft)
Clearance When Facing Other Panels < 480V	0.9 Meter (3 Ft)
The width of the working space in front of the Panel	The width of Panel or 0.762 Meter which is Greater.
Headroom of working spaces for panel boards (Up to 200Amp)	Up to 2 Meter
Headroom of working spaces for panel boards (More than 200Amp &Panel height is max 2 Meter)	Up to 2 Meter(If Panel height is max 2 Meter)
Headroom of working spaces for panel boards (More than 200Amp &Panel height is more than 2 Meter)	If Panel height is more than 2 Meter than clearance should not less than panel Height
Entrance For Panel (More than 1200 Amp and over 1.8 m Wide)	One entrance required for working space (Not less than 610 mm wide and 2.0 m high)
Personal Door For Panel (More than 1200 Amp)	Personnel door(s) intended for entrance to and egress from the working space less than 7.6 m from the nearest edge of the working space
Dedicated Electrical Space	Required Space is width and depth of the Panel and extending from the floor to a height of 1.8 m (6 ft) above the equipment or to the structural ceiling, whichever is lower
The door(s) shall open in the direction of egress and be equipped with panic bars, pressure plates, or other devices that are normally latched but open under simple pressure	
the work space shall permit at least a 90 degree opening of equipment doors or hinged panels	

Clearance for Conductor Entering in Panel (NES 408.5):	
Description of Clearance	**Distance (min)**
Spacing between The conduitor raceways(including their end fittings) and Bottom of Enclosure	> than 75 mm (3 in) above the bottom of the enclosure
Spacing Between Bottomof Enclosure and Insulated bus bars, their supports,	200 mm
Spacing Between Bottom of Enclosure and Non insulated bus bars	200 mm

Clearance between Bare Metal Bus bar in Panel (NES 408.5):			
Voltage	**Opposite Polarity Mounted on Same Surface**	**Opposite Polarity Where Held Free in Air**	**Live Parts to Ground**
Up to 125 V	19.1 mm	12.7 mm	12.7 mm
125 V to 250 V	31.8 mm	19.1 mm	12.7 mm
250 V to 600 V	50.8 mm	25.4 mm	25.4 mm

Clearance of Outdoor electrical panel to Fence/Wall (NES 110.31):	
Voltage	**Distance (min)**
600 V to 13.8 KV	3.05 Meter
13.8 K V to 230 KV	4.57 Meter
Above 230 KV	5.49 Meter

Working Space around Indoor Panel/Circuit Board (NES 110.34):

Voltage	Exposed live parts to Not live parts(or grounded parts)	Exposed live parts to Grounded parts (concrete, brick, and walls).	Exposed live parts on both sides
601 V to 2.5 K V	0.914 Meter (3 Ft)	1.2 Meter (4 Ft)	1.5 Meter (5 Ft)
2.5 K V to 9.0 K V	1.2 Meter (4 Ft)	1.5 Meter (5 Ft)	1.8 Meter (6 Ft)
9.0 K V to 25 K V	1.5 Meter (5 Ft)	1.8 Meter (6 Ft)	2.5 Meter (8 Ft)
25 K V to 75 K V	1.8 Meter (6 Ft)	2.5 Meter (8 Ft)	3.0 Meter (10 Ft)
Above 75 KV	2.5 Meter (8 Ft)	3.0 Meter (10 Ft)	3.7 Meter (12 Ft)

Clearance around an Outdoor electrical panel (NES 110.31):

Description of Clearance	Distance (min)
Clear work space:	Not less than 2.0 Meter high(Measured vertically from the floor or platform) or not less than 914 mm (3 ft) wide (Measured parallel to the equipment).
Entrance For Panel:(More than 1200 Amp and over 1.8 m Wide)	One entrance required for working space (Not less than 610 mm wide and 2.0 m high)
Entrance For Panel: On Large panels exceeding 1.8 Meter in width	One Entrance at each end of the equipment.
Nonmetallic or Metal-enclosed Panel in general public and the bottom of the enclosure is less than 2.5 m (8 ft) above the floor or grade level	Enclosure door or hinged cover shall be kept locked.

Elevation of Unguarded Live Parts above Working Space (NES 110.34E)

Voltage	Elevation (min)
600 V to 7.5 KV	2.8 Meter
7.5 K V to 35 KV	2.9 Meter
Above 35 KV	2.9 Meter + 9.5 mm/KV

Working Space for Panel (Code Georgia Power Company):

Voltage	Exposed live parts to Not live parts(or grounded parts)	Exposed live parts to Grounded parts (concrete, brick, and walls).	Exposed live parts on both sides
Up to 150 V	3.0 Meter	3.0 Meter	3.0 Meter
150 V to 600 V	3.0 Meter	3.5 Meter	4.0 Meter
600 V to 2.5 KV	3.0 Meter	4.0 Meter	5.0 Meter
2.5 KV to 9 KV	3.0 Meter	5.0 Meter	6.0 Meter
9 KV to 25 KV	5.0 Meter	6.0 Meter	6.0 Meter

Chapter: 32 Safety Clearance & Protection for Transformer

Clearance of Outdoor Liquid Insulated Transformers and Buildings (NEC):					
Liquid	**Liquid Volume (m3)**	**Fire Resistant Wall**	**Non-Combustible Wall**	**Combustible Wall**	**Vertical Distance**
Less Flammable	NA	0.9 Meter	0.9 Meter	0.9 Meter	0.9 Meter
	<38 m3	1.5 Meter	1.5 Meter	7.6 Meter	7.6 Meter
	>38 m3	4.6 Meter	4.6 Meter	15.2 Meter	15.2 Meter
Mineral Oil	<1.9 m3	1.5 Meter	4.6 Meter	7.6 Meter	7.6 Meter
	1.9 m3 to 19 m3	4.6 Meter	7.6 Meter	15.2 Meter	15.2 Meter
	> 19 m3	7.6 Meter	15.2 Meter	30.5 Meter	30.5 Meter

Clearance between Two Outdoor Liquid Insulated Transformers (NEC)		
Liquid	**Liquid Volume (m3)**	**Distance**
Less Flammable	NA	0.9 Meter
	<38 m3	1.5 Meter
	>38 m3	7.6 Meter
Mineral Oil	<1.9 m3	1.5 Meter
	1.9 m3 to 19 m3	7.6 Meter
	> 19 m3	15.2 Meter

Dry Type Transformer Indoor Installation (NES 420.21)	
Voltage	**Distance (min)**
Up to 112.5 KVA	300 mm (12 in.) from combustible material unless separated from the combustible material by a heat-insulated barrier.
Above 112.5 KVA	Installed in a transformer room of fire-resistant construction.
Above 112.5 KVA with Class 155 Insulation	separated from a fire-resistant barrier not less than 1.83 m (6 ft) horizontally and 3.7 m (12 ft) vertically

Dry Type Transformer Outdoor Installation (NES 420.22):	
Voltage	**Distance (min)**
Above 112.5 KVA with Class 155 Insulation	separated from a fire-resistant barrier not less than 1.83 m (6 ft) horizontally and 3.7 m (12 ft) vertically

Non-Flammable Liquid-Insulated Transformer Indoor Installation (NES 420.21):	
Voltage	**Distance (min)**
Over 35KV	Installed indoors Vault (Having liquid confinement area and a pressure-relief vent for absorbing any gases generated by arcing inside the tank, the pressure-relief vent shall be connected to a chimney or flue that will carry such gases to an environmentally safe area
Above 112.5 KVA	Installed in a transformer room of fire-resistant construction.
Above 112.5 KVA (Class 155 Insulation)	separated from a fire-resistant barrier not less than 1.83 m (6 ft) horizontally and 3.7 m (12 ft) vertically

Oil Insulated Transformer Indoor Installation (NES 420.25)	
Voltage	**Distance (min)**
Up to 112.5 KVA	Installed indoors Vault (With construction of reinforced concrete that is not less than 100 mm (4 in.) thick.
Up to 10 KVA & Up to 600V	Vault shall not be required if suitable arrangements are made to prevent a transformer oil fire from igniting
Up to 75 KVA & Up to 600V	Vault shall not be required if where the surrounding Structure is classified as fire-resistant construction.
Furnace transformers (Up to 75 kVA)	Installed without a vault in a building or room of fire resistant construction

Transformer Clearance from Building (IEEE Stand):	
Transformer	**Distance from Building (min)**
Up to 75 KVA	3.0 Meter
75 KVA to 333 KVA	6.0 Meter

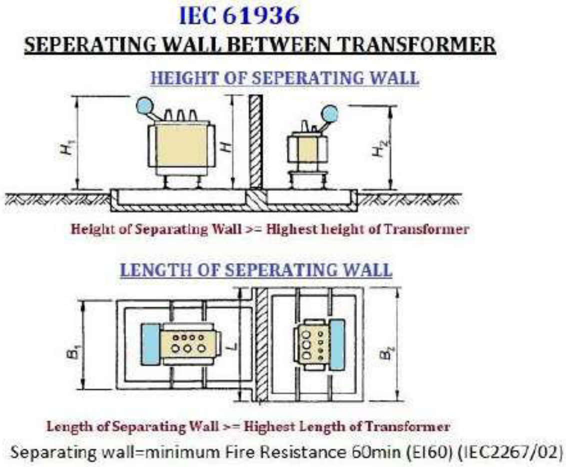
More than 333 KVA	9.0 Meter

Transformer Clearance Specifications (Stand: Georgia Power Company):	
Description of Clearance	**Distance (min)**
Clearance in front of the transformer	3.0 Meter
Between Two pad mounted transformers (including Cooling fin)	2.1 Meter
Between Transformer and Trees, shrubs, vegetation(for unrestricted natural cooling	3.0 Meter
The edge of the concrete transformer pad to nearest the building	4.2 Meter
The edge of the concrete transformer pad to nearest building wall, windows, or other openings	3.0 Meter
Clearance from the transformer to edge of (or Canopy) building (3 or less stories)	3.0 Meter
Clearance in front of the transformer doors and on the left side of the transformer, looking at it from the front. (For operation of protective and switching devices on the unit.)	3.0 Meter
Gas service meter relief vents.	0.9 Meter
Fire sprinkler values, standpipes and fire hydrants	1.8 Meter
The water's edge of a swimming pool or any body of water.	4.5 Meter
Facilities used to dispense hazardous liquids or gases	6.0 Meter
Facilities used to store hazardous liquids or gases	3.0 Meter
Clear vehicle passageway at all times, immediately adjacent of Transformer	3.6 Meter
Fire safety clearances can be reduced by building a suitable masonry fire barrier wall (2.7 Meter wide and 4.5 Meter Tall) 0.9 Meter from the back or side of the Pad Mounted Transformer to the side of the combustible wall	
Front of the transformer must face away from the building.	

Clearance of Transformer-Cable-Overhead Line (Stand: Georgia Power Company)			
Description of Clearance	**Horizontal Distance (mm)**		
	to pad-mounted transformers	**to buried HV cable**	**to overhead HV Line**
Fuel tanks	7.5 Meter	1.5 Meter	7.5 Meter
Granaries	6.0 Meter	0.6 Meter	15 Meter
Homes	6.0 Meter	0.6 Meter	15 Meter
Barns, sheds, garages	6.0 Meter	0.6 Meter	15 Meter
Water wells	1.5 Meter	1.5 Meter	15 Meter
Antennas	3.0 Meter	0.6 Meter	Height of Antenna + 3.0 Meter

Guide values for Outdoor Transformer Clearances (IEC 61936-1-Table 3)			
Transformer type	**Liquid volume**	**Clearance to other transformers or non-combustible building surface**	**Clearance to combustible building surface**
Oil insulated transformers (O)	1000 Litre to 2000 Litre	3 Meter	7.6 Meter
	2000 Litre to 20000 Litre	5 Meter	10 Meter
	20000 Litre to 45000 Litre	10 Meter	20 Meter
	More than 45000 Litre	15.2 Meter	30.5 Meter
Less flammable liquid insulated transformers (K) without enhanced protection	1000 Litre to 3800 Litre	1.5 Meter	7.6 Meter
	More than 3800 Litre	4.6 Meter	15.2 Meter
Less flammable liquid insulated transformers (K) with enhanced protection	**Clearance to building surface or adjacent transformers**		
	Horizonal =0.9 Meter		
	Vertical=1.5 Meter		
Dry-type transformers (A)	**Fire behaviour class**	**Clearance G to building surface or adjacent transformers**	
		Horizontal	**vertical**
	F0	1.5 Meter	3 Meter
	F1/F2	NILL	NILL

Note:	If automatically activated fire extinguishing equipment is installed, the clearance can be reduced
Note:	If it is not possible to allow for adequate clearance as indicated in table 3, fire-resistant separating walls with the following dimensions shall be provided:
	Between transformers (see figure) separating walls. For example EI 60 in accordance
	(i) Height: top of the expansion chamber (if any), otherwise the top of the transformer tank;
	(ii) Length: width or length of the sump (in the case of a dry-type transformer, the width or length of the transformer, depending upon the direction of the transformer);
Note:	Where transformers with a liquid volume below 1000 Litre are installed near combustible walls, special fire precautions may be necessary depending on the nature and the use of the building



Minimum Requirements for the Installation of Indoor Transformers (IEC 61936-1-Table 4)		
Transformer type	**Liquid volume**	**Safeguard**
Oil insulated transformers (O)	<=1000 Litre	EI 60 respectively REI 60
	More than 1000 Litre	EI 90 respectively REI 90 or EI 60 respectively REI 60 and automatic sprinkler protection
Less flammable liquid insulated tansformers (K) without enhanced protection		EI 60 respectively REI 60 or automatic sprinkler protection
Less flammable liquid insulated tansformers (K) with enhanced protection	<= 10 MVA and Um <= 38 kV	EI 60 respectively REI 60 or separation distances 1.5 Meter horizontally and 3.0 Meter vertically
Dry-type transformers (A)	**Fire behaviour class**	
	F0	EI 60 respectively REI 60 or separation distances 0.9 Meter horizontally and 1.5 Meter vertically
	F1/F2	Non-combustible walls
Note:	Between transformers and buildings separating walls shall be provided. For example EI 60; if additional fire separating wall is not provided, fire rating of the building wall should be increased, for example REI 90	

IS 3034: 1993	
SIZE OF TRANSFORMER	**FIRE PROTECTION**
<=10 MVA or Oil filled Transformers with oil capacity of <=2 000 Litres	No fixed fire protection equipment (such as high velocity spray) is required
>10 MVA or Oil filled Transformers with oil capacity of >2 000 Litres	High velocity water spray system, shall be provided. This system shall be separately mounted and designed to take into account the possibility of a transformer explosion.
	The water spray deluge valve house shall be located outside the

	transformer fire zones and protected from radiant heat and other fire effects. The actuation of this system shall be automatic but manual operating valves shall also be provided
	The positioning of the nozzles should be such to protect all surfaces of the transformer and to give discharge rate for the system not less than 10 Ipm/m of the area to be protected.
	The automatic high velocity water spray shall be of pre-active with quartzoid bulbs.
Distance between two transformers is less than 15 Meter apart or where the oil capacity > 2000 Litres	Fire barriers walls shall be provided between transformers.
Transformers having an aggregate oil capacity exceeding 2000 litres but an individual oil capacity of fewer than 5000 litres	Separating walls shall not be necessary.
If the distance between transformers and other apparatus is more than 6 Meter	
If the transformers are protected by an approved high-velocity water spray system	

IS 3034: 1993-Table 1 Clearance from Water Spray Equipment to Live Un Attended Electrical Components

Nominal Line Voltage	Design BIL	Minimum Clearance
up to 15KV	110KV	178MM
23KV	150KV	254MM
34.5KV	200KV	330MM
46KV	250KV	432MM
69KV	350KV	635MM
115KV	550KV	940MM
138KV	650KV	1118MM
161KV	750KV	1321MM
196 TO 230KV	900-1050KV	1600-1930MM
287 TO 380KV	1175-1550KV	2210-3048MM
500KV	1675-1880KV	3327-3607MM
500 TO 700KV	1925 -2300KV	3886-4674MM

Section 64 in The Indian Electricity Rules, 1956

2000 litres of oil installed, whether indoor or out-doors	The baffle walls of 4-hour fire rating shall be provided between the apparatus in the following cases
	(i) Single phase banks in the switch-yards of generating stations and substations.
	(ii) On the consumer premises
	(iii) Where adequate clearance between the units is not available
	Provisions shall be made for suitable oil soak pit and where use of more than 9000 litres of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tanks receptacles or chambers containing the same, special precautions shall be taken to prevent the spread of any fire resulting from the ignition of the oil from any cause and adequate provision shall be made for extinguishing any fire which may occur. Spare oil shall not be stored in an such sub-station or switch station
Where it is necessary to locate the Transformer /Sub-Station in the basement following measures shall be taken	The room shall necessarily be in the first basement at the periphery of the basement.
	The entrances to the room shall be provided with fire resisting doors of 2 hours fire rating. A curb (sill) of a suitable height shall be provided at the entrance in order to prevent the flow of oil from a ruptured transformer into other parts of the basement. Direct access to the transformer room shall be provided from outside.
	The transformer shall be protected by an automatic high velocity water spray system or by carbon dioxide or BCF(Bromochlorodifeuromethane) or

	BTM (Bromotrifluromethane) fixed installation system.
	Oil filled transformers installed indoors shall not be on any floor above the ground or below the first basement.
	A sub-station or a switch station with apparatus having more than 2000 litres of oil shall not be located in the basement where proper oil draining arrangement cannot be provided.

CEA Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010. Clause 54	
>=33 kV voltage	Transformers shall be separated from one another by a firewall.

Fire protection for power plants (NFPA 850)		
LOCATION	**TYPE OF TRANSFORMER**	**DETAILS**
OUTDOOR	Oil-insulated outdoor type transformer containing 1890 litres or more of oil	It is strongly recommended that any is separated from nearby structures by a 2-hour–rated firewall
		Wherever a firewall is installed between transformers it should extend at least 1 ft (0.31 m) above the top of the transformer shell and oil tank and at least 2 ft (0.61 m) beyond the width of the transformer and cooling radiators.
INDOOR	Dry type Transformer	Dry-type transformers are strongly preferred for use inside buildings.
	oil-insulated transformer	In case however, an oil-insulated transformer is installed indoors, then if its oil content exceeds 379 Litres, then it should be separated from nearby areas by a fire barrier of 3-hour fire resistance rating.
		In case an automatic fire extinguishment system is installed, then it is allowed that the fire resistance rating of the fire barrier is reduced to 1 hour.

Outdoor Oil-Insulated Transformer Separation Criteria (NFPA 850 - Table 6.1.4.3)	
Transformer O il Capacity	**Minimum (Line-of-Sight) Separation Without Firewall**
<1893 Litre	1.5 Meter
1893 litre to 18925 litre	7.5 Meter
>18925 litre	15 Meter

IS 1646	
Type of Transformer	**Description**
Each oil-filled apparatus, such as transformer, bank of static condensers, including high tension circuit breakers, switch and main distribution boards, having an **individual or aggregate oil capacity of 2000 litres (Indoor)**	Transformer shall also be segregated from all other apparatus by **355 mm thick fire resisting brick wall or 230 mm thick RCC.** The separating wall shall be carried right up to the roof level unless the roof is more than 3 Meter above the highest point of the equipment, in which case the wall shall be carried up to a height at least 600mm
	(i) This provision need not be applied to furnace and rectifier transformers as also to transformer of testing apparatus or other equipment of which the transformer is an integral part, whether they are oil-filled or not.
	(ii) The requirements given under this rule, however, do not apply to dty type transformers, or transformers having sulphur hexafluoride, non-flammable coolants and having primary voltage not mote than 33 kV.
	(iii) If the substation supplies power to fire pumps, separating walls as described above will be necessary between the various items irrespective of the oil contents.
Every oil-filled apparatus, such as transformer, static condenser, switchgear or oil circuit breaker having an **individual or aggregate oil capacity of 2000 litres or more (Indoor)**	Transformer shall be housed in a locked, weather and fire resistant building and shall be properly ventilated to the outside of the building only.
	(i) The building housing the oil-filled apparatus shall be separated by a distance of **not less than 6 Meter from all other buildings.**
	(ii) If the building housing the transformer is within 6 m of the surrounding building there shall not be any door or window opening in the substation or the surrounding building.
	(iii) If the building or compartment housing oil-filled apparatus is

	communicating with another building or compartment, the substation shall be segregated by separating **walls of 355 mm thick brick wall or 230 mm thick RCC**, carried up to roof level with door openings therein protected by single fireproof doors of 2 **hour rating.**
	(iv) Notwithstanding the above, if the substations supplies power to fire pumps, the same shall be segregated from, the adjoining building by **400 mm thick brick wall or 300 mm thick RCC wall without any door opening** there in where, however, door openings are absolutely necessary, the openings shall be protected by double fire resisting doors of **2 hour rating each.** If the substation is attached to a stormed structure, in addition to segregations, it will also be necessary for the substation to be provided with RCC slab roof.
Each building or compartment housing oil filled apparatus **containing 2000 litres or more (Indoor)**	Transformer shall be provided with oil drains of at least 150 mm in diameter and soak pits, the latter being not less than 2.5 m away from the substation.
	Floors shall be sloped not less than 1 in 96 towards oil drains.
	The soak pits shall be of sufficient capacity to take the entire oil content of the equipment and designed to provide for drainage of liquids to a safe location.
	A minimum clearance of 750 mm shall be provided between the transformer or other apparatus and enclosing or separating walls.
Transformers and equipment installed outdoors, having an **individual or aggregate oil content of 2 000 litres or more (Outdoor)**	Transformer shall be located in a suitably fenced and locked enclosure separated on all sides by at least 6 Meter from any building including substation.
	Separating walls are necessary between transformers having an individual or aggregate oil content of 2000 litres.
	There should be no door or window opening in the surrounding building, if the transformers are within 6 m thereof.
	If the transformers are within 6 Meter of doors and window openings of surrounding buildings then they shall be protected by single fire proof doors and 6 mm thick wired glass in steel frames respectively.
	Separating walls shall not be necessary in case of transformers having an aggregate oil capacity exceeding 2000 Litres but individual oil capacity of less than 5000 Litres if the distance between transformers and other apparatus is more than 6 Meter or if the transformers ate protected by an approved high velocity water spray system.
	Where however oil capacity of individual transformer is larger than 5 000 litres separating walls shall be provided unless all equipment/building/plant are located at a clear distance of not less than the following
	5000 To 20000 Liter Oil Capacity of Individual Transformer= 8Meter Clear Separating Distance
	Over 20 000 Liter Oil Capacity of Individual Transformer= 15Meter Clear Separating Distance

IS: 1002	
Indoor Transformer	Transformers installed inside buildings, where the oil capacity exceeds 2 000 litres of oil, shall be provided with oil soak pits. Oil soak pits may also be made of RCC tanks.
	For indoor transformers, Oil soak pits shall be provided either under the transformer or outside the transformer room.
Two or more transformers are installed side by side	They shall be separated by fire-separation walls. Fire separation walls are deemed to be adequate from fire-safety point of view, even if oil capacity of individual transformers do not exceed 2 000 litres, and total capacity of all transformers installed side by side exceeds 2 000 litres.
Soak Pit	The capacity of the oil soak pit shall be such that to soak the entire oil content of the transformer, it is intended for individual soak pits for each transformer (wherever necessary) with capacity as above or a common soak pit to contain the entire oil content of the biggest of the transformers shall be adequate.

Chapter: 33 Safety Clearance for Sub Station Equipments

Minimum Clearance in Substation:

Voltage	Highest Voltage	Lighting Impulse Level (Kvp)	Switching Impulse Level (Kvp)	Minimum Clearance		Safety Clearance (Mt)	Ground Clearance (Mt)
				Phase-Earth	Phase-Phase (Mt)		
11KV	12KV	70		0.178	0.229	2.600	3.700
33KV	36KV	170		0.320	0.320	2.800	3.700
132KV	145KV	550		1.100	1.100	3.700	4.600
		650		1.100	1.100	2.700	4.600
220KV	245KV	950		1.900	1.900	4.300	5.500
		1050		1.900	1.900	4.300	5.500
400KV	420KV	1425	1050(P-E)	3.400	4.200	6.400	8.000

Electrical Clearance in Substation:

Voltage	Height of I Bay From Ground	Height of II Bay From Ground	Bay Width	Phase-Phase	Between Equipment	Earth Wire From Ground
132KV (Single)	8 Mt	-	11.0 Mt	3 Mt	3 Mt	10.5 Mt
220KV (Single)	12.5 Mt	-	18 Mt	4.5 Mt	4.5 Mt	15.5 Mt
220KV (Double)	18.5 Mt	25 Mt	25 Mt	4.5 Mt	4.5 Mt	28.5 Mt
400KV	15.6 Mt	22 Mt	22 Mt	7 Mt	>6 Mt	30 Mt

Standard Bay Widths in Meters:

Voltage	Bay Width (Meter)
11KV	4.7 Meter
33KV	4.7 Meter
66KV	7.6 Meter
132KV	12.2 Meter
220KV	17 Meter
400KV	27 Meter

Standard Bus and Equipment Elevation:

Voltage	Equipment live Terminal Elevation (Meter)	Main Bus		Take of Elevation (Meter)
		Low	High	
11 KV/33KV	2.8To 4	5.5 To6.5	9	6.5To8.5
66KV	2.8To 4	6To8	9To 10.5	9.5
132KV	3.7To5	8To9.5	13.5To14.5	12To12.5
220KV	4.9To5.5	9To13	18.5	15To18.5
400KV	8.0	15.5	-	23

Phase spacing for strung Bus:

Voltage	Clearance
11KV	1300 mm
33KV	1300 mm
66KV	2200 mm
132KV	3000 mm
220KV	4500 mm
400KV	7000 mm

Minimum Clearance of Live Parts from Ground:

Voltage	Minimum Clearance to Ground (Mt)	Section Clearance (Mt)
11KV	3.700	2.600
33KV	3.700	2.800
66KV	4.600	3.000
132KV	4.600	3.500

220KV	5.500	4.300
400KV	8.000	7.000

Insulator String:

Voltage	No of Suspension String	Length (mm)	No of Disc for Tension String	Length in (mm)
66KV	5	965	6	1070
132KV	9	1255	10	1820
220KV	14	1915	15	2915
400KV	23	3850	2 X 23	5450

Nominal Span:

Voltage	Normal Span (Meter)
66KV	240-250-275
132KV	315-325-335
220KV	315-325-335
400KV	315-325-335

Minimum Ground Clearance:

Voltage	Ground (Meter)
66KV	5.5
132KV	6.1
220KV	7.0
400KV	8.0
800KV	12.4

Indoor Substation Minimum Clearances:

Distance	Descriptions
0.9 Meter	Horizontally between any item of equipment and the substation wall
0.6 Meter	Horizontally between any Two items of equipment
1.2 Meter	Horizontally in front of any HV switchgear

Clearance of Conductor on Tower:

Voltage	Tower Type	Vertical Space (Mt)	Horizontal Space(Mt)	Total Height From Ground(Mt)
66KV	A	1.03	4.0	15.91
	B	1.03	4.27	15.42
	C	1.22	4.88	16.24
132KV	A	7.140	2.17	23.14
	B	4.2	6.29	22.06
	C	4.2	7.15	22.68
	D	4.2	8.8	24.06
220KV	A	5.2	8.5	28.55
	B	5.25	10.5	29.08
	C	6.7	12.6	31.68

Norms of Protection for EHV Class Power Transformers:

Voltage ratio & capacity	HV Side	LV Side	Common relays
132/33/11KV up to 8 MVA	3 O/L relays + 1 E/L relay	2 O/L relays + 1 E/L relay	Buchholz, OLTC Buchholz, OT, WT
132/33/11KV above 8 MVA and below 31.5 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Buchholz, OLTC Buchholz, OT, WT
132/33KV, 31.5 MVA &above	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Over flux, Buchholz, OLTC PRV, OT, WT
220/33 KV, 31.5MVA & 50MVA 220/132KV, 100 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 dir. relay	Differential, Over flux, Buchholz, OLTC PRV, OT, WT
400/220KV 315MVA	3 directional O/L relays (with dir. High set) +1 directional E/L relays. Restricted E/F relay + 3 Directional O/L relays for action	3 directional O/L relays (with dir. High set)+1 directional E/L relays. Restricted E/F relay	Differential, Over flux, Buchholz, OLTC PRV, OT, WT and overload (alarm) relay

The bottom most portion of any insulator or bushing in service should be at a minimum height of 2500 mm above ground level.

Location of L.A (From T.C Bushing):

Voltage	BIL KV Peak	Distance (Mt)
11KV	75	12
33KV	200	15
66KV	325	24
132KV	550	35
220KV	900 To 1050	Close To T.C
400KV	1425 To 1550	

Lighting Arrestor Rating:

Rated Voltage	Highest Voltage	L.A Rating
132kv	145kv	120kv To 132kv
220kv	245kv	198kv To 216kv
400kv	420kv	336kv

Location of Lighting Arrestor:

Rated Voltage	Max Distance from Equipment
132kv	35 meter To 45 meter
220kv	Closed To Transformer
400kv	Closed To Transformer

Size of Corona Ring:

Rated Voltage	Size of Corona Ring
Less than 170 KV	160mm Ring Put on HV end
170KV To 275KV	350mm Ring Put on HV end
More than 275KV	450mm Ring Put on HV end
More than 275KV	350mm Ring Put on HV end

Capacity of Sub Station as per GERC:

Size of S/S	Electrical Load
66 KV	80 MVA
132 KV	150 MVA
220 KV	320 MVA
400 KV	1000 MVA

Breaking / Short Circuit Capacity of Sub Station:

Size of S/S	Short Circuit Current
66 KV	25 KAmp for 1 or 3 sec
132 KV	31.5 KAmp for 1 or 3 sec
220 KV	40 KAmp for 1 or 3 sec
400 KV	40 KAmp for 1 or 3 sec

Fault Clear Time:

Size of S/S	Fault Clear Time
66 KV	300 mili Sec
132 KV	160 mili Sec
220 KV	120 mili Sec
400 KV	100 mili Sec

Normal Type of Conductors:

Voltage	Main Bus	Auxiliary Bus
11KV	Twin ACSR Zebra	ACSR Zebra
33KV	ACSR Zebra	ACSR Zebra
132KV	ACSR Zebra	ACSR Panthers
220KV	Twin ACSR Zebra	ACSR Zebra
400KV	1/14.2 mm Dia Alu Pipe	Twin ACSR Moose

Number of Disc Insulator:		
System	**Number**	**Strength (KN)**
11KV	4	120KN
33KV	4	120KN
132KV	10	120KN
220KV	14	70KN
220KV (Anti Fog)	2 X 15	120KN
400KV (Anti Fog)	2 X 25	120KN

Minimum Clearance:			
Voltage	**Phase to Earth Wire**	**Phase to Phase**	**Section Clearance**
2.2KV	28cm	33cm	27.45cm
33KV	380cm	43cm	27.7cm
132KV	107cm	12cm	25cm
220KV	178cm	20.6cm	42.8cm
400KV	350cm	40cm	65cm

Ground Clearance:	
Voltage	**Meter**
33KV	3.7meter
66 KV	6.1meter
132 KV	6.1meter
220 KV	7.0meter
400 KV	8.8meter

Conductor Spacing:						
Voltage	**Highest Voltage**	**Lighting Impulse Level (Kvp)**	**Min Clearance**		**Ground Clearance**	**Safety working Clearance**
			Phase to Earth	**Phase to Phase**		
11KV	12kv	70	178mm	229mm	3700mm	2600mm
33KV	36kv	170	320mm	320mm	3700mm	2800mm
132 KV	145kv	550	1300mm	1300mm	4600mm	3700mm
220 KV	245kv	950	2100mm	2100mm	5500mm	4300mm
400 KV	420kv	1425	3400mm	4200mm	8000mm	6400mm

Bus bar Materials:	
Description	**Bus Bar and Jumper Material**
400 kV Main Bus	114.2 mm dia. Aluminum pipe
400 kV equipment interconnection	114.2 mm dia. Aluminum pipe
400 kV overhead bus & droppers in all bays.	Twin ACSR Moose
220 kV Main Bus	Quadruple / Twin ACSR Zebra / Twin AAC
220 kV Auxiliary Bus	ACSR Zebra
220 kV equipment interconnection	Twin ACSR Zebra / Single ACSR Zebra
220 kV overhead bus & droppers in all bays.	Twin ACSR Zebra / Single ACSR Zebra
132 kV Main Bus	ACSR Zebra
132 kV Auxiliary Bus	ACSR Panther
132 kV equipment interconnection	ACSR Zebra / ACSR Panther
132 kV overhead bus & droppers in all bays.	ACSR Panther
33 kV Main Bus	ACSR Zebra
33 kV Auxiliary Bus	ACSR Zebra
33 kV equipment interconnection, overhead bus and droppers:	
(i) Bus coupler & transformer bay	ACSR Zebra
(ii) Feeder bay.	ACSR Panther
11 kV Main Bus	Twin ACSR Zebra
11 kV Auxiliary Bus	ACSR Zebra
11 kV equipment interconnection, overhead bus and droppers:	
(i) Transformer bay	Twin ACSR Zebra / Single ACSR Zebra
(ii) Bus coupler	ACSR Zebra

Chapter: 34 Typical Value of Sub Station Equipments

Transformer / Reactor:

No	Equipment / test data	Permissible limits	Reference
A)	Transformer oil		
	a) BDV		
	-At the time of first charging	600 kV (Gap – 2.5 mm) – Minimum	IS – 1866
	-During O&M	50 kV (Gap – 2.5 mm) – Minimum	IS – 1867
	b) Moisture content		IS – 1868
	-At the time of first charging	15 PPM (Max.)	IS – 1869
	-During O&M	25 PPM (Max.)	IS – 1870
	c) Resistivity at 90 degree C	0.1-1012 Ohm-CM (Min.)	IS – 1871
	d) Acidity	0.2 mg KOH/gm (Max.)	IS – 1872
	e) IFT at 27 degree C	0.018 N/M (Min.)	IS – 1873
	f) Tan delta at 90 degree C	0.20 (Max.)	IS – 1874
	g) Flash point	126 Deg. C (Min.)	IS – 1875
B)	Vibration level for reactors	200 Microns (Peak to Peak)	IS – 1876
		60 Microns (Average)	IS – 1877
C)	Tan delta for bushing at 20 Deg. C	0.007*	IEC – 137
D)	Capacitance for bushing	+ 5% variation	IEC – 138
E)	IR value for winding	1000 M-Ohm By 5.0/10.0 kV Megger	IEC – 139
F)	Tan delta for windings at 20 Deg. C	0.007*	IEEE/C57.12.90.1980
G)	Contact resistance of bushing terminal connectors	10 M. Ohm / Connector	NGC.UK Recommendations
H)	Turret Neutral CT ratio errors	39	IS – 2705

Circuit Breakers

No	Equipment / test data	Permissible limits	Reference
A)	Dew point of SF6 gas	Dew point values as per Annexure – II	
B)	Dew point of operating air	-45 Deg. C at ATM. Pressure	
C)	CB Operating timings	400 kV 220KV	
	a) Closing time (Max.)	150 MS 200MS	
	b) Trip time (Max.)	25 MS 35MS	
	c) Close/trip time, Pole discrepancy		
	– Phase to Phase (Max.)	3.33 MS 3.33MS	
	-Break to break (Max.) of same phase	2.5 MS 2.5MS	
D)	PIR time		
	BHEL make	12-16 MS	Mfgs. Recomm
	ABB make	8-12 MS	Mfgs. Recomm
	NGEF make	8-12 MS	Mfgs. Recomm
	M&G make	8-12 MS	Mfgs. Recomm
	TELK make	8-12 MS	Mfgs. Recomm
	ABB make (HVDC)	8-12 MS	Mfgs. Recomm
E)	PIR opening time prior to opening of main contacts (ABB, CGL, NGEF make CBs)	5 MS (Min.) at rated pressure	Mfgs. Recomm
F)	Pir and main contacts overlap time [BHEL, M&G, ABB (imported) make CBs]	6 MS (Min.) at rated pressure	Mfgs. Recomm
G)	Tan delta of grading capacitors	0.007 at 20 Deg. C	
H)	Capacitance of grading capacitors	Within + 10% / -5% of the rated value	IEC 359
I)	Contact resistance of CB	150 M. Ohm	
J)	Contact resistance of CB terminal connector	10 M. Ohm per connector	UK Recomm
K)	IR value:		
	1. Phase – earth	1000 MOhm (Min.) by 5.0 / 10.0 kV Megger	
	2. Across open contacts	1000 MOhm (Min.) by 5.0/10.0 kV Megger	
	3. Control cables	50 MOhm (Min.) by 0.5 kV Megger	

L)	Pressure switch settings		
	-SF6 gas pressure switches	Within + 0.1 Bar of set value	
	-Operating air pr. Switches	Within + 0.1 Bar of set value	
	-Operating oil pr. Switches	Within + 0.1 Bar of set value	
M)	BDV of oil used for MOCB		
	-At the time of filling	40 kV at 2.5 mm Gap (Min.)	Mfgs. Recomm
	-During O&M	20 kV at 2.5 mm Gap. (Min.)	Mfgs. Recomm

Current Transformer

No	Equipment / test data	Permissible limits	Reference
A)	IR value		
	1. Primary – earth	1000 M – Ohm (Min.) by 5.0/10.0 kV Megger	
	2. Secondary – earth	50 M – Ohm (Min.) by 0.5 kV Megger	
	3. Control cables	50 M-Ohm (Min.) by 0.5 kV Megger	
B)	Tan delta value	0.007* at 20 Deg. C	
C)	Terminal Connector	10 M-Ohm per connector	NGC,UK Recommend
D)	CT ratio errors	+ 3% -Protection cores	IS – 2705
D)	CT ratio errors	+ 1% -Metering cores	IS – 2706

Capacitive Voltage

No	Equipment / test data	Permissible limits	Reference
A)	Tan Delta	0.007* at 20 Deg. C	
B)	Capacitance	Within +10%/-5% of the rated value	IEC – 358
C	Contact resistance of terminal connector	10 M-Ohm per connector	NGC, UK Recommendations
D)	IR Value	IR Value	
	1. Primary – earth	1000 M – Ohm (Min.) by 5.0/10.0 kV Megger	
	2. Secondary – earth	50 M – Ohm (Min.) by 0.5 kV Megger	
	3. Control cables	50 M-Ohm (Min.) by 0.5 kV Megger	
E)	EMU tank oil parameters	EMU tank oil parameters	
	a) BDV (Min.)	30 kV (Gap. –2.5 mm)	IS – 1866
	b) Moisture content (Max.)	35 ppm	-do-
	c) Resistivity at 90 Deg. C	0.1 – 1012 Ohm. – CM	-do-
	d) Acidity	0.5 mg kOH /gm (Max.)	-do-
	e) IFT at 27 Deg. C	0.018 N/M (Min.)	-do-
	f) Tan delta at 90 Deg. C	1.0 Max.	-do-
	g) Flash point	125 Deg. C (Min.)	-do-
F)	CVT voltage ratio errors	+ 5% protection cores	IEEE/C93.1.1990
F)	CVT voltage ratio errors	+ 0.5% metering cores	IEC 186

Isolators

No	Equipment / test data	Permissible limits	Reference
A)	Contact resistance	300 MΩ. (Max.)	
B)	Contact resistance of terminal connector	10 MΩ per connector	UK Recommendations
C)	IR value		
	1. Phase – earth	1000 MΩ (Min.) by 5.0/10.0 kV Megger	UK Recommendations
	2. Across open contacts	1000 MΩ (Min.) by 5.0/10.0 kV Megger	UK Recommendations
	3. Control cables	50 MΩ (Min.) by 0.5 kV Megger	

Surge Arrester

No	Equipment / test data	Permissible limits	Reference
A)	Leakage current	500 M-Amp. (Resistive)	Hitachi, Japan Recom.
B)	IR value	1000 MΩ (Min.)	Hitachi, Japan Recom.

Miscellaneous

No.	Equipment / test data	Permissible limits	Reference
A)	Station earth resistance	1.0 Ohm (Max.)	
B)	Thermo vision scanning		

	Temp. up to 15 Deg. C (above ambient)	Normal	
	Temp. above 15-50 Deg. C (above ambient)	Alert	
	Temp. above 50 Deg. C (above ambient)	To be immediately attended	
C)	Terminal connectors – Contact resistance	10 M-Ohm per connector	HGC, UK Recommendations
D)	IR values		
	1. All electrical motors	50 M-Ohm (Min.) by 0.5 kV Megger	
	2. Control cables	50 M-Ohm (Min) by 0.5 kV Megger	
	3. Lt. Transformers	100 M.-Ohm (Min.) by Megger	
	4. Lt. Switchgears	100 M – Ohm (Min.) by 0.5 kV Megger	

Batteries

No.	Equipment / test data	Permissible limits	Reference
A)	Terminal connector resistance	10 M – Ohm + 20%	ANSI/IEEE – 450 1989
B)	Specific gravity	1200 + 5 GM/L at 27 Deg. C	

Temperature Correction Factor for Tan Delta Measurement

Sr. No.	Oil temperature Deg. C	Correction factor(K)
1	10	0.8
2	15	0.9
3	20	1.0
4	25	1.12
5	30	1.25
6	35	1.40
7	40	1.55
8	45	1.75
9	50	1.95
10	55	2.18
11	60	2.42
12	65	2.70
13	70	3.00

If Tan Delta of bushing/winding/CVT/CT is measured at oil temperature T Deg. C. Then Tan Delta at 20 Deg. C shall be as given below

Tan Delta at 20 Deg. C = Tan Delta at Temp T Deg. C / Factor K

Dew Point Limits for SF6 Gas in EHV Circuit Breakers

No	Make of C.B	Dew point at rated Pr. Deg. C	Corresponding dew point at Atmospheric Press	Remarks
1	BHEL	-15	-36	At the time of commissioning
		-7	-29	During O&M
		-5	-27	Critical
2	M&G	--	-39	At the time of commissioning
			-32	During O&M
3	CGL	-15	-35	At the time of commissioning
		-10	-31	During O&M
4	ABB	-15	-35	At the time of commissioning
		-5	-26	During O&M
5	NGEF	-15	-36	At the time of commissioning
		-7	-29	During O&M

Note: Dew point of SF6 gas varies with pressure at which measurement is carried out. So it is to be ensured that if measurement is done at pressure other than atmospheric pressure, it needs to be converted to the atmospheric pressure.

Chapter: 35 Minimum Specification of CT Metering

Particular	11 kV	33 kV	132 kV	220 kV
Highest System Voltage (kV rms)	12	36	145	245
CT ratio.	2000-1000/1-1	800-400/1-1	400/1-1	800/1-1
	1600-800/1-1	600-300/1-1		
	1200-600/1-1	400-200/1-1		
	800-400/1-1	300-150/1-1		
	600-300/1-1	100-50/1-1		
	400-200/1-1			
	300-150/1-1			
Number of metering cores	Two Nos	Two Nos	Two Nos	Two Nos
Rated continuous thermal current.	120% of rated primary current	120% of rated primary current	120% of rated primary current	120% of rated primary current
Rated short time thermal current of primary for 1 sec. (kA)	25	25	31.5	40
CT characteristics : a) Rated primary current (Amps.)	2000-1000	800-400	400	800
	1600-800	600-300		
	1200-600	400-200		
	800-400	300-150		
	600-300	100-50		
(b) Rated Secondary current (Amps.)	1	1	1	1
(c) Class of accuracy.	0.2	0.2	0.2	0.2
(d) Max. instrument security factor	5	5	5	5
(e) Rated burden (VA).	30	30	30	40

Minimum Acceptable Specification of Voltage Transformer for Metering:

No	Particulars	245 kV CVTs	145 kV CVTs
1	Highest System Voltage (kV)	245 kV	145 kV
2	Rated Capacitance (pF)	4400 pf with tolerance + 10% and – 5%	
3	For low voltage terminal over entire carrier frequency range.		
	(a) Stray capacitance	Shall not exceed 200 pf	
	(b) Stray conductance	Shall not exceed 20 us	
4	(a) High frequency capacitance for entire carrier frequency	within 80% to 150% of rated capacitance	
	(b) Equivalent series resistance over the entire frequency	less than 40 Ohms	
5	No. of secondary windings for potential device.	Two	Two
6	Transformation ratio:		
	(i) Winding –I & Winding –II	20 kV- \/3/110 -\/3V	
7	Rated secondary burden		
	(i)Winding –I (VA) & Winding –II (VA)	50 VA	50 VA
8	Accuracy Class :		
	(i)Winding –I (VA) & Winding –II (VA)	0.2 for metering	
9	Voltage factor for winding – I & II	1.2 Cont. & 1.5 for 30 secs.	
10	IS to which CVTs conform.	IS 3156 with latest amendment	
11	IS to which Insulating Oil conform.	IS 335 with latest amendment	

Minimum Acceptable Specification of Single Phase Voltage Transformer for Metering

No	Particulars	33 kV	11 kV
1	Highest System Voltage (kV rms)	36	12
2	Transformation ratio.	33kV/ V3/ 110/ V3	11 kV/110 V
3	Number of windings.	Two	Two
4	Rated output/ burden (VA) per winding /phase.	50	50
5	Accuracy class. (At 10 to 100% of VA burden)	0.2	0.2
6	Rated voltage factor and duration.	1.2 continuous & 1.5 for 30 secs.	
7	IS to which PT conforms.	3156 with latest amendment	

HV Line- IS: 5613	
Overhead Line	Pole Foundation hole should be drilled in the ground with the use of earth-augers. However, if earth-augers are not available a dog pit of the size I.2 x O.6 m should be made in the direction of the line. The depth of the pit shall be in accordance-with the length of the pole to be planted in the ground as given in respective Indian Standards.
Tublar Pole	Steel Tubular Poles, Rolled Steel Joists and Rails - A suitable pad of cement concrete, stone or steel shall be provided at the bottom of the pit, before the metallic pole is erected. Where metal works are likely to get corroded (points where the pole emerges out of the ground), a cement concrete muff, 20 cm above and 20 cm below the ground with sloping top shall be provided.
RCC Pole	RCC poles generally have larger cross-section than the PCC poles and, therefore, the base plates or muffing are usually not provided for these types of poles. However, for PCC poles, a base plate (40 x 40 x 7 cm concrete block) shall be provided. Cement concrete muff with sloping top may also be provided, 20 cm above and 20 cm below-the ground level, when the ground or local conditions call for the same.
H.V Line (120m To 160m Span)	The insulators should be attached to the poles directly with the help of 'D' type or other suitable clamps in case of vertical configuration of conductors or be attached to the cross arms with the help of pins in case of horizontal configuration.
H.V Line (120m To 160m Span)	Pin insulator and recommended for use on straight runs and up to maximum of 10' deviation.
H.V Line (120m To 160m Span)	The disc insulators are intended for use a pole positions having more than 30' angle or for dead ending of I1 kV lines.
H.V Line (120m To 160m Span)	For lines having=A bend of 10" to 30', either double cross arms or disc insulators should be used for HT lines up to 11 kV. For low and medium voltage line, shackle insulators should be used
H.V Line (120m To 160m Span)	**For Vertical configuration for Conductor erection:** Distance between Pole's Top to Disc insulation=200mm. Between Disc insulator to Disc Insulator=1000mm. Between Disc insulator to Guy Wire=500mm.
Stay Wire Angle with Pole	Overhead lines supports at angles and terminal positions should be well stayed with stay wire, rod, etc. The angle between the pole and the wire should be about 45" and in no case should be less than 30". If the site conditions are such that an angle or more than 30" between the pole and the stay wire cannot be obtained, special stays such as, foot stay, flying stay or struts may be used
Stay Wire	Hard drawn galvanized steel wires should be used as stay wires. The tensile strength of these wires shall not be less than 70 kgf/mm2. Only standard wires should be used for staying purpose.
Stay Rod	Mild steel rods should be used for stay rods. The tensile strength of these rods shall not be less than 42 kgf/mm2
Stay Anchor	Stays should be anchored either by providing base plates of suitable dimensions or by providing angle iron or rail anchors of suitable dimensions and lengths.
Guy Insulator	Stay wires and rods should be connected to the pole with a porcelain guy insulator. Wooden insulators should not be used. Suitable clamps should be used to coMeCt stay wires and rods to its anchor. For low and -medium voltage lines a porcelain guy insulator should be inserted in the stay wire at a height of 3 m vertically above the ground level. For high voltage lines, however, the stays may be directly anchored.
Stay Setting	The inclination of stay relative to the ground is roughly determined before making the hole for excavation. This enables the position of the stay hole to be fixed so -that when the stay is set, the stay rod will have the correct inclination and will come out of the ground at the correct distance from the pole. The stay rods should be securely fixed to the ground by means of a suitable anchor
O/H Conductor Drum	In loading, transportation and unloading conductor drums should be protected against injury. The conductor drums should never be dropped and may be Tolled only as indicated by the arrow on the drum side. The drums should be

	distributed along the route at distance approximately equal to the length of the conductor wound on the drum.
Binding of O/H Conductor	The insulators should be bound with the line conductors with the help of copper binding wire in case of copper conductors, galvanized iron binding wire for galvanized iron conductors and aluminum binding wire or tape for aluminum and steelinforced aluminum conductors (ACSR). The size of the binding wire shall not be 'less than 2 mm"
Different Voltage on Same Support	Where conductors forming parts of systems at different voltages are erected on the same supports. Adequate clearance and guarding shall be provided to guard against the danger to lineman and others from the lower voltage system being charged above its normal working voltage by leakage from or contact with the higher voltage system. The clearance between the bottom most conductor of the system placed at the top and the top most conductor of the other system should not be less than 1.2m.
Jumper	Jumpers from dead end points on one side of the pole to the dead end side on the other wide of the pole should be made with conductor of same material and current carrying capacity as that of the line conductor. The jumpers should be tied with the line conductor with a suitable clamp. If the material of the jumper wire is different from that of the line conductor, suitable bimetallic clamps should be used. If copper and aluminium bimetallic clamps are to be used, it should be ensured that the aluminium conductor is situated above the copper conductor so that no copper contaminated water comes in contact with aluminium.
Jumper Clearance	For high voltage lines the jumpers should be so arranged that there is minimum clearance of 0.3 m under maximum deflection condition due to wind between the live jumpers and other metallic parts. This may involve erection of insulators and dead weights specially for fixing the jumpers.
Binding of O/H Line	Length of Binding wire on Insulator (From outer surface if Insulator to end of binding wire) should be **6D**(Where D=Diameter of O/H Conductor)
O/H Patrolling	All overhead lines should be patrolled periodically at intervals not exceeding 3 months from the ground when the line is live.
Pole Earthing	All metal poles including reinforced cement concrete and pre-stressed cement concrete poles shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected with earth ordinarily at 3 points in every kilometre, the spacing between the points being as nearly equidistant as possible. Alternatively each pole, and metallic fitting attached thereto shall be efficiently earthed.
Stay wire Earthing	All stay wires of low and medium voltage lines other than those which are connected with earth by means of a continuous earth wire shall have an insulator inserted at a height of not less than 3 m from the ground.
Earthing Wire Size	The cross-sectional area of the earth conductor Sims not be less than 16 mm2 if of copper, and 25 mm2 if of galvanized iron or steel.
Conductor Clearance	Fixing Cross Arm in Low and Medium Voltage in Horizontal Configuration:
P-P-N Clearance	**Up to 650V Horizontal "V" Shape Cross arm(P-P(Street Light)-Neutral):** Phase to Neutral=750mm , Phase to Phase(Streetlight at Top of Pole)=325mm,Last Phase-Cross Arm end=80mm
P-P-N Clearance	**650V to 11KV Horizontal Cross arm(P-P(Street Light)-N) :** Phase-Phase=300mm,Phase-Phase(Street Ltg)=300mm, Phase-Neutral=300mm,Last Phase-Cross Arm end=80mm
P-P-N Clearance	**Low and Medium Voltage Line (Horizontal Configuration):** Less than 75cm Sag =P-P 30cm 76cm To 120cm Sag =P-P 45cm 121cm To 145cm Sag =P-P 60cm
P-P-N Clearance	**Low and Medium Voltage Line (Vertical Configuration):** Less than 70m Sag =P-P 20cm 71m To 100m Sag =P-P 30cm
P-P-N Clearance	**High Voltage Line (Horizontal Configuration):** Up to 120m Sag =Phase to Phase= 40cm 140m To 225m Sag =Phase to Phase= 65cm
P-P-N Clearance	Double Circuit on Same Pole at different level : Distance between Two Circuit is 120cm.
O/H Conductor	Choice of Conductors: The physical and electrical properties of different conductors shall be in accordance with relevant Indian Standards. All

	conductors shall have a breaking strength of not less than 350 kg. However, for low voltage lines with spans less than 15 m and installed either on owner's or consumer's premises, conductors with breaking strength of not less than 140 kg may be used.
Voltage Variation	In accordance with the Indian Electricity Rules voltage variation for low voltage lines should not be more than ± 6 percent and for high voltage lines should not be more than ± 6 percent to ± 9 percent
Span (Up to 11KV)	Recommended Span Lengths: The recommended span lengths for lines up to 11 kV are 45, 60, 65, 75, 90, 105 and 120 meters
Span (Up to 11KV)	There are no fixed rules for spacing arrangement of overhead line conductors. However, the following formula gives an economical spacing of conductors: **D=500+18U+(L*L/50)** Where D=Spacing between conductor(mm), U=Voltage(p-p in kv),L=Span in meter
Clearance(Up to 11KV)	Min height of any conductor of an overhead line across any street (Low Medium Voltage)=5.8m
Clearance(Up to 11KV)	Min height of any conductor of an overhead line across any street (High Voltage)=6.1m
Clearance(Up to 11KV)	Minimum height of any conductor of an overhead line along any street(Low &Medium Voltage)=5.5m
Clearance(Up to 11KV)	Minimum height of any conductor of an overhead line along any street(High Voltage)=5.8m
Clearance(Up to 11KV)	Minimum height of any conductor (bare) of an overhead line erected elsewhere(Low &Medium Voltage)=4.6m
Clearance(Up to 11KV)	Minimum height of any conductor (bare) of an overhead line erected elsewhere(High Voltage)=4.6m
Clearance(Up to 11KV)	Minimum height of any conductor (insulated) of an overhead line erected elsewhere(Low &Medium Voltage)=4.0m
Clearance(Up to 11KV)	Minimum height of any conductor (insulated) of an overhead line erected elsewhere(High Voltage)=4.0m
Clearance(Up to 11KV)	Minimum clearance of overhead line conductor from buildings(Low & Medium Voltage)=2.5m
Clearance(Up to 11KV)	Minimum clearance of overhead line conductor from buildings(High Voltage)=3.7m
Span(11KV To 220KV)	**System Voltage** — **Number Of Circuit** — **Span (Meter)** 33KV (over Pole) — Single — 90 To 135 Meter 33KV — Single — 180 To 305 Meter 33KV — Double — 180 To 305 Meter 66KV — Single — 204 To 305 Meter 66KV — Double — 240 To 320 Meter 220KV — Single — 320 To 380 Meter 220KV — Double — 320 To 380 Meter
Danger Plate(11KV To 220KV)	Danger and number plates are located on Face (Feeding End (S/S))of pole
Anti Climbing Device(11KV To 220KV)	Leg 1 (Right End Leg (Feeding End (S/S)) represents the leg with step bolts and anti-climb device gate if any. If two legs with step bolts are required, the next is No. 3 leg (Dignotical opposite of Leg1)
Clearance(11KV To 220KV)	**Voltage** — **Circuit** — **P-P Vertical** — **P-P Horizontal** 33KV (over Pole) — Single — 1.5 Meter — 1.5 Meter 33KV — Single/Double — 1.5 Meter — 1.5 Meter 66KV — Single/Double — 2.0 Meter — 3.5 Meter 110KV — Single/Double — 3.2 Meter — 5.5 Meter 220KV — Single/Double — 4.9 Meter — 8.4 Meter
Clearance(11KV To 220KV)	In case triangular formation has to be adopted, the conductor lying below an upper one shall be staggered out by a distance of **X=V/150** Where V=System Voltage, X=staggered distance in meters
Clearance(11KV To 220KV)	The earth wire sag shall be not more than 90 percent of the corresponding sag of power conductor under still air conditions for the entire specified temperature range
Clearance(11KV To 220KV)	**Line Voltage(KV)** — **Spacing between P-E (m)** 33KV — 1.5meter 66KV — 3.0meter 110KV — 4.5meter 132KV — 6.1meter

	220KV 8.5meter
Earthing (11KV To 220KV)	All metal supports and all reinforced and prestressed cement concrete supports of overhead lines and metallic fittings attached thereto, shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected with earth ordinarily at 3 points in every kilometer, the spacing between the points being as nearly equidistant as possible. Alternatively, each support and metallic fittings attached thereto shall be efficiently earthed.
Earthing(11KV To 220KV)	Each stay-wire shall be similarly earthed unless an insulator has been placed in it at a height not less than 3.0 meters from the ground
Tower Height (up to 400KV)	The transmission lines and transmission line structures of height 45 m and above shall be notified to the Directorate of Flight Safety (DFS), Air Headquarters (Air HQ), New Delhi.
Tower Height (up to 400KV)	For construction of any transmission line/structure or a portion thereof, falling within a radius of 20 km around the Defence aerodromes and air to firing ranges provisions of the Aircraft Act 1934, Section 9A as amplified by the associated Gazette Notification SO 988 Part II, Section 3,
Tower Height (up to 400KV)	Within a radius of 10 km around aerodromes and air to ground firing ranges, all transmission lines and structures of height 45 meters or more shall be provided with day and night visual aids.
Line Marker (up to 400KV)	Line Markers :Colored globules of 40-50 cm diameter made of reinforced fibber glass or any other suitable material, weighing not more than 4.5 kg each with suitable clamping arrangement and drainage holes shall be installed on the earth wire(s) in such a manner that the top of the marker is not below the level of the earth wire. Up to 400-metre span, one globule shall be provided in the middle of the span on the highest earth wire. In case of double earth wires, the globule may be provided on any one of them. For span greater than 400-metres, one additional globule may be provided for every additional 200-metre span or part thereof. Half orange and half white colored globule should be used.
Structure Marking (up to 400KV)	Structure Marking: The structure portion excluding cross-arms above 45 m height shall be painted in alternate bands of international orange and white colours. The bands shall be perpendicular to the vertical axis and the top and bottom bands shall be orange. There shall be an odd number of bands. The maximum height of each band shall be 5 m.
Span(up to 400KV)	Minimum ground clearance from lowest point of power conductor shall be 8 840 mm.
Span(up to 400KV)	Minimum mid-span vertical clearance between power conductor and ground wire in still air at normal design span shall be 9 000 mm.
Clearance (up to 400KV)	Vertical clearances above Railway Track : 220KV To 400KV =19.3 Meter
Shield Angle (400KV)	**For 440KV :**Shielding Angle= 20°
Clearance (400KV)	**For 440KV :**Maximum Length of Suqeusion Strings from Shackle Attachment at Hanger to Centre Line of Conductor =3 850 mm
Clearance (400KV)	**For 440KV :**Maximum Length of Tension Strings from Tower Attachment to Compression Dead-End Attachment=5600mm
Clearance (400KV)	**For 440KV :**Minimum Ground Clearance from Lowest Point of Power Conductor=8400mm
Clearance (400KV)	**For 440KV :**Minimum Mid-Span Vertical Clearance Between Power Conductor end Ground Wire in Stilt Air=9000mm
Clearance (400KV)	**For 440KV :**Right-of-way and transport requirements of maintenance, the following right-of-way width for 400 kV lines are recommended: Single/Double Circuit=50meter
Clearance (400KV)	For 400KV Road Crossing: At all important crossings, the towers shall be fitted with normal suspension or tension insulator strings depending on the type of towers but the ground clearance at the roads under maximum temperature and in still air shall be such that even with conductor bundle broken in adjacent span, the ground clearance of the conductor from the road surface shall not be less than 8.84 meters. At all national highways tension towers shall be used. The crossing span, however, shall not exceed 25 meters in any case.

Electrical Pole- IS: 1678			
PCC Pole	**Class of Pole**	**Length of Pole**	**Min Ultimate Transverse Load**

	Class 1	17 Meter	3000 Kg
	Class 2	17 Meter	2300 Kg
	Class 3	17 Meter	1800 Kg
	Class 4	17 Meter	1400 Kg
	Class 5	16 Meter	1100 Kg
	Class 6	12.5 Meter	1000 Kg
	Class 7	12 Meter	800 Kg
	Class 8	12 Meter	700 Kg
	Class 9	11Meter	450 Kg
	Class 10	9 Meter	300 Kg
	Class 11	7.5Meter	200 Kg
PCC Pole Tolerance	Tolerance: The tolerance of overall length of the poles shall be + 15 mm.		
	The tolerance on cross-sectional dimensions shall be + 3 mm.		
	The tolerance on cross-sectional dimensions shall be + 3 mm.		
	The tolerance on uprightness of the pole shall be 0.5 per cent		
PCC Pole depth in Ground:	**Length of Pole**		**Min depth in ground**
	6 Meter To 7.5 Meter		1.2 Meter
	8 Meter To 9 Meter		1.5 Meter
	9.5 Meter To 11 Meter		1.8 Meter
	11.5 Meter To 13 Meter		2.0 Meter
	13.5 Meter To 14.5 Meter		2.2 Meter
	15 Meter To 16.5 Meter		2.3 Meter
	17 Meter		2.4 Meter

Porcelain Insulator- IS:1445		
Porcelain Insulator	Type A	An insulator unit in which the lengths of the shortest puncture patch through solid insulating material is at least equal to half the length of the shortest flash over path through air outside the insulator
	Type B	An insulator or an insulator unit in which the length of the shortest puncture patch through solid insulating material is less than half the length of the shortest flash over path through air outside the insulator.

Overhead Line (As per CPWD)			
Steel Tubular Pole	1/6 length of Steel Tubular Pole + 30 cm from base shall be coated with Black Bituminous paint on both internally and externally. The remaining portion of the pole shall be painted with Red oxide.		
Cross arm	LV/MV Line:MS angle iron of size not less than 50mmX50mmX6mm(4.5kg/meter)		
	11KV Line: MS angle iron of size not less than 65mmX65mmX6mm(5kg/meter)		
	LV/MV Line:MS Chanel iron size not less than 75mmX40mmX4.8mm (7.14kg/meter)		
	11KV Line: MS Chanel iron size not less than 75mm X40mmX4.8mm (7.14kg/meter)		
	LV/MV Line: Min distance shall be 5cm between centre of insulation pin and end of cross arm.		
	11KV Line: Min distance shall be 10cm between center of insulation pin and end of cross arm.		
Cross arm Length	**Voltage**	**No of Horizontal Conductor**	**Length of Cross Arm**
	LV/MV	2 Conductors	55cm
	LV/MV	4 Conductors	115cm
	LV/MV	4 Conductors Guard	175cm
	11KV	3 Conductors	225cm
Struts	The Pit for Struts shall be located not less than 1.8meter from pole side. The depth of Pit shall be at least 1.2meter		
Danger board	All Support carrying HV Line shall be fitted with Danger Board(IS:2551) at height of 3meter.		
Anti Climbing Device	For HV Line(IS:278-1978) having 4Point Barbs 75mm+12mm apart weight 128/125 gm/meter shall be wrapped helically with pitch of 75mm around Limb of Pole height of 3.5meter to 5 to 6 meter.		

Insulator	For LV/MV Overhead Line: Pin/Shackle Insulator and For 11KV Line Pin/Disc Insulator
	For Pin Insulator for LV/MV line: Stalk Length 135mm Shank Length 125 mm , min Load 2KN.
	For Pin Insulator for 11KV line:Stalk Length 165mm Shank Length 150 mm ,min Load 2KN.
D Clamp	D clamp shall be made of MS Flat size of 50mmX6mm,height of 75mm Galvanized and only used for vertical configuration for LV/MV Line only.
Pole Top Clamp	Pole Top clamp made from Flat iron 50mmX8mm.
Stay wire Rod	Stay wire Rod shall not be less than 1.8 m Long and 19mm Dia.Ankor Plate shall not be less than 45mmX45mmX7.5mm.
Overhead Conductor (min)	For LV Line : AAC(All Alu.Cond) 7/1/2.21mm, ACSR 6/1/1/2.11mm, AAAC(All Alu.Alloy Cond) 7/2.09mm(20Sqmm)
	For 11KV/33KV Line : AAC(All Alu.Cond) N/A, ACSR 6/1/1/2.11mm, AAAC(All Alu.Alloy Cond) 7/2.56mm(30Sqmm)
Binding Wire	Binding Wire with insulator shall be with 2.6mm(12SWG) soft aluminum wire.
Earthing in Overhead Line	Earthing wire shall not be less than 4mm(8SWG) and min 3 earthling Pit per KM shall be required.
	If there is no Continuous wire for earthling in overhead line than each pole should be earthed.

D.P STRUCTURE- (IE RULES)
Only one connection with earth has been provided for the frame of A B switch. One more Separate and Distinct connection with earth should be provided for frame of the A B switch.
Only one connection with earth has been providing for the frame of the H G fuse. One more Separate and distinct connection with earth should be provided for the frame of HG fuse.
Metal cover of the transformer (top cover) on which the HV and or LV bushing are Housed should be Looped to earth to avoid any fault current passing through fastening bolts
The earthling lead of the HV lighting arrester is not kept separate but it mixed with other Connections. The earthling lead from the HV lighting arrester should not be used for earthling Any other gear and should be taken to a separate electrodes
The GI pipe enclosing the MV circuits on the secondary side of the transformer are Not earthed. This should be earthed.
The earth lead from the HV lighting arrestor is taken through GI pipe. The above earth lead Should not Pass through any iron steel pipes.
The AB switch handle has not been earthed. The same should be earthed effectively.
Masonry through are not provided for the earth electrodes. Masonry through should be Provided for the Earth electrodes
No name board has been provided for the substation. A name board with all particulars Should be providing.
There is no fuse control on the secondary side of the transformer but only the outgoing Feeders are provided with fuse control. Porcelain fuse unit of adequate capacity should be Provided for the transformer on the secondary side and only from these fuse unit supply to the outgoing feeders should be tapped
The handle of the AB switch has been fixed at a height of about 4-5 feet's for easy operation.
The UN supported length of jumper in the transformer structure is more than5 feet. The same Should be restricted to a length of 5feet
All the open wiring on the secondary side of the transformer should be closed in conduits.
The secondary control of porcelain fuse carrier is not housed in distribution box. They should Be housed in the distribution box No breather has been provided for the transformer a breather should be provided for the transformer.
Some of the fuse units are broken. The broken fuse units should be replaced by fresh unit
The feeders emanating from the secondary fuse control are not provided with separate fuse Unit individually. Further one feeder is tapped from another. There should not be any tapping In the feeder and the entire emanating feeder should be provided with fuse units individually
The providing pipe of the AB switch has not been earthed. The same should be earthed Effectively.
Earthed called guarding has not been provided at the place where the HV/MV lines are Crossing the road. Suitable earthed cradle guarding should be provided for the road crossing.
The metal parts of the DP structure distribution box have rusted badly and requires Repainting. Repainting should be carried out to the above structure and should be maintained Properly
All the routine maintenance work on the transformer like testing of transformer oil etc should Be periodically and the result obtained should be recorded up to date in a separate register

The earth electrodes provided should be tested periodically for satisfactory results and Results obtained should be recorded up to date in a separated register
The HV jumpers connected on the tension side are to be connected to the slack side or U Loop connection on the line
No HV LA is provided for the protection of the transformer which should Be provided
The metallic fittings of the insulators, strain dishes are to be looped to earth leads of Structure
Bushes are not provided for the ends of conduit pipes enclosing MV wires on the secondary Sides. Bushes are to be provides for the ends of conduit pipes
The insulated wires on the secondary side of the transformer are deteriorated and they Should be replaced by healthy wire
Danger notices have been provided the transformer section. Danger notice is to be provided For the transformer section.
Oil leak in the LV bushing of the transformer should be attended
The position of the HV/LV is to be shifted to the other side so that the clearance between The live jumper and earthed metal parts should not less than12 inches
The transformer base channel from ground is less than 7 feet and the clearance to HV live Point from ground is less than 12 feet. The above clearances are to be provided.
The transformer neutral is provided with only one earthy. The neutral should be provided With one more earth connection
The transformer neutral earth lead is looped with body. The neutral earth leads should be Separated from the transformer body
The transformer body is earthed with signal earth connection. The transformer body should Be provided with two separate and distinct earth locations

Central Electricity Authority (Measures relating to Safety and Electric Supply)-2010	
Electric Vehicle Charging Stations (Chapter XI-11.7)	
Public Charging Stations	Private charging at residences offices shall be permitted. Distribution Companies (DISCOMs) may facilitate the same.
	Setting up of Public Charging Stations (PCS) shall be a de-licensed activity and any individual/entity is free to set up public charging stations provided that, such stations meet the technical, safety as well as performance standards and protocols laid down below as well as any further norms standards specifications laid down by Ministry of Power and Central Electricity Authority (CEA) from time to time.
PROTECTION	All electric vehicle charging stations shall be provided with protection against the overload of input supply and output supply fittings.
	The electric vehicle charging station shall be equipped with a protective device against the uncontrolled reverse power flow from vehicle.
	Suitable lightning protection system shall be provided for the electric vehicles charging stations as per Indian Standards Code IS/ IEC 62305.
	A cord extension set or second supply lead shall not be used in addition to the supply lead for the connection of the electric vehicle to the electric vehicle charging point and it shall be so constructed sothat it cannot be used as a cord extension set.
	An adaptor shall not be used to connect a vehicle connector to a vehicle inlet.
HEIGHT	All electric vehicle charging points shall be installed so that any socket-outlet of supply is at least **800 MM above the finished ground level.**
AREA	The electric vehicle parking place shall be such that the connection on the vehicle when parked for charging shall be within **5 meters from the electric vehicle charging point.**
	Portable socket-outlets are not permitted to be used for electric vehicle charging.
D.C Charging	A vehicle connector used for Direct Current (D.C.) charging shall be locked on a vehicle inlet if the voltage is higher than 60 V D.C. and the vehicle connector shall not be unlocked (if the locking mechanism is engaged) when hazardous voltage is detected through charging process including after the end of charging and in case of charging system malfunction, a means for safe disconnection shall be provided.
	The Direct Current (D.C.) electric vehicle charging point shall disconnect supply of electricity to prevent overvoltage at the battery, if output voltage exceeds maximum voltage limit sent by the vehicle.
	The electric vehicle charging points shall not energize the charging cable when the vehicle connector is unlocked and the voltage at which the vehicle connector unlocks shall be lower than 60V.
Earth protection system for charging stations.	All Residual current device for the protection of supplies for electric vehicle shall
	(a) have a residual operating current of not greater than 30 Ma
	(b) interrupt all live conductors, including the neutral
	(c) have a performance at least equal to Type A and be in conformity with IS 732-2018.
	Each electric vehicle charging points shall be supplied individually by a dedicated final sub-circuit protected by an overcurrent protective device complying with IEC 60947-2, IEC 60947-6-2 or the IEC 60269 series and the overcurrent protective device shall be part of a switchboard.
	All electric vehicle charging stations shall be supplied from a sub-circuit protected by a voltage independent residual current device and also providing personal protection that is compatible with a charging supply for an electric vehicle.
	All electric vehicle charging stations shall be provided with an earth continuity monitoring system that disconnects the supply in the event that the earthing connection to the vehicle becomes ineffective.
	A protective earth conductor shall be provided to establish an equipotential connection between the earth terminal of the supply and the conductive parts of the vehicle which shall be of sufficient rating to satisfy the requirements of IEC 60364-5-54.

Fire Fighting System in electric vehicle charging stations	Enclosure of charging stations shall be made of fire retardant material with self-extinguishing property and free from Halogen.
	Fire detection, alarm and control system shall be provided as per relevant Indian Standards.
	Power supply cables used in charging station or charging points shall conform to IEC 62893-1 and its
Testing of charging stations	All apparatus of charging stations shall have the insulation resistance value as stipulated in the relevant IEC 61851-1.
Inspection and periodic assessment of charging stations.	Every charging station shall be tested and inspected by the owner or the Electrical Inspector or Chartered Electrical Safety Engineer before energisation of charging stations.
	The owner of the charging station shall ensure that test and inspection of charging station is being carry out every year in the initial period
MAINTENANCE RECORDS	The owner of the charging station shall keep records in regard to design, construction and labelling to be compatible with a supply of standard voltage at a nominal frequency of 50 Hertz of the charging station.
	The owner of the charging station shall keep records of the relevant test certificate as indicated in these regulations and as per IEC 61851.
	The owner of the charging station shall keep records of the results of every inspection, testing and periodic assessment and details of any issues observed during the assessment and any actions required to be taken in relation to those issues.

Model Building Bye-Laws, 2016

10.4 Electric Vehicle Charging Infrastructure (EVCI):

No of EV Charging	Based on the occupancy pattern and the total parking provisions in the premises of the various building types, charging infrastructures shall be provided only for EVs, which is currently assumed to be **20% of all vehicle holding capacity (including 2Wheelers and PVs(Cars)) / Parking capacity at the premise.**	
Residential Buildings (Plotted house)	Charging Infrastructure	individual house/ self-use
	Ownership of Station	Private (Owner)
	Connection / Metering	Domestic Meter
	Type of Charging	Slow Charger
	Mode of Charging	A.C (Single Phase Gun)
	Norms of Provision	Min. 1 SC and additional Provisions as per the owner individual.
All other buildings (including Group Housing)	Charging Infrastructure	PCS (commercial use)
	Ownership of Station	Service provider
	Connection / Metering	Commercial Metering and Payment
	Type of Charging	As per min. requirements specified in MoP Guidelines
	Mode of Charging	A.C or D.C
	Norms of Provision	4Wheeles =1 SC for each 3 Evs / 1 FC for each 10EVs
		3Wheeles =1 SC for each 2 Evs
		2Wheeles =1 SC for each 2 Evs
		PV (Buses) =1 FC for each 10 EVs

Charging Infrastructure for Electric Vehicles (EV) -Guidelines & Standards (No.12/2/2018-EV)

Electric Vehicle Chargers Guidelines

CHARGER TYPE	CHRGER CONNECTION	RATED OUTPUT VOLTAGE	NO OF CONNECTOR GUNS (CG)	CHARGING VEHICLE TYPE
FAST	COMBINE CHARGING SYSTEM (CCS) (Min 50KW)	200V to 700V or Higher	1CG	4 Wheelers
	CHArge de Move, (CHAdeMO) (Min 50KW)	200V to 500V or Higher	1CG	4 Wheelers

	Type-2 AC (Min 22KW)	380V to 415V	1CG	4 Wheelers, 3 Wheelers, 2 Wheelers
SLOW / MODERATE	Bharat DC-001 (15KW)	48V	1CG	4 Wheelers, 3 Wheelers, 2 Wheelers
	Bharat DC-001 (15KW)	72V or Higher	1CG	4 Wheelers, 3 Wheelers, 2 Wheelers
	Bharat AC-001 (10KW)	230V	3CG of 3.3KW each	4 Wheelers, 3 Wheelers, 2 Wheelers
Charging Station for e-two/three wheelers shall be free to install any charger other than those specified above subject to compliance of technical & safety standards as laid down by CEA.				

Indian Standards EV Charging notified by BIS of 01.11.2021					
CHARGER	**LEVEL / POWER**	**CHARGING DEVICE / PROTOCOL**	**EV-EVSE Communication**	**Charge Point Plug/ Socket**	**VEHICLE INLET / CONNECTOR**
Light EV AC Charge Point	**Level 1** (Up to 7 KW)	IS-17017-22-1	Bluetooth Low Energy	IS-60309	As per EV manufacturer
Light EV DC Charge Point	**Level 1** (Up to 7 KW)	IS-17017-25 [CAN]	IS-17017-25 [CAN]	Combined Socket under development	IS-17017-2-6
Park bay AC Charge Point	**Level 2** (Normal Power to 1 kW / 22 Kw)	IS-17017-1	IS-15118 [PLC] for Smart Charging	IS-17017-2-2	IS-17017-2-2
Park bay DC Charge Point	**Level 2** (Normal Power to 1 kW/ 22 Kw)	IS-17017-23	IS-17017-24 [CAN] IS-15118 [PLC]	IS-17017-2-2	IS-17017-2-2
DC Charging Protocol	**Level 3** (DC 50 kW to 250 Kw)	IS-17017-23	IS-17017-24 [CAN] IS-15118 [PLC]		IS-17017-2-3
eBus Charging Station (Dual Gun Charging Station)	**Level 4** (DC High Power (250 kW > 500 kW))	IS-17017-23-2	IS-15118 [PLC]		IS-17017-2-3
eBus Charging Station (Automated Pantograph Charging Station)	**Level 4** (DC High Power (250 kW > 500 kW))	IS-17017-3-1	IS-15118 [PLC]		IS-17017-3-2

EVSE POWER RATINGS NITI AYOG (TABLE-2)			
TYPE OF CHARGING	**POWER LEVEL**	**CURRENT TYPE**	**COMPATIBLE EV SEGMENTS**
Normal power charging	P<=7 KW	AC & DC	E-2 Wheelers, E-3 Wheelers, E-Cars, other LCVs (up to 1 ton)
	7 KW < P <= 22 KW	AC & DC	
High power charging	22 KW < P <= 50 KW	DC	E-Cars, LCVs and MCVs (1-6 tons)
	50 KW < P <= 200 KW	DC	

A.C Capacity		
Ton	**KW**	**H.P**
0.64	2.1	0.8
0.80	2.8	1
1.00	3.7	1.25
1.28	4.6	1.6
1.60	5.6	2
2.00	7.31	2.5
2.56	9.35	3.2
3.20	11.6	4
4.00	14.4	5
4.48	16.7	5.6
6.40	22.1	8
8.00	29.1	10
1TON=	3000 K.Cal/Hr	
	1200 BTU/Hr	
	3.516 KW	
	1.25 HP (VRV / VRF Only)	
	4.7 HP	
	12660 KJ/Hr	

Air Condition Capacity Application wise	
Application	**Average Load**
Residence	400 to 600 sq. ft. floor area per ton
Apartment (1 or 2 room)	400 sq. ft. of floor area per ton
Office Building	190 to 360 sq. ft. floor area per ton
Office Building Large Interior	340 Sq Foot Floor Area / Ton
Office Building Large Exterior	250 Sq Foot Floor Area / Ton
Restaurant	200 Sq Foot Floor Area / Ton
Bar or Tavern	9 people per ton
Cocktail Lounge	175 Sq Foot Floor Area / Ton
Computer Room	50 – 150 Sq Foot Floor Area / Ton
Bank (main area)	225 Sq Foot Floor Area / Ton
Barber Shop	250 Sq Foot Floor Area / Ton
Beauty Shop	180 Sq Foot Floor Area / Ton
School Classroom	250 Sq Foot Floor Area / Ton
Bowling Alley	1.5 – 2.5 tons per alley
Motel	400 Sq Foot Floor Area / Ton
Groceries – Supermarket	350 Sq Foot Floor Area / Ton
Hospital Room	280 Sq Foot Floor Area / Ton
Hotel Public Spaces	220 Sq Foot Floor Area / Ton
Drug Store	150 Sq Foot Floor Area / Ton
Factory (precision manufacturing)	275 Sq Foot Floor Area / Ton
Small Shop	225 Sq Foot Floor Area / Ton
Department Store	400 Sq Foot Floor Area / Ton
School Classroom	250 Sq Foot Floor Area / Ton

Air Condition Capacity Range		
Air Conditioner Machine	**Capacity Range**	**Suitable for**
Room air conditioner	0.5 to 2 TR per unit	Up to 1000 Sq Foot Floor Area
Packaged unit integral air-cooled condenser	3 to 50 TR	1000 to 10000 Sq Foot Floor Area
Split system with outdoor air-cooled condenser	0.5 to 50 TR,	100 to 10000 Sq Foot Floor Area
Central air-conditioning chilled water system with air cooled condensers	20 to 400 TR	More than 4000 Sq Foot Floor Area
Central air-conditioning chilled water systems with outdoor water cooled	20 to 2000 TR	More than 4000 Sq Foot Floor Area

condenser		

Air Supply Requirement (For Heating & Cooling Load)	
Equipment	**Appro. Airflow Rate**
Gas/Oil Furnace	1 CFM per 100 Btu/hr
Electric Furnace	50 – 70 CFM per kW input
Electric Air-conditioning	400 CFM per ton
Precision Air Conditioning	500 CFM/ton
Comfort Cooling Air Conditioning	400 CFM/ton
Dehumidification	200 CFM/ton
Heat Pump	450 CFM per ton

HVAC Chillier Selection	
Type of Chiller	**Ton**
Reciprocating	Up to 25 tons (88kW)
Reciprocating or Screw	25 to 80 tons (88 to 280kW)
Reciprocating, Screw or Centrifugal	80 to 200 tons (280 to 700kW)
Screw or Centrifugal	200 to 800 tons (700 to 2800kW)
Centrifugal	Above 800 tons (2800 kW)
Air-cooled chilled water system	40 to 200 TR
Water-cooled chilled water system	200 TR and above

HVAC Power Consumption (IS 1391)	
Cooling Capacity (Kcal/Hr)	**Maximum Power Consumption (KW)**
3000	1.65
4S00	2.3
6000	3.1
7500	3.6
9000	4.4
1 kcal/Hr= 1.16278 watt	

HVAC Noise Level (IS 1391)		
Rated Cooling Capacity (Kcal/Hr)	**Maximum Noise Level (DBA)**	
	Indoor	**Outdoor**
4500 or less	58	68
5000 or more	62	70

Split AC Copper Pipe Size (Blue Star)		
A.C Capacity	**Suction Pipe**	**Discharge Pipe (Liquid)**
Up to 1 Ton	12.7mm (1/2")	6.4mm (1/4")
1 To 4 Ton	15.9mm (5/8")	9.5mm (3/8")
5 To 6 Ton	19.1mm (3/4")	9.5mm (3/8")
7 To 8 Ton	22.2mm (7/8")	12.7mm (1/2")
9 To 11 Ton	28.6mm (1 1/8")	12.7mm (1/2")
12 To 19 Ton	28.6mm (1 1/8")	15.9mm (5/8")
20 To 27Ton	34.9mm (1 3/8")	19.1mm (3/4")
28 To 42Ton	41.5mm (1 5/8")	19.1mm (3/4")
Normal Split A.C Copper Pipe Maximum Length = 15Meter		
VRV System Copper Pipe Maximum Length = 150Meter		

Split AC Copper Pipe Length		
A.C Capacity	**Maximum Pipe Length**	**Maximum Indoor & Outdoor Height Difference**
0.5 Ton	15 Meter	5 Meter
0.6 Ton	15 Meter	5 Meter
0.75 Ton	15 Meter	5 Meter
1 Ton	20 Meter	10 Meter
1.5 Ton	25 Meter	10 Meter
2 Ton	25 Meter	10 Meter
2.5 Ton	30 Meter	10 Meter

3 Ton	30 Meter	20 Meter
3.5 Ton	30 Meter	20 Meter
4 Ton	30 Meter	20 Meter

Split AC Copper Pipe Additional Refrigerant Charge			
Total Pipe Length	**50 Meter**	**60 Meter**	**70 Meter**
Additional Refrigerant	None	250 gm (25gm/Meter)	500 gm (25gm/Meter)

Copper Pipe Thickness			
Pipe Size	**Thickness**	**Tube Gauge**	**Type**
6.4mm (1/4")	0.8 mm	21	Soft
9.5mm (3/8")	0.8 mm	21	Soft
12.7mm (1/2")	0.8 mm	21	Soft
15.9mm (5/8")	1 mm	19	Soft
19.1mm (3/4")	1 mm	19	Soft
22.2mm (7/8")	1 mm	19	Hard
28.6mm (1 1/8")	1.2 mm	18	Hard
34.9mm (1 3/8")	1.2 mm	18	Hard
41.5mm (1 5/8")	1.3 mm	18	Hard
De-Oxidised Copper Tubes (DHP) , Copper 99.9%			
Soft Copper as per ASTM B68			
Hard Copper as per ASTM B75 / ASTM280 / BS 2871			

Gas Pressure For any Ton Capacity			
Refergerent	**Suction / Running Pressure (PSI)**	**Discharge Pressure (PSI)**	**Standing Pressure (PSI)**
	Machine ON	**Machine ON**	**Machine OFF**
R 22	60 To 70	250To 300	156
R 32	120	490	260
R 134A	35	158 To 199	95
R 290	65	275 To 300	125
R 404A	87	270 To 356	190
R 407C	63	247 To 307	153
R 410A	110 To 120	400 To 500	250
R 417A	65	261	140

Nitrogen Pressure Test		**Vaccum**	
3 Minutes	150 PSI	<= 500 Micron	for 24 Hours
5 Minutes	325 PSI		
24 Hours	500 PSI		
vaccum	< 500 Micron		

Insulation Thickness			
Referigerent Pipe	**Insulation**	**Drain Pipe**	**Insulation**
22.22mm To 28.58mm	19mm	**25mm / 32mm /40mm**	6mm
12.7mm To 19.05mm	13mm / 19mm		
6.35mm To 9.2mm	9mm / 13mm		

Referent Pipe Insulation			
Pipe	**Pipe size**	**Insulation Type (EPDM or NBR)**	
		Standard conditions 86°F (30°C), < 85%	**High humidity conditions(a) 86°F (30°C), >85%**
Liquid Pipe	1/4" (6.35 mm) To 3/8" (9.52 mm)	3/8" (9 mm)	3/8" (9 mm)
	1/2" (12.70 mm) To 2" (50.80 mm)	1/2" (13 mm)	1/2" (13 mm)
Vapor Pipe	1/4" (6.35 mm) To 7/8" (22.23)	1/2" (13 mm)	3/4" (19 mm)

The distance between the supports of the copper pipes.	
Diameter	**Distance (m)**
≤ 20 mm	1 Meter
20 To 40 mm	1.5 Meter
≥ 40 mm	2 Meter

The permitted length and drop difference		
Pipe length	Max. pipe length	<= 240 Meter
	Equivalent length from the first branch to the farthest indoor unit	<= 40 Meter
Drop height	Drop height between indoor unit and outdoor unit	<= 110 Meter
	Drop height between indoor units	<= 30 Meter

Factory Fabricated	
Duct Size	**Gauge of GI sheet**
1 - 900 mm	26
901 -1200 mm	24
1201 -1800 mm	22
1801 - 2100 mm	20
2101 - above	18

Site Fabricated	
Duct Size	**Gauge of GI sheet**
Up to 750mm	24
750mm- 1500 mm	22
1510 mm- 2250 mm	20
above 2250 mm	18

Horizontal Ductwork		
Ducts Size		**Maximum Spacing**
Area (m2)	**Diameter**	
less than 0.4	less than 125 mm	2.5 Meter
0.4 to 1	125 to 1000 mm	2 Meter
more than 1	more than 1000 mm	1.2 Meter

Vertical Ductwork	
Ducts Type	**Maximum Spacing (Meter)**
round	3.6 Meter
rectangular	3 Meter

Rectangular Duct Sheet Thickness as per CPWD		
Longest side (mm)	**Minimum sheet thickness**	
	Galvanized Sheet Steel (GSS) IS: 277	**For Aluminum IS:737**
750 mm and below	0.63mm (22 Gauge)	0.8mm (20 Gauge)
751 mm to 1500 mm	0.8mm (20 Gauge)	1mm (18 Gauge)
1501 mm to 2250 mm	1mm (18 Gauge)	1.5 mm (15 Gauge)
2251 mm & above	1.25mm (16 Gauge)	1.8 (13 Gauge)

Round Duct Sheet Thickness as per CPWD		
Longest side (mm)	**Minimum sheet thickness**	
	Galvanized Sheet Steel (GSS) IS: 277	**For Aluminum IS:737**
150 mm to 500 mm	0.63mm (22 Gauge)	0.8mm (20 Gauge)
501 mm to 750 mm	0.8mm (20 Gauge)	1mm (18 Gauge)
751 mm to 1000 mm	0.8mm (20 Gauge)	1mm (18 Gauge)
1001 mm to 1250 mm	1mm (18 Gauge)	1.5 mm (15 Gauge)
1251 mm and above	1.25mm (16 Gauge)	1.8 (13 Gauge)

DUCT Support OR Gripple Wire Support			
Duct Size (mm)	**Spacing (M)**	**Size of MS Angle (mm x mm)**	**Size of Rod Dia (mm)**
Upto 750	2.4	32x32x3	8
751 to 1000	2	40x40x5	10
1000 to 1500	2	40x40x5	10
1501 to 2250	2	50x50x6	12
2251 to above	2	50x50x6	12

Round Duct Support			
Round Duct Size	**Spacing of Supports**	**Size of M.S. Angle (mm)**	**Dia. of Hanger Rod**
Up to 500 mm	1.5 meter	40 x 40 x 6	12 mm
501 to 1200 mm	1.5 meter	40 x 40 x 6	12 mm
1201 to 2250 mm	1.5 meter	50 x 50 x 6	15 mm

Normal Ducting:		
Larger duct-dimension	**Spacing of Supports (m)**	**Sheet thickness, SWG (mm)**
Up to 750 mm	1.5 To 2	2 24 G (0.63 mm) (25x25 GI flanges acceptable)
751 to 1500 mm	1.5 To 2	22 G (0.80 mm) (25x25x3 MS flanges up to 1000mm; 40x40x5 MS flanges beyond 1000mm)
1501 mm to 2250 mm	1.5 To 2	20 G (1.00 mm) (40x40x5 MS flanges)
Above 2250 mm	1.5 To 2	18 G (1.20 mm) (50x50x6 MS flanges)

Supporting details for Low-Pressure system			
LARGER SIDE OF DUCT mm	**SUPPORTING ANGLE mm**	**VERTICAL ROD DIAMETER mm**	**MAXIMUM SPACING BETWEEN SUPPORTS mm**
Upto 900	40x40x6	10	3000
901 to 1500	50x50x6	10	3000
1501 to 2400	50x50x6	10	2400
2401 and above	65x65x6	12	2400

Supporting details for Round Duct					
DUCT DIAMETER mm	**STRAP**			**ROD**	
	No	**WIDTH mm**	**THICKNESS G**	**No**	**DIAMETER mm**
Upto 600	1	25	22	1	7
601 to 900	1	25	20	1	10
901 to 1250	2	25	20	2	10
1251 t o1500	2	25	18	2	10
1501 to 2100	2	25	18	2	10

Area	**Ceiling Height**	**Diffuser size(dia.)**
Up to 12 sqm	2.4 – 2.7m	200mm
Up to 12 sqm	3m	250mm
Up to 20 sqm	2.4m – 2.7m	250mm
Up to 20 sqm	3m	300mm
Over 20 sqm		multiple diffusers

Additional refrigerant charged volume	
Liquid pipe Size	**R410A (kg/m)**
6.4 mm	0.022
9.5 mm	0.057
12.7 mm	0.11
15.9 mm	0.18
19.1 mm	0.26
22.2 mm	0.37

25.4 mm	0.45

Drain Pipe Capacity		
Condensate water volume : V (L/h)=Indoor Unit (HP)x2	I.D (mm)	Thickness (mm)
V ≤ 14	Φ 25	3
14 < V ≤ 88	Φ 30	3.5
88 < V ≤ 175	Φ 40	4
175 < V ≤ 334	Φ 50	4.5
334 < V	Φ 80	6
*If Slop is <1% than select next higher Size of Drain Pipe		

System Problems				
System Problem	Discharge Line Pressure	Suction Line Pressure	Suction Line Temperature	Compressor Amp
Over Gas Charge	High ↑	High ↑	Low ↓ (Ice on Sction Pipe)	High ↑
Under Gas Charge	Low ↓	Low ↓	High ↑	Low ↓
Capilary Block	Low ↓	Low ↓	High ↑	Low ↓
Less Air Flow on Evoparetor (Indoor Unit)	Low ↓	Low ↓	Low ↓	Low ↓
Less Air Flow on Condesor (Outdoor Unit)	High ↑	High ↑	High ↑	High ↑
Dirty Condesor (Outdoor Unit)	High ↑	High ↑	High ↑	High ↑
Low Ambient Temperature	Low ↓	Low ↓	Low ↓	Low ↓
High Ambient Temperature	High ↑	High ↑	High ↑	High ↑
Insuffient Compressor	Low ↓	High ↑	High ↑	Low ↓

Centrifugal Fans (As per CPWD)			
Type	Characteristics	Typical Applications	Efficiency (%)
Radial	High pressure, medium flow, efficiency close to tube-axial fans, power increases continuously	Various industrial applications, suitable for dust laden, moist air/ gases	72–79
Forward curved blades	Medium pressure, high flow, dip in pressure curve, efficiency higher than radial fans, power rises continuously	Low pressure HVAC, packaged units, suitable for clean and dust laden air/ gases	60–65
Backward curved blades	High pressure, high flow, High efficiency, power reduces as flow increases beyond point of highest efficiency	HVAC, various industrial applications forced draft fans,	79–83
Airfoil type	Same as backward curved type, highest efficiency	Same as backward curved, but for clean air applications	79–83

Axial Flow Fans (As per CPWD)			
Type	Characteristics	Typical Applications	Efficiency (%)
Propeller	Low pressure, high flow, low efficiency, peak efficiency close to point of free air delivery (zero static pressure)	Air-circulation, ventilation, exhausts.	45–50
Tube axial	Medium pressure, high flow, higher efficiency than propeller type, dip in pressure-flow curve before peak pressure	HVAC, drying ovens, exhaust Systems	67–72
Vane axial	High pressure, medium flow, dip in pressure-flow curve, use of guide vanes improves Efficiency exhausts	High pressure applications including HVAC systems	78–85

Thickness of sheets for Rectangular Ductwork (As per CPWD)		
Longest side (mm)	**Minimum sheet thickness**	
	For GSS	**For Aluminium**
750 mm and below	0.63 mm	0.8 mm
751 mm to 1500 mm	0.8 mm	1 mm
1501 mm to 2250 mm	1 mm	1.5 mm
2251 mm & above	1.25 mm	1.8 mm
All ducts shall be fabricated either from Galvanized Sheet Steel (GSS) conforming to IS: 277 or aluminum sheets conforming to IS: 737. The steel sheets shall be hot dip galvanized with MAT finish with coating of minimum 120 grams per square meter (GSM) of Zinc, GI sheets shall be lead free, eco friendly and Ro HS compliant		

Thickness of sheet for Round Ducts (As per CPWD)		
Diameter of duct, mm	**Thickness of Sheet**	
	For GSS	**For Aluminium**
150 to 500 mm	0.63 mm	0.8 mm
501 to 750 mm	0.8 mm	0.8 mm
751 to 1000 mm	0.8 mm	1 mm
1001 to 1250 mm	1 mm	1.5 mm
1251 mm and above	1.25 mm	1.8 mm
All sheet metal connections, partitions and plenums required for flow of air through the filters, fans etc. shall be at least 1.25 mm thick galvanized steel sheets, in case of G.I. sheet ducting or 1.8 mm thick aluminium sheet, in case of aluminium sheet ducting and shall be stiffened with 25 mm x 25 mm x 3 mm angle iron braces.		
Circular ducts, where provided shall be of thickness as specified in IS: 655 as amended up to date.		
Aluminium ducting shall normally be used for clean room applications, hospitals works and wherever high cleanliness standards are functional requirements		

Duct's Associated Items (As per CPWD)		
Application	**Duct Width**	**Angle size**
Flanges	Up to 1000 mm	35 mm x 35 mm x 3 mm
Flanges	1001 mm to 2250 mm	40 mm x 40 mm x 3 mm
Flanges	More than 2250 mm	50 mm x 50 mm x 3 mm
Bracings	Up to 1000 mm	25 mm x 25 mm x 3 mm
Bracings	More than 1000 mm	40 mm x 40 mm x 3 mm
Support angles	Up to 1000 mm	40 mm x 40 mm x 3 mm
Support angles	1001 mm to 2250 mm	40 mm x 40 mm x 3 mm
Support angles	More than 2250 mm	Size and type of RS section shall be decided in individual cases
Hanger rods shall be of mild steel and of at least 10 mm dia for ducts up to 2250 mm size, and 12 mm dia for larger sizes		
All nuts, bolts and washers shall be zinc plated steel. All rivets shall be galvanized or shall be made of magnesium - aluminium alloy. Self tapping screws shall not be used.		

VRF/ VRV and the Central Chilled water system (As per CPWD)			
Points	**VRF AC**	**Chilled Water based AC**	**Remarks**
System Base	It is Gas Base System	It is Water Base System	
Peak Power Demand	1.6KW/TR peak. (Efficiency drastically reduces at high ambient)	1.3KW/TR Peak. (IKW/TR<0.6 now for chilling units.)	Higher size & cost of Power Supply Capital Equipment like Transformers etc. & thus higher Cu losses in VRF system.
Annual Power Consumption	1.15 to 1.20	1	Annually extra expenditure of 15 to 20% in electricity bills in VRF system.

Security & Safety of Equipment & System	Copper piping on terrace & in building	MS piping	VRF system equipments/ materials prone to theft & damage by miscreants
Terrace Space	Almost 80% terrace is used for ODUs & Cu pipe & power cables	Only Cooling Towers need to be installed at terrace.	Problem of cleaning terrace & loss of water proofing also occurs over time.
Water Scarcity	No water required	Regular Supply of Water required for condenser cooling	Major advantage in VRF system but, now STPs are generating water for meeting up to 75% of AC Plant demand. Water drift losses also being reduced by use of Geothermal Energy.
Air Quality of Conditioned space	RH, Co2, Bacteria, dust & other pollutants Control only to very limited extent.	Full control	Sick building syndrome is taken care of in Water based system with AHUs and demand based fresh air supply.
Service / Attending to faults	Personnel have to go into the room. Problems of condensate dripping in rooms.	Such problems limited only in AHUs.	
Long Term Benefits	Maintenance Expensive	Low Cost Maintenance	
Fire Safety	Refrigerant in system goes to all areas in building and is combustible at high temperatures, releasing toxic products of combustion.	Only water in AHUs and Air only in rooms through ducts. Refrigerant is limited to only within the Chilling Units.	Water based system is safer.
Life	10 Years	15-20 Years	
Applications	Home or Small office with variable occupancy. More cost effective in room redundancy cases.	Large office, continuously large air conditioning loads, proper controlled conditioning of space.	

Comparison of VRF and VRV System (As per CPWD)

Application	**Variable Refrigerant Flow (VRF) system**	**VRV System with Chiller based Air conditioners**
Power Consumptions	Up to 1.6 KW/TR of refrigeration.	Up to 1.3 KW/TR of refrigeration.
Application	Most of the VRF units are designed at an ambient temperature of 36°C, and so its use would not be suitable if the system is used in places with hotter temperature.	Customization in design of the Chiller system can be done with respect to ambient temperature
Performance in Hot Temperature	If the system is used at hotter place then system de-rates.	This is not the case in chiller based system.
Space	It requires more space for its outdoor unit as maximum size of outdoor unit available is 60 hp, so a large no. of outdoor units would be required to fulfill the requirement of 3500-4000 TR	It can be managed by a single plant room.
Design	its design is very complex	Its design is comparatively less complex
COP	its CoP (Coefficient of Performance) varies from 3 to 4.2; a higher CoP implies greater efficiency	Its CoP varies from 5.4 (for 750 TR chiller) to 6.3 (for 1000 TR chiller)
Efficiency	Its part load efficiency is good if used at more than 50 % rated capacity	Its part load efficiency is good even at one – third of the rated capacity.

Chapter: 39 Ventilation / Ceiling Fan Reference

Recommended values for Air Changes (NBC-5.2.2.1) & CPWD	
Application	**Air Change per Hour**
Assembly rooms	4 to 8
Bakeries	20 to 30
Banks/building societies	4 to 8
Bathrooms	6 to 10
Bedrooms	2 to 4
Billiard rooms	6 to 8
Cafes and coffee bars	10 to 12
Canteens	8 to 12
Cellars	3 to 10
Changing rooms	6 to 10
Churches	1 to 3
Cinemas and theatres	10 to 15
Club rooms 12, Min	12 to 15
Compressor rooms	10 to 12
Conference rooms	8 to 12
Corridors	5 to 10
Dairies	8 to 12
Dance halls	12
Dye works	20 to 30
Electroplating shops	10 to 12
Entrance halls	3 to 5
Factories and work shops	8 to 10
Foundries	15 to 30
Garages	6 to 8
Glass houses	25 to 60
Gymnasium	6
Hair dressing saloon	10 to 15
Hospitals sterilizing	15 to 20
Hospital wards	6 to 8
Hospital domestic	15 to 20
Laboratories	6 to 15
Launderettes	10 to 15
Laundries	10 to 30
Lavatories	6 to 15
Lecture theatres	5 to 8
Libraries	3 to 5
Lift cars	20
Living rooms	3 to 6
Mushroom houses	6 to 10
Offices	6 to 10
Paint shops (not cellulose)	10 to 20
Photo and X-ray dark room	10 to 15
Public house bars	12
Recording control rooms	15 to 25
Recording studios	10 to 12
Restaurants	8 to 12
Schoolrooms	5 to 7
Shops and supermarkets	8 to 15
Shower baths	15 to 20
Stores and warehouses	3 to 6
STP rooms	30
Squash courts	4
Swimming baths	10 to 15
Toilets	6 to 10
Underground vehicle parking	6
Utility rooms	15 to 30

Welding shops	15 to 30
Note: The ventilation rates may be increased by 50 % where heavy smoking occurs or if the room is below the ground.	

Recommended values for Air Changes			
Application	**Air Change per Minute**	**Application**	**Air Change per Minute**
Assembly Hall	7	Forge Room	3
Auditorium	10	Locker Room	3
Barber Shop	6	Toilet	3
Basement	8	Dance Hall	5
Battery Room	4	Foundry	4
Boiler Room	1	Machine Shop	8
Bowling Alley	5	Transformer Room	1
Engine Room	6	Department Store	6
Gymnasium	8	Garage	5
Projection Booth	2	Plating Room	3
Church	15	Warehouse	12
Factory	6	Dry Cleaning	5
Laundry	2	General Office	10
Summer Cooling	1	Pressing Room	1
Classroom	6	Welding Shop	2

Ventilation Requirement					
Application	**Occupancy (people/ 1000ft2)**	**CFM/ person**	**Application**	**Occupancy (people/ 1000ft2)**	**CFM/ person**
Food and Beverage Service			**Offices**		
Dining rooms	70	20	Office space	7	20
Cafeteria, fast food	100	20	Reception areas	60	15
Bars, cocktail lounges	100	30	Conference rooms	50	20
Kitchen (cooking	20	15	**Hotels, Resorts**		
Theatres			Bedrooms		
Classroom	50	15	Living rooms		
Music rooms	50	15	Lobbies	30	15
Libraries	20	15	Conference rooms	50	20
Auditoriums	150	15	Assembly rooms	120	15
Showrooms			Dry cleaning, laundry	30	30
Basement & Street	30		**Hospitals**		
Upper floors	20		Operating rooms	20	30
Malls and arcades	20		Patient rooms	10	25
Smoking lounges	70	60	Laboratories	30	20
Beauty shops	25	25	Procedure rooms	20	15
Hardware stores	8	15	Pharmacies	20	15
Sports Area			Physical therapy	20	15
Spectator areas	150	15	**Public Spaces**		
Games rooms	70	25	Smoking lounge	70	60
Playing rooms	30	20	Elevators	70	60
Ballrooms and discos	100	25			

Standard Exhaust Fan Size							
Fan DIA (MM / inches)	**Speed (RPM)**	**Input Power (W)**	**Phase**	**Current (A)**	**M3/HR (CFH)**	**M3/MI (CFM)**	**Sound level dB**
150/6"	1200	24	Single	0.1	270	5	44 To 50
200/8"	1350	28	Single	0.12	500	8	44 To 50

250/10"	1350	36	Single	0.15	800	13	44 To 50
305/12"	1400	50	Single	0.4	1710	29	50 To 55
305/12"	900	50	Single	0.21	1145	19	35 To 40
380/15"	1400	160	Single	0.75	3250	54	60 To 65
380/15"	1400	150	Three	0.45	3250	54	60 To 65
380/15"	900	90	Single	0.4	2000	33	50 To 55
380/15"	900	100	Three	0.29	2000	33	50 To 55
457/18"	1400	410	Single	1.7	6120	102	65 To 70
457/18"	1400	410	Three	0.65	6120	102	65 To 70
457/18"	900	150	Single	0.65	3900	65	55 To 60
457/18"	900	150	Three	0.3	3900	65	55 To 60
610/24"	700	240	Single	0.4	7100	118	55 To 60
610/24"	900	500	Three	0.5	7100	118	55 To 60
610/24"	900	500	Single	2.6	9400	157	60 To 65
610/24"	900	500	Three	0.85	9400	157	60 To 65
750/30"	900	870	Single	3.8	12000	200	70 To 75
750/30"	900	910	Three	1.8	12000	200	70 To 75
900/36"	700	1200	Three	2.4	28100	468	75 To 80

Standard Power with Air Delivery of Fan as per the IS 374 Code

Fan Size	Type	AC / DC	Minimum Air Delivery	Maximum Power Input
900	Capacitor	AC	130 m3/min	42 Watt
		DC	130 m3/min	38 Watt
1050	Capacitor	AC	150 m3/min	48 Watt
		DC	150 m3/min	41 Watt
1200	Capacitor	AC	200 m3/min	50 Watt
		DC	200 m3/min	44 Watt
1400	Capacitor	AC	245 m3/min	60 Watt
		DC	245 m3/min	51 Watt
1500	Capacitor	AC	270 m3/min	63 Watt
		DC	270 m3/min	53 Watt

Size of Ceiling Fan

Area	Suggested Fan Size
Up to 9 Square Meters	900mm (36″)
Up to 12 Square Meters	1067mm (42″)
Up to 18 Square Meters	1200mm (48″)
Up to 30 Square Meters	1300mm (52″)
Up to 40 Square Meters	1400mm (56″)

Size and Number of Ceiling Fans for Rooms (As per NBC Table-10)

Room Width	Room Length										
	Fan Size (mm) /No of Fan										
	4 Meter	5 Meter	6 Meter	7 Meter	8 Meter	9 Meter	10 Meter	11 Meter	12 Meter	14 Meter	16 Meter
3 Meter	1200/1	1400/1	1500/1	1050/2	1200/2	1400/2	1400/2	1400/2	1200/3	1400/3	1400/3
4 Meter	1200/1	1400/1	1200/2	1200/2	1200/2	1400/2	1400/2	1500/2	1200/3	1400/3	1500/3
5 Meter	1400/1	1400/1	1400/2	1400/2	1400/2	1400/2	1400/2	1500/2	1400/3	1400/3	1500/3
6 Meter	1200/2	1400/2	900/4	1050/4	1200/4	1400/4	1400/4	1500/4	1200/6	1400/6	1500/6
7 Meter	1200/2	1400/2	1050/4	1050/4	1200/4	1400/4	1400/4	1500/4	1200/6	1400/6	1500/6
8 Meter	1200/2	1400/2	1200/4	1200/4	1200/4	1400/4	1400/4	1500/4	1200/6	1400/6	1500/6
9 Meter	1400/2	1400/2	1400/4	1400/4	1400/4	1400/4	1400/4	1500/4	1400/6	1400/6	1500/6
10 Meter	1400/2	1400/2	1400/4	1400/4	1400/4	1400/4	1400/4	1500/4	1400/6	1400/6	1500/6

11 Meter	1500/2	1500/2	1500/4	1500/4	1500/4	1500/4	1500/4	1500/4	1500/6	1500/6	1500/6
12 Meter	1200/3	1400/3	1200/6	1200/6	1200/6	1400/6	1400/6	1500/6	1200/7	1400/9	1400/9
13 Meter	1400/3	1400/3	1200/6	1200/6	1200/6	1400/6	1400/6	1500/6	1400/9	1400/9	1500/9
14 Meter	1400/3	1400/3	1400/6	1400/6	1400/6	1400/6	1400/6	1500/6	1400/9	1400/9	1500/9

Ceiling Fan Criteria (As per NBC)	
Capacity of a ceiling fan	=55D m3/min ,D= the longer dimension of a room
Height of fan blades above the floor	= (3H + W)/4, where H is the height of the room, W is the height of work plane.
Minimum distance between fan blades and the ceiling	=0.3 m.

Size Your Fan for the Room (ENERGY STAR)	
Room Size	**Fan Size**
Up to 75 sq. ft.	29 To 36 inches or smaller
75 to 144 sq. ft.	36 to 42 inches
144 to 225 sq. ft.	44 to 50 inches
225 to 400 sq. ft.	50 to 54 inches
Over 400 Sq. ft	54 To 72 inches multiple fans installed

Minimum Efficacy Levels of Ceiling Fans (ENERGY STAR)	
Airflow (CFM)	**Minimum Efficacy Level (CFM/W)**
Low	At low speed, airflow of 1250 CFM and an efficiency of 155 cfm/W.
Medium	At medium speed, airflow of 3000 CFM and an efficiency of 100 cfm/W.
High	At high speed, airflow of 5000 CFM and an efficiency of 75 cfm/W.

Ceiling Fan Rod Extend Length	
Ceiling Height	**Pole Length**
8 Feet	No Down rod
9 Feet	6 Inches
10 Feet	12 Inches
11 Feet	18 Inches
12 Feet	24 Inches
13 Feet	36 Inches
14 Feet	48 Inches
15 Feet	60 Inches
20 Feet or greater	72 Inches

Ceiling Fan Height Chart	
Ceiling Height	**Distance**
< 8 Feet	Choose a low-profile ceiling fan. 18" Minimum distance blade to wall. 7' minimum distance blade to floor.
> 9 Feet	Choose a ceiling fan down rod. 18" Minimum distance blade to wall.

Distance between Two Fans	
Fan Size	**Distance**
36" (900mm)	1.8 Meter
42" (1000mm)	2 Meter
48" (1200mm)	2.5 Meter
56" (1400mm)	3 Meter

Fan Blade Pitch Angle and No of Blade	
Fan Blade pitch	It is the angle of fan's blades (measured in degrees) and it is in conjunction with the fan motor,
	It is show how well fan is able to circulate air.
	Higher blade pitches typically move more air in cubic feet per minute, or CFM.
	The optimal blade pitch for a ceiling fan is between 12 and 15 degrees.

Blade number	It can contribute to the amount of air movement as well.
	The typical ceiling fan comes standard with 4 or 5 blades.
	Fans with more blades are usually quieter but also move less air.

Ceiling Fan Size Guide

Room Size	Room Type	Blade Span	CFM Rating
Up to 100 Sq. Ft	Bathroom, Breakfast Nooks, Utility Rooms, Small Bedrooms, Porches	29" To 36" (700 to 900mm)	
100 To 144 Sq. Ft	Bathroom, Breakfast Nooks, Utility Rooms, Small Bedrooms, Porches	36" To 42" (700 to 1000mm)	1,000 To 3,000
100 To 225 Sq. Ft	Medium Bedrooms, Kitchens, Dining Rooms, Dens, Patios	44" To 50" (1200 to 1270mm)	1,600 To 4,500
225 To 400 Sq. Ft	Master Bedrooms, Family Rooms, TV Rooms, Small Garages, Gazebos	Over 50" (1270mm)	2,300 To 6,500
Over 400 Sq. Ft	Great Rooms, Large Garages, Basements, and Open Floor Plans	Over 62" (1600mm)	5,500 To 13,500

Ceiling Fan Size

Room Size	Fan Blade Sweep
< 90 Sq.Foot	15" to 42" (400 to 1000mm)
90 to 100 Sq.Foot	44" to 46" (1000 to 1200mm)
100 to 150 Sq.Foot	52" to 54" (1300 to 1400mm)
> 150 Sq.Foot	56" to 70" (1400 to 1800mm)

Ceiling Fan Speed and RPM

Speed	Watt	RPM	Air Flow (M3/Hr)	Efficiency (M3/Hr/Watt)
Low	62.3	171	8736	140
Medium	34.9	130	6774	197
High	15.2	86	4066	267

Various distance of Ceiling Fan in Room

Ceiling Fan Blades and Floor	7 ft
Ceiling Fan Blades and Ceiling	8 to 10 inches
Ceiling Fan Blades and Light fixtures.	39 inches
Ceiling Fan Blades and Wall	18 inches

Minimum Efficacy Levels of Ceiling Fans (ENERGY STAR)

Speed	Air Flow	Efficiency (CFM/Watt)
At low speed	1250 CFM	155 cfm/W
At medium speed	3000 CFM	100 cfm/W
At high speed	5000 CFM	75 cfm/W

Size of Rod / Cord for Hanging Light (As per NBC)

Nominal Cross-Sectional Area of Twin Cord mm for Hanging Light	Maximum Permissible Weight mm2 kg
0.5	2
0.75	3
1	5
1.5	5.3
2.5	8.8
4	14

Chapter: 40 Fire Fighting Reference

Class of Fire		
CLASS	**Type of Fire**	**Type of Fire Extinguisher**
Class A	Fires involving Paper, Wood, Textile, Packing materials and the like.	Water, foam, ABC dry power and halocarbons.
Class B	Fires involving Oil, Petrol, Solvent, Grease, Paints, Celluloid and the like.	Foam, dry powder, clean agent and carbon dioxide extinguishers
Class C	Fires involving Electrical Hazards, Motor Vehicle Gaseous substance under pressure.	Dry powder, clean agent and carbon dioxide extinguishers
Class D	Fires involving Chemicals, Metal and active like Magnesium ,titanium	Extinguishers with special dry powder for metal tires

Area covered by Fire Extinguisher (NBC)	
Type of Fire Extinguishers	**Coverage (Floor) Area**
Water/ Sand Bucket	100 sq.mt.
Sprinklers	6 sq.mt.
Extinguishers (9 Liter)	600 sq.mt.
Heat Detectors	16 sq.mt.
Hydrant Riser (Outlet 100 mm dia with landing valve and First aid hose reel)	930 sq.mt
Smoke Detectors	50 sq.mt.

Water Requirement for the Fire Fighting (AS per NBC)
Fire demand in Liters/Minutes (Q)= 3000 P
P = Population in Thousands
Note: The above rate must be maintained at a minimum pressure of 1 to 1.5 kg / cm2 for at least four hours.

Water Requirement for Wet Riser/Down Corner System (NBC -TABLE 4)		
Residential Buildings	**U.G. Water Storage Tank Static**	**Terrace Tank**
15 to 30 meters	50,000 Liter	10,000 Liter
30 to 45 meters	1,00,000 Liter	20,000 Liter
Above 45 meters	2,00,000 Liter	40,000 Liter

Water Requirement for Wet Riser/Down Corner System (NBC -TABLE 5)		
Business Building	**U.G. Water Storage Tank Static**	**Terrace Tank**
15 m to 30 m	100000 lts (50000 lts if covered area in G.F is less than 300sq.m.)	20,000 lts
30 m to 45 m	20000 lts	20,000 lts
Above 45 m	250000 lts	50,000 lts

Classification of fire Pumps (As per IS 15301)	
Pump Size	**Location of Pump Installation**
450 Liter/Min	Pumps to be installed on the terrace to feed the Down Comer System.
900 Liter/Min	Pumps to be installed on the terrace to feed the Down Comer System.
2280 Liter/Min	Pumps are to be housed in the pump house.
2850 Liter/Min	Pumps are to be housed in the pump house.
4500 Liter/Min	Pumps are to be housed in the pump house.
For special risks 6700 Liter/Min	Pumps are to be housed in the pump house.

Suction and Delivery Pipe Sizes (IS 3844)			
Pump Size	**Pump Location**	**Suction**	**Delivery**
450 Liter/min	Terrace	50 mm	50 mm
900 Liter/min	Terrace	75 mm	50 mm
1400 Liter/min	Terrace	100 mm	100 mm
2280 Liter/min	Fire Pump	150 mm	150 mm
2850 Liter/min	Fire Pump	200 mm	150 mm
4500 Liter/min	Fire Pump	250 mm	200 mm
6700 Liter/min	Fire Pump	250 mm	200 mm

Different Types of Fire Extinguishers for Different Classes of Fires (IS 2190)					
Type of Extinguisher	IS	Type of Fires			
		Class A	Class B	Class C	Class D
water type (gas cartridge)	IS 940 , IS 13385	S	NS	NS	NS
water type (stored pressure)	IS 6234	S	NS	NS	NS
mechanical foam type (gas cartridge)	IS 10204, IS 13386	S	S	NS	NS
mechanical foam type (stored pressure)	IS 14951,IS 15397	S	S	NS	NS
dry powder type (stored pressure)	IS 13849	S	S	S	NS
dry powder type (gas cartridge)	IS 2171 , IS 10658	S	S	S	NS
dry powder type for metal fires	IS 11833	NS	NS	NS	S
carbon dioxide type	IS 2878, IS 8149	NS	S	S	NS
clean agent gas type	IS 15683	S	S	S	NS
halon 1211 type	IS 4862 , IS 11108	S	S	S	NS

PRESSURE TESTING OF FIRE EXTINGUISHERS (IS 2190)				
Type of Extinguisher	IS	Test Interval (Year)	Test Pressure (kg/cm2)	Pressure Maintained for Min. (kg/cm2)
Water type (gas cartridge)	IS 940	3	35	2.5
Water type (stored pressure)	IS 6234	3	35	2.5
Water type (gas cartridge)	IS 13385	3	35	2.5
Mechanical foam type (gas cartridge)	IS 10204	3	35	2.5
Mechanical foam type (stored pressure)	IS 15397	3	35	2.5
Mechanical foam type (gas cartridge)	IS 13386	3	35	2.5
Mechanical foam type (gas cartridge) 135 liter	IS 14951	3	35	2.5
Dry powder (stored pressure)	IS l3849	3	35	2.5
Carbon dioxide	IS 2878	5	250	2.5
Clean agent	IS 15683	3	35	2.5
Dry powder (gas cartridge)	IS2171, IS10658	3	35	2.5

LIFE OF FIRE EXTINGUISHERS (IS 2190)	
Type of Extinguisher	Life Time, Year
Water type	10
Foam type	10
Powder type	10
Carbon dioxide	15
Clean agent	10

Flange Details		
Pipe Dia	Flange Thickness	No. of holes
200 mm.	24 mm.	12
150 mm and 125 mm	22 mm.	8
100 mm and 80 mm	20 mm.	8
65 mm.	18mm	4
40 mm and below.	16mm	4

Pipe Support Details			
Nominal Pipes Diameter	Hanger rod diameter	Hanging Strip Size (Thick x Width)	Spacing between supports
25 mm	8 mm	25 x 1.5 mm	2 Meter
32 mm	8 mm	25 x 1.5 mm	2.5 Meter
40 mm	8 mm	25 x 1.5 mm	2.5 Meter
50 mm	10 mm	30 x 2 mm	2.5 Meter
65 mm	10 mm	30 x 2 mm	2.5 Meter
80 mm	10 mm	30 x 2 mm	2.5 Meter
100 mm*	12 mm*	30 x 2 mm	2.5 Meter

125 mm*	12 mm*	30 x 2 mm	3 Meter
150 mm*	16 mm*	30 x 3 mm	3 Meter
200 mm*	16 mm*	30 x 3 mm	3 Meter
* As per Site Requirement Fabrication Support may be used.			
For Single pipes of size 100 mm and above, with the prior approval 50xx50xx6 mm MS Angle iron and for Double Pipe 75x75x6mm with U Clamp with Fastener may be used for Supporting horizontal Pipe from ceiling.			

Sprinkler Qty

Pipe Size	Mi. Sprinkler Qty	Max.Sprinkler Qty
25 mm	1	2
32 mm	3	4
40 mm	5	7
50 mm	8	15
65 mm	16	30
80 mm	31	60
100 mm*	61	100
150 mm*	More than 100	

Supporting Chanel & U Bolt

Pipe Size	Chanel	U Bolt Dia
Up to 50 mm	38x38xx6 mm	9 mm
65 To 100 mm	75x75x6 mm	12 mm
125 To 200 mm	88x88x9 mm	15 mm

Pipe Support Details

MS Angle(mm)	Anchor Fasteners	Width
40X40X5	12MM	200MM both Side of Pipe

Holiday Test Voltage (IS 15337)

Thickness of Coating	Test Voltage, Max
2 mm	10KV
3 mm	12KV
4 mm	15KV

Recommended Welding Electrode Size

Average Thickness of Plate or Sections	Maximum Electrode Size	Current Range
1.5 To 2.0 mm	2.5 mm	60 To 95 Amp
2.0 To 5.0 mm	3.2 mm	110 To 130 Amp
5.0 To 8.0 mm	4.0 mm	140 To 165 Amp
>8.0 mm	5.0 mm	170 To 260 Amp

Washer Size (TYPE-A) IS: 2016 TABLE II

BOLT-SIZE (MM)	WASHER MATERIAL: MILD STEEL		
	INTERNAL - DIA MM	EXTERNAL - DIA MM	THICKNESS (MM)
M1.6	1.8	4	0.4
M1.8	2.1	5	0.4
M2	2.4	5	0.4
M2.2	2.6	6	0.5
M2.5	2.9	6.5	0.5
M3	3.4	7	0.5
M3.5	4	8	0.5
M4	4.5	9	0.8
M4.5	5	10	1

M5	5.5	10	1
M6	6.6	12.5	1.6
M7	7.6	14	1.6
M8	9	17	1.6
M10	11	21	2
M12	14	24	2.5
M14	16	28	2.5
M16	18	30	3.15
M18	20	34	3.15
M20	22	37	3.15
M22	24	39	3.15
M24	26	44	4
M27	30	50	4
M30	33	56	4
M33	36	60	5
M36	39	66	5
M39	42	72	6
M42	45	78	6
M45	48	85	8
M48	52	92	8

INSTALLATION OF FIRE EXTINGUISHERS (IS 2190)

Occupancy	Type of Occupancy	Nature of Occupancy	Class of Fire	Typical Examples
Group A	Residential buildings	Low Hazard	CLASS A	Lodging or rooming, one or two family houses, private dwellings, dormitories, apartment houses, flats, up to 4 star hotels, etc
		Low Hazard	CLASS C	Small kitchens having LPG connection, electrical heaters, etc
		Medium Hazard	CLASS A	Multi-storied buildings, multi-risk buildings, five star hotels, etc
Group B	Educational buildings	Low Hazard	CLASS A	Tutorials, vocational training institutes, evening colleges, commercial institutes
		Medium Hazard	CLASS A	Schools, colleges, etc
Group C	Institutional buildings	Medium Hazard	CLASS A	Hospitals, sanatoria, homes for aged, orphanage jails, etc
Group D	Assembly buildings-D-1	High Hazard	CLASS A	Theatres, assembly halls, exhibition halls, museums, restaurants places of worship, club rooms, dance halls, etc, having seating capacity of over 1 00 persons
	Assembly buildings-D-2	High Hazard	CLASS A	Theatres, assembly halls, exhibitions halls, museums, restaurants, places of worship, club rooms, dance halls, etc, having seating capacity less than 1 000 persons
	Assembly buildings-D-3	High Hazard	CLASS A	Theatres, assembly halls, exhibition halls, museums, restaurants, places of worship, club rooms, dance halls, etc, but having accommodation for more than 300 persons, but less than 1 000 persons, with no permanent seating arrangement
	Assembly buildings-D-4 / D5	Low Hazard	CLASS A	Theatres, assembly halls, exhibition halls, museums, restaurants, places of worship, club rooms, dance halls, etc, but having accommodation less than 300 and those not covered under D-l to D-3
Group E	Business buildings-E-1	Special Hazard	CLASS A	Offices, banks, record rooms, archives, libraries, data processing centers, etc
	Business buildings-E-2	Medium Hazard	CLASS B	Laboratories, research establishment, test houses, etc
	Business buildings-	Special	CLASS A	Computer installations

	E-3	Hazard		
Group F	Mercantile buildings	Medium Hazard	CLASS A	Shops, stores, markets, departmental stores, underground shopping centers, etc
Group G	Industrial buildings	Low Hazard	CLASS A	Small industrial units
		Medium Hazard	CLASS A	Corrugated carton manufacturing units, paper cane units, packing case manufacturing units, cotton waste manufacturing units
		HH	CLASS A	Large number yards, saw mills, godowns and warehouses storing combustible materials, cold storages, freight depots, etc
		Low Hazard	CLASS B	Demonstration chemical plants, small chemical processing plants, pilot plants, etc
		Medium Hazard	CLASS B	Workshops, painting shops, large kitchens, industrial canteens, generator rooms, heat treatment shops, tread rubber manufacturing units, petrol bunks, tubes and Haps units, etc
		High Hazard	CLASS B	Petroleum processing units, chemical plants, industrial alcohol plants, effluent treatment plants, etc
		High Hazard	CLASS C	Fertilizer plants, petrochemical plants, LPG bottling plants, etc
		High Hazard	CLASS D	All processes involving use of combustible highly flammable materials, reactive metals and alloys, including their storage
Group H	Storage buildings	Medium Hazard	CLASS B	Flammable liquid stores, storage in drums and cans in open, paints and varnishes go down
		High Hazard	CLASS B	Tank farms, chemical and petroleum bulk storage depots, large service stations, truck and marine terminals, underground LDO/furnace oil storage yards, etc
		Medium Hazard	CLASS C	LPG distribution godown/office, distribution storage godowns/offices of D, N, H, Argon and other industrial gases
		High Hazard	CLASS C	Storage and handling of gas cylinders in bulk, gas plant, gas holders (Horton), spheres, etc
Group J	Hazardous	-	-	Buildings used for storage, handling, manufacture and processing of highly combustible explosive materials. (Risks involved in terms of class of fire and intensity of fire has to be assessed on case to case basis and statutory authorities to be consulted, environmental factors and mutual aid facilities to be taken into account before deciding on the fire extinguisher requirements.)

RECOMMENDED EQUIPMENT TO BE INSTALLED (IS 2190)		
Class of Fire	**Occupancy**	**No of Fire Systems**
CLASS A	Low Hazard	One 9 liter water expelling extinguisher or ABC 5 kg/6 kg fire extinguisher, for every 200 m2 of floor area or part thereof with minimum of two extinguishers per compartment or floor of the building.
	Medium Hazard	Two 9 liter water expelling extinguishers or ABC 5 kg / 6 kg fire extinguisher, for every 200 m2 with minimum of 4 extinguishers per compartment floor.
	Medium Hazard	Provision as per MH occupancy; in addition to one 50 liter water CO2/25 kg ABC fire extinguisher for every 100 m2 of floor area
	Special Hazard	One 4.5 kg capacity carbon dioxide or one 2/3 kg capacity clean agent extinguisher for every 100 m2 of floor area or part thereof with minimum of two extinguishers
CLASS B	Low Hazard	One 9 liter foam extinguisher, mechanical or BC or ABC, 5 kg/6 kg fire extinguisher, for every 200 m2 of floor area or part thereof with minimum

		of two extinguishers per compartment or floor.
	Medium Hazard	Two 9 liter foam extinguisher, mechanical type, or 5/6 kg dry powder extinguisher (or one of each type) for every 200 m2 area with minimum of four extinguisher per compartment
	Medium Hazard	Provision as per MH, and in addition to one 50 liter mechanical foam type extinguisher or 25 kg BC fire extinguisher for every 100 m2 or part thereof one l35 liter foam mechanical extinguisher for every 300 m2 of floor area
CLASS C	Low Hazard	One 2/3 kg dry powder of clean agent extinguisher for every 20 m2 of floor area
	Medium Hazard	One 10 kg dry powder extinguisher (stored pressure) or 6.5 kg carbon dioxide extinguisher or 5 kg clean agent for 100 m2 of floor area or part thereof, with minimum of one extinguishers of the same type for every compartment;
	High Hazard	Dry powder extinguisher (stored pressure) of 10 kg or 6.5 kg CO2 extinguisher, or 5 kg clean agent extinguisher for every 100 m2 of floor area or part thereof, subject to a minimum of two extinguishers of same type per room or compartment.
CLASS D	High Hazard	One 10 kg dry powder extinguisher with special dry powder for metal fires for every 100 m2 of floor area or part thereof with minimum of two extinguishers per compartment/room

Size of the Mains for Fire Fighting as per Type of Building (IS 3844)

Mains of Fire Fighting	Type of Building	Building Height
100 mm single outlet landing valves	**I) Residential buildings (A)**	
	a) Lodging housing	15 Meter to 45 Meter
	b) Dormitory	15 Meter to 45 Meter
	c) Family private dwellings	15 Meter to 45 Meter
	d) Apartment houses	15 Meter to 45 Meter
	e) With shopping area not exceeding 250 m2	15 Meter to 45 Meter
	f) Hotel buildings up to 3 star grade	15 Meter to 24 Meter and area not exceeding 600 m2 per floor
100 mm single outlet landing valves	II) Educational buildings (B)	Above 15 m but not exceeding 35 m
100 mm single outlet landing valves	III) Institutional buildings (C)	Above 15 m but not exceeding 35 m
100 mm single outlet landing valves	a) For hospitals and sanatorium with beds not exceeding 100no's	Above 15 m but not exceeding 25 m
100 mm single outlet landing valves	b) For custodial places and mental institutions	Above 15 m but not exceeding 35 m
100 mm single outlet landing valves	IV) Assembly buildings (D)	Above 15 m but not exceeding 24 m and total floor area not exceeding 500 m2/floor
100 mm single outlet landing valves	V) Business buildings (E)	Above I5 m but not exceeding 24m
100 mm single outlet landing valves	VI) Mercantile buildings (F)	Above 15m but not exceeding 24 m
100 mm single outlet landing valves	VII) Industrial buildings (G)	Above 15 m but not exceeding 24 m
150mm with twin outlet landing	VIII) All buildings classified under(I) To (IV)	Above 45 m
150mm with twin outlet landing	IX) All buildings classified under(v) above with shopping area not exceeding 250 m2	Above 24 m
150mm with twin outlet landing	X) All buildings classified under (vi) above	Above 24 m and area exceeding 600 m2
150mm with twin outlet landing	XI) Hotel buildings of 4 star and 5 star grade	Above 15 m
150mm with twin outlet	XII) All buildings classified under II and III above	Above 25 m/35 m as applicable

landing		
150mm with twin outlet landing	XIII) All buildings classified under IV above	Above 25 m and area exceeding 500m2/floor
150mm with twin outlet landing	XIV) All buildings classified under V above	Above 24 m
150mm with twin outlet landing	XV) All buildings classified under VI above	Above 24 m but not exceeding 35 m
150mm with twin outlet landing	XVI) All buildings classified under VII above	Above 24 m but not exceeding 35 m
150mm with twin outlet landing	XVII) All storage buildings (H)	Above 10 m but not exceeding 24 m

As per (IS 3844)	
Type of Riser	Internal hydrants form part of any of the following systems
	a) Dry-riser system,
	b) Wet-riser system,
	c) Wet-riser-cum-down-comer system
	d) Down-comer system.
Dry-Riser System (for Cold Region)	Dry-riser main system can be installed in buildings under Group A (iI, ii, ii, iv), where the height of building is above 15 m but not exceeding 24 m up to terrace level and where the water supply for firefighting is immediately available either through the underground water storage tank/tanks or through water mains/town's main
	Dry-riser system does not include hose reel, hose cabinets, fire hose and branch pipes.
Wet-Riser System	Wet-riser system should be provided in the types of buildings according to the provision mentioned. The system should consist of a pipe or number of pipes depending on the area and height of the buildings permanently charged with water under pressure with landing valves, hose reel, hose, branch pipe, etc, at every floor level
	A provision of pressure differential switch to start the pump automatically, so that water under pressure is advisable for operational hydrant, hose reels, etc, as soon as the water is drawn from hydrant landing valves causing drop in pressure. The system also incorporates a stand-by pump to come into operation automatically when the normal power supply source fails.
	The distribution of wet-riser installation in the building should be so situated as not to be farther than 30 m from any point in the area covered by the hydrant and at a height of 0.75 m to 1 m from the floor. The rising mains should not be more than 50 m apart in horizontal.
	Fire service inlet with gate and non-return valve to charge the riser in the event of failure of the static pump directly from the mobile pump of the tie services should: be provided on the wet-riser system. The, fire service inlet for 100 mm internal diameter rising main should have collecting head with 2 numbers of 63 mm inlets and for 150 mm rising main, collecting head with 4 numbers of 63 mm inlets should be provided.
	For wet-risers down-comer system, two pumps of different capacities one for the wet-riser and the other for down-comer system should be installed. The pumps should be fed from normal source of power supply and also by an alternative source in case of failure of normal source.
	For a wet-riser system, two automatic pumps should be installed to independently feed the wet riser main, one of which should act as stand-by, each pump being supplied by a different source of power. The pump shall be arranged so that when acting as duty-pump, operate automatically when one or more hydrant is opened thus causing a drop in pressure. The stand-by pump should be arranged to operate automatically in case of failure of the duty pump. The system should have an interlocking arrangement so that only one of the pumps operates at a time.
Wet-Riser-cum-Down-Comer	A wet-riser-cum-down-comer system should be provided in the type of buildings indicated in Table 1 of IS 3844 according to the provision mentioned.

	Priming of the main pump and terrace pump in case of wet-riser-cum-down, or both the pumps in case of wet-riser installation, should be automatic. This can be achieved either by having flooded suction, or by a priming tank with foot valve arrangement. However, a flooded suction is preferable.
Down-Comer System	Single headed landing valve, connected to a 100 mm diameter pipe taken from the terrace pump delivery should be provided at each floor/landing, A hose reel conforming to IS 884 : 1985 and directly tapped from the down-comer pipe should also be provided on each floor/landing.

As per (IS 3844)	
Riser	The position of risers should be located within lobby approach staircase or within, the staircase enclosure when there is no lobby. However, the risers or the landing valves connected
Landing Valve	Landing valves should be installed on each floor level and on the roof, if accessible, in such a way that control line of landing valve is 1 to 1.2 m above the floor level.
Fire Hoses	In buildings with basements, the internal hydrants as well as the hose reel installations should be extended to cover the basement area also, over and above sprinkler system
	Fire hoses should be of sufficient length to, carry water from the nearest source of water supply to the most distant point in the area covered by a hydrant, by the normal route of travel. For each internal hydrant (single headed), there should be a total length of not less than.30 m of 63 mm conforming to Type A of IS 636 : 1988 or provided in two lengths of not more than 15 m each wire wound with coupling together with branch pipe conforming to IS 2871
	Such spare hoses also should be in length of not more than 15 m complete with coupling. Hoses and accessories should be kept in hose cabinet painted fire red and constructed preferably of wood with glass front
Hose Box	Unless impracticable by structural considerations, the landing valves should always be housed in hose boxes. Such hose boxes should be made of MS plates of 2 mm minimum thickness with glass front. The size of the box should be adequate to accommodate single/double headed landing valves with 2 or 4 lengths of fire hose each of 15 m length, and one or two branch pipes. The hose reel may or may not be accommodated inside the hose box.
	Building fitted with wet-riser/wet-riser-down-comer mains should, have access roads to within 6 m from the boundary line of the building and the nearest wet-riser stack should not be more than 15 m from the boundary line of the building.
Hose Reels	In addition to wet-riser systems, first aid hose reels should be installed on all floors of buildings above 15 m in height. The hose reel should be directly taken from the wet-riser pipe by means of a 37 mm socket and pipe to which the hose reel is to be attached.
	The hose reel should be sited at each floor level, staircase, lobby or mid-landing adjacent to, exits in corridors in such a way that the nozzle of the hose can be taken into every room and within 6 m of any part of a room keeping in view the layout and obstructions. Tbe doors provided for the hose reel recesses should he capable of opening to approximately 180". when installation is in open areas, the position should be above head height and the nozzle retainer and tbe inlet valve should be at about 900 mm above floor level.
Air Valve	To allow any trapped air in the rising main to escape when water is pressurized into system,air release valve should be incorporated above the highest outlet of each main.
External Hydrant	For external hydrants, piping (water main) should be laid preferably underground, to avoid it getting damaged by moving vehicles, etc. To avoid rusting, underground pipes should be either of cast iron conforming to IS 1536 in which case it should be properly treated with a coat of primary paint with two coats of bitumen paint. The pipes should be properly supported of pedestals - not more than 3 m apart. Underground pipes should be laid 1 m below to avoid damage during road repair, etc, and at road crossings where heavy vehicles are expected to pass, it should pass
Jockey Pump	For bigger buildings or major installations, where chance of such leakage is very considerable, it is desirable to install a small pump (using a small motor and 200/300 liter/min pump) with pressure switches for automatic start and stop.
Using Wet-Riser System Pump for Partial Sprinkler System	In main high rise buildings, the basement is used for car parking/housing transformers/or storages and other floors may be used as shopping areas departmental stores, etc, the total area used for such purpose being small, in such cases, the same wet-riser pump may be used for feeding the sprinkler system provided that:

	a)the total area of the basement to be protected is less than 500 m2. b) the total area utilized as shops departmental stores is less than 1000 m2. c)the pump has a capacity of at least 2850 l/min with suitable motor.

AS per IS 15301	
Foundation of Pump	Pumps are to be mounted on a concrete foundation having minimum M grade of reinforced concrete as M15..
	The thickness of the foundation shall be 50 mm minimum for small pumps up to 900 Liter/min capacity, 75 mm for pumps up to 2280 Liter/min capacity and 100 Liter/min for bigger pumps up to 4 500 Liter/min. For extra ordinary big pumps, the thickness may go up to 150 mm. The size of the foundation shall cover the full length and width of the pump and at least 150 mm on the front and back of the pump and 75 mm on the sides as clearance.
Pump Room Location	Normally, pump rooms shall be located 6 m away from all surrounding buildings and overhead structures
	Where this is not feasible, they may be attached to a building provided a perfect separation wall having 4 hour fire rating is constructed between the pump room and the attached building, the roof of the pump room is of RCC construction at least 100 mm thick and access to the pump room is from the outside. The pump rooms shall normally have brick/concrete walls and non-combustible roof with adequate lighting, ventilation and drainage arrangements.
	Transformer cubicles inside the sub-stations shall be separated from H.T. and L.T. cubicles and from each other by walls of brick/stone/concrete blocks or 355 mm thickness or of RCC of 200 mm thickness with door openings, if any, therein being protected by single fireproof doors having 2-hour fire resistance
	Transformers installed outdoors, which are supplying power to fire pump shall also be located at least 6 m away from all surrounding buildings including sub-station or D.G. House, where this is not feasible, all door and window openings of the building within 6 m of the transformers] shall be protected by single fireproof doors and 6 mm thick wired glasses in steel framework respectively.

Fire Safety for Group A - Residential Buildings – Above 15 m in height (IS 3844)						
Type of Fire Protection	**A3- Dormitories, A4- Apartments Houses**				**A5- Hotels**	
Fire Safety	**15 Mts To 35 Mts**	**35 Mts To 45 Mts**	**45 Mts To 60 Mts**	**Above 60 Mts**	**15 Mts To 30 Mts**	**Above 30 Mts and A6 Hotels (Starred)**
Fire Extinguishers	**Minimum 2 per floor Depending upon the Area and Travel Distance**					
Terrace Level Over Head Tank	25,000 liters capacity	5,000 liters (5,000 liters if basement)	10,000 liters capacity	25,000 liters capacity	20,000 liters capacity	20,000 liters capacity
Under Ground Water Tank	Not Required	75,000 liters capacity	75,000 liters capacity	1,00,000 liters capacity	1,50,000 liters capacity	2,00,000 liters capacity
Terrace Fire Pump	900 LPM at Terrace level Tank	Not Required	Not Required	Not Required	Not Required	Not Required
Fire Pump near Under Group Water Tank	Not Required	1 electric pump & 1 Diesel pump of capacity 1620 LPM & Jockey Pump 180 LPM	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	1 electric pump & 1 Diesel pump of capacity 2280LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2850 LPM & Jockey Pump 180 LPM
Hose Reel Assembly	Required	Required	Required	Required	Required	Required
Down Comer System	Required	Not Required	Not Required	Not Required	Not Required	Not Required
Wet Riser System	Not Required	Required	Required	Required	Required	Required

Yard Hydrant	Not Required	Not Required	Required	Required	Required	Required
Fire Service Inlet	Required	Required	Required	Required	Required	Required
Manually Operated Fire Alarm Call Point (MCP)	Required	Required	Required	Required	Required	Required
Automatic Detection & Alarm System	Not Required	Not Required	Not Required	Required	Required	Required
Automatic Sprinkler System	Required if area of basement exceeds 200 Sq.mts	Required if area of basement exceeds 200 Sq.mts	Required	Required	Required	Required

Fire Safety for Group B - Educational Buildings of above 15 Meter in height (IS 3844)

Type of Fire Protection Required	**B-1 Schools up to Senior Secondary Level** **B-2 All others/training Institutions (Ground + One Storey)**
Fire Extinguishers	Minimum 2 per floor. Depending up on the Area and Travel Distance
Terrace Level Over Head Tank	25000 Liters Capacity
Under Ground Water Tank	Not required
Terrace Fire Pump	900 LPM
Fire Pump near Under Ground Water Tank	Not required
Hose Reel Assembly	Required
Down Comes System	Required
Wet Riser System	Not required
Yard Hydrant	Not required
Fire Service Inlet	Required
Manually Fire Alarm Call Point (MCP)	Required
Automatic Detection and Alarm System	Not required
Automatic Sprinkler System	Required if area of basement exceeds 200 sq.mts

Fire Safety for Group C - Institutional Buildings > 15 m in height (IS 3844)

Type of Fire Protection Required	**C1- Hospitals, Sanatoria and Nursing Home**		**C2 - Custodial Institutions** **C3 - Penal and Mental Institutions**	
Fire Safety (Active Measures)	**15 Mts not exceeding**	**24 Mts not exceeding**	**15 Mts not exceeding**	**24 Mts not exceeding**
	24 Mts	**30 Mts**	**24 Mts**	**30 Mts**
Fire Extinguishers	**Minimum 2 per floor Depending upon the Area and Travel Distance**			
Terrace Level Over Head Tank	20,000 liters capacity	20,000 liters capacity	10,000 liters capacity	20,000 liters capacity
Under Ground Water Tank	1.00,000 liters capacity	1,50,000 liters capacity	75,000 liters capacity	1,00,000 liters capacity
Terrace Fire Pump	Not required	Not Required	Not Required	Not Required
Fire Pump near Under Group Water Tank	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM
Hose Reel Assembly	Required	Required	Required	Required
Down Comer System	Not Required	Not Required	Not Required	Not Required
Wet Riser System	Required	Required	Required	Required
Yard Hydrant	Required	Required	Required	Required

Fire Service Inlet	Required	Required	Required	Required
Manually Operated Fire Alarm Call Point (MCP)	Required	Required	Required	Required
Automatic Detection & Alarm System	Required	Required	Required	Required
Automatic Sprinkler System	Required	Required	Required	Required

Fire Safety for Group D - Assembly Buildings > 15 m in height (IS 3844)

Type of Fire Protection Required	D1 - Theater over 1000 persons, D2 up to 1000 persons D3 - Permanent Stage over 300 persons		D6 - Not exceeding 30 mtrs	D7 - Elevated or underground for assembly not covered D1-D6
	D4 – up to 300 persons, D5 all others			
Fire Safety	**15 Mts To 24 Mts**	**24 Mts To 30 Mts**	**15 Mts not exceeding**	**24 Mts not exceeding**
Fire Extinguishers	**Minimum 2 per floor Depending upon the Area and Travel Distance**			
Terrace Level Over Head Tank	10,000 liters capacity	20,000 liters capacity	20,000 liters capacity	20,000 liters capacity
Under Ground Water Tank	75,000 liters capacity	1,00,000 liters capacity	1,00,000 liters capacity D1-D5, 2,00,000 liters for D6 Multiplex	1,00,000 liters capacity
Terrace Fire Pump	Not required	Not Required	Not Required	Not Required
Fire Pump near Under Group Water Tank	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2850 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2850 LPM & Jockey Pump 180 LPM
Hose Reel Assembly	Required	Required	Required	Required
Down Comer System	Not Required	Not Required	Not Required	Not Required
Wet Riser System	Required	Required	Required	Required
Yard Hydrant	Required	Required	Required	Required
Fire Service Inlet	Required	Required	Required	Required
Manually Operated Fire Alarm Call Point (MCP)	Required	Required	Required	Required
Automatic Detection & Alarm System	Required	Required	Required	Required
Automatic Sprinkler System	Required	Required	Required	Required

Fire Safety for Group E - Business Buildings >15 m in height (IS 3844)

Type of Fire Protection Required	**E1 offices, banks, professional establishments, like offices of architects, engineers, doctors, lawyers and police stations, E2 - Laboratories research establishments, libraries and test houses. E3 - Computer installations, E4 - Telephone Exchanges, E5**		
Fire Safety	**15 Mts To 24 Mts**	**24 Mts To 30 Mts**	**Above 30 mt**
Fire Extinguishers	Minimum 2 per floor Depending upon the Area and Travel Distance	Minimum 2 per floor Depending upon the Area and Travel Distance	Minimum 2 per floor Depending upon the Area and Travel Distance
Terrace Level Over Head Tank	10,000 Liters capacity	20,000 liters capacity	20,000 liters capacity
Under Ground Water Tank	75,000 liters capacity	1,00,000 liters capacity	2,00,000 liters capacity

Terrace Fire Pump	Not required	Not Required	Not Required
Fire Pump near Under Group Water Tank	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2850 LPM & Jockey Pump 180 LPM
Hose Reel Assembly	Required	Required	Required
Down Comer System	Not Required	Not Required	Not Required
Wet Riser System	Required	Required	Required
Yard Hydrant	Required	Required	Required
Fire Service Inlet	Required	Required	Required
Manually Operated Fire Alarm Call Point (MCP)	Required	Required	Required
Automatic Detection & Alarm System	Required	Required	Required
Automatic Sprinkler System	Required	Required	Required

Fire Safety for Group F Mercantile Building Above 15 m in height (IS 3844)

Type of Fire Protection Required	F1 - Shops, Stores up to 500 Sq.m, F2 - Shops, Stores more than 500 Sq. mtrs.		F3 - Underground shopping centre and Storage
Fire Safety (Active Measures)	**15 Mts To 24 Mts**	**24 Mts To 30 Mts**	
Fire Extinguishers	**Minimum 2 per floor Depending upon the Area and Travel Distance**		
Terrace Level Over Head Tank	10,000 liters capacity	10,000 liters capacity	10,000 liters capacity
Under Ground Water Tank	1,00,000 liters capacity	1,50,000 liters capacity	1,50,000 liters capacity
Terrace Fire Pump	Not required	Not Required	Not Required
Fire Pump near Under Group Water Tank	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	2 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM
Hose Reel Assembly	Required	Required	Required
Down Comer System	Not Required	Not Required	Not Required
Wet Riser System	Required	Required	Required
Yard Hydrant	Required	Required	Required
Fire Service Inlet	Required	Required	Required
Manually Fire Call Point (MCP)	Required	Required	Required
Automatic Detection & Alarm System	Required	Required	Required
Automatic Sprinkler System	Required	Required	Required

Fire Safety for Group G Industrial Buildings Above 15 m in height not to be permitted 18 Mts in height (IS 3844)

Type of Fire Protection	G1 - Low Hazard Industries			G2 - Moderate Hazard Industries			
	BUILT UP AREA						
Fire Safety	**Up to 100 Sq.mt**	**More than 100 Sq.mt. & up to 500 Sq.mt**	**More than 500 Sq.mtrs**	**Up to 100Sq.mtrs**	**More than 100Sq.mtrs and up to 500 Sq.mtrs**	**More than 500Sq. mtrs and up to 1000 Sq.mtrs**	**Up to 1000 Sq.mt**
Fire Extinguishers	**Minimum 2 per floor Depending upon the Area and Travel Distance**						
Terrace Level	5000 liters	5000 liters add	10,000	10,000	10,000	20,000	20,000

Over Head Tank	in case of basement area exceeds 200m²	5000 liters if the provision of sprinkler in basement	liters capacity	Liters capacity	Liters capacity	Liters capacity	Liters capacity
Under Ground Water Tank	NO	NO	1,00,000 liters	NO	NO	75,000 Liters capacity	1,00,000 Liters capacity
Terrace Fire Pump	450 LPM	450 LPM	450 LPM	900 LPM	900 LPM	900 LPM	900 LPM
Fire Pump near Under Group Water Tank	NO	NO	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	NO	NO	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM	1 electric pump & 1 Diesel pump of capacity 2280 LPM & Jockey Pump 180 LPM
Hose Reel Assembly	NO	YES	YES	YES	YES	YES	YES
Down Comer System	NO	YES	YES	NO	NO	YES	YES
Wet Riser System	NO	YES	YES	NO	NO	YES	YES
Yard Hydrant	NO	YES	YES	NO	NO	YES	YES
Fire Service Inlet	NO	YES	YES	NO	NO	YES	YES
Manually Operated Fire Alarm Call Point (MCP)	NO	YES	Not Required	NO	NO	YES	YES
Automatic Detection & Alarm System	NO	YES	Required	NO	NO	YES	YES
Automatic Sprinkler System	YES (if there is basement)	YES (if there is basement)	YES	YES	YES	YES	YES

Fire Fighting Clause (Gujarat Fire Prevention and Life Safety Regulations, 2023)

Clause	Head	Description
15.5.3	External Stairs:	The external stairs shall be constructed of non- combustible materials and any doorway leading to it shall have the required fire resistance.
		No external staircase, used as a fire escape, shall be inclined at an angle greater than 45° from the horizontal.
		External stairs shall have straight flight not less than **1250 mm wide with 250 mm treads and risers not more than 190 mm**. The number of risers shall be limited to 15 per flight.
		Handrail s shall be of height not less than **700 mm and not exceeding 850 - 900 mm**. There shall be provisions of balusters with maximum gap of 150 mm.
15.5.4	Horizontal Exit Door:	A horizontal exit shall be equipped with at least one fire/smoke door of minimum **2 hour fire resistanc**e of self-closing type. Further, it should have direct connectivity to the fire escape staircase for evacuation.
		Doors in horizontal exits shall be open able at all times from both side
15.5.7	Exit Door ways	**Size:** No exit doorway shall be less than **1000 mm in width** except assembly buildings where door width shall be **not less than 2000 mm.**
		Height: All doorways shall be not less than **2000 mm in heigh**

		Opening Direction: Exit doorways shall open outwards, that is, away from the room, but shall not obstruct the travel along any exit. No door, when opened, shall reduce the required width of stairway or landing to less than **900 mm.** Overhead or sliding doors shall not be installed.
		Exit door shall not open immediately upon a flight of stairs. A-landing equal to at least the width of the door (not less than 900mm) shall be provided in the stairway at each doorway,
		The level of landing shall be the same as that of floor, which it serves. Manual door should incorporate kick plate 300 mm high to withstand impact of wheelchair footrest where doors are glazed. Door handle and locks should be positioned **between 900-1000 mm from floor level.**
		Mirror: Mirrors shall not be placed in exit doors to avoid confusion regarding the direction of exit.
15.9	**Corridors / Passageways & Stairs Case**	**Flight:** No flight shall contain more than **12 to 16 risers,** but in residential buildings, in narrow plots and in high density Housing a single flight staircase may be permitted.
		Risers: The maximum height of a riser shall be 190mm. in a residential building and 16 cm. in any other occupancy. However, on an internal stairway within a dwelling unit a riser may be 25 cm high.
		Head room: The minimum head room in a passage under the landing of a staircase under the staircase shall be 2.2 meter.
		Tread Width: The minimum width of tread without nosing shall be **250 mm** for internal staircase of residential buildings, other than fire escapes. This shall be **300 mm** for assembly, hotels, educational, institutional, business and other buildings. The treads be constructed and maintained in a manner to prevent slipping.
		Hand Rail: Hand rail a minimum height of **0.9 meter** from the centre of the tread shall be provided.
		Floor indicator: The number of each floor shall be conspicuously painted in figures at least 15 cm large on the wall facing the fight of a stairway or at such suitable place as is distinctly visible from the fights.
		No Provision of Natural Ventilation : In case of any building having height more than 15 Meter and no provision of natural ventilation on either side of corridor, in such building, smoke exhaust system having make-up air and exhaust air system or alternatively, pressurization system with supply air system shall be required for the exit access corridors
15.8	**Internal /Additional Staircases**	**Around Lift Shaft:** A staircase shall not be provided around a lift shaft unless provided with fire stop door of **1 hour** rating at every floor level and no other openings in the inside walls
		NO Services pass from Staircase: No gas piping, electrical panels& appliances or AC ducts shall be allowed in the stairway. However, service shafts/ ducts may be permitted. Electrical Shafts/ ducts shall have not less than2-hour fire resistance. For other service shafts/ ducts, the fire resistance shall be not less than 1 hour.
		Electrical Meter: Electric meters shall not be located below the staircase or along the exit route. Electric meters room shall be adequately ventilated & easily accessible
		Colour Band : All steps, edges must have a contrasting colour band of **50 mm width** stretched entirely across the step width for uses other than residential use.
		Hand Rail: Continuous handrails shall be provided on both sides including the wall (if any) at two levels: upper at 850 mm - 900 mm and lower at 700 mm to be measured from the base of the middle of the treads to the top of handrails. Balusters/ Railing shall be provided in such a way that the width of staircase does not reduce. The maximum gap between balusters shall be 150 mm.
		Min Head Room: The minimum headroom in a passage under the landing of a staircase and the stair shall be **2.2 meter.**
		Lift Opening: Lifts shall not open in staircase.
		Single Staircase: In case of single staircase, it shall terminate at the ground floor level and the access to the basement shall be by a separate staircase.

		Exit Signages: The exit way with arrow indicating the way to the escape route shall be provided at a height of 1.8 meter from the floor level on the wall and shall be illuminated by electric light connected to corridor circuits. All exit way marking signs should be flush with the wall and so designed that no mechanical damage shall occur to them due to moving of furniture or other heavy - equipment. Further,
		Landing Floor Signages: All landings of floor shall have floor indicating the number of floors as per byelaws. The floor indication board shall be placed on the wall immediately facing the flight of stairs and nearest to the landing. It shall be of size not less than 0.5 m x 0.5 m.
		Width of Staircase: Residential building, Hotel building, educational building, Institutional buildings, (i.e., hospital), Mercantile, business, storage industrial, hazardous, buildings
		Height up to 25 Meter: 1.2 Meter
		Height > 25 Meter: 2 Meter
		Assembly buildings :2 Meter
		External Exit Door: External exit door of staircase enclosure at ground level shall open directly to the open spaces.
17 /18	**Staircase**	**Buildings of Height more than 15 meters up to 25 meters:** If the lifts and staircase from higher floors go directly to the basement then this area shall be protected by 1 hour fire resistance construction including fire doors subject to opinion and requirement of local fire authority in specially designed building have to be considered and observed.
		Buildings of Height more than 25 meters up to 45 meters: For Buildings up to 45 meters (excluding parapet wall, lift and stair cabin, OH tank) & each floor area more than 3000 sq. meters- ventilated from two sides/cross ventilated/external staircases connected through a lobby-travel distance not to exceed 25 meters.
		Buildings of Height more than 25 meters up to 45 meters: If the lift and staircase from higher floors go directly to the basements then this area shall be protected by 2 hours fire resistant construction including fire doors.
		Buildings of Height more than 45 meters up to 70 meters: For more than 45 meters (excluding parapet wall, lift and stair cabin, OH tank) & each floor area more than 3000 sq. meters- ventilated from two sides/cross ventilated/external staircases connected through a lobby-travel distance not to exceed 25 meters.
		Buildings of Height more than 45 meters up to 70 meters: Width of staircase shall be 2 meters width for all buildings.
		Buildings of Height more than 45 meters up to 70 meters: The staircase shall be of RCC construction & ventilated and shall be kept open except the parapet wall, all the space above the parapet wall shall be kept open.
15.18	**Ventilation:**	All enclosures should have openable windows and vents to be opened in case of fire or smoke accumulation.
		Centrally Air Condition: If the floor or the building is centrally air-conditioned then a provision to stop the air handling unit should be provided and it shall be blocked by a damper and the same air duct should act as smoke extractors with the extraction fan switching on automatically, if a fire or smoke is detected
		Ventilation from the Top and Skylight etc.: - Where an open well for light and ventilation, within the space enclosed by a stairway and its landings, is proposed to be provided, the least horizontal dimensions of which are equal to two times the width of the staircase. A ventilating skylight with provided fixed or movable louvers to the satisfaction of the competent Authority.The glazed roof of the skylight shall not be less than 3.7 sq. meters in area. No lift or any other fixture shah be erected in such staircase well.
17 /18 /19	**Ventilation:**	**Buildings of Height more than 15 meters up to 70 meters:** If a centrally located staircase is provided with pressurization and fire-resistant doors, the central staircase shall be in addition to the ventilated staircases require for the floor area, maintaining the travel distance.

		Buildings of Height more than 45 meters up to 70 meters: The staircase shall be designed/ located at the exterior part of the building. If the staircase is in the center of the building and is not ventilated then a fire escape staircase (fire tower) has to be installed on either side of the building with travel distance not more than 30 meters.
		Ventilation of stair-cases: Every stair case provided under the foregoing clauses shall be lighted and ventilated to the satisfaction of the Authority from an open-air space not less than 1 sq.mt.
		Windows in stair-case Bay: There shall be provided a window or windows of an aggregate area of at least 1.2 sq. meters on each storey in such of the wall of the stair-case room which abuts on such 1 sq.mt. open air space to right and ventilate such staircase.
15.21	**Air Conditioning**	**Return Air:** Escape routes like staircases, common corridors, lift lobbies, etc., shall not be used as return air passage.
		Ducting Gauge: The ducting shall be constructed of substantial gauge metal as per IS: 655- Specification for Metal Air Ducts.
		Duct Passing through Floor: Wherever the ducts pass through firewalls or floors, the opening around the ducts shall be sealed with materials having fire resistance rating of the compartment.
		Duct Insulation Material : The materials used for insulating the duct system (inside or outside) shall be of non-combustible material. Glass wool shall not be wrapped or secured by any material of combustible nature.
		Fire Damper / Smoke Detector: Proper arrangements by way of automatic fire dampers, working on fusible link/or smoke detector principle for isolating all ducting at every floor from the main riser, shall be made.
		AHU : The air-handling units shall be separate for each floor and air ducts for every floor shall be separate and in no way interconnected with the ducting of any other floor.
		If the air-handling unit serves more than one floor, the conditions given below shall be complied in addition to the recommendations above.
		AHU in case of Fire: When the automatic fire alarm operates, the respective air-handling units of the air-conditioning system shall automatically be switched off.
		Plenum for Return Air: Where plenum is used for return air passage, ceiling and its fixtures shall be of non-combustible material.
15.25	**Fire Control Room**	**Building height having more than 45 Meter and Floor area 3000 sq. meter and more on each floor:** There shall be a control room on the entrance floor of the building with communication system (suitable public address system) to all floors and facilities for receiving the message from different floors. Details of all floor plans along with the details of firefighting equipment and installations shall be displayed in the fire control room.
		The fire control room shall also have facilities to detect the fire on any floor through indicator board's connection; fire detection and alarm system on all floors.
		The fire staff in charge of the fire control room shall be responsible for maintenance of the various services and the firefighting equipment and installations in coordination with security, electrical and civil staff of the building.
15.28	**Basement**	The staircase of basements shall be of enclosed type having fire resistance of not less than **2 hours** and shall be situated at the periphery of the basement to be entered at ground level only from the open air and in such position that smoke from any fire in the basement shall not obstruct any exit serving the ground and upper storey of the building. It shall communicate with basement through a lobby provided with fire resisting self-closing doors of one hour resistance. If the travel distance exceeds the desired level, additional staircases shall be provided at proper places. The basement shall not open in to the staircase or lift well directly. If so then it has to be protected by **2 hours fire resistant self-closing doors**,
		Ventilation: The basement shall be provided with natural ventilations and more than one basement shall have mechanical extractors for smoke venting shall be designed to permit 6 changes per hour in case of fire or distress call. For normal operations, air changes schedule shall be as per National Building Code of India.

		Discharge apparatus of all natural draft smoke vents shall be so arranged as to be readily accessible for opening by fire service person.
		Use of basement for kitchen shall not be permitted. Building services such as, boiler rooms in basement shall comply with the provisions of the IE Act/ Rules.
		The basement of 200 sq. meters or more shall be protected with provisions of Part 4 National Building Code of India
		Each basement shall be separately ventilated. First basement to be naturally ventilated @ 2.5% of the ceiling area. Other basements shall be mechanically ventilated
15.14	**Uses Permitted in Basement**	**For all buildings: For** Parking, safe deposit vault, A.C. Plant, Grey water treatment plant, Sewage Treatment Plant, water tank, storage other than inflammable material, non-habitable use.
		For Hospitals exceeding 2000 Sq. meter of built-up area: For Radiation-production device, Radiation Therapy room, MRI or X-Ray room, laundry and housekeeping.
		For Malls and/or exceeding 2000 Sq.meter of built-up area: For Security Cabin, Electric Cabin, General room, boiler room, laundry, housekeeping, store, lockers, rest room and communication room separated by brick masonry walls of at least 230 cm.
		Total cumulative built-up area for above listed usage shall not exceed 25% of the basement area. However, no kind of any transformer shall be permitted in cellar / basement or within the building.
15.27	**Refuge Area**	**Building Height up to 25 Meter :** Minimum area of 15 m2 on external wall with minimum width of 0.75 m at every 18 meter height; for floor area up to 1000 m2. If floor areal 1000 m2, another Refuge Area on another end of the floor.
		Building Height 25 to 39 Meter : One refuge area on the floor immediately above 25 meter.
		Building Height above 39 Meter : One refuge area on the floor immediately above 39 m and so on after every 15 meter
		Note:- Residential flats in multistorey buildings with balcony need not be provided with refuge area, however flats without balcony shall be provided with refuge area as given above.
15.32	**Fire Check Floor/ Fire Cut OFF Floor**	**High-rise building height more than 70 meter :** shall be provided with fire check floor (entire floor) above 70 meter at immediate habitable floor level. Periphery of the Fire Check floor shall not be enclosed The fire check floor shall not be used for any purpose and it shall be maintain the same clean and free of encumbrances and encroachments at all times.
		Drinking water facility and toilet facility shall be provided.
15.33	**Glass facades**	No glass facades shall be permitted in School and Hospital buildings
		The distance between building structure and glass facade must not be more than 300 mm
		To restrict spread of fire, there must be an automatic water curtain system on each floor.
		No glass façade shall be permitted at the external face of the staircase.
		Every floor must have a two-way opening measuring 1.5m×1.5m in the wall, as access points for rescue workers. They must properly label as "Emergency Exit.
		Glass facade for high rise building shall be of 1 hour fire resistance.

PART-2

Electrical Calculations

Chapter: 1 Calculate Transformer Protection (As per NEC)

NEC, Code 450.4: (Calculate over current Protection on the Primary)

- According to NEC 450.4, “each transformer 600 volts, nominal, or less shall be protected by an individual over current device installed in series with each ungrounded input conductor.
- Such over current device shall be rated or set at not more than 125% of the rated full-load input current of the auto transformer.
- Further, according to NEC Table 450.3(B), if the primary current of the transformer is less than 9 amps, an over current device rated or set at not more than 167% of the primary current shall be permitted. Where the primary current is less than 2 amps, an over current device rated or set at not more than 300% shall be permitted.
- Example: Decide Size of circuit breaker (over current protection device) is required on the primary side to protect a 75kva 440v-230v 3ø transformer.
- 75,000va / (440V x √3) = 98.41 amps.
- The current (amps) is more than 9 amps so use 125% rating.
- 123 amps x 1.25 = 112.76 amps
- Use 125amp 3-pole circuit breaker (the next highest fuse/fixed-trip circuit breaker size per NEC 240.6).
- The over current device on the primary side must be sized based on the transformer KVA rating and not sized based on the secondary load to the transformer.

NEC, Code 450.3B:(Calculate over current Protection on the Secondary)

- According to NEC Table 450.3(B), where the secondary current of a transformer is 9 amps or more and 125% of this current does not correspond to a standard rating of a fuse or circuit breaker, the next higher standard rating shall be required. Where the secondary current is less than 9 amps, an over current device rated or set at not more than 167% of the secondary current shall be permitted.
- Example: Decide Size of circuit breaker (over current protection device) is required on the secondary side to protect a 75kva 440v-230v 3ø transformer.
- We have Calculate the secondary over current protection based on the size of the transformer, not the total connected load.
- 75kva x 1,000 = 75,000va
- 75,000va / (230V x √3) = 188.27 amps. (Note: 230V 3ø is calculated)
- The current (amps) is more than 9 amps so use 125% rating.
- 188.27 amps x 1.25 = 235.34 amps.
- Therefore: Use **300amp 3-pole circuit breaker** (per NEC 240.6).

NEC, Section 450-3(a):(Transformers over 600 volts, Nominal)

- For primary and secondary protection with a transformer impedance of 6% or less, the primary fuse must not be larger than 300% of primary Full Load Amps (F.L.A.) and the secondary fuse must not be larger than 250% of secondary F.L.A.

NEC, Section 450-3(b):(Transformers over 600 volts, Nominal)

- For primary protection only, the primary fuse must not be larger than 125% of primary F.L.A.
- For primary and secondary protection the primary feeder fuse must not be larger than 250% of primary F.L.A. if the secondary fuse is sized at 125% of secondary F.L.A.

NEC, Section 450-3(b):(Potential (Voltage) Transformer)

- These shall be protected with primary fuses when installed indoors or enclosed

NEC, Section 230-95(Ground-Fault Protection of Equipment).

- This section show that 277/480 volt “wye” only connected services, 1000 amperes and larger, must have ground fault protection in addition to conventional over current protection.
- The ground fault relay (or sensor) must be set to pick up ground faults which are 1200 amperes or more and actuate the main switch or circuit breaker to disconnect all ungrounded conductors of the faulted circuit.

NEC, Section 110-9 – Interrupting Capacity.

- Any device used to protect a low voltage system should be capable of opening all fault currents up to the maximum current available at the terminal of the device.
- Many over current devices, today, are used in circuits that are above their interrupting rating.
- By using properly sized Current Limiting Fuses ahead of these devices, the current can usually be limited to a value lower than the interrupting capacity of the over current devices.

NEC, Section 110-10 – Circuit Impedance and Other Characteristics.

- The over current protective devices, along with the total impedance, the component short-circuit withstand ratings, and other characteristics of the circuit to be protected shall be so selected and coordinated so that the circuit protective devices used to clear a fault will do so without the occurrence of extensive damage to the electrical components of the circuit.
- In order to do this we must select the over current protective devices so that they will open fast enough to prevent damage to the electrical components on their load side.

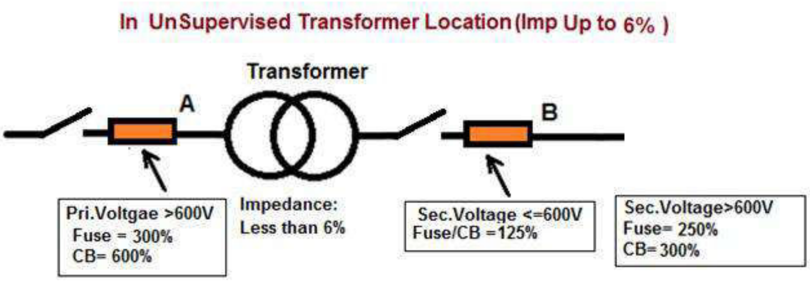
Chapter: 2 Calculate Transformer O/C Protection (NEC 450.3)

Introduction:

- The over current protection required for transformers is consider for Protection of Transformer only.Such over current protection will not necessarily protect the primary or secondary conductors or equipment connected on the secondary side of the transformer.
- When voltage is switched on to energize a transformer, the transformer core normally saturates. This results in a large inrush current which is greatest during the first half cycle (approximately0.01 second) and becomes progressively less severe over the next several cycles (approximately 1 second) until the transformer reaches its normalmagnetizing current.
- To accommodate this inrush current, fuses are often selected which have time-current withstand values of at least 12 times transformer primary rated current for 0.1 second and 25 times for 0.01 second. Some small dry-type transformers may have substantially greater inrush currents.
- To avoid using oversized conductors, over current devices should be selected at about 110 to 125 percent of the transformer full-load current rating. And when using such smaller over current protection, devices should be of the time-delay type (on the primary side) to compensate for inrush currents which reach 8 to 10 times the full-load primary current of the transformer for about 0.1 s when energized initially.
- Protection of secondary conductors has to be provided completely separately from any primary-side protection.
- A supervised location is a location where conditions of maintenance and supervision ensure that only qualified persons will monitor and service the transformer installation.
- Over current protection for a transformer on the primary side is typically a circuit breaker. In some instances where there is not a high voltage panel, there is a fused disconnect instead.
- It is important to note that the over current device on the primary side must be sized based on the transformer KVA rating and not sized based on the secondary load to the transformer

Over current Protection of Transformers > 600 V (NEC 450.3 (A))

1) Unsupervised Location of Transformer (Transformer Impedance <6%)

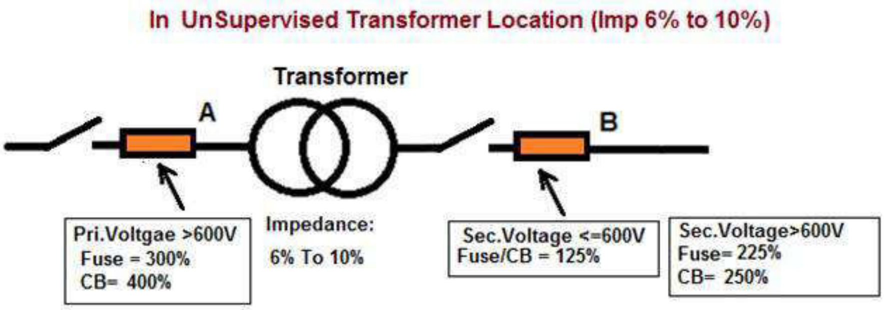


- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 300% of Pri. Full Load Current or Next higher Standard size. or
- Rating of Pri.Circuit Breaker at Point A= 600% of Pri. Full Load Current or Next higher Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage <=600V):**
- Rating of Sec. Fuse / Circuit Breaker at Point B= 125% of Sec. Full Load Current or Next higher Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage >600V):**
- Rating of Sec. Fuseat Point B= 250% of Sec. Full Load Current or Next higher Standard size. or
- Rating of Sec.Circuit Breaker at Point B= 300% of Sec. Full Load Current.

Example: 750KVA, 11KV/415V 3Phase Transformer having Impedance of Transformer 5%

- Full Load Current At Primary side=750000/(1.732X11000)=39A
- Rating of Primary Fuse = 3X39A= 118A, So Standard Size of Fuse =125A.
- OR Rating of Primary Circuit Breaker =6X39A=236A, So Standard Size of Circuit Breaker =250A.
- Full Load Current at Secondary side=750000/ (1.732X415) =1043A.
- Rating of Secondary of Fuse / Circuit Breaker = 1.25X1043A=1304A, So Standard Size of Fuse =1600A.

2) Unsupervisedof Transformer (Transformer Impedance 6% to 10 %)

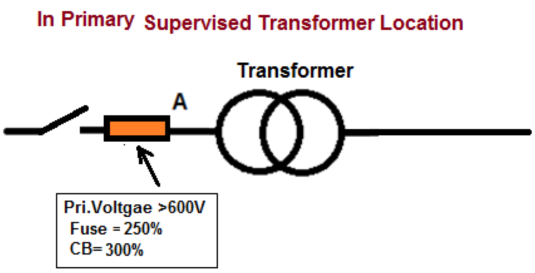


- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 300% of Primary Full Load Current or Next higher Standard size.
- Rating of Pri. Circuit Breaker at Point A= 400% of Primary Full Load Currentor Next higher Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage <=600V):**
- Rating of Sec. Fuse / Circuit Breaker at Point B= 125% of Sec. Full Load Currentor Next higher Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage >600V):**
- Rating of Sec. Fuse at Point B= 225% of Sec. Full Load Current or Next higher Standard size.
- Rating of Sec.Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next higher Standard size.

Example: 10MVA, 66KV/11KV 3Phase Transformer, Impedance of Transformer is 8%

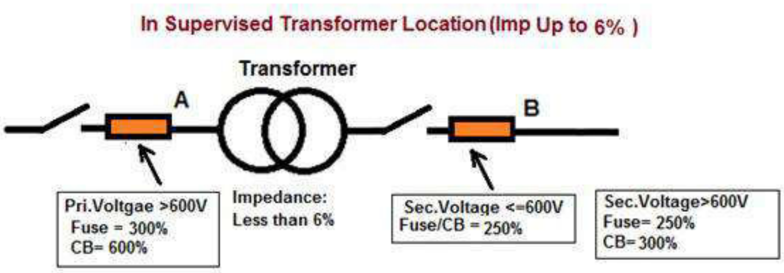
- Full Load Current At Primary side=10000000/(1.732X66000)=87A
- Rating of Pri. Fuse = 3X87A= 262A, So Next Standard Size of Fuse =300A.
- OR Rating of Pri. Circuit Breaker =6X87A=525A, So Next Standard Size of Circuit Breaker =600A.
- Full Load Current at Secondary side=10000000/ (1.732X11000) =525A.
- Rating of Sec. Fuse = 2.25X525A=1181A, So Next Standard Size of Fuse =1200A.
- OR Rating of Sec. Circuit Breaker =2.5X525A=1312A, So Next Standard Size of Circuit Breaker =1600A.

3) Supervised Location in Only Primary side of Transformer:



- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 250% of Primary Full Load Current or Next higher Standard size.
- Rating of Pri. Circuit Breaker at Point A= 300% of Primary Full Load Currentor Next higher Standard size.

4) Supervised Location of Transformer (Transformer Impedance Up to 6%):



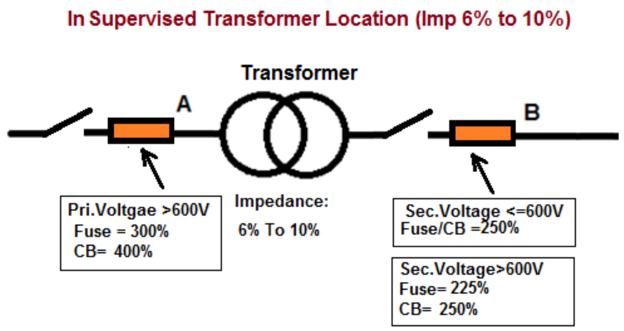
- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 300% of Pri. Full Load Current or Next Lower Standard size.
- Rating of Pri.Circuit Breaker at Point A= 600% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage <=600V):**

- Rating of Sec. Fuse / Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next higher Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage >600V):**
- Rating of Sec. Fuseat Point B= 250% of Sec. Full Load Current or Next Lower Standard size.
- Rating of Sec.Circuit Breaker at Point B= 300% of Sec. Full Load Current or Next Lower Standard size.

Example: 750KVA, 11KV/415V 3Phase Transformer having Impedance of Transformer 5%

- Full Load Current At Primary side=750000/(1.732X11000)=39A
- Rating of Primary Fuse = 3X39A= 118A, So Next Lower Standard Size of Fuse =110A.
- OR Rating of Primary Circuit Breaker =6X39A=236A, So Next Lower Standard Size of Circuit Breaker =225A.
- Full Load Current at Secondary side=750000/ (1.732X415) =1043A.
- Rating of Secondary of Fuse / Circuit Breaker = 2.5X1043A=2609A, So Standard Size of Fuse =2500A.

5) Supervised Location of Transformer (Transformer Impedance 6% to 10%):



- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 300% of Pri. Full Load Current or Next Lower Standard size.
- Rating of Pri.Circuit Breaker at Point A= 400% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage <=600V):**
- Rating of Sec. Fuse / Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next higher Standard size.
- **Over Current Protection atSecondary Side (Secondary Voltage >600V):**
- Rating of Sec. Fuseat Point B= 225% of Sec. Full Load Current or Next Lower Standard size.
- Rating of Sec.Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next Lower Standard size.

Example: 750KVA, 11KV/415V 3Phase Transformer having Impedance of Transformer 8%

- Full Load Current At Primary side=750000/(1.732X11000)=39A
- Rating of Primary Fuse = 3X39A= 118A, So Next Lower Standard Size of Fuse =110A.
- OR Rating of Primary Circuit Breaker =4X39A=157A, So Next Lower Standard Size of Circuit Breaker =150A.
- Full Load Current at Secondary side=750000/ (1.732X415) =1043A.
- Rating of Secondary of Fuse / Circuit Breaker = 2.5X1043A=2609A, So Standard Size of Fuse =2500A.

Difference in Selection of C.B between Supervised Locations an Unsupervised Location

- Here we see two notable conditions while we select Fuse / Circuit Breaker in Supervised Location and Unsupervised Location.
- First notable Condition is Primary Over current Protection. In Unsupervised Location Fuse in Primary side is 300% of Primary Current or Next Higher Standard size and in Supervised Location is 300% of Primary Current or Next Lower Standard size.Here Primary Over current Protection is same in both conditions (300%) But Selecting Size of Fuse/Circuit Breaker is Different.
- Lets us Check with the Example for 750KVA, 11KV/415V 3Phase Transformer.
- Full Load Current At Primary side=750000/(1.732X11000)=39A
- In Unsupervised Location: Rating of Primary Fuse = 3X39A= 118A, So Next Higher Standard Size =125A
- In Supervised Location: Rating of Primary Fuse = 3X39A= 118A, So Next Lower Standard Size =110A
- Second notable Condition is Secondary Over current Protection increased from 125% to 250% for unsupervised to Supervised Location.

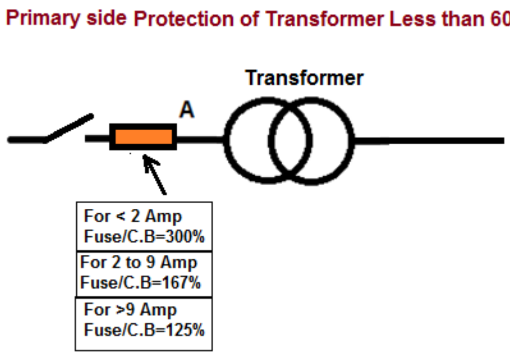
Summary of over current Protection for more than 600V:

Maximum Rating of Over current Protection for Transformers more than 600 Volts						
Location Limitations	Transformer Rated Impedance	Primary Protection (More than 600 Volts)		Secondary Protection		
				More than 600 Volts		Less than 600 Volts
		Circuit Breaker	Fuse Rating	Circuit Breaker	Fuse Rating	C.Bor Fuse

Any location	Less than 6%	600%(NH)	300%(NH)	300 %(NH)	250%(NH)	125%(NH)
	6% To 10%	400%(NH)	300%(NH)	250%(NH)	225%(NH)	125%(NH)
Supervised locations only	Any	300%(NH)	250%(NH)	Not required	Not required	Not required
	Less than 6%	600%	300%	300%	250%	250%
	6% To 10%	400%	300%	250%	225%	250%
NH: Next Higher Standard Size.						

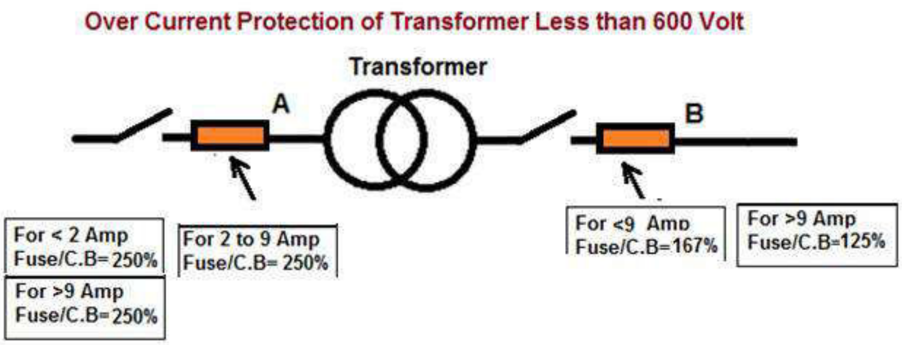
Over current Protection of Transformers for < 600 V (NEC 450.3 (B))

1) Only Primary side Protection of Transformer:



- **Over Current Protection at Primary Side (Less than 2A):**
- Rating of Pri. Fuse / C.B at Point A= 300% of Pri. Full Load Current or Next Lower Standard size.
- Example: 1KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side=1000/(1.732X480)=1A
- Rating of Primary Fuse = 3X1A= 3A, So Next Lower Standard Size of Fuse =3A.
- **Over Current Protection at Primary Side (2A to 9A):**
- Rating of Sec. Fuse / C.B at Point A= 167% of Pri. Full Load Current or Next Lower Standard size.
- Example:3KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side=3000/(1.732X480)=4A
- Rating of Primary Fuse = 1.67X4A= 6A, So Next Lower Standard Size of Fuse =6A.
- **Over Current Protection at Primary Side (More than 9A):**
- Rating of Pri. Fuse / C.B at Point A= 125% of Pri. Full Load Current or Next Higher Standard size.
- Example: 15KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side=15000/(1.732X480)=18A
- Rating of Primary Fuse = 1.25X18A= 23A, So Next Higher Standard Size of Fuse =25A.

2) Primary and Secondary side Protection of Transformer:



- **Over Current Protection at Primary Side (Less than 2A):**
- Rating of Pri. Fuse / C.B at Point A= 250% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection at Primary Side (2A to 9A):**
- Rating of Sec. Fuse / C.B at Point A= 250% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection at Primary Side (More than 9A):**
- Rating of Pri. Fuse / C.B at Point A= 250% of Pri. Full Load Current or Lower Higher Standard size.

Example:25KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side=125000/(1.732X480)=30A

- Rating of Primary Fuse = 2.50X30A= 75A, So Next Lower Standard Size of Fuse =70A.
- **Over Current Protection atSecondary Side (Less than 9A):**
- Rating of Pri. Fuse / C.B at Point B= 167% of Sec. Full Load Current or Lower Standard size.
- Example:3KVA, 480/230 3Phase Transformer, Full Load Current at Sec. Side=3000/(1.732X230)=8A
- Rating of Primary Fuse = 1.67X8A= 13A, So Next Lower Standard Size of Fuse =9A.
- **Over Current Protection atSecondary Side (More than 9A):**
- Rating of Pri. Fuse / C.B at Point A= 125% of Pri. Full Load Current or Higher Standard size.

Example:15KVA, 480/230 3Phase Transformer, Full Load Current at Sec. Side=15000/(1.732X230)=38A

- Rating of Primary Fuse = 1.25X38A= 63A, So Next Higher Standard Size of Fuse =70A.

Summary of over current Protection for Less than 600V:

Maximum Rating of Over current Protection for Transformers Less than 600 Volts					
Protection Method	**Primary Protection**			**Secondary Protection**	
	More than 9A	**2A to 9A**	**Less than 2A**	**More than 9A**	**Less than 9A**
Primary only protection	125%(NH)	167%	300%	Not required	Not required
Primary and secondary protection	250%	250%	250%	125%(NH)	167%
NH: Next Higher Standard Size.					

Chapter: 3 Calculate Size of Transformer & Voltage Drop due to Starting of Single Large Motor

- Calculate Voltage drop in Transformer ,1000KVA,11/0.480KV,impedance 5.75%, due to starting of 300KW,460V,0.8 Power Factor, Motor code D(kva/hp).Motor Start 2 times per Hour and The allowable Voltage drop at Transformer Secondary terminal is 10%.

Motor current / Torque:

- **Motor Full Load Current= (Kwx1000)/(1.732x Volt (L-L)x P.F)**
- Motor Full Load Current=300x1000/1.732x460x0.8= 471 Amp.
- **Motor Locked Rotor Current =Multiplier x Motor Full Load Current**

Locked Rotor Current (Kva/Hp)		
Motor Code	**Min**	**Max**
A	3.15	
B	3.16	3.55
C	3.56	4
D	4.1	4.5
E	4.6	5
F	5.1	5.6
G	5.7	6.3
H	6.4	7.1
J	7.2	8
K	8.1	9
L	9.1	10
M	10.1	11.2
N	11.3	12.5
P	12.6	14
R	14.1	16
S	16.1	18
T	18.1	20
U	20.1	22.4
V	22.5	

- Min Motor Locked Rotor Current (L1)=4.10x471=1930 Amp
- Max Motor Locked Rotor Current(L2) =4.50x471=2118 Amp
- **Motor inrush Kva at Starting (Irsm)=Volt x locked Rotor Current x Full Load Current x 1.732 / 1000**
- Motor inrush Kva at Starting (Irsm)=460 x 2118x471x1.732 / 1000=1688 Kva

Transformer:

- **Transformer Full Load Current= Kva/(1.732xVolt)**
- Transformer Full Load Current=1000/(1.732x480)=1203 Amp.
- **Short Circuit Current at TC Secondary (Isc) =Transformer Full Load Current / Impedance.**
- Short Circuit Current at TC Secondary= 1203/5.75= 20919 Amp
- **Maximum Kva of TC at rated Short Circuit Current (Q1) = (Volt x Iscx1.732)/1000.**
- Maximum Kva of TC at rated Short Circuit Current (Q1)=480x20919x1.732/1000= 17391 Kva.
- **Voltage Drop at Transformer secondary due to Motor Inrush (Vd)= (Irsm) / Q1**
- Voltage Drop at Transformer secondary due to Motor Inrush (Vd) =1688/17391 =10%
- Voltage Drop at Transformer Secondary is 10% which is within permissible Limit.
- **Motor Full Load Current<=65% of Transformer Full Load Current**
- 471 Amp <=65%x1203 amp = 471 Amp<= 781 Amp
- Here Voltage Drop is within Limit and Motor Full Load Current<=TC Full Load Current.
- **Size of Transformer is Adequate.**

Chapter: 4 Calculate Size of Transformer & Voltage Drop due to Starting of Multiple No of Motor

- Calculate Voltage drop in Transformer, 1000KVA, 11/0.480KV, impedance 5.75%, due to starting of 300KW Three Phase Motor and 5KW Single Phase Motor, 460V (Line-Line), 0.8 Power Factor, Locked Rotor Current is 450% and the allowable Voltage drop at Transformer Secondary terminal is 10%.

Motor current / Torque:

- **Motor Full Load Current= (Kwx1000)/(1.732x Volt (L-L)x P.F)**
- Motor Full Load Current=300x1000/1.732x460x0.8= 471 Amp.
- **Motor Full Load Current= (Kwx1000)/(Volt (L-P)x P.F)**
- Motor Full Load Current=10x1000/ (460/1.732)x0.8= 24 Amp.
- Total Motor Full Load Current=471+24=494 Amp
- **Motor inrush Kva at Starting (Irsm)=Volt x locked Rotor Current x Full Load Currentx1.732 / 1000**
- Motor inrush Kva at Starting (Irsm)=460 x 2118x494x1.732 / 1000=1772 Kva

Transformer:

- **Transformer Full Load Current= Kva/(1.732xVolt)**
- Transformer Full Load Current=1000/(1.732x480)=1203 Amp.
- **Short Circuit Current at TC Secondary (Isc) =Transformer Full Load Current / Impedance.**
- Short Circuit Current at TC Secondary= 1203/5.75= 20919 Amp
- **Maximum Kva of TC at rated Short Circuit Current (Q1) = (Volt x Iscx1.732)/1000.**
- Maximum Kva of TC at rated Short Circuit Current (Q1) =480x20919x1.732/1000= 17391 Kva.
- **Voltage Drop at Transformer secondary due to Motor Inrush (Vd)= (Irsm) / Q1**
- Voltage Drop at Transformer secondary due to Motor Inrush (Vd) =1772/17391 =10.2%
- **Motor Full Load Current<=65% of Transformer Full Load Current**
- 494 Amp <=65%x1203 amp = 471 Amp<= 781 Amp
- Here Motor Full Load Current<=TC Full Load Current but Voltage Drop is High (10.20%) so Size of Transformer is Not Adequate.
- **Required to increase the size of Transformer.**

Chapter: 5 Calculation Size of Circuit Breaker/ Fuse for Transformer (As per NEC)

- Calculate Size of Circuit Breaker or Fuse on Primary and Secondary side of Transformer having following Detail
- Transformer Details(P)= 1000KVA
- Primary Voltage (Vp)= 11000 Volt
- Secondary Voltage (Vs)= 430 Volt
- Transformer Impedance= 5%
- Transformer Connection = Delta / Star
- Transformer is in unsupervised condition.

Calculations:

- Transformer Primary Current (Ip)= P/1.732xVp
- Transformer Primary Current (Ip)=1000000/1.732x11000=52.49Amp
- Transformer Secondary Current (Is)= P/1.732xVs
- Transformer Secondary Current (Is)=1000000/1.732x430=1342.71Amp
- AS per NEC 450.3, Max.Rating of C.B or Fuse is following % of its Current according to it's Primary Voltage,% Impedance and Supervised/Unsupervised Condition.

Max Rating of Over current Protection for Unsupervised Transformer More than 600 Volts					
%Imp	**Primary**		**secondary**		
	>600Volt		>600Volt		<600Volt
	C.B	Fuse	C.B	Fuse	C.B/Fuse
Up to 6%	600%	300%	300%	250%	125%
More than 6%	400%	300%	250%	225%	125%

Max Rating of Over current Protection for Supervised Transformer More than 600 Volts					
%Imp	**Primary**		**secondary**		
	>600Volt		>600Volt		<600Volt
	C.B	Fuse	C.B	Fuse	C.B/Fuse
Up to 6%	600%	300%	300%	250%	250%
More than 6%	400%	300%	250%	225%	250%

Max Rating of Over current Protection for Transformers Primary Voltage Less than 600 Volts					
Protection Method	**Primary Protection**			**Secondary Protection**	
	More than 9A	**2A to 9A**	**Less than 2A**	**More than 9A**	**Less than 9A**
Primary only protection	125%	167%	300%	Not required	Not required
Primary and secondary protection	250%	250%	250%	125%	167%

Size of Fuse / Inverse Time C.B as per NEC (Amp)						
1	25	60	125	250	600	2000
3	30	70	150	300	700	2500
6	35	80	160	350	800	3000
10	40	90	175	400	1000	4000
15	45	100	200	450	1200	5000
20	50	110	225	500	1600	6000

For Primary Side:

- Transformer Primary Current (Ip) =52.49Amp and impedance is 5%
- **As per above table in not supervised condition Size of Circuit Breaker= 600% of Primary Current**
- Size of Circuit Breaker = 52.49 x 600% =315Amp

- If Transformer is in supervised condition then Select Circuit Breaker near that size but if Transformer is in unsupervised condition then Select Circuit Breaker next higher size.
- Rating of Circuit Breaker =350Amp (Next Higher Size of 300Amp)
- Size of Fuse = 52.49 x300% =157Amp
- **Rating of Fuse =160Amp (Next Higher Size of 150Amp)**

For Secondary Side:

- Transformer Secondary Current (Is) =1342.70Amp and impedance is 5%
- As per above table in not supervised condition Size of Circuit Breaker= 125% of Secondary Current
- Size of Circuit Breaker = 1342.70 x 125% =1678Amp
- If Transformer is in supervised condition then Select Circuit Breaker near that size but if Transformer is in unsupervised condition then Select Circuit Breaker next higher size.
- **Rating of Circuit Breaker =2000Amp (Next Higher Size of 1600Amp)**
- Size of Fuse = 1342.70 x125% =1678Amp
- Rating of Fuse =2000Amp (Next Higher Size of 1600Amp)

Results:

- **Size of Circuit Breaker on Primary Side=350Amp**
- **Size of Fuse on Primary Side=160Amp**
- **Size of Circuit Breaker on Secondary Side=2000Amp**
- **Size of Fuse on Secondary Side=2000Amp**

Chapter: 6 Calculate Transformer Regulation & Losses (As per Transformer Name Plate)

- KVA rating of Transformer(P)=16000VA ,
- Primary voltage(Vp)=11000V ,Secondary voltage(Vs)=433V
- No load losses(W0)=72Watt ,No load current(I0)=0.59Amp
- Full load losses(W)=394Watt , Impedance voltage(Vi)=480Volt.
- LV resistance(Rs) =219.16 miliΩ ,HV resistance(Rp) =215.33 Ω
- Amb temperature(c)=30 Deg C
- Total Connected Load on Transformer(Pl)=10000VA

Calculation:

- % Loading of Transformer=Pl/P=10000/16000 = 63%

I2R Calculation:

- HV Full load current (Ip) =P/Vpx1.732 = 16000/11000x1.732=0.84Amp
- LV Full load current (Is)=P/Vsx1.732 =16000/433x1.732=21.33Amp
- HV Side I2R losses= IpxIpxRp
- HV Side I2R losses= 0.84x0.84x215.33=227.8Watt-----(A)
- LV Side I2R losses= IsxIsxRs
- LV Side I2R losses==21.33x21.33x219.16=149.63Watt---(B)
- Total I^2 R losses @ Amb temp(Ir)=A+B=227.8+149.63=377.43Watt
- Total Stray losses @ Amb temp (Ws) =Full Load Losses-I2R Losses
- Total Stray losses @ Amb temp (Ws) =394-377.43=16.57 Watt
- I^2 R losses @75° c temp =Irx310/235xc =149.63x310/235x30 =441.52Watt
- Stray loses @ 75° c temp =(Wsx(235+c))/310 =(16.57x(235+30))/310=14.16 Watt
- Total Full load losses at @75° c=441.52+14.16=455.69 Watt
- Total Impedance at ambient temp (Ax)=Vix1.732/Ip
- Total Impedance at ambient temp(Ax)=480x1.732/0.84=989.94Ω
- Total Resistance at amb temp (Ar)=Ir/IpxIp
- Total Resistance at amb temp (Ar)=377.43/0.84x0.84=535.15Ω
- Total Reactance (X)=√AxxAx+ArxAr=√989.98x989.94+535.15x535.15=832.82Ω
- Resistance at@ 75° c (R)= (310xAr)/(235+c)=310x535.15/235+30 = 626.03Ω
- Impedance at 75° c (X1)=√2X+2R=√2x626.03+2x832.82 = 1041.88Ω
- Percentage Impedance = (X1x0.5774xIpx100)/Vp=(1041.88x0.5774x0.84x100)/11000=4.59%
- Percentage Resistance (R%) =(Rx0.5774xIpx100)/Vp=(626.03x0.5774x0.84x100)/11000=2.76%
- Percentage Reactance(X%) = (Xx0.5774xIpx100)/Vp
- Percentage Reactance(X%) = (832.82 x0.5774x0.84x100)/11000=3.67%

Regulation

- Regulation at Unity P.F =2.76
- Regulation at Unity at 0.8 P.F =((R% x cosØ)+(X% x SinØ))+(0.005x((R% x SinØ)+(X% x CosØ)))
- Regulation at Unity at 0.8 P.F =((2.76 x 0.8)+(3.67 x 0.6))+(0.005x((2.76 x0.6)+(3.67 x 0.8)))=4.43

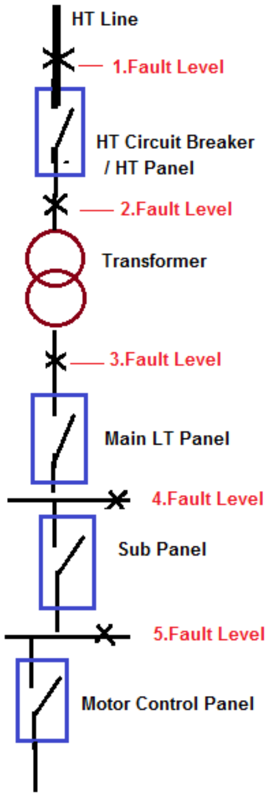
Results

- **Total I^2 R losses @ Amb. temp(Ir)= 377.43Watt**
- **Total Stray losses @ Amb. temp (Ws) =16.57 Watt**
- **Regulation at Unity P.F =2.76**
- **Regulation at Unity at 0.8 P.F =4.43**

Chapter: 7 Calculate Fault Current (Base KVA Method)

Example:

- Calculate Fault current at each stage of following Electrical System SLD having details of.
- Main Incoming HT Supply Voltage is 6.6 KV.
- Fault Level at HT Incoming Power Supply is 360 MVA.
- Transformer Rating is 2.5 MVA.
- Transformer Impedance is 6%.



Calculation:

- Let's first consider Base KVA and KV for HT and LT Side.
- Base KVA for HT side (H.T. Breaker and Transformer Primary) is 6 MVA
- Base KV for HT side (H.T. Breaker and Transformer Primary) is 6.6 KV
- Base KVA for LT side (Transformer Secondary and down Stream) is 2.5 MVA
- Base KV for LT side (Transformer Secondary and down Stream) is 415V

Fault Level at HT Side (Up to Sub-station):

(1) Fault Level from HT incoming Line to HT Circuit Breaker

- HT Cable used from HT incoming to HT Circuit Breaker is 5 Runs , 50 Meter ,6.6KV 3 Core 400 sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0990 Ω/Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.05X0.1230) / 5
- Total Cable Resistance=0.001023Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.05X0.0990) / 5
- Total Cable Reactance =0.00099Ω
- **Total Cable Impedance (Zc1)=√(RXR)+(XxX)**
- Total Cable Impedance (Zc1)=0.0014235 Ω--------(1)
- **P.U Reactance at H.T. Breaker Incoming Terminals (X Pu)= Fault Level / Base KVA**

- P.U Reactance at H.T. Breaker Incoming Terminals (X Pu)= 360 / 6
- P.U. Reactance at H.T. Breaker Incoming Terminals(X Pu)= 0.01666 PU------(2)
- **Total Impedance up to HT Circuit Breaker (Z Pu-a)= (Zc1)+ (X Pu)=(1)+(2)**
- Total Impedance up to HT Circuit Breaker(Z Pu-a)=0.001435+0.01666
- Total Impedance up to HT Circuit Breaker (Z Pu-a)=0.0181Ω.------(3)
- **Fault MVA at HT Circuit Breaker= Base MVA / Z Pu-a.**
- Fault MVA at HT Circuit Breaker= 6 / 0.0181
- **Fault MVA at HT Circuit Breaker= 332 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 332 / 6.6
- **Fault Current at HT Circuit Breaker = 50 KA**

(2) Fault Level from HT Circuit Breaker to Primary Side of Transformer

- HT Cable used from HT Circuit Breaker to Transformer is 3 Runs , 400 Meter ,6.6KV 3 Core 400 sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0990 Ω/Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.4X0.1230) / 3
- Total Cable Resistance=0.01364Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.4X0.0990) / 5
- Total Cable Reactance =0.01320Ω
- **Total Cable Impedance (Zc2)=√(RXR)+(XxX)**
- Total Cable Impedance (Zc2)=0.01898 Ω--------(4)
- **P.U Impedance at Primary side of Transformer (Z Pu)= (Zc2 X Base KVA) / (Base KV xBase KVx1000)**
- P.U Impedance at Primary side of Transformer (Z Pu)=(0.01898X6) /(6.6x6.6x1000)
- P.U Impedance at Primary side of Transformer (Z Pu)=0.0026145 PU------(5)
- Total Impedance(Z Pu)=(4) + (5)
- Total Impedance(Z Pu)=0.01898+0.0026145
- Total Impedance(Z Pu)=0.00261------(6)
- **Total Impedance up to Primary side of Transformer (Z Pu-b)= (Z Pu)+(Z Pu-a) =(6)+(3)**
- Total Impedance up to Primary side of Transformer (Z Pu-b)=0.00261+0.0181
- Total Impedance up to Primary side of Transformer (Z Pu-b)=0.02070Ω.-----(7)
- **Fault MVA at Primary side of Transformer= Base MVA / Z Pu-b.**
- Fault MVA at Primary side of Transformer = 6 / 0.02070
- **Fault MVA at Primary side of Transformer= 290 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 290 / 6.6
- **Fault Current at Primary side of Transformer= 44 KA**

(3) Fault Level from Primary Side of Transformer to Secondary side of Transformer:

- Transformer Rating is 2.5 MVA and Transformer Impedance is 6%.
- **% Reactance at Base KVA = (Base KVA x % impedance at Rated KVA) /Rated KVA**
- % Reactance at Base KVA = (2.5X6)/2.5
- % Reactance at Base KVA =6%
- **P.U. Reactance of the Transformer(Z Pu) =% Reactance /100**
- P.U. Reactance of the Transformer(Z Pu)= 6/100=0.06 Ω-----(8)
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c)=(Z Pu)+(Z Pu-b)=(7)+(8)
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c)=0.06+0.02070
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c)=0.0807 Ω-----(9)
- **Fault MVA at Transformer Secondary Winding = Base MVA / Z Pu-c**
- Fault MVA at Transformer Secondary Winding = 2.5/0.0807

- **Fault MVA at Transformer Secondary Winding =31 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 31 / (1.732x0.415)
- **Fault Current at Transformer Secondary Winding = 43 KA**

Fault Level at LT Side (Sub-station to Down stream):

(4) Fault Level from Transformer Secondary to Main LTPanel

- LT Cable used from Transformer Secondary to Main LT Panel is 13 Runs , 12 Meter ,1.1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0618 Ω/Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.012X0.1230) / 13
- Total Cable Resistance=0.00009Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.012X0.0618) / 13
- Total Cable Reactance =0.00006Ω
- **Total Cable Impedance (Zc3)=√(RXR)+(XxX)**
- Total Cable Impedance (Zc3)=0.00011 Ω--------(10)
- **P.U Impedance at Main LT Panel (Z Pu)= (Zc3 X Base KVA) / (Base KV xBase KVx1000)**
- P.U Impedance at Main LT Panel (Z Pu)=(0.00011X2.5x1000)/(0.415x0.415X1000)
- PP.U Impedance at Main LT Panel (Z Pu)=0.001601Ω ------(11)
- **Total Impedance up to Main LT Panel(Z Pu-d)= (Zc3)+ (Z Pu-c)=(11)+(9)**
- Total Impedance up to Main LT Panel (Z Pu-d)=0.001601+0.0807
- Total Impedance up to Main LT Panel (Z Pu-d)=0.082306 Ω.------(12)
- **Fault MVA at Main LT Panel= Base MVA / Z Pu-a.**
- Fault MVA at Main LT Panel = 2.5 / 0.082306
- **Fault MVA at Main LT Panel= 30 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 30 / (1.732X0.415)
- **Fault Current at Main Lt Panel = 42 KA**

(5) Fault Level from Main LTPanelto Sub Panel:

- LT Cable used from Main LT Panel to Sub Panel is 2 Runs , 160 Meter ,1.1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0618 Ω/Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.160X0.1230) / 2
- Total Cable Resistance=0.008184Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.160X0.0618) / 2
- Total Cable Reactance =0.004944Ω
- **Total Cable Impedance (Zc4)=√(RXR)+(XxX)**
- Total Cable Impedance (Zc4)=0.0095614 Ω--------(13)
- **P.U Impedance at Sub Panel (Z Pu)= (Zc4 X Base KVA) / (Base KV xBase KVx1000)**
- P.U Impedance at Sub Panel(Z Pu)=(0.0095614 X2.5x1000)/(0.415x0.415X1000)
- PP.U Impedance at Sub Panel(Z Pu)=0.13879Ω ------(14)
- **Total Impedance up to Sub Panel (Z Pu-e)= (Zc4)+ (Z Pu-d)=(14)+(12)**
- Total Impedance up to Sub Panel(Z Pu-e)=0.13879+0.082306
- Total Impedance up to Sub Panel(Z Pu-e)=0.2211 Ω.------(15)
- **Fault MVA at Sub Panel = Base MVA / Z Pu-a.**
- Fault MVA at Sub Panel= 2.5 / 0.2211
- **Fault MVA at Sub Panel = 11 MVA**

- **Fault Current = Fault MVA / Base KV**
- Fault Current = 11 / (1.732X0.415)
- **Fault Current at Sub Panel= 16 KA**

(6) Fault Level from Sub Panel to Motor Control Panel:

- LT Cable used from Sub Panel to Motor Control Panel is 6 Runs , 150 Meter ,1.1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0739 Ω/Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.150X0.1230) / 6
- Total Cable Resistance=0.003075Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.150X0.0739) / 6
- Total Cable Reactance =0.0018475Ω
- **Total Cable Impedance (Zc5)=√(RXR)+(XxX)**
- Total Cable Impedance (Zc4)=0.003587 Ω--------(16)
- **P.U Impedance at Motor Control Panel (Z Pu)= (Zc5 X Base KVA) / (Base KV xBase KVx1000)**
- P.U Impedance at Motor Control Panel(Z Pu)=(0.003587 X2.5x1000)/(0.415x0.415X1000)
- PP.U Impedance at Motor Control Panel(Z Pu)=0.05207Ω ------(17)
- **Total Impedance up to Motor Control Panel(Z Pu-f)= (Zc5)+ (Z Pu-e)=(17)+(15)**
- Total Impedance up to Motor Control Panel(Z Pu-e)=0.13879+0.2211
- Total Impedance up to Motor Control Panel(Z Pu-e)=0.27317 Ω.------(15)
- **Fault MVA at Motor Control Panel= Base MVA / Z Pu-a.**
- Fault MVA at Motor Control Panel= 2.5 / 0.27317
- **Fault MVA at Motor Control Panel = 9 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 9 / (1.732X0.415)
- **Fault Current at Motor Control Panel= 13 KA**

Summary of Calculation:

Sr.No	Fault Location	Fault MVA	Fault Current (KA)
1	At HT Circuit Breaker	332	50
2	At Primary Side of Transformer	290	44
3	At Secondary Side of Transformer	31	43
4	At Main LT Panel	30	42
5	At Sub Main Panel	11	16
6	At Motor Control Panel	9	13

Chapter: 8 Calculate Technical Losses of Distribution Line

- There are two types of Losses in distribution Line. (1) Technical Losses and (2) Commercial Losses.
- Distribution Company should calculate technical and commercial losses so that Commercial losses are not implemented to all consumers.
- Technical Losses of the Distribution line mostly depend upon Electrical Load,type and size of conductor, length of line etc.
- Let's try to calculate Technical Losses of one of the 11 KV Distribution Line which have following parameter.
- Main length of 11 KV Line is 6.18 Kms and Maximum Amp is12 Amps.
- Total nos. of Distribution Transformer on Feeder 25 KVA= 3 No, 63 KVA =3 No,100KVA=1No.
- 25KVA Transformer Iron Losses = 100 W, Copper Losses= 720 W, Average LT Line Loss= 63W.
- 63KVA Transformer Iron Losses =200 W, Copper Losses=1300 W, Average LT Line Loss=260W.
- 100KVA Transformer Iron Losses =290 W, Copper Losses=1850 W, LT Line Loss=1380W.
- Unit sent out during to feeder is 490335 Kwh
- Unit sold out during from Feeder is 353592 Kwh
- Normative Load diversity Factor for Urban feeder is 1.5 and for Rural Feeder is 2.0

Calculation:

- **Total Connected Load=No's of Connected Transformer.**
- Total Connected Load= (25x3) + (63x3) + (100x1)=364 KVA.
- **Peak Load = 1.732 x Line Voltage x Max Amp**
- Peak Load = 264 / 1.732x11x12 =228
- **Diversity Factor (DF) = Connected Load (In KVA) / Peak Load.**
- Diversity Factor (DF) = 364 /228=1.15
- **Load Factor (LF)= Unit Sent Out (Kwh) / 1.732 x Line Voltage x Max Amp. x P.F. x 8760**
- Load Factor (LF)=490335 / 1.732x11x12x0.8x8760 =0.3060
- **Loss Load Factor (LLF)= (0.8 x LFx LF)+ (0.2 x LF)**
- Loss Load Factor (LLF)= (0.8 x 0.3060 x 0.3060) + (0.2 x 0.306) = 0.1361

Calculation of Iron losses:

- **Total Annual Iron loss in Kwh =Iron Loss in Watts X Nos of TC on the feeder X8760 / 1000**
- Total Annual Iron loss (25KVA TC)=100x3x8760 /1000 =2628 Kwh
- Total Annual Iron loss (63KVA TC)=200x3x8760 /1000 =5256 Kwh
- Total Annual Iron loss (100KVA TC)=290x3x8760 /1000 =2540 Kwh
- Total Annual Iron loss =2628+5256+2540 =10424Kwh

Calculation of Copper losses:

- **Total Annual Copper loss in Kwh =Cu Loss in Watts XNos of TC on the feeder LFX LF X8760 / 1000**
- Total Annual Copper loss (25KVA TC)=720x3x0.3x0.3x8760 /1000 =1771 Kwh
- Total Annual Copper loss (63KVA TC)=1300x3x0.3x0.3x8760 /1000 =3199 Kwh
- Total Annual Copper loss (100KVA TC)=1850x1x0.3x0.3x8760 /1000 =1458 Kwh
- Total Annual Copper loss =1771+3199+1458=6490Kwh
- **HT Line Losses (Kwh)=0.105 x (Conn. Load x 2) x Length x Resistance x LLF /(LDF x DF x DF x 2)**
- HT Line Losses= 1.05 x(265x2) x 6.18 x 0.54 x 0.1361 /1.5 x 1.15 x1.15 x 2 = 831 Kwh
- **Peak Power Losses= (3 x Total LT Line Losses) / (PPLxDFxDFx 1000)**
- Peak Power Losses= 3 x (3x63+3x260+1x1380) /1.15 x 1.15 x 1000 = 3.0
- **LT Line Losses (Kwh)= (PPL.) x (LLF) x 8760**
- LT Line Losses =3 x 0.1361 x 8760=3315 Kwh
- **Total Technical Losses= (HT Line Losses + LT Line Losses + Annual Cu Losses + Annual Iron Losses)**
- Total Technical Losses = (831+ 3315 + 10424 + 6490)
- **Total Technical Losses = 21061 Kwh**
- **% Technical Loss= (Total Losses) / (Unit Sent Out Annually) x 100**
- % Technical Loss= (21061/490335) x100
- **% Technical Loss=4.30%**

Chapter: 9 Calculate Voltage Regulation of 11KV / 22KV / 33KV Overhead Line (As per REC)

- **% Voltage Regulation= (1.06xPxLxPF) / (LDFxRCxDF)**
- Where
- P=Total Power in KVA , L= Total Length of Line from Power Sending to Power Receiving in KM.
- PF= Power Factor in p.u
- RC= Regulation Constant (KVA-KM) per 1% drop.
- RC=(KVxKVx10)/(RCosΦ+XSinΦ)
- LDF= Load Distribution Factor.
- LDF= 2 for uniformly distributed Load on Feeder.
- LDF>2 If Load is skewed toward the Power Transformer.
- LDF= 1 To 2 If Load is skewed toward the Tail end of Feeder.
- DF= Diversity Factor in p.u

Permissible Voltage Regulation (As per REC):

Maximum Voltage Regulation at any Point of Distribution Line			
Part of Distribution System	**Urban Area (%)**	**Suburban Area (%)**	**Rural Area (%)**
Up to Transformer	2.5	2.5	2.5
Up to Secondary Main	3	2	0.0
Up to Service Drop	0.5	0.5	0.5
Total	**6.0**	**5.0**	**3.0**

Required Size of Capacitor:

- Size of capacitor for improvement of the Power Factor from Cos ø1 to Cos ø2 is
- **Required size of Capacitor(Kvar) = KVA1 (Sin ø1 – [Cos ø1 / Cos ø2] x Sin ø2)**
- Where KVA1 is Original KVA.

Optimum location of capacitors:

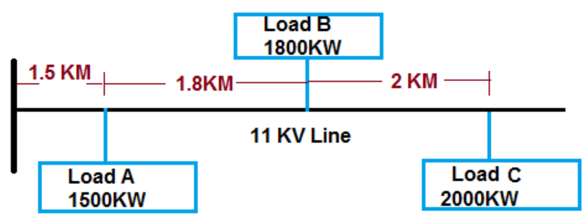
- **L = [1 – (KVARC / 2 KVARL) x (2n-1)]**
- Where,
- L = distance in per unit along the line from sub-station.
- KVARC = Size of capacitor bank, KVARL = KVAR loading of line
- n = relative position of capacitor bank along the feeder from sub-station if the total capacitance is to be divided into more than one Bank along the line. If all capacitance is put in one Bank than values of n=1.

Voltage Rise due to Capacitor installation:

- **% Voltage Rise = (KVAR(Cap)x Lx X) / 10xVx2**
- Where,
- KVAR(Cap)=Capacitor KVAR, X = Reactance per phase, L=Length of Line (mile), V = Phase to phase voltage (KV)

Calculate % Voltage Regulation of Distribution Line at Trail end:

- Calculate Voltage drop and % Voltage Regulation at Trail end of following 11 KV Distribution system , System have ACSR DOG Conductor (AI 6/4.72, GI7/1.57),Current Capacity of ACSR Conductor =205Amp,Resistance =0.2792Ω and Reactance =0 Ω, Permissible limit of % Voltage Regulation at Trail end is 5%.



Method-1 (Distance Base):

- **Voltage Drop = ((√3x(RCosΦ+XSinΦ)x I) / (No of Conductor/Phase x1000))x Length of Line**

Voltage drops at Load A

- Load Current at Point A (I) = KW / 1.732xVoltxP.F=1500 / 1.732x11000x0.8 = 98 Amp.
- Required No of conductor / Phase =98 / 205 =0.47 Amp =1 No
- Voltage Drop at Point A = ((√3x(RCosΦ+XSinΦ)xI) / (No of Conductor/Phase x1000))x Length of Line
- Voltage Drop at Point A =((1.732x (0.272x0.8+0x0.6)x98) / 1x1000)x1500) = 57 Volt
- Receiving end Voltage at Point A = Sending end Volt-Voltage Drop= (1100-57) = 10943 Volt.
- % Voltage Regulation at Point A = ((Sending end Volt-Receiving end Volt) / Receiving end Volt) x100
- % Voltage Regulation at Point A = ((11000-10943) / 10943)x100 = 0.52%
- **% Voltage Regulation at Point A =0.52 %**

Voltage drops at Load B

- Load Current at Point B (I) = KW / 1.732xVoltxP.F=1800 / 1.732x11000x0.8 = 118 Amp.
- Distance from source= 1500+1800=3300 Meter.
- Voltage Drop at Point B = ((√3x(RCosΦ+XSinΦ)xI) / (No of Conductor/Phase x1000))x Length of Line
- Voltage Drop at Point B =((1.732x (0.272x0.8+0x0.6)x98) / 1x1000)x3300) = 266 Volt
- Receiving end Voltage at Point B = Sending end Volt-Voltage Drop= (1100-266) = 10734 Volt.
- % Voltage Regulation at Point B= ((Sending end Volt-Receiving end Volt) / Receiving end Volt) x100
- % Voltage Regulation at Point B= ((11000-10734) / 10734)x100 = 2.48%
- **% Voltage Regulation at Point B =2.48 %**

Voltage drops at Load C

- Load Current at Point C (I) = KW / 1.732xVoltxP.F=2000 / 1.732x11000x0.8 = 131 Amp
- Distance from source= 1500+1800+2000=5300 Meter.
- Voltage Drop at Point C = ((√3x(RCosΦ+XSinΦ)xI) / (No of Conductor/Phase x1000))x Length of Line
- Voltage Drop at Point C =((1.732x (0.272x0.8+0x0.6)x98) / 1x1000)x5300) = 269 Volt
- Receiving end Voltage at Point C = Sending end Volt-Voltage Drop= (1100-269) = 10731 Volt.
- % Voltage Regulation at Point C= ((Sending end Volt-Receiving end Volt) / Receiving end Volt) x100
- % Voltage Regulation at Point C= ((11000-10731) / 10731)x100 = 2.51%
- **% Voltage Regulation at Point C =2.51 %.**
- Here Trail end Point % Voltage Regulation is 2.51% which is in permissible limit.

Method-2 (Load Base):

- **% Voltage Regulation =(I x (RcosØ+XsinØ)x Length) / No of Cond.per Phase xV (P-N))x100**

Voltage drops at Load A

- Load Current at Point A (I) = KW / 1.732xVoltxP.F=1500 / 1.732x11000x0.8 = 98 Amp.
- Distance from source= 1.500 Km.
- Required No of conductor / Phase =98 / 205 =0.47 Amp =1 No
- Voltage Drop at Point A = (I x (RcosØ+XsinØ)x Length) / V (Phase-Neutral))x100
- Voltage Drop at Point A =((98x(0.272x0.8+0x0.6)x1.5) / 1x6351) = 0.52%
- **% Voltage Regulation at Point A =0.52 %**

Voltage drop at Load B

- Load Current at Point B (I) = KW / 1.732xVoltxP.F=1800 / 1.732x11000x0.8 = 118 Amp.
- Distance from source= 1500+1800=3.3Km.
- Required No of conductor / Phase =118 / 205 =0.57 Amp =1 No
- Voltage Drop at Point B = (I x (RcosØ+XsinØ)x Length) / V (Phase-Neutral))x100
- Voltage Drop at Point B =((118x(0.272x0.8+0x0.6)x3.3)/1x6351) = 1.36%
- **% Voltage Regulation at Point A =1.36 %**

Voltage drop at Load C

- Load Current at Point C (I) = KW / 1.732xVoltxP.F =2000 / 1.732x11000x0.8 = 131Amp.
- Distance from source= 1500+1800+2000=5.3Km.
- Required No of conductor / Phase =131/205 =0.64 Amp =1 No
- Voltage Drop at Point C = (I x (RcosØ+XsinØ)x Length) / V (Phase-Neutral))x100
- Voltage Drop at Point C =((131x(0.272x0.8+0x0.6)x5.3)/1x6351) = 2.44%
- **% Voltage Regulation at Point A =2.44 %**

Here Trail end Point % Voltage Regulation is 2.44% which is in permissible limit.

Chapter: 10 Calculate Size & Voltage Drop of HT / LT Cable

Calculate Voltage Drop and Size of Electrical cable for following data.

- **Electrical Details:** Electrical Load of 80KW, Distance between Source and Load is 200Meter,System Voltage 415V Three Phase, Power Factor is 0.8,Permissible Voltage drop is 5%, Demand Factor is 1,
- **Cable Laying Detail:** Cable is directed buried in Ground in trench at the depth of 1 meter. Ground Temperature is approximate 35 Deg. No of Cable per Trench is 1. No of Run of Cable is 1 Run.
- **Soil Details:** Thermal Resistivity of Soil is not known. Nature of Soil is Damp Soil.

Calculation:

- **Consumed Load= Total Load x Demand Factor**
- Consumed Load in KW= 80 x 1 =80KW
- **Consumed Load in KVA= KW/P.F**
- Consumed Load in KVA =80/0.8=100KVA
- Full Load Current= (KVAx1000) / (1.732xVoltage)
- Full Load Current= (100x1000)/ (1.732x415) = 139Amp.
- Calculating Correction Factor of Cable from following data :
- Temperature Correction Factor (K1) When Cable is in Air is

Temperature Correction Factor in Air :K1		
Ambient Temp©	Insulation	
	PVC	XLPE/EPR
10	1.22	1.15
15	1.17	1.12
20	1.12	1.08
25	1.06	1.04
35	0.94	0.96
40	0.87	0.91
45	0.79	0.87
50	0.71	0.82
55	0.61	0.76
60	0.5	0.71
65	0	0.65
70	0	0.58
75	0	0.5
80	0	0.41

- **Ground Temperature Correction Factor (K2):**

Ground Temperature Correction Factor:K2		
Ground Temp©	Insulation	
	PVC	XLPE/EPR
10	1.1	1.07
15	1.05	1.04
20	0.95	0.96
25	0.89	0.93
35	0.77	0.89
40	0.71	0.85
45	0.63	0.8
50	0.55	0.76
55	0.45	0.71
60	0	0.65
65	0	0.6
70	0	0.53
75	0	0.46
80	0	0.38

- **Thermal Resistance Correction Factor (K4) for Soil (When Thermal Resistance of Soil is known):**

Ther.Resi Correction Factor: K4	
Soil Thermal Resistivity: 2.5 KM/W	
Resistivity	K3
1	1.18
1.5	1.1
2	1.05
2.5	1
3	0.96

- **Soil Correction Factor(K4) of Soil (When Thermal Resistance of Soil is not known):**

Soil Correction Factor:K4	
Nature of Soil	K3
Very Wet Soil	1.21
Wet Soil	1.13
Damp Soil	1.05
Dry Soil	1
Very Dry Soil	0.86

- **Cable Depth Correction Factor (K5):**

Cable Depth Factor (K5)	
Laying Depth(Meter)	Rating Factor
0.5	1.1
0.7	1.05
0.9	1.01
1	1
1.2	0.98
1.5	0.96

- **Cable Distance correction Factor (K6):**

Cable Distance Correction Factor(K6)					
No of Circuit	Nil	cable Diameter	0.125m	0.25m	0.5m
1	1	1	1	1	1
2	0.75	0.8	0.85	0.9	0.9
3	0.65	0.7	0.75	0.8	0.85
4	0.6	0.6	0.7	0.75	0.8
5	0.55	0.55	0.65	0.7	0.8
6	0.5	0.55	0.6	0.7	0.8

- **Cable Grouping Factor (No of Tray Factor) (K7):**

No of Cable/Tray	(Cable Grouping factor K7)==No of Tray				
	1	2	**3**	4	6	8
1	1	1	1	1	1	1
2	0.84	0.8	0.78	0.77	0.76	0.75
3	0.8	0.76	0.74	0.73	0.72	0.71
4	0.78	0.74	0.72	0.71	0.7	0.69
5	0.77	0.73	0.7	0.69	0.68	0.67
6	0.75	0.71	0.7	0.68	**0.68**	0.66
7	0.74	0.69	0.675	0.66	0.66	0.64
8	0.73	0.69	0.68	0.67	0.66	0.64

- According to above Detail correction Factors are
- Ground Temperature Correction Factor (K2) =0.89
- Soil Correction Factor (K4)=1.05
- Cable Depth Correction Factor (K5)=1.0
- Cable Distance correction Factor (K6)=1.0
- **Total De rating Factor= k1x k2 x k3 x K4 x K5 x K6 x K7**
- Total De rating Factor= 0.93

Selection of Cable:

- For selection of Proper Cable following Conditions should be satisfied

- (1) Cable De rating Amp should be higher than Full Load Current of Load.
- (2) Cable Voltage Drop should be less than Defined Voltage drop.
- (3) Cable Short Circuit Capacity should be higher than System S.C Capacity at that Point.
- **Selection of Cable Case (1):**
- Let's Select 3.5Core 70 Sq.mm cable for Single run.
- Current Capacity of 70 Sq.mm cable is 170Amp,Resistance=0.57Ω/Km and Reactance=0.077 mho/Km
- Total De rating Current of 70 Sq.mm Cable= 170x0.93 =159 Amp.
- **Voltage Drop of Cable= (1.732x Full Load Current x (RcosǾ+jsinǾ)x Cable Lengthx100) / (Line Voltage x No of Runx1000)**
- Voltage Drop of Cable= (1.732x139x(0.57x0.8+0.077x0.6)x200x100)/(415x1x1000)=5.8%
- **Voltage Drop of Cable=5.8%**
- Here Voltage drop for 70 Sq.mm Cable (5.8%) is higher than Define Voltage drop (5%) so either select higher size of cable or Increase no of Cable Runs.
- If we Select 2 No's of Run than Voltage drop is 2.8% which is within limit (5%) but to use 2 no's of Run of cable of 70 Sq.mm Cable is not economical so It is necessary to use next higher size of Cable.
- **Selection of Cable Case (2):**
- Let's Select 3.5Core 95 Sq.mm cable for Single run, S.C Capacity =8.2KA.
- Current Capacity of 95 Sq.mm cable is 200Amp,Resistance=0.41Ω/Km and Reactance=0.074 mho/Km
- Total De rating Current of 70 Sq.mm Cable= 200x0.93 =187 Amp.
- Voltage Drop of Cable= (1.732x139x(0.41x0.8+0.074x0.6)x200x100)/(415x1x1000)=2.2%
- **Voltage Drop of Cable=2.2%**
- To decide 95Sq.mm Cable, Cable selection condition should be checked.
- (1) Cable De rating Amp (187 Amp) is higher than Full Load Current of Load (139 Amp) =O.K
- (2) Cable Voltage Drop should (2.2%) is less than Defined Voltage drop (5%) =O.K
- (3) Cable S.C Capacity (8.2KA) is higher than System S.C Capacity at that Point (6.0KA) =O.K
- **95 Sq.mm Cable satisfied all three conditions so it is advisable to use 3.5 Core 95 Sq.mm cable**

Chapter: 11 Calculate Size of Cable Tray

Example:

- Calculate Size of Cable Tray for Following Cable Schedule. Cable Tray should be perforated and 20% spare Capacity. Distance between each Cable is 10mm. Cable are laying in Single Layer in Cable Tray.

(1) 2 No's of 3.5Cx300 Sq.mm XLPE Cable having 59.7mm Outer Diameter and 5.9 Kg/Meter weight
(2) 2 No's of 3.5Cx400 Sq.mm XLPE Cable having 68.6mm Outer Diameter and 6.1 Kg/Meter weight
(3) 3 No's of 3.5Cx25 Sq.mm XLPE Cable having 25mm Outer Diameter and 0.5 Kg/Meter weight

Calculation:

Total Outer Diameter of all Cable Passing in to Cable Tray:

- Diameter of 300Sq.mm Cable =No of Cable X Outer Diameter of Each Cable
- Diameter of 300Sq.mm Cable =2X59.7 = 119.4 mm
- Diameter of 400Sq.mm Cable =No of Cable X Outer Diameter of Each Cable
- Diameter of 400Sq.mm Cable =2X68.6= 137.2 mm
- Diameter of 25Sq.mm Cable =No of Cable X Outer Diameter of Each Cable
- Diameter of 25Sq.mm Cable =3X28= 84 mm
- Total Diameter of All Cables laying in Tray = (119.4+137.2+54)mm
- **Total Diameter of All Cables laying in Tray = 340.6mm**

Total Weight of Cables Passing in to Cable Tray:

- Weight of 300Sq.mm Cable =No of Cable X Weight of Each Cable
- Weight of 300Sq.mm Cable =2X5.9= 11.8 Kg/Meter
- Weight of 400Sq.mm Cable = No of Cable X Weight of Each Cable
- Weight of 400Sq.mm Cable =2X6.1= 12.2 Kg/Meter
- Weight of 25Sq.mm Cable = No of Cable X Weight of Each Cable
- Weight of 25Sq.mm Cable =3X0.5= 1.5 Kg/Meter
- Total Weight of All Cables laying in Tray = (11.8+12.2+1.5) Kg/Meter
- **Total Weight of All Cables laying in Tray =25.5 Kg/Meter**

Total Width of all Cables:

- Total Width of all Cables = (Total No of Cable X Distance between Each Cable) + Total Cable Outer Diameter
- Total Width of all Cables = (7 X 10) + 340.6
- Total Width of all Cables = 410.6 mm
- Taking 20% Spare Capacity of Cable Tray
- Final Width of all Cables = 1.2%X4106.6
- **Calculated Width of All Cables = 493 mm**

Total Area of Cable:

- Total Area of Cable = Final width of Cables X Maximum Height Cable
- Total Area of Cable = 493 X 69.6 =28167 Sq.mm
- Taking 20% Spare Capacity of Cable Tray
- Final Area of all Cables = 1.2%X28167
- **Calculated Area of all Cable =33801 Sq.mm**

CASE-(I):

- Considering Single Run of Cable Tray having Size of 300X100mm, 120Kg/Meter Weight Capacity
- Area of Cable Tray =Width of Cable Tray X Height of Cable Tray
- Area of Cable Tray =300X100 = 3000 Sq.mm
- **Checking Width of Cable Tray**
- Calculated Width of Cable Tray as per Calculation=No of Layer of Cable X No of Cable Tray Run X Width of Cables
- Width of Cable Tray as per Calculation=1X1X493 =493 mm
- **Checking Depth of Cable Tray**

- Actual depth of Cable Tray = No of Layer of Cable X Maximum Diameter of Cable
- Actual depth of Cable Tray=1X68.6 =68.6mm
- **Checking Weight of Cable Tray**
- Actual Weight of Cables=25.5 Kg/Meter

Results:

- Calculated Cable Tray width (493mm)> Actual Cable Tray width (300mm) = **Faulty Selection**
- Calculated depth of Cable Tray (68.6mm)< Actual Depth of Cable Tray (100mm) = **O.K**
- Calculated Weight of all Cables (25.5Kg/Mt) < Actual Weight of Cable Tray (125.5 Kg/Mt) =**O.K**
- **Required to select higher size Cable Tray due to small Cable Tray width.**

CASE-(II):

- Considering Single Run of Cable Tray having Size of 600X100mm, 120Kg/Meter Weight Capacity
- Area of Cable Tray =Width of Cable Tray X Height of Cable Tray
- Area of Cable Tray =600X100 = 6000 Sq.mm
- **Checking Width of Cable Tray**
- Width of Cable Tray as per Calculation=No of Layer of Cable X No of Cable Tray Run X Width of Cables
- Width of Cable Tray as per Calculation=1X1X493 =493 mm
- **Checking Depth of Cable Tray**
- Actual depth of Cable Tray = No of Layer of Cable X Maximum Diameter of Cable
- Actual depth of Cable Tray=1X68.6 =68.6mm
- **Checking Weight of Cable Tray**
- Actual Weight of Cables=25.5 Kg/Meter

Results:

- Calculated Cable Tray width (493mm)< Actual Cable Tray width (600mm) = **O.K**
- Calculated depth of Cable Tray (68.6mm)< Actual Depth of Cable Tray (100mm) = **O.K**
- Calculated Weight of all Cables (25.5Kg/Mt) < Actual Weight of Cable Tray (125.5 Kg/Mt) =**O.K**
- Remaining Cable Tray width Area =100%-(Calculated Cable tray width/ Actual Cable Tray Width)
- Remaining Cable Tray width Area =100%-(493/600)% =17.9%
- Remaining Cable Tray Area =100%-(Calculated Cable tray Area/ Actual Cable Tray Area)
- Remaining Cable Tray Area =100%-(33801/60000) =43.7%
- **Selection of 600X100 Cable Tray is O.K**

Conclusion

- **Size of Cable Tray= 600X100mm**
- **Type of Cable Tray=Perforated**
- **No of Cable Tray Run= 1No**
- **No of layer of Cables in Cable Tray=1 Layer**
- **Remaining Cable Tray width Area =17.9%**
- **Remaining Cable Tray Area =43.7%**

Chapter: 12 Calculate Cable Trunking Size

Example:

- Calculate PVC Trunking size for following Power Cables running through Trunking.
- Consider 10% as Future expansion

(1) 30 No's of 1.5 Sq.mm Stranded Cables
(2) 50 No's of 2.5 Sq.mm Stranded Cables
(3) 20 No's of 4 Sq.mm Stranded Cables

Cable Factor for Trunking as per IEEE		
Type of Cable	**Size of Cable**	**Factor**
Solid	1.5	7.1
Solid	2.5	10.2
Stranded	1.5	8.1
Stranded	2.5	11.4
Stranded	4	15.2
Stranded	6	22.9
Stranded	10	36.3
Stranded	16	50.3
Stranded	25	75.4
Stranded	35	95
Stranded	50	132.7
Stranded	70	176.7
Stranded	95	227
Stranded	120	284
Stranded	150	346

Trunking Factor As per IEEE	
Trunking Size (mm)	**Factor**
75 X 25	738
50 X 37.5	767
100 X 50	993
50 x 50	1037
75 X 37.5	1146
100 X 37.5	1542
75 X 50	1555
100 X 50	2091
75 X 75	2371
150 X 50	3161
100 X 75	3189
100 X 100	4252
150 X 75	4787
150 X 100	6414
150 X 150	9575

Calculations:

- As per Table Cable Factor for 1.5 Sq.mm Stranded Cable=8.1
- As per Table Cable Factor for 2.5 Sq.mm Stranded Cable=11.4
- As per Table Cable Factor for 2.5 Sq.mm Stranded Cable=22.9
- **Total Cable Factor= No of Cables X Cable Factor**
- **Total Cable Factor=**(30X8.1)+(50X11.4)+(20X22.9) =1271
- **Total Cable Factor After 10% Future Expansion=1271+127 =1398**
- As per Table Suitable Size for PVC Trunking for Cable Factor 1398 is 100 X 37.5
- **Suitable PVC Trunking is 100 X 37.5 mm**

Chapter: 13 Calculate Conduit Size for Cable /Wires

Example:

- Calculate Size of Conduit (Hume Pipe) for Following Size of Cables
- 5 No's of 3.5 Core 50 Sq.mm XLPE Cable. Diameter of cable is 28mm
- 3 No's of 3.5 Core 185 Sq.mm XLPE Cable. Diameter of cable is 54mm

% Fill Up Area of Conduit	
No of Cables	**% Fill up Area of Conduit**
Up to 2 No's	53%
2 No's	31%
More Than 2 No's	40%

Calculations:

- **Area of Cable =3.14 X (Radius/2)2**
- Area of 50 Cable =3.14X (28/2)2 =615.44 Sq.mm
- Total Area of 50 Cable=No of Cable X Area of Each Cable
- Total Area of 50 Cable=5X615.44 =3077.2
- Area of 185 Cable =3.14X (54/2)2 = 2289 Sq.mm
- Total Area of 185 Cable=No of Cable X Area of Each Cable
- Total Area of 185 Cable=3X2289=6867.18
- Total Area of Conductor= Total Area of 50 Cable+ Total Area of 185 Cable
- Total Area of Conductor=3077.2+6867.18
- **Total Area of Conductor=9944 Sq.mm**
- **Suppose We Select 150mm Diameter Hume Pipe**
- Total area of 150 mm Diameter Hume Pipe =3.14 X (Radius/2)2 =3.14X(150/2)2.
- Total area of 150 mm Diameter Hume Pipe=17662 Sq.mm.
- % Fill up Area of Conduit due to Cables as per above Table is 40%
- Actual Fill up Area of Hume Pipe =40% X Area of Conduit =40% X 17662
- Actual Fill up Area of Hume Pipe =7065 Sq.mm
- **Required No of Conduit = Total Area of Cables / Actual Fill up Area of Conduit**
- Required No of Conduit = 9944 / 7065
- **Required No of Conduit= 2 No's**
- **Suppose We Select 3000mm Diameter Hume Pipe**
- Total area of 300 mm Diameter Hume Pipe =3.14 X (Radius/2)2 =3.14X(300/2)2.
- Total area of 150 mm Diameter Hume Pipe=70650 Sq.mm.
- Actual Fill up Area of Hume Pipe =40% X Area of Conduit =40% X 70650
- Actual Fill up Area of Hume Pipe =28260 Sq.mm
- **Required No of Conduit = Total Area of Cables / Actual Fill up Area of Conduit**
- Required No of Conduit = 9944 / 28260
- **Required No of Conduit= 1 No's**

Results:

- **Either We Select**
- **2 No's of 185 mm Diameter Conduit /Hume Pipe or**
- **1 No's 300 mm Diameter Conduit /Hume Pipe**

Chapter: 14 Calculate Size of Pole Foundation & Wind Pressure on Pole

Example:

- Calculate Pole foundation size and Wind pressure on Pole for following Details.
- Tubular Street Light Pole (430V) height is 11 Meter which is in made with three different size of Tubular Pipe.
- First Part is 2.7 meter height with 140mm diameter,
- Second part of Pole is 2.7 meter height with 146 mm diameter and
- Third part of Pole is 5.6 meter height with 194 mm diameter.
- Weight of Pole is 241 kg and there is no any other Flood Light Fixtures Load on Pole.
- Total Safety Factor is 2.
- Wind zone category is 3.
- Pole is installed in open terrain with well scattered obstructions having height generally between 1.5 m to 10 m.
- Foundation of pole is 700mm length, 700mm width and 1.95 meter depth. The Average weight of foundation concrete is 2500 Kg/M3.

Calculation:

Wind Pressure according to Location:

- Wind Zone is 3 so Wind Speed as per following Table.

Basic Wind Speed-Vb (As per IS 802-Part1)	
Wind Zone	**Basic Wind Speed, vb m/s**
1	33
2	39
3	44
4	47
5	50
6	55

- Wind Speed (vb) = 44Mile/Second.
- Co-efficient Factor (K0)=1.37
- K0 is a factor to convert 3 seconds peak gust speed into average speed of wind during 10 minutes period at a level of 10 meters above ground. K0 may be taken as 1.375.
- The Pole is used for 430Vand wind zone is 3 so Risk Co-efficient (K1) as per following Table

Table 2 Risk Coefficient K1 for Different Reliability Levels and Wind Zones (As per IS 802-Part1)						
Reliability Level	**Wind Zone-1**	**Wind Zone-2**	**Wind Zone-3**	**Wind Zone-4**	**Wind Zone-5**	**Wind Zone-6**
1 (Up to 400KV)	1	1	1	1	1	1
2 (Above 400KV)	1.08	1.1	1.11	1.12	1.13	1.14
3 (River Crossing)	1.17	1.22	1.25	1.27	1.28	1.3

- Risk Co-efficient (K1) =1
- Terrain category (K2) for Open terrain with well scattered obstructions having height generally between 1.5 m to 10 m is 1 as per following Table
- Terrain category (K2)=1

Terrain Roughness Coefficient, K2 (As per IS 802-Part1)			
Terrain Category	**Category 1**	**Category 2**	**Category 3**

	Exposed open terrain with no obstruction and in which the average height of any object surrounding the structure is less than 1.5 m.	Open terrain with well scattered obstructions having height generally between 1.5 m to 10 m.	Terrain with numerous closely spaced obstructions.
Coefficient, K2	1.08	1	0.85

- Reference Wind Speed (Vr)= Vb / K0.
- Reference Wind Speed (Vr)= 44 / 1.37 =32 Mile/Second.
- Design wind Speed (vd)= Vr X K1 X K2.
- Design wind Speed (vd)= 32 X 1 X 1 =32 Mile/Second.
- Design Wind Pressure (Pd)=0.6 x vd2
- Design Wind Pressure (Pd)=0.6 x (32)2 =614.4 N/m2
- **Design Wind Pressure (Pd)=614.4/10 =61.4 Kg/m2**

Foundation Detail:

- Total Weight =Pole Weight +Foundation Weight.
- Total Weight = 241 +(0.7x0.7x1.95x2500) =2620.75 Kg
- Stabilizing Moment = Total Weight X (Foundation Length/2)
- **Stabilizing Moment = 2620.75 X (0.7/2) = 920.41 Kg/Meter.**

Pole Detail:

- First Part of Pole (h1) = 2.7 meter
- Diameter of First Part (d1) =140mm
- Second Part of Pole (h2) = 2.7 meter
- Diameter of Second Part (d2) =146mm
- Third Part of Pole (h3) = 5.6 meter
- Diameter of Third Part (d3) =194mm .

Wind Pressure on Pole:

- Overturning Moment due to the wind on 1st Part of the pole=pdxh1xd1x(h1/2+h2+h3)x0.6
- Overturning Moment due to the wind on 1st Part of the pole=61.4x2.7x(140/1000)x(2.7/2+2.7+5.61)x0.6
- **Overturning Moment due to the wind on 1st Part of the pole=134.47 Kg/meter----I**
- Overturning Moment due to the wind on 2nd Part of the pole=pdxh2xd2x(h2/2+h3)x0.6
- Overturning Moment due to the wind on 2nd Part of the pole=61.4x2.7x(146/1000)x(2.7/2+5.61)x0.6
- **Overturning Moment due to the wind on 2nd Part of the pole=112.76 Kg/meter.----II**
- Overturning Moment due to the wind on 3rd Part of the pole=pdxh3xd3x(h3/2)x0.6
- Overturning Moment due to the wind on 3rd Part of the pole=61.4x5.6x(194/1000)x(5.6/2)x0.6
- **Overturning Moment due to the wind on 3rd Part of the pole=112.14 Kg/meter.---III**
- **Total Overturning Moment on Pole due to Wind=134.47+112.76+112.14=359.36 Kg/meter.**

Safety Factor:

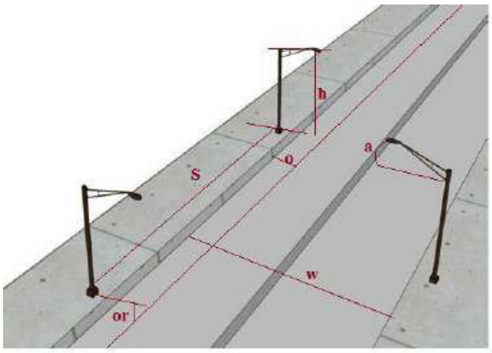
- Calculated Safety Factor= Stabilizing Moment / Total Overturning Moment on Pole.
- Calculated Safety Factor=920.41/ 359.36 =2.56.
- **For safe Design Calculated Safety Factor > Safety Factor**
- Here Calculated Safety Factor (2.56) > Safety Factor (2) hence
- **Design is OK**

N.B: If Calculated Safety Factor < Safety Factor then Change Foundation Size (Length, width or depth)

<u>Chapter: 15   Calculate Number of Street Light Pole</u>

Typical Calculation of Road Lighting:

- Luminaries are properly selected and mounted on a location most feasible and effective with minimum cost. For a 230 volts system, a voltage drop of 5% is allowed although in extreme cases 15% voltage drop is sometimes tolerated.



Street Lighting Features (BIS, 1981)
A: Angle of Tilt   **Or:** Outreach   **S:** Spacing
W: Width   **H:** Mounting Height   **O:** Overhang

- **Street illumination level in Lux (E)=(FxAl x (cu x mf)) / (w x d)**
- E = The illumination in Lux , w = Width of the roadway , d = Distance between luminaries
- F=Pole Arrangement (Single Side of Road =1, Both Side Staggered of Road=1, Both Side Opposite of Road=2, Twin Central of Road=1)
- cu = Coefficient of utilization. Which is dependent on the type of fixture, mounting height, width of roadway and the length of mast arm of outreach.
- **Al = Average lumens, Al = (E x w x d) / FxCu x mf**
- The typical value of Al is
- 20500 lumens for 400 watts , 11500 lumens for 250 watts and 5400 lumens for 125 watts
- The value of Al varies depending upon the type of lamp specified.
- **mf :** It is the maintenance factor (Normally 0.8 to 0.9)

(1) Calculate Lamp watt for street Light Pole:

- Calculate Lamp Lumen for street Light Pole having Road width of 7 meter, distance between two Pole is 50 meter, Pole Arrangement is Single Side of Road,Maintenance factor is 0.9, Coefficient of utilization factor is 0.29, light pedestrian traffic is medium and Vehicular traffic is very light and Road is concrete road.
- **<u>Solution:</u>**
- From Above table Recommended of illumination (E) in Lux is 6.46 per sq. meter.
- w = 7.00 meters , d = 50 meters , mf = 0.9, cu = 0.29
- To decide Lamp Watt It is necessary to calculate Average Lumens of Lamp (Al).
- **Average Lumen of Lamp (Al)=(E x w x d) / FxCu x mf**
- Al=(6.46x7x50)/(1x0.29x0.9)= 8662.83 Average lumens
- Lamp lumen of a 250 watts lamp is 11,500 lm which is the nearest value to 8662.83 lumens. Therefore, a 250 watts lamp is acceptable.
- Let's Computing for the actual illumination E for 250 Watt Lamp
- illumination (E)=(FxAl x (cu x mf)) / (w x d) = (1x11500x0.29x0.9) / (7x50) = 8.57 lumens per sq meter.
- **<u>Conclusion:</u>**
- Actual illumination (E) for 250 Watt is 8.57 lumens per sq meter which is higher than recommended illumination (E) 6.46.
- **Hence 250 watt gives adequately lighting.**

(2) Calculate Spacing between two Light Poles:

- Calculate Space between Two Pole of Street Light having Fixture Watt is 250W , Lamp output of the Lamp (LL) is 33200 lumens , Required Lux Level (E) is 5 lux , Width of the road (W) = 11.48 feet (3.5 M),Height of the pole (H)

= 26.24 feet (8 M) ,Coefficient of utilization (CU) = 0.18, Lamp Lumen Depreciation Factor (LLD) = 0.8 ,Luminaries dirt Depreciation Factor (LDD) = 0.9

- **Solution:**
- Luminaries Spacing (S) = (LLxCUxLLDxLDD) / (ExW)
- Luminaries Spacing (S) = (33200x0.18x0.9x0.8) / (5x11.48)
- **Luminaries Spacing (S) = 75 feet (23 Meters)**

(3) Calculation of the allowed illumination time:

- **The allowed illumination time in hours T = k.t.1000/E.**
- Where: k = extension factor , t = permissible time in hours at 1000 lux, unfiltered daylight, E = luminance (lx)

Extension Factor	
Lamp	**Extension Factor**
Incandescent lamps,	2.7 to 3.2
Halogen reflector lamps	2.5 to 3.5
Halogen capsules	2.5 to 3.5
High-pressure metal-halide	1.1 to 2.1
High-pressure sodium lamps	4
Fluorescent lamps	1.9 to 2.7

- **Example:**
- In sunlight (100000 lux) and extension factor 1: The permissible illumination time (T) =1 x 70 x 1000/100 000 = 0.7 hour.
- In halogen light (200 lux) and extension factor 2.3: The permissible illumination time (T) = 2.3 x 70 x 1000/200 = 805 hours.
- In UV-filtered halogen light (200 lux) and extension factor 3.5: The permissible illumination time (T) = 3.5 x 70 x 1000/200 = 1225 hours.

(4) Calculate Uniformity Ratio:

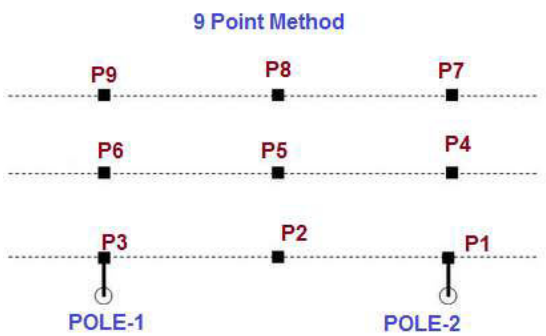
- Once luminaries spacing has been decided It is necessary to check the uniformity of light distribution and compare this value to the selected lighting
- **Uniformity Ratio (UR) = Eav /Emin**
- Eav= average maintained horizontal luminance
- Emin = maintained horizontal luminance at the point of minimum illumination on the pavement

(5) Energy Saving Calculations:

- At a simplistic level, the cost of running a light is directly related to the wattage of the globe plus any associated ballast or transformer. The higher the wattage, the higher the running cost and it is a straightforward calculation to work out the running cost of lamp over its lifetime:
- **Running cost = cost of electricity in $/kWh x wattage of lamp x lifetime in hours.**

Calculate Lux Level for Street Lighting

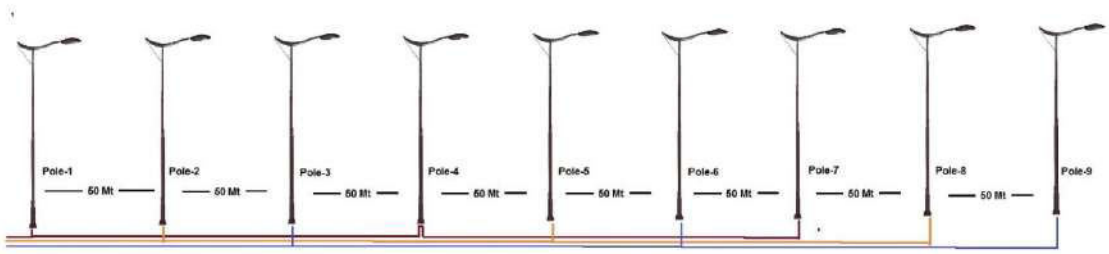
- The Average Lux Level of Street Light is measured by 9 point method. Make two equal quadrants between two Street light poles. on the lane of light poles(one side pole to road). We have 3 points P1,P2 and P3 under the light pole then P4 & P7 are points opposite pole 1 or Point P3 same is applicable for P6 and P9 for Pole 2.
- **The average lux = [(P1+P3+P7+P9)/16]+[(P2+P6+P8+P4)/8]+[P5/4]**



Chapter: 16 Calculate Cable Voltage Drop for Street Light Poles

Example:

- Calculate Voltage drop of Cable for Street Light Pole. System Voltage is 230V (P-N), Power Factor=0.75. Allowable Voltage Drop = 4% .The Detail of Pole & cable are
- **Pole Detail:**
- Section feeder Pillar is 50 meter away from Pole-1
- Distance between each Pole is 50 Meter Distance
- Luminar of Each Pole Fitting = 2 No's
- Luminar Watt =250 Watt
- **Cable Detail:**
- Size of Cable= 4CX10 Sq.mm.
- First Pole is connected in R Phase Next Pole is connected in Y Phase Than Next Pole is connected in B Phase. Next Pole is connected again R Phase.
- Resistance of Cable=3.7 Ω/Km
- Reactance of Cable=0.1 Ω/Km



Calculation:

Load of Each Pole

- Load of Each Pole = (Watt of Each Luminar X No of Luminar) / Volt X P.F
- Load of Each Pole = (250X2) /(230X0.75)
- Load of Each Pole = 2.9 Amp

For Pole Pole-1:

- Pole Connected on "R" Phase
- Total Distance of Pole for "R" Phase =50 Meter ,
- % Voltage drop of Cable= (Current X (Rcosφ + JSinnφ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X50 / (230x1x1000)
- % Voltage drop of Cable= 0.18% --------------------------------(1)

For Pole Pole-2:

- Pole Connected on "Y" Phase
- Total Distance of Pole for "Y" Phase =50+50=100 Meter ,
- % Voltage drop of Cable= (Current X (Rcosφ + JSinnφ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X100 / (230x1x1000)
- % Voltage drop of Cable= 0.36% --------------------------------(2)

For Pole Pole-3:

- Pole Connected on "B" Phase
- Total Distance of Pole for "B" Phase =50+50+50=150 Meter ,
- % Voltage drop of Cable= (Current X (Rcosφ + JSinnφ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X150 / (230x1x1000)
- % Voltage drop of Cable= 0.54% --------------------------------(3)

For Pole Pole-4:

- Pole Connected on "R" Phase
- Total Distance of Pole for "R" Phase =150+50=200 Meter ,

- % Voltage drop of Cable= (Current X (Rcosɸ + JSinnɸ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X200 / (230x1x1000)
- % Voltage drop of Cable= 0.72% --------------------------------(4)

For Pole Pole-5:

- Pole Connected on "Y" Phase
- Total Distance of Pole for "Y" Phase =200+50=250 Meter ,
- % Voltage drop of Cable= (Current X (Rcosɸ + JSinnɸ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X250 / (230x1x1000)
- % Voltage drop of Cable= 0.9% --------------------------------(5)

For Pole Pole-6:

- Pole Connected on "B" Phase
- Total Distance of Pole for "B" Phase =250+50=300 Meter ,
- % Voltage drop of Cable= (Current X (Rcosɸ + JSinnɸ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X300 / (230x1x1000)
- % Voltage drop of Cable= 1.07% --------------------------------(6)

For Pole Pole-7:

- Pole Connected on "R" Phase
- Total Distance of Pole for "R" Phase =300+50=350 Meter ,
- % Voltage drop of Cable= (Current X (Rcosɸ + JSinnɸ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X350 / (230x1x1000)
- % Voltage drop of Cable= 1.25% --------------------------------(7)

For Pole Pole-8:

- Pole Connected on "Y" Phase
- Total Distance of Pole for "Y" Phase =350+50=400 Meter ,
- % Voltage drop of Cable= (Current X (Rcosɸ + JSinnɸ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X400 / (230x1x1000)
- % Voltage drop of Cable= 1.43% --------------------------------(8)

For Pole Pole-9:

- Pole Connected on "B" Phase
- Total Distance of Pole for "B" Phase =400+50=450 Meter ,
- % Voltage drop of Cable= (Current X (Rcosɸ + JSinnɸ) X Distance) / (Volt X No of Cable X 1000)
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X450 / (230x1x1000)
- % Voltage drop of Cable= 1.61% --------------------------------(9)

Total Voltage Drop:

- Voltage Drop in "R" Phase = 0.18+0.72+1.25 =2.15 %
- Voltage Drop in "Y" Phase =0.36+0.90+1.43 =2.69 %
- Voltage Drop in "B" Phase =0.54+1.07+1.61 =3.22 %
- **% Voltage drop in each Phase is Max 3.22% Which is less than 4%**

Results:

Phase	No of Pole	Load (Amp)	Voltage Drop
R	3	9	2.15 %
Y	3	9	2.69 %
B	3	9	3.22 %
Total	**9**	**9**	**2.55 %**

Chapter: 17 Calculate Street Light Pole Watt / Area & Distance

Calculate Distance between each Street Light Pole:

- **Example:** Calculate Distance between each streetlight pole having following Details,
- Road Details: The width of road (W) is 11.5 Foot.
- Pole Details: The height of Pole is 26.5 Foot.
- Luminaries of each Pole: Wattage of Luminaries is 250 Watt, Lamp Out Put (LL) is 33200 Lumen, Required Lux Level (Eh) is 5 Lux, Coefficient of Utilization Factor (Cu) is 0.18, Lamp Lumen Depreciation Factor (LLD) is 0.8, Lamp Lumen Depreciation Factor (LLD) is 0.9.
- Space Height Ratio should be less than 3.
- **Calculation:**
- **Spacing between each Pole=(LL*CU*LLD*LDD) / Eh*W**
- Spacing between each Pole=(33200x0.18x0.8x0.9) / (5x11.5)
- Spacing between each Pole= 75 Foot.
- Space Height Ratio = Distance between Pole / Road width
- Space Height Ratio = 3. Which is less than define value.
- **Spacing between each Pole is 75 Foot.**

Calculate Street Light Luminas Watt:

- **Example:** Calculate Streetlight Watt of each Laminar of Street Light Pole having following Details,
- Road Details: The width of road (W) is 7 Meter. Distance between each Pole (D) is 50 Meter.
- Required Illumination Level for Street Light (L) is 6.46 Lux per Square Meter. Luminous efficacy is 24 Lumen/Watt. Maintenance Factor (mf) 0.29, Coefficient of Utilization Factor (Cu) is 0.9.
- **Calculation:**
- **Average Lumen of Lamp (Al) =** 8663 Lumen.
- **Average Lumen of Lamp (Al) =(LxWxD) / (mfxcu)**
- Average Lumen of Lamp (Al)= (6.46x7x50) / (0.29x0.9)
- Average Lumen of Lamp (Al)=8663 Lumen.
- **Watt of Each Street Light Laminar =** Average Lumen of Lamp / Luminous efficacy
- Watt of Each Street Light Laminar = 8663 / 24
- **Watt of Each Street Light Luminas = 361 Watt**

Calculate Required Power for Street Light Area:

- **Example:** Calculate Streetlight Watt of following Street Light Area,
- Required Illumination Level for Street Light (L) is 6 Lux per Square Meter.
- Luminous efficacy (En) is 20 Lumen per Watt.
- Required Street Light Area to be illuminated (A) is 1 Square Meter.
- **Calculation:**
- **Required Streetlight Watt = (Lux per Sq.Meter X Surface Area of Street Light) / Lumen per Watt.**
- Required Streetlight Watt = (6 X 1) / 20.
- **Required Streetlight Watt = 0.3 watt per Square Meter.**

Chapter: 18 Calculate Number Lighting Fixture / Lumen for Indoor Lighting

- An office area is 20meter (Length) x 10meter (width) x 3 Meter (height). The ceiling to desk height is 2 meters. The area is to be illuminated to a general level of 250 lux using twin lamp 32 watt CFL luminaires with a SHR of 1.25. Each lamp has an initial output (Efficiency) of 85 lumens per watt. The lamps Maintenance Factor (MF) is 0.63 ,Utilization Factor is 0.69 and space height ratio (SHR) is 1.25

Calculation:

Calculate Total Wattage of Fixtures:

- **Total Wattage of Fixtures= No of Lamps X each Lamp's Watt.**
- Total Wattage of Fixtures=2x32=64Watt.

Calculate Lumens per Fixtures:

- **Lumens per Fixtures = Lumen Efficiency(Lumen per Watt) x each Fixture's Watt**
- Lumens per Fixtures= 85 x 64 = 5440Lumen

Calculate No's of Fixtures:

- **Required No of Fixtures = Required Lux x Room Area / MFxUFx Lumen per Fixture**
- Required No of Fixtures =(250x20x10) / (0.63x0.69x5440)
- **Required No of Fixtures =21 No's**

Calculate Minimum Spacing Between each Fixture:

- The ceiling to desk height is 2 meters and Space height Ratio is 1.25 so
- Maximum spacing between Fixtures =2x1.25=2.25meter.

Calculate No of Row Fixture's Row Required along with width of Room:

- Number of Row required = width of Room / Max. Spacing= 10/2.25
- **Number of Row required=4.**

Calculate No of Fixture's required in each Row:

- Number of Fixture Required in each Row = Total Fixtures / No of Row = 21/4
- **Number of Fixture Required in each Row = 5 No's:**

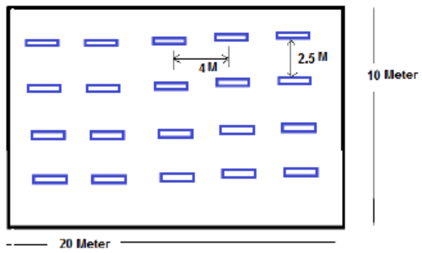
Calculate Axial Spacing between each Fixture:

- Axial Spacing between Fixtures = Length of Room / Number of Fixture in each Row
- Axial Spacing between Fixtures =20 / 5 = 4 Meter

`

-

- Transverse Spacing between Fixtures = width of Room / Number of Fixture's row
- Transverse Spacing between Fixtures = 10 / 4 = 2.5 Meter.



Conclusion:

- **No of Row for Lighting Fixture's= 4 No**
- **No of Lighting Fixtures in each Row= 5 No**
- **Axial Spacing between Fixtures= 4.0 Meter**
- **Transverse Spacing between Fixtures= 2.5 Meter**
- **Required No of Fixtures =21 No's**

Chapter: 19 Calculate LUX Level and Uniformity at Indoor & Outdoor Lighting

Introduction:

- Working plane illuminance (Lux Level) need to be measured in the field for cross check of whether the existing installation meets a design requirement or not.
- Field surveys may also be useful to identifying the causes of complaints about lighting, hence the results of field surveys may be useful for the designer, installers and end users.
- There are various methods are developed for field measurement of Interior Lighting and External Lighting.
- The Measurement Methods recommended by the various national lighting bodies are generally similar or slightly derivatives to each other. The most common method / Standard is BEE, CIBSE, IES and DIN code
- The most of methods require to measurement of illuminance at points on a grid at working-plane height or at Floor, but the grid size and position of the measuring points may be differed from various standard to standard.
- The IES method and its derivatives use the position of the grid according to the luminaire locations.
- The CIBSE and DIN methods use a position of grid according to the room size.
- The techniques of analysis of the field measurement results also differ

Basic Requirements for Exterior & Interior Light Level Measurement

- The following Points should be considered for accurate measurement of interior and exterior lighting Lux level.
- Where possible, use the same calibrated illuminance measurement meter (LUX Meter) If the same meter is not available, use the same make and model of calibrated meter to minimize error.
- When taking measurements, verify that any objects/materials are not blocking any light to the meter head. The use of a remote meter head cabled to the meter body is recommended to prevent the operator from blocking the meter's "view" of the lighting system being measured.
- In Outdoor Lighting it is essential to measure of illuminance should be done in night (proper dark).
- For indoor lighting, measurements with lights ON and Lights OFF technique can be followed and the daylight variation is not too much and the survey time is not too long.
- In an installation of fluorescent discharge lamps, the lamps must be switched on at least 30 minutes before the measurement to allow for the lamps to be completely warmed up.
- In many situations, the measuring plane may not be specified or even non-existent. Hence it is necessary to define measurement height, typically 0.8 to 1 meter from the ground or floor level.
- The lux measurement procedure simply requires positioning a meter's sensor on the surface or location where you wish to measure the incident light.
- The sensor should face the light source at a right angle. If the sensor is not perpendicular to the light, the measurement will be incorrect, though some lux meters have a cosine correction to account for the angle.
- Meters that require a colour correction factor may have a means of inputting the CCF to adjust the result for LEDs or fluorescent lights; otherwise, you will have to manually multiply the measured lux by the CCF.

Indoor Illumination (Lux Level) Measurement.

(1) As per Room Index Method (as per BEE Code / CIBSE Code):

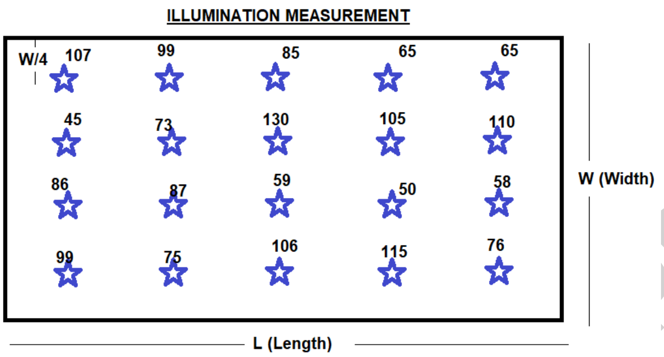
- This methos is more suitable where measuring Plan / Points for an interior is more rectangular than square. First, we need to be found Room Index.
- Based on the room index, the minimum number of illuminance measurement points is decided by Room Index Number
- **Room Index (RI) = (L x W) / H x (L+ W)**
- Where L = Length of Room
- W = Width of Room
- H= Height of the luminaires above the plane of measurement

Table 4-2: Number of points for measuring illuminance		
Room index	**Minimum number of measurement points**	
	For ± 5% accuracy	For ± 10% accuracy
RI < 1	8	4
1 < RI < 2	18	9

2 < RI < 3	32	16
RI > 3	50	25

Sample calculation

- Measure Illumination Level of an office room have length, L = 7.5 m and width W = 5 m,
- **Solution:**
- Suppose Height of Illumination from Floor is 2 Meter
- Room Index RI = (L x W) / H x (L+ W) = (7.5 x 5) / 2 x (7.5+ 5)
- Room Index RI = 1.5
- From Table 4.2 minimum Illumination Measure Points should be 18 No's
- The illuminance measurements Points with Measured Value in Lux are marked on the grid.

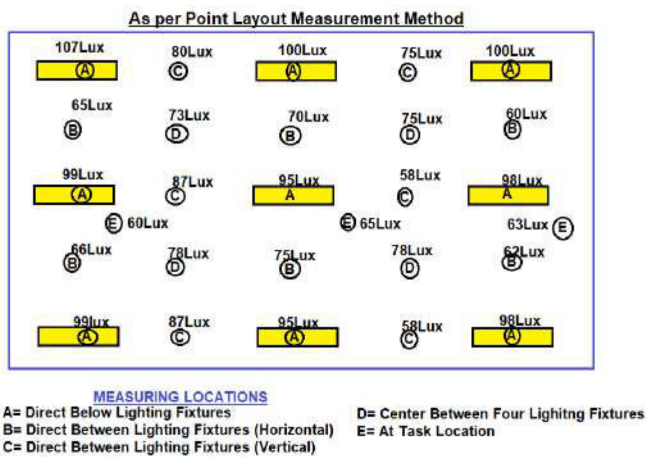


Measurement Reading Details				
107 Lux	99 Lux	85 Lux	65 Lux	65 Lux
45 Lux	73 Lux	130 Lux	105 Lux	110 Lux
86 Lux	87 Lux	59 Lux	50 Lux	58 Lux
99 Lux	75 Lux	106 Lux	115 Lux	76 Lux

- **Min =45 Lux , Max= 130 Lux ,Average =85 Lux**
- **U1=MIN/AVG=0.5 Lux**
- **U2=MIN/MAX=0.3 Lux**

(2) As per Point Layout Method

- For office and other task areas, identify a set of measurements points on desktops and other work surfaces that best represents lighting conditions in the space.
- It may not be possible to develop a uniform spacing grid, but points should be chosen that represent the various lighting conditions across the space.
- For each separate horizontal grid, identify a vertical plane representative of the lighting in the area (typically the gridline directly between two light fixtures).
- On this vertical plane, set a grid (line) of points at 1.5 Meter above the site surface at each of the corresponding horizontal measurement points.
- The following figures provide sample layouts for selecting horizontal measurement points for typical areas where lighting measurements are taken



Measurement Reading Details

107 Lux	80 Lux	**100 Lux**	75 Lux	**100 Lux**
65 Lux	73 Lux	70 Lux	75 Lux	60 Lux
99 Lux	87 Lux	**95 Lux**	58 Lux	**98 Lux**
60 Lux		65 Lux		63 Lux
66 Lux	78 Lux	75 Lux	78 Lux	62 Lux
99 Lux	87 Lux	**95 Lux**	58 Lux	**98 Lux**

- **Min =58 Lux , Max= 107 Lux ,Average =80 Lux**
- **U1=MIN/AVG=0.7 Lux**
- **U2=MIN/MAX=0.5 Lux**

(3) AS per Deutsch Norm DIN 5035

- In this Method the working plane divide into a number of sections which are at least rectangular, of ratio of length to side not less than 1: 2 but which are preferably of square shape.
- A square grid of minimum size 1 meter is established within each section with a measurement point at the centre of each square.
- The grid module defining the measurement points is selected so as not to coincide with the luminaire grid in either principal direction.
- In exceptionally large interiors the grid size may be up to 5 meters. there is not any mention of accuracy limits of the method, but this is not surprising given the flexibility which the user of the method is allowed in choice of grid size.
- The DIN system is the only one of the three methods studied to give any advice concerning illuminance measurements in obstructed interiors. Areas of the working plane located between large obstructions are treated for measurement purposes as separate spaces.

	--1Meter--	--1Meter--	--1Meter--	--1Meter--	--1Meter--	--1Meter--	--1Meter--	--1Meter--	--1Meter--
-1Meter-	30	35	30	35	32	35	30	30	32
-1Meter-	30	100	30	30	95	35	30	90	32
-1Meter-	35	50	35	40	40	35	30	35	32
-1Meter-	35	55	30	40	42	35	40	38	30
-1Meter-	34	100	40	35	90	40	35	100	36
-1Meter-	30	55	35	35	35	35	30	35	30
-1Meter-	35	50	40	38	38	30	40	50	32
-1Meter-	30	99	35	35	98	35	35	100	39
-1Meter-	35	30	34	33	32	30	31	32	35

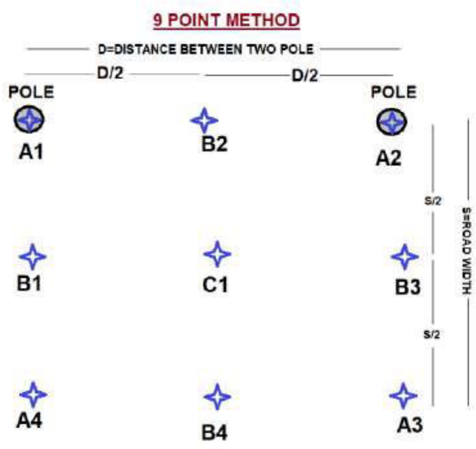
Min	30 Lux
Max	100 Lux
Avg	42 Lux
U0 or U1=MIN/AVG	0.7 Lux
Ul or U2=MIN/MAX	0.3 Lux

Lighting Fixture

OUTDOOR ILLUMINATION (LUX LEVEL) MEASUREMENT

(A). Nine Point Method for Determining Lux Levels in Street Lighting

- The Lux Level of Street Light is measured by 9-point method.
- We need to make two equal quadrants between two light poles and between Pole and Rode edge.
- Two Measuring Points below Light Pole (A1,A2) and Two opposite side of Pole at Road Edge (A3,A4).
- Two Point between Pole and Road edge (B1,B3).
- One Point Between Pole (B2) and on One Point between opposite side of Pole at road edge (B4)
- One Point is at centre (C1).
- **Average Lux = (A1+A2+A3+A4)/16 + (B1+B2+B3+B4)/8 +C1/4**



- **Solution**

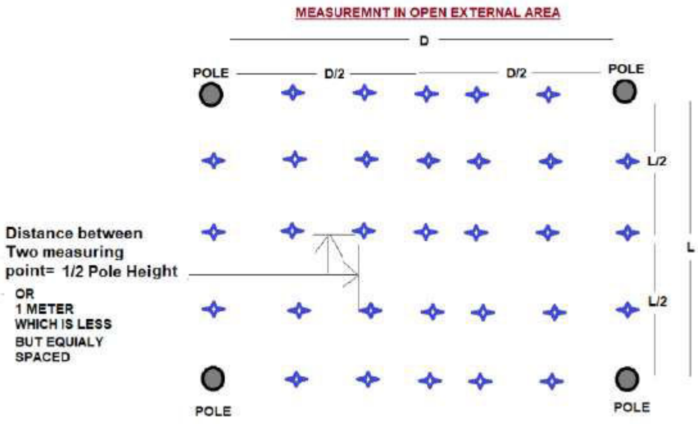
26 Lux	27 Lux	13 Lux
12 Lux	15 Lux	14 Lux
26 Lux	32 Lux	22 Lux

- Average Lux = (A1+A2+A3+A4)/16 + (B1+B2+B3+B4)/8 +C1/4
- Average Lux = (26+26+13+22)/16 + (12+27+14+32)/8 +15/4
- **Average Lux =20Lux**
- **Min : 12 Lux, Max: 32 Lux ,Average 20 Lux**
- **U1=MIN/AVG =0.58**
- **U2=MIN/MAX=0.38**

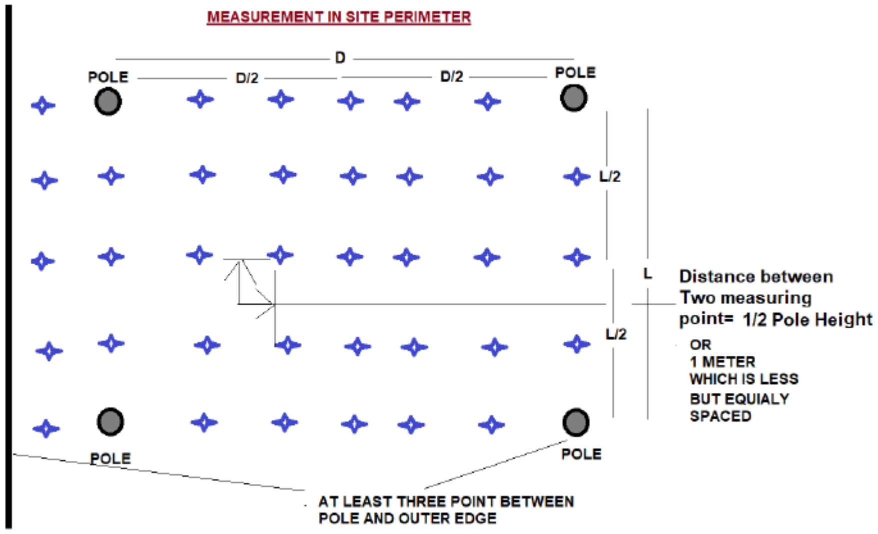
(B). As per Grid Point Set Up Measurement

- Identify a horizontal grid of measurement points on the Illumination Measurement site surface. Locate measurement points on gridlines covering the test measurement area.
- Ensure that the spacing between measurement points is uniform in both directions and is less than one-half the pole height or less than 4.5 Meter, whichever is smaller.
- For installations with lights spaced less than 4.5 Meter apart, locate measurement points no farther apart that one-half the pole height, with at least three points between poles in both directions.
- Record the location of all measurement grids and point layouts with dimensions from surrounding poles or other structures. Provide this information, including a sketch or rendering of the grid layouts.
- For open areas such as main parking, make the measurement grid large enough to cover at least four poles of this Area layout and at least two Pole are covered.
- For site perimeter open areas or areas adjacent to a building edge establish the test area measurement grid in a typical perimeter or building edge area. The depth of the test area should extend from the paved site boundary or building edge inward to the nearest line of light poles that are at least 4.5 Meter from the boundary or building edge.
- The width of the test area must cover at least two of the poles in the line that is at least 4.5 Meter from the the boundary or building edge.

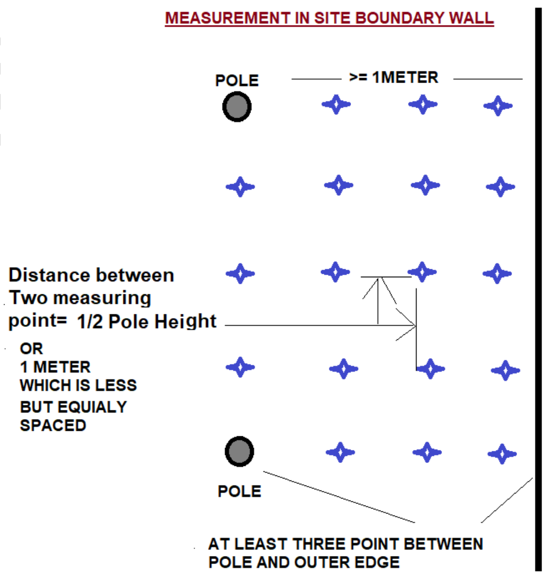
(A) In Open Area



(B) In the Area of Site Perimeter



(C) Near Site Boundary Area:



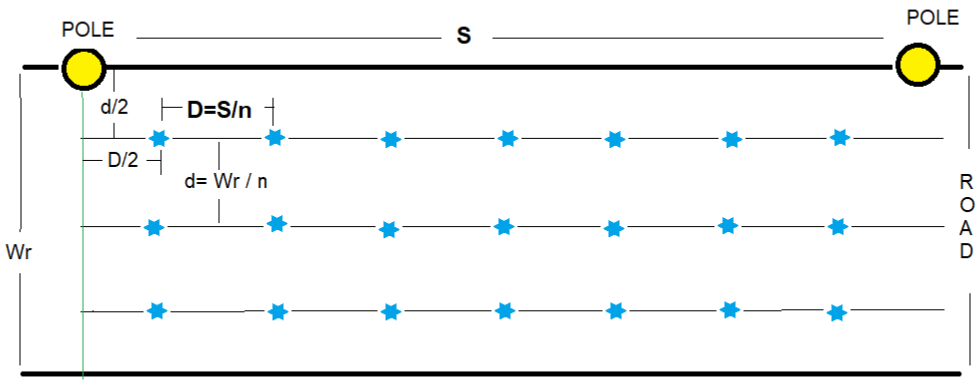
(C). Grid Method to measure illumination on the road

- The arrangement of the measuring points depends on the distance between the Illumination Pole and the width of the Road.
- The measurement of illuminance should be performed on the area in longitudinal direction two consecutive luminaires in the same row and in transverse direction the width of the area with the same illumination class, i.e. if the road and adjacent pavement or bicycle path have the same illumination class, they may be considered as

one area during the measurements. The measuring points should be distributed evenly within the measuring field.

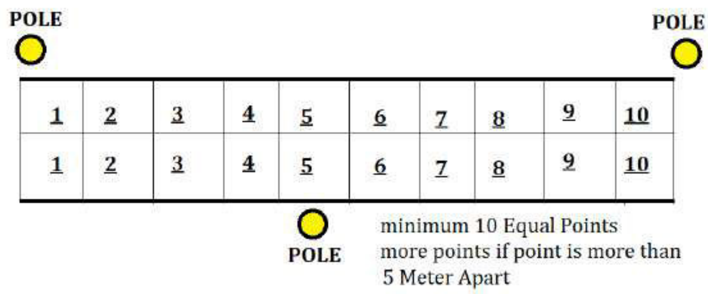
- The distance between the measuring points (D in Meter) in the longitudinal direction should be calculated using the formula
- **The distance between the measuring point in longitude (D)=S / N**
- where:
  S= the distance between the luminaires in [m], N= the number of measurement points in the longitudinal direction, for S ≤ 30 m, it is N = 10, for S > 30 m, the smallest integer giving D ≤ 3 m.
- The distance between measurement points (d in Meter) in the transverse direction should be calculated with the formula:
- **The distance between the measuring point in transverse (d) = Wr / n**
- where: Wr= the width of the road or the area under consideration in Meter.
- n = the number of measurement points in the transverse direction equal to 3 or more and being an integer giving d ≤ 1.5 m.
- The distance between the points and the edges of the surface under consideration should be D/2 in the longitudinal direction and d/2 in the transverse direction. The location of the measurement points in the measuring field is shown in Figure.

Grid Method to measure illumination on the road



(D). Equal Space Method

- In this Method at least10 equal measuring Points are taken between two lighting Pole on one side of the Roadway.
- These measurement points cannot be spaced more than 5 meters apart. Two lines of measurement points are needed per driving lane, one-half lane width apart.
- Once you have taken all of your illuminance measurements, you can calculate an average illuminance for the section of roadway you have measured.



What is Lighting Uniformity

- light uniformity refers to the uniformity of lighting in an environment. It is necessary to maintain the uniformity of light in order to make sure that everything is perfectly visible in the room.
- Uniformity is the ratio of the minimum lighting level to the average lighting level in a specified area.
- **U1 = E Min / E Average**
- **U2 = E Min / E Maximum**

- U & E stands for uniformity & illuminance respectively.
- Uniformity is a quality parameter for the overall illuminance distribution.
- It is quite useful to use this uniformity ratio to describe how the lights are evenly distributed on the ground. If the difference between minimum and average lux is small, then the ratio is high, which gives better light uniformity.
- The maximum lighting uniformity is 1, which means the lux levels in all the sampling points are the same. However, it is very unlikely to achieve this maximum value for artificial lighting.
- If the uniformity is very low for the outdoor or indoor lighting, the citizens, workers, or athletes might feel uncomfortable, and thus their vision is affected.
- The more uniform the light distribution, the better the illuminance and the more comfortable the visual experience. The closer the illuminance uniformity is to 1, the better, otherwise the smaller the more visual fatigue.

How to improve Lighting Uniformity

- Adjust the aiming angle of the floodlight,
- The lights irradiated by the floodlights should overlap each other,
- Use pole lights, high-power floodlights, street lights, etc. to supplement lighting.

Light Uniformity Standard

- There are different light uniformity standards that need to be followed depending on the nature of the environment
- Most focus-intensive tasks require a uniformity index of around 0.6, whereas, technical drawing and other demanding tasks require a ratio of at least 0.7.
- Uniformity value greater than 0,60 is recommended in working areas. Because, above this level, the change in light levels cannot be sensed by people and that makes them comfortable. Proper lighting of the environment also helps employees work more comfortably when looking at the computer screen.
- Due to low uniformity in road lighting, the homogeneity of lighting will be distorted. So, very bright and very dark spots will occur on the road. If brightness changed very often, this will cause eye strain and stresses the drivers
- In order to avoid these situations, average uniformity value greater than 0.35 or 0.4 is required according to road lighting class.

Standard	Area	Ratio of Minimum/Average Illumination
UK CIBSE and German DIN guidelines	The general lighting scheme	0.6 and 0.8
NBC-2005, page no 759	Working Area	Not Less than 0.7

Table-6: Recommended Levels of Illumination (BIS, 1981)

Type of Road	Road Characteristics	Ratio of Minimum/Average Illumination
A-1	Important traffic routes carrying fast traffic	0.4
A-2	Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	0.4
B-1	Secondary roads with considerable traffic like local traffic routes, shopping streets	0.3
B-2	Secondary roads with light traffic	0.3

EUROPEAN STANDARD- EN 12464-1:2011

Space	Uniformity U0 (Emin / Em)
Areas with traffic and corridors	0.4
Stairways, escalators, and travelators	0.4
Lifts	0.4
Loading bays	0.4
Coffee-break rooms	0.4
Technical facilities	0.4
Storage spaces	0.4
Electronics workshops, testing, and adjustments	0.7

Ball-mill areas and pulp plants	0.4
Offices and writing	0.6
Check-out areas	0.6
Waiting rooms	0.4
Kitchens	0.6
Parking areas	0.4
Classrooms	0.6
Auditoriums	0.6

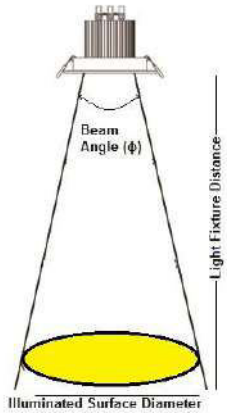
EUROPEAN STANDARD- EN 12464-1:2011	
Task illuminance	≥ 0.7
Illuminance of immediate surrounding areas	≥ 0.5

Football Field Lighting Design	
Nature of the Sports Field	**Required U1 Light Uniformity**
Class I such as for a National Competition	≥ 0.7
Class II such as for a League	≥ 0.6
Class III such as for a Training Ball Field	≥ 0.5
Industrial and Commercial Lighting Uniformity Requirement	
The Area	The Light Uniformity Standard
Highway	0.4-0.6
Sports field	0.5-0.8
Office	0.4-0.6
Parking Lot	0.4-0.5
Warehouse	0.4-0.6
Running Track	0.3-0.5
Airport	0.2-0.3

Chapter: 20 Calculate Lighting Fixture's Beam Angle and Lumen

Example 1: Calculate Lighting Fixture's Lumen and Illumination Diameter of following details.

- Required illumination at surface is 1390 Lux
- The distance from Lighting Fixture to illumination surface is 3 Meter.
- The Fixture Beam Angle is 10 Degree.



Calculation:

- Required Lux at Surface (E2) =1390 Lux.
- Distance between Lighting Fixture and Surface (D) = 3 Meter.
- Fixture Beam Angle (ϕ)= 10°
- Irradiance at 1.0 meter (E1)= DxDxE2
- Irradiance at 1.0 meter (E1)=1390x3x3 =12510 Lumen / M2
- **Irradiance at 1.0 meter (E1)= 12510 Lumen / M2**
- Solid Angle of The Lamp (Ω) =2xπx(1-COS(ϕ/2))
- Solid Angle of The Lamp (Ω) =2x3.14x(1-COS(10/2)) =6.28x(1-0.996)
- **Solid Angle of the Lamp (Ω) =0.0239 Steradian.**
- Required Lumen of Lighting Fixtures= E1x Ω
- Required Lumen of Lighting Fixtures=12510x0.0239
- **Required Lumen of Lighting Fixtures=299 Lumen.**
- **Illumination Diameter at surface =0.018xDx ϕ**
- Illumination Diameter at surface =0.018x3x10
- **Illumination Diameter at surface =0.54 Meter.**

Example 2: Calculate Lighting Fixture's Beam Angle and Illumination Diameter of following details.

- Required illumination at surface is 22 Lux
- Lighting Fixture Lumen is 1547 Lumen.
- The distance from Lighting Fixture to illumination surface is 4 Meter.

Calculation:

- Required Lux at Surface (E2) =22 Lux.
- Distance between Lighting Fixture and Surface (D) = 4 Meter.
- Irradiance at 1.0 meter (E1)= DxDxE2
- Irradiance at 1.0 meter (E1)=4x4x22 =352 Lumen / M2
- **Irradiance at 1.0 meter (E1)= 352 Lumen / M2**
- **Solid Angle of The Lamp (Ω) = Lumen of Lighting Fixtures / E1**

- Solid Angle of the Lamp (Ω) =1547 / 352
- **Solid Angle of the Lamp (Ω) =4.394 Steradian.**
- **Solid Angle of The Lamp (Ω) =2xπx(1-COS(ϕ/2))**
- 4.39 =2x3.14x(1-COS(ϕ/2))
- **Fixture Beam Angle (ϕ)=145°**
- **Illumination Diameter at surface =0.018xDx ϕ**
- Illumination Diameter at surface =0.018x4x145
- **Illumination Diameter at surface =10.44 Meter.**

Example 3: Calculate Lux Level and Illumination Diameter of following details.

- Lighting Fixture Lumen is 299 Lumen.
- The distance from Lighting Fixture to illumination surface is 3 Meter.
- The Fixture Beam Angle is 10 Degree.

Calculation:

- Required Lux at Surface (E2) =1390 Lux.
- Distance between Lighting Fixture and Surface (D) = 3 Meter.
- Fixture Beam Angle (ϕ)= 10°
- **Solid Angle of The Lamp (Ω) =2xπx(1-COS(ϕ/2))**
- Solid Angle of The Lamp (Ω) =2x3.14x(1-COS(10/2)) =6.28x(1-0.996)
- **Solid Angle of the Lamp (Ω) =0.0239 Steradian.**
- **Lumen of Lighting Fixtures= E1x Ω**
- 299= E1x0.0239
- Irradiance at 1.0 meter (E1)= Lumen of Lighting Fixtures / Ω
- Irradiance at 1.0 meter (E1)=299 / 0.0239
- **Irradiance at 1.0 meter (E1)= 12506 Lumen / M2**
- **Lux at Surface (E2) = E1 / (DxD)**
- Lux at Surface (E2) =12506 / (3x3)
- **Lux at Surface (E2) =1389.5 Lux**

Chapter: 21 Calculation of Flood Light, Facade Light, Street Light and Sinage Light

- Outdoor Lighting can be classified according to the location where it can be installed or its function which use to highlight landscape area.
- Outdoor Lighting can be classified as

a) Flood Lighting,
b) Facade Lighting and
c) Signage Lighting
d) Street Light

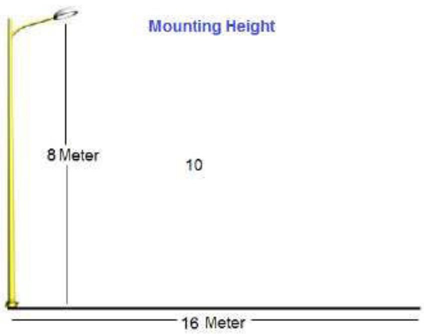
(A). General Outdoor Flood Lighting:

- Normally Pole mounted floodlights are used to illuminate general lighting area of parking lots and storage yards.
- There are three factor should be consider while designing of outdoor flood lighting.

1) Mounting Height.
2) Spacing.
3) Aiming Distance.
4) Horizontal Aiming.

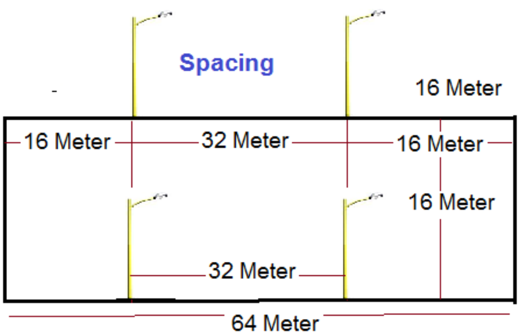
1) Mounting Height:

- Mounting height should be one half the distance across the area to be lighted.
- If the area to be lighted is 16 Meter, the lowest recommended mounting height is 8 Meter.
- **Mounting height = 1/2 distance to be lighted**
- **1/2 (16 Meter.) = 8 Meter.**



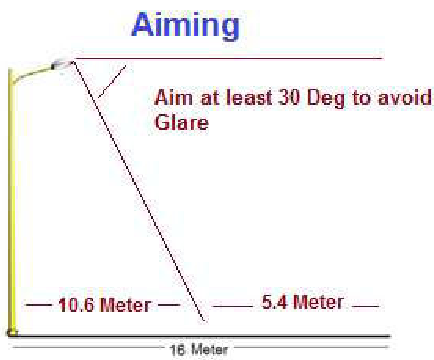
2) Spacing:

- When more than one Luminar / pole is required than distance between two adjacent luminar / Pole is 4 times Mounting height of luminar /pole.
- If the mounting height of luminar /Pole is 8 Meter than distance between adjacent Luminar is 32 Meter.
- **Pole Spacing = 4 x mounting height.**
- **4 (8 Meter pole) = 32 Meter between poles**



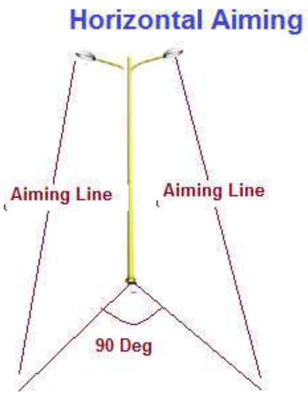
3) Vertical Aiming:

- The fixture should be aimed 2/3 of the distance across the area to be lighted and at least 30 degrees below horizontal.
- If the area to be lighted is 16 Meter across, the recommended aiming point is 10.6 Meter.
- **Aiming point = 2/3 Distance to be lighted.**
- 2/3 (16 Meter) = 10.6 Meter aiming point
- To minimize glare, the recommended aiming point distance should never exceed twice the mounting height.
- If a pole is 8 Meter high, the vertical aiming point should not exceed 16 Meter.
- **2 (8 Meter mounting height) = 16 Meter.**



4) Horizontal Aiming:

- When two floodlights is mounted to a single pole then horizontal aiming also must be considered.
- Each floodlight should be vertically aimed according to the two-thirds rule.
- **The floodlights should be aimed up to 90 degrees apart.**

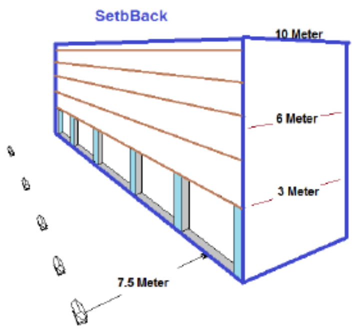


(B). Facade Lighting:

- Normally Facade Lighting are used to illuminate Building area from Outer Side.
- There are three factor should be consider while designing of outdoor Facade Lighting.
  1) Setback.
  2) Spacing.
  3) Aiming

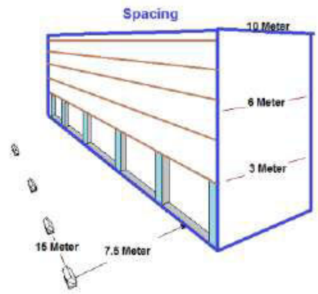
1) Setback:

- The recommended setback should be 3/4 times the building height.
- If a building is 10 Meter tall, the recommended setback is 7.5 Meter from the building.
- If the locating the floodlight closer to the building will sacrifice uniformity and If setting it further back will result in loss of efficiency.
- **Setback distance = 3/4 x Building height**
- **3/4 x (10 Meter) = 7.5 Meter**



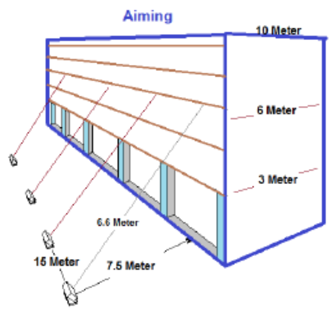
2) Spacing:

- Spacing of floodlights should not be exceeding two times the setback distance.
- If the setback is 7.5 Meter the floodlights should not be placed more than 15 Meter apart.
- **Spacing = 2 x setback distance**
- **7.5 Meter x 2 = 15 Meter**



3) Aiming:

- The floodlight should be aimed at least 2/3 the height of the building.
- If a building is 10 Meter high, the recommended aiming point is approximately 6.6 Meter high.
- After installation aiming can be adjusted to produce the best fine appearance.
- **Aiming Point = 2/3 x Building Height**.
- **2/3 (10 Meter) = 6.6 Meter high**



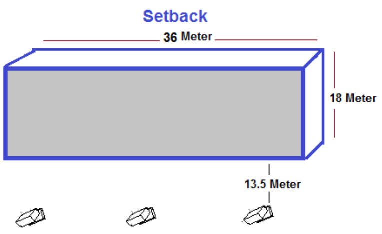
(C). Sinage Lighting:

- Normally Sinage Lighting are used to illuminate Sinage Board either Floor Mounted or Pole Mounted
- There are three factor should be consider while designing of Sinage Board Lighting.
  1) Setback.
  2) Spacing.
  3) Aiming

1) Setback:

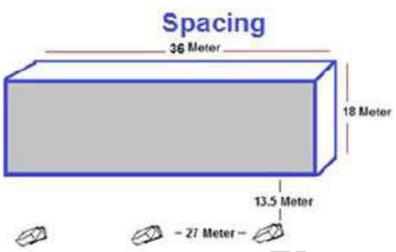
- When using floodlights to light a sinage, the setback should be 3/4 the sign height
- If the sinage height is 18 Meter then the setback distance would be 13.5 Meter.
- If the floodlight closer to sinage will sacrifice uniformity while setting it further back will in a loss of efficiency.

- **Setback distance = 3/4 x sinage height**
- **3/4 (18 Meter) = 13.5 Meter.**



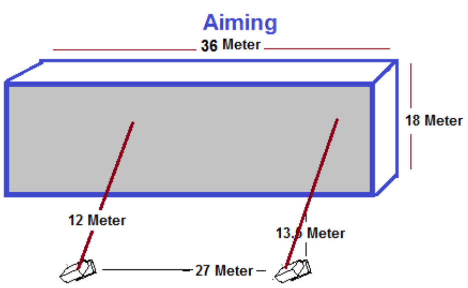
2) Spacing:

- The spacing floodlights should not be exceed two times the setback distance.
- If the setback is 13.5 Meter, the floodlights should not be placed more than 27 Meter apart.
- **Spacing = 2 x setback distance.**
- **13.5 Meter x 2 = 27 Meter.**



3) Aiming:

- The floodlight should be aimed at least 2/3 up the sign.
- If a sign is 18 Meter tall, then the floodlight should be aimed approximately 12 Meter high.
- Aiming can be adjusted to produce the best appearance.
- Mounting a full or upper visor to the floodlight can reduce unwanted glare.
- **Aiming point = 2/3 x sign height**
- **2/3 (18 Meter.) = 12 Meter high**



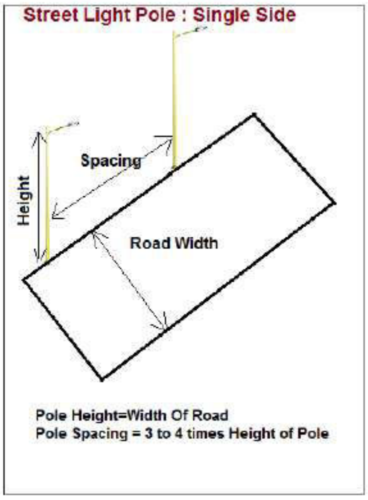
(D).Street Light Pole Height & Spacing (as per CPWD):

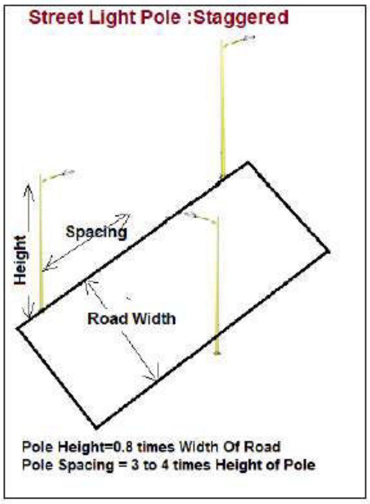
- There are four type of Street Light Pole arrangement.
  1) One side Type.
  2) Staggered Type.
  3) Opposite Type.
  4) Central Type.
- **As per CPWD we can calculate Pole Height and Spacing as per under**

1) One side Street Light Pole arrangement.

- **Pole Height = Width of Road.**
- **Pole Spacing = 3 to 4 Times Height of Pole.**

- If the Road width is 8 Meter than
- Pole Height=8 Meter & Pole Spacing =24 to 32 Meter.



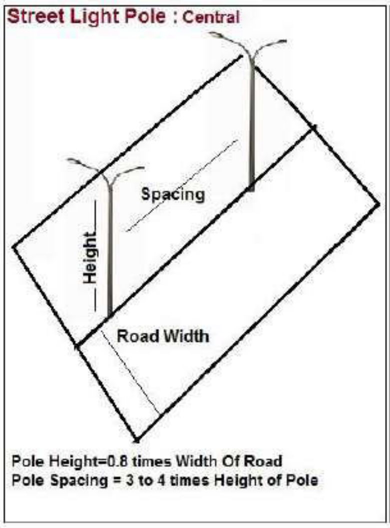


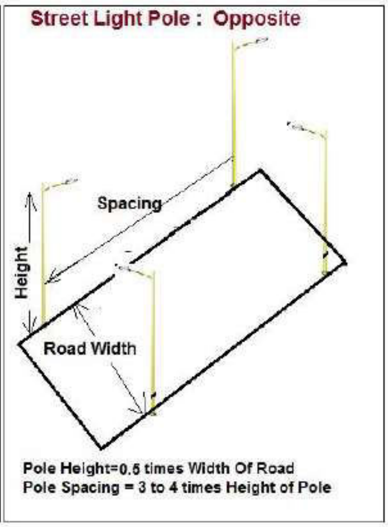
2) Staggered Type Street Light Pole arrangement.

- **Pole Height = 0.8-time Width of Road.**
- **Pole Spacing = 3 to 4 Times Height of Pole.**
- If the Road width is 8 Meter than
- Pole Height=6.4 Meter & Pole Spacing =24 to 32 Meter.

3) Opposite side Street Light Pole arrangement.

- **Pole Height = 0.5 time Width of Road.**
- **Pole Spacing = 3 to 4 Times Height of Pole.**
- If the Road width is 8 Meter than
- Pole Height=6.4 Meter & Pole Spacing =24 to 32 Meter.





4) Central Street Light Pole arrangement.

- **Pole Height = 0.8 time Width of Road.**
- **Pole Spacing = 3 to 4 Times Height of Pole.**
- If the Road width is 8 Meter than
- Pole Height=4 Meter & Pole Spacing =24 to 32 Meter.

Chapter:22 Calculate Lighting Protection for Building / Structure

Example:

- Calculate Whether Lighting Protection is required or not for following Building. Calculate No of Down Conductor for Lighting Protection
- **Area of Building / Structure:**
- Length of Building (L) = 60 Meter ,Width of Building (W) = 28 Meter , Height of Building (H) = 23 Meter.
- **Lighting Stock Flushing Density**
- Number of Thunderstorm (N)= 80.00 Days/Year
- Lightning Flash Density (Ng)=69 km2/Year
- Application of Structure (A)= Houses & Buildings
- Type of Constructions (B)= Steel framed encased without Metal Roof
- Contests or Consequential Effects (C)= Domestic / Office Buildings
- Degree of Isolations (D)= Structure in a large area having greater height
- Type of Country (E)= Flat country at any level
- Maximum Acceptable Overall Risk Factor =0.00000001

Reference Table As per IS:2309

Thunder Storm Days / Year	Lightning Flash Density (Flashes to Ground /km^2/year)
5	0.2
10	0.5
20	1.1
30	1.9
40	2.8
50	3.7
60	4.7
80	6.9
100	9.2

Application of Structure	Factor
Houses & Buildings	0.3
Houses & Buildings with outside aerial	0.7
Factories / workshop/ Laboratories	1
Office blocks / Hotel	1.2
Block of Flats / Residences Building	1.2
Churches/ Hall / Theatres / Museums, Exhibitions	1.3
Departmental stores / Post Offices	1.3
Stations / Airports / Stadium	1.3
Schools / Hospitals / Children's Home	1.7
Others	1.2

Type of Constructions	Factor
Steel framed encased without Metal Roof	0.2
Reinforced concrete without Metal Roof	0.4
Steel framed encased with Metal Roof	0.8
Reinforced concrete with Metal Roof	1
Brick / Plain concrete or masonry without Metal Roof	1.4
Timber framed or clad without Metal Roof	1.7
Brick / Plain concrete or masonry with Metal Roof	2
Timber framed or clad with Metal Roof	

Contests or Consequential Effects	Factor
Domestic / Office Buildings	0.3
Factories / Workshop	0.3

Industrial & Agricultural Buildings	0.8
Power stations / Gas works	1
Telephone exchange / Radio Station	1
Industrial key plants, Ancient monuments	1.3
Historic Buildings / Museums / Art Galleries	1.3
Schools / hospitals / Children Homes	1.7

Degree of Isolations	Factor
Structure in a large area having greater height	0.4
Structure located in a area of the same height	1
Structure completely Isolated	2

Calculation:

Collection Area (Ac)=(L x W) + 2 (L x H) + 2(W x H) +(3.14 x H2)

- Collection Area (Ac) = (60x28)+2x(60x23)+2x(28x23)+(3.14x23x23)
- Collection Area (Ac) =7389 Meter2

Probable No of Strikes to Building / Structure (P)= Ac x Ng x 10-6 No's / Year

- Probable No of Strikes to Building / Structure (P)= 7389x69x10-6 No's / Year
- Probable No of Strikes to Building / Structure (P)= 0.05098 No's / Year

Overall Multiplying Factor (M) =A x B x C x D x E

- Application of Structure (A)= Houses & Buildings as per Table Multiplying Factor = 0.3
- Type of Constructions (B)= Steel framed encased without Metal Roof as per Table Multiplying Factor =0.2
- Contests or Consequential Effects (C)= Domestic / Office Buildings as per Table Multiplying Factor =0.3
- Degree of Isolations (D)= Structure in a large area having greater height as per Table Multiplying Factor =0.4
- Type of Country (E)= Flat country at any level so as per Table Multiplying Factor =0.3
- Overall Multiplying Factor (M) =0.3x0.2x0.3x0.4x0.3=0.00216

Overall Risk Factor Calculated (xc)= M x P

- Overall Risk Factor Calculated (xc)= 0.00216 x0.05098= 0.000110127

Base Area of Structure (Ab) = (LxW)

- Base Area of Structure (Ab)=60x28=1680 Meter2

Perimeter of Structure (P) =2x (L+W)

- Perimeter of Structure (P)=2x(60+28)=176 Meter

Lighting Protection Required or Not

- **If Calculated Overall Risk Factor Calculated > Maximum Acceptable Overall Risk Factor than only Lighting Protection Required**
- Here Calculated Overall Risk Factor is 0.000110127 > Max Acceptable Overall Risk Factor is 0.00000001
- **Lighting Protection is Required**

No of Down Conductor

- **Down Conductors As per Base Area of Structure (s) =1+(Ab-100)/300**
- Down Conductors As per Base Area of Structure (s) =1+(1680-100)/300
- **Down Conductors As per Base Area of Structure (s) =6 No's**
- Down Conductors As per Perimeter of Structure (t)= P/30 = 176/30
- **Down Conductors As per Perimeter of Structure (t)= 6 No's**
- **Minimum No of Down Conductor is 6 No's**

Results:

- **Lighting Protection is Required**
- **Down Conductors As per Base Area of Structure (s) =6 No's**
- **Down Conductors As per Perimeter of Structure (t)= 6 No's**
- **Minimum No of Down Conductor is 6 No's**

Chapter:23 Calculate Size of Neutral Earthing Transformer

Main Transformer Detail

- Primary Voltage(PVL): 33KV
- Secondary Voltage (SVL): 11 KV
- Frequency(f)=50Hz
- Transformer Capacitance / Phase(c1)=0.006 µ Farad
- Transformer Cable Capacitance / Phase(c2)= 0.0003 µ Farad
- Surge Arrestor Capacitance / Phase(c3)=0.25 µ Farad
- Other Capacitance / Phase(c4)=0 µ Farad

For Neutral Earthing Transformer:

- Primary Voltage of the Grounding Transformer (Vp) =11KV
- Secondary Voltage of the Grounding Transformer (Vs) =240V
- Neutral Earthing Transformer % Reactance (X%)=40%
- % of Force field condition for Neutral Earthing Transformer (ff) =30%
- Neutral Earthing Transformer overloading factor(Of)=2.6
- Neutral Earthing Transformer Base KV (Bv) =240V=0.240KV

Calculation:

- **Phase to Neutral Voltage (Vp1) =SVL /1.732**
- Phase to Neutral Voltage (Vp1) =11 /1.732 = 6.35 KV
- **Phase to Neutral Voltage under Force Field Condition (Vf) =Vp + (Vpxff)**
- Phase to Neutral Voltage under Force Field Condition (Vf)=6.35+ (6.35x30%) =8.26KV
- Total Zero Sequence Capacitance (C)=c1+c2+c3+c4
- Total Zero Sequence Capacitance (C)=0.006+0.0003+0.25+0=0.47730 µ Farad
- Total Zero Sequence Capacitance Reactance to Ground (Xc)=10*6 / (2x3.14xfxC)
- Total Zero Sequence Capacitance Reactance to Ground (Xc)=10*6 / (2x3.14x50x0.47730)=6672.35 Ω/Phase
- **Capacitive charging current/phase (Ic)=Vf / Xc**
- Capacitive charging current/phase (Ic)=8.26x1000 / 6672.35 = 1.24Amp
- **Total Capacitive charging current (It) =3xIc**
- Total Capacitive charging current (It) =3xIc =3x1.24 =3.71Amp
- **Rating of Neutral Earthing Transformer (Pr)=VpxIt**
- Rating of Neutral Earthing Transformer (Pr)=11x3.71=40.83KVA
- **Size of Neutral Earthing Transformer (P)=Pr/ Of**
- **Size of Neutral Earthing Transformer (P)=40.83/ 2.6 = 16KVA**
- **Residual Capacitive reactance (Xct) =Xc/3**
- l Capacitive reactance (Xct) = 6672.35 /3 =2224.12Ω
- Turns Ratio of the Grounding Transformer (N)= Vp/Vs =11000/240 =45.83
- **Required Grounding Resistor value at Secondary side (Rsec)=Xct/NxN**
- Required Grounding Resistor value at Secondary side (Rsec)=2224.12 /45.83x45.83 =1.059 Ω
- Required Grounding Resistor value at primary side (Rp)=Xct
- Grounding Resistor value at primary side (Rp)= 2224.12Ω
- **Neutral Earthing Transformer Secondary Current=P/Vs**
- Neutral Earthing Transformer Secondary Current=16000/230= 65.44Amp
- **Neutral Earthing Transformer Secondary Resistor Current (for 30 Sec)=1.3xItxN**
- Neutral Earthing Transformer Secondary Resistor Current (for 30 Sec)=1.3x3.71x45.83=221.18Amp
- Neutral Earthing Transformer Reactance Base(Base X)=BvxBv/P/1000
- Neutral Earthing Transformer Reactance Base(Base X)=0.24x0.24/11/1000=3.67Ω
- Neutral Earthing Transformer Reactance in PU (Xpu)=X% =40%=0.04Pu
- **Neutral Earthing Transformer Reactance (X)=Xpu x BaseX**
- Neutral Earthing Transformer Reactance (X)=0.04x3.67 =0.15Ω

- **Neutral Earthing Transformer X/R Ratio=X/Rsec**
- Neutral Earthing Transformer X/R Ratio=0.15/1.059 = 0.14
- **Fault current through Neutral (single line to ground fault) (If)=Vp1/Rp**
- Fault current through Neutral (single line to ground fault) (If)=6.35x1000/2224.12 =2.86Amp
- **Short time Rating of Neutral Earthing Transformer=PxOf =16x2.6 =41KVA**

Result:

- **Rating of Neutral Earthing Transformer (P)=40.83/ 2.6 = 16KVA**
- **Short time Rating of Neutral Earthing Transformer=41KVA**
- **Ratio of Neutral Earthing Transformer =11000/240 Volt**
- **Neutral Earthing Transformer Secondary Current=65.44Amp**
- **Required Grounding Resistor value at primary side (Rp)=2224.12Ω**
- **Required Resistance at secondary side (Rsec)= 1.059Ω**
- **Neutral Earthing Transformer Secondary Resistor Current (for 30 Sec) = 221.18Amp**

Chapter: 24 Calculate Number of Earthing Pits

Introduction:

- Number of Earthing Electrode and Earthing Resistance depends on the resistivity of soil and time for fault Current to pass through (1 sec or 3 sec). If we divide the area for earthing required by the area of one earth plate gives the no of Earth pits required.
- There is no general rule to calculate the exact no of earth Pits and Size of Earthing Strip, But discharging of leakage current is certainly dependent on the cross section area of the material so for any equipment **the earth strip size is calculated on the current to be carried by that strip.** First the leakage current to be carried is calculated and then size of the strip is determined.
- For most of the Electrical equipments like Transformer, DG set etc., the General concept is to have 4 no earth pits.2 no's for body earthing With 2 separate strips with the pits shorted and 2 nos for Neutral with 2 separate strips with the pits shorted.
- **The Size of Neutral Earthing Strip should be Capable to carry neutral current of that equipment. The Size of Body Earthing should be capable to carry half of neutral Current.**
- For example for 100kVA transformer, the full load Current is around 140A.The strip connected should be Capable to carry at least 70A (neutral current) which means a Strip of GI 25x3mm should be enough to carry the current And for body a strip of 25x3 will do the needful.
- Normally we consider the strip size that is generally used as Standards. However a strip with lesser size which can carry a current of 35A can be used for body earthing. The reason for using 2 earth pits for each body and neutral and then shorting them is to serve as back up. If one strip gets Corroded and cuts the continuity is broken and the other Leakage current flows through the other run thery by completing the circuit. Similarly for panels the no of pits should be 2 nos. The size can be decided on the main incomer Breaker.
- For example if main incomer to breaker is 400A, then Body earthing for panel can have a strip size of 25x6 mm Which can easily carry 100A.
- Number of earth pits is decided by considering the total Fault current to be dissipated to the ground in case of Fault and the current that can be dissipated by each earth Pit.
- Normally the density of current for GI strip can be roughly 200 amps per square cam. Based on the length and dia of the Pipe used the Number of Earthing Pits can be finalized.

(1) Calculate Numbers of Pipe Earthing:

(A) Earthing Resistance & No of Rod for Isolated Earth Pit (Without Buried Earthing Strip):

- **The Earth Resistance of Single Rod or Pipe electrode is calculated as per BS 7430:**
- **R=ρ/2x3.14xL (loge (8xL/d)-1)**
- Where ρ=Resistivity of Soil (Ω Meter),
- L=Length of Electrode (Meter),
- D=Diameter of Electrode (Meter)
- **Example:** Calculate Isolated Earthing Rod Resistance. The Earthing Rod is 4 Meter Long and having 12.2mm Diameter, Soil Resistivity500 Ω Meter.
- R=500/ (2x3.14x4) x (Loge (8x4/0.0125)-1) =156.19 Ω.
- **The Earth Resistance of Single Rod or Pipe electrode is calculated as per IS 3040:**
- **R=100xρ/2x3.14xL (loge(4xL/d))**
- Where ρ=Resistivity of Soil (Ω Meter),
- L=Length of Electrode (cm),
- D=Diameter of Electrode (cm)
- **Example:**Calculate Number of CI Earthing Pipe of 100mm diameter, 3 Meter length. System has Fault current 50KA for 1 Sec and Soil Resistivity is 72.44 Ω-Meters.
- **Current Density At The Surface of Earth Electrode (As per IS 3043):**
- **Max. Allowable Current Density I = 7.57x1000/(√ρxt) A/m2**
- Max. Allowable Current Density = 7.57x1000/(√72.44X1)=889.419 A/m2
- Surface area of one 100mm dia. 3 meter Pipe= 2 x 3.14 x r x L=2 x 3.14 x 0.05 x3 = 0.942 m2
- **Max. current dissipated by one Earthing Pipe = Current Density x Surface area of electrode**
- Max. current dissipated by one Earthing Pipe = 889.419x 0.942 = 837.83 A say **838 Amps**
- Number of Earthing Pipe required =Fault Current /Max.current dissipated by one Earthing Pipe.

- Number of Earthing Pipe required= 50000/838 =59.66 Say **60 No's.**
- **Total Number of Earthing Pipe required = 60 No's.**
- **Resistance of Earthing Pipe (Isolated) R=100xρ/2x3.14xLx(loge (4XL/d))**
- Resistance of Earthing Pipe (Isolated) R=100x72.44/2x3.14x300x(loge (4X300/10))=7.99 Ω/Pipe
- Overall resistance of 60 No of Earthing Pipe=7.99/60=**0.133 Ω.**

(B) Earthing Resistance & No of Rod for Isolated Earth Pit (With Buried Earthing Strip):

- **Resistance of Earth Strip(R) As per IS 3043=ρ/2x3.14xLx (loge (2xLxL/wt)).**
- **Example:** Calculate GI Strip having width of 12mm , length of 2200 Meter buried in ground at depth of 200mm,Soil Resistivity is 72.44 Ω-Meter
- Resistanceof Earth Strip(Re)=72.44/2x3.14x2200x(loge (2x2200x2200/.2x.012))= **0.050 Ω**
- From above Calculation Overall resistance of 60 No of Earthing Pipe (Rp) = **0.133 Ω.** And it connected to bury Earthing Strip. Here Net Earthing Resistance =(RpxRe)/(Rp+Re)
- Net Earthing Resistance==(0.133x0.05)/(0.133+0.05)= **0.036 Ω**

(C) Total Earthing Resistance & No of Electrode for Group of Electrode (Parallel):

- In cases where a single electrode is not sufficient to provide the desired earth resistance, more than one electrode shall be used. The separation of the electrodes shall be about 4 M.
- The combined resistance of parallel electrodes is a complex function of several factors, such as the number and configuration of electrode the array.
- **The Total Resistance of Group of Electrode in different configurations as per BS 7430:**
- **Ra=R (1+λa/n)** Where a= **ρ/2X3.14XRXS**
- Where S= Distance between adjustment Rod (Meter),
- λ =Factor Given in Table,
- n= Number of Electrode,
- ρ=Resistivity of Soil (Ω Meter),
- R=Resistance of Single Rod in Isolation (Ω)

Factors for parallel electrodes in line (BS 7430)	
Number of electrodes (*n*)	**Factor (λ)**
2	1.0
3	1.66
4	2.15
5	2.54
6	2.87
7	3.15
8	3.39
9	3.61
10	3.8

- For electrodes equally spaced around a hollow square, e.g. around the perimeter of a building, the equations given above are used with a value of λ taken from following Table.
- For three rods placed in an equilateral triangle, or in an L formation, a value of λ = 1.66 may beassumed.

Factors for electrodes in a hollow square(BS 7430)	
Number of electrodes (*n*)	**Factor (λ)**
2	2.71
3	4.51
4	5.48
5	6.13
6	6.63
7	7.03
8	7.36
9	7.65
10	7.9
12	8.3
14	8.6
16	8.9

18	9.2
20	9.4

- For Hollow Square Total Number of Electrode (N) = (4n-1).
- The rule of thumb is that rods in parallel should be spaced at least twice their length to utilize the full benefit of the additional rods.
- If the separation of the electrodes is much larger than their lengths and only a few electrodes are in parallel, then the resultant earth resistance can be calculated using the ordinary equation for resistances in parallel.
- In practice, the effective earth resistance will usually be higher than Calculation. Typically, a 4 spike array may provide an improvement 2.5 to 3 times. An 8 spike array will typically give an improvement of maybe 5 to 6 times.
- The Resistance of Original Earthing Rod will be lowered by Total of 40% for Second Rod, 60% for third Rod,66% for forth Rod
- **Example:** Calculate Total Earthing Rod Resistance of 200 Number arranges in Parallel having 4 Meter Space of each and if it connects in Hollow Square arrangement. The Earthing Rod is 4 Meter Long and having 12.2mm Diameter, Soil Resistivity500 Ω.
- First Calculate Single Earthing Rod Resistance
- R=500/ (2x3.14x4) x (Loge (8x4/0.0125)-1) =136.23 Ω.
- Now Calculate Total Resistance of Earthing Rod of 200 Number in Parallel condition.
- a=500/(2x3.14x136x4)=0.146
- Ra (Parallel in Line) =136.23x (1+10x0.146/200) =**1.67 Ω.**
- If Earthing Rod is connected in Hollow Square than Rod in Each side of Square is 200=(4n-1) so n=49 No.
- Ra (In Hollow Square) =136.23x (1+9.4x0.146/200) =**1.61 Ω.**

(2) Calculate Numbers of Plate Earthing:

- **The Earth Resistance of Single Plate electrode is calculated as per IS 3040:**
- **R=ρ/A√(3.14/A)**
- Where ρ=Resistivity of Soil (Ω Meter),
- A=Area of both side of Plate (m2),
- **Example:**Calculate Number of CI Earthing Plate of 600x600 mm, System has Fault current 65KA for 1 Sec and Soil Resistivity is 100Ω-Meters.
- **Current Density At The Surface of Earth Electrode (As per IS 3043):**
- **Max. Allowable Current Density I = 7.57x1000/(√ρxt) A/m2**
- Max. Allowable Current Density = 7.57x1000/(√100X1)=757 A/m2
- Surface area of both side of single 600x600 mmPlate= 2 x lxw=2 x 0.06x0.06 = 0.72 m2
- **Max. current dissipated by one Earthing Plate = Current Density x Surface area of electrode**
- Max. current dissipated by one Earthing Plate =757x0.72= **545.04Amps**
- **Resistance of Earthing Plate (Isolated)(R)=ρ/A√(3.14/A)**
- Resistance of Earthing Plate (Isolated)(R)=100/0.72x√(3.14/.072)=290.14 Ω
- Number of Earthing Plate required =Fault Current /Max. current dissipated by one Earthing Pipe.
- Number of Earthing Plate required= 65000/545.04 =**119 No's.**
- **Total Number of Earthing Plate required = 119 No's.**
- Overall resistance of 119No of Earthing Plate=290.14/119=**2.438 Ω.**

Calculating Resistance of Bared Earthing Strip / Wire:

1) Calculation for earth resistance of buried Strip/Conductor (As per IEEE):

- The Earth Resistance of Single Strip of Rod buried in ground is
- **R=ρ/Px3.14xL (loge (2xLxL/Wxh)+Q)**
- Where ρ=Resistivity of Soil (Ω Meter),
- h=Depth of Electrode (Meter),
- w=Width of Strip or Diameter of Conductor (Meter)
- L=Length of Strip or Conductor (Meter)
- P and Q are Coefficients

2) Calculation for earth resistance of buried Strip/Conductor (As per IS 3043):

- The Earth Resistance of Single Strip of Rod buried in ground is
- **R=100xρ/2x3.14xL (loge (2xLxL/Wxt))**

- Where ρ=Resistivity of Soil (Ω Meter),
- L=Length of Strip or Conductor (cm)
- w=Width of Strip or Diameter of Conductor (cm)
- t= Depth of burial (cm)
- **Example:** Calculate Earthing Resistance of Earthing strip/wire of 36mm Diameter, 262 meter long buried at 500mm depth in ground, soil Resistivity is 65 Ω Meter.
- Here R = Resistance of earth rod in W.
- r = Resistivity of soil(Ω Meter) = 65 Ω Meter
- l = length of the rod (cm) = 262m = 26200 cm
- d = internal diameter of rod(cm) = 36mm = 3.6cm
- h = Depth of the buried strip/rod (cm)= 500mm = 50cm
- Resistance of Earthing Strip/Conductor (R)=ρ/2x3.14xL (loge (2xLxL/Wt))
- Resistance of Earthing Strip/Conductor (R)=65/2x3.14x26200xln(2x26200x26200/3.6x50)
- Resistance of Earthing Strip/Conductor (R)== **1.7Ω**

Calculate Minimum Cross Section area of Earthing Conductor:

- **Cross Section Area of Earthing Conductor As per IS 3043 (A) =(If x$\sqrt{t}$) / K**
- Where t= Fault current Time (Second).
- K= Material Constant.
- **Example:** Calculate Cross Section Area of GI Earthing Conductor for System has 50KA Fault Current for 1 second. Corrosion will be 1.0 % Per Year and No of Year for Replacement is 20 Years.
- Cross Section Area of Earthing Conductor (A) =(If x$\sqrt{t}$) / K
- Here If=50000 Amp
- T= 1Second
- K=80 (Material Constant, For GI=80, copper K=205, Aluminium K=126).
- Cross Section Area of Earthing Conductor (A) =(50000x1)/80
- Cross Section Area of GI Earthing Conductor (A)=625 Sq.mm
- Allowance for Corrosion = 1.0 % Per Year & Number of Year before replacement say = 20 Years
- Total allowance = 20 x 1.0% =20%
- Safety factor = 1.5
- Required Earthing Conductor size = Cross sectional area x Total allowance x Safety factor
- Required Earthing Conductor size = 1125 Sq.mm say 1200 Sq.mm
- **Hence, Considered 1Nox12x100 mm GI Strip or 2Nox6 x 100 mm GI Strips**

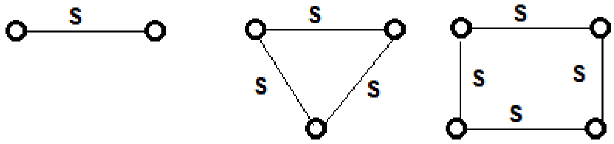
Thumb Rule for Calculation of Earth Resistance & Number of Earthing Rod:

- The approximate earth resistance of the Rod/Pipe electrodes can be calculated by
- **Earth Resistance of the Rod/Pipe electrodes R= K x ρ/L**
- Where ρ = Resistivity of earth in Ohm-Meter
- L= Length of the electrode in Meter.
- d= Diameter of the electrode in Meter.
- K=0.75 if 25< L/d < 100.
- K=1 if 100 < L/d < 600
- K=1.2 o/L if 600 < L/d < 300
- **Number of Electrode if find out by Equation of R(d) =(1.5/N) x R**
- Where R(d) =Desired earth resistance
- R= Resistance of single electrode
- N= No. of electrodes installed in parallel at a distance of 3 to 4 Meter interval.
- **Example:** Calculate Earthing Pipe Resistance and Number of Electrode for getting Earthing Resistance of 1Ω ,Soil Resistivity of ρ=40, Length=2.5Meter, Diameter of Pipe= 38 mm.
- Here L/d = 2.5/0.038=65.78 so K=0.75
- The Earth Resistance of the Pipe electrodes R= K x ρ/L=0.75x65.78=12 Ω
- One electrode the earth resistance is 12 Ω.
- To get Earth resistance of 1 Ωthe total Number of electrodes required =(1.5x12)/1 =18 No

Calculating Resistance & Number of Earthing Rod:

- **Reference:**As per EHV Transmission Line Reference Book page: 290 and Electrical Transmission & Distribution Reference Book Westinghouse Electric Corporation, Section-I Page: 570-590.
- **Earthing Resistance of Single Rods: R = ρx[ln (2L/a)-1]/(2x3.14xL)**

- **Earthing Resistance of Parallel Rods: $R = \rho x[\ln (2L/A]/ (2x3.14xL)$**
- Where L= length of rod in ground Meter,
- a= radius of rod Meter
- ρ = ground resistivity, ohm- Meter
- $A= \sqrt{(axS)}$
- S= Rod separation Meter



Earthing Rod Arrangement

Factor affects on Ground resistance:

- The NEC code requires a minimum ground electrode length of 2.5 meters (8.0 feet) to be in contact with the soil. But, there are some factor that affect the ground resistance of a ground system:
- **Length / Depth of the ground electrode**: double the length, reduce ground resistance by up to 40%.
- **Diameter of the ground electrode**: double the diameter, lower ground resistance by only 10%.
- **Number of ground electrodes**: for increased effectiveness, space additional electrodes at least equal to the depth of the ground electrodes.
- **Ground system design**: single ground rod to ground plate.

The GI Earthing Conductor sizes for various Equipments:

No	Equipments	Earth Strip Size
1	HT switchgear, structures, cable trays & fence, rails, gate and steel column	55 X 6 mm (GI)
2	Lighting Arrestor	25 X 3 mm (Copper)
3	PLC Panel	25 X 3 mm (Copper)
4	DG & Transformer Neutral	50X6 mm (Copper)
5	Transformer Body	50X6 mm (GI)
6	Control & Relay Panel	25 X 6 mm (GI)
7	Lighting Panel & Local Panel	25 X 6 mm (GI)
8	Distribution Board	25 X 6 mm (GI)
9	Motor up to 5.5 kw	4 mm2 (GI)
10	Motor 5.5 kw to 55 kw	25 X 6 mm (GI)
11	Motor 22 kw to 55 kw	40 X 6 mm (GI)
12	Motor Above 55 kw	55 X 6 mm (GI)

Selection of Earthing System:

Installations/ Isc Capacity	IR Value Required	Soil Type/ Resistivity	Earth System
House hold earthing/3kA	8 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Single Electrode
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
Commercial premises, Office / 5kA	2 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
Transformers, substation earthing, LT line equipment/ 15kA	less than 1 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
LA, High current Equipment./ 50kA	less than 1 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
PRS, UTS, RTUs, Data processing centre etc./5KA	less than 0.5 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes

Size of Earthing Conductor:

- Ref IS 3043 &Handbook on BS 7671: The Lee Wiring Regulations by Trevor E. Marks.

Size of Earthing Conductor		
Area of Phase Conductor S (mm2)	Area of Earthing conductor (mm2) When It is Same Material as Phase Conductor	Area of Earthing conductor (mm2) When It is Not Same Material as Phase Conductor
S < 16 mm2	S	SX(k1/k2)
16 mm2<S< 35 mm2	16 mm2	16X(k1/k2)
S > 35 mm2	S/2	SX(k1/2k2)
K1 is value of Phase conductor,k2 is value of earthing conductor		
Value of K for GI=80, Alu=126,Cu=205 for 1 Sec		

Standard Earthing Strip/Plate/Pipe/wire Weight:

GI Earthing Strip:

Size (mm2)	Weight
20 x 3	500 gm Per meter
25 x 3	600 gm Per meter
25 x 6	1/200 Kg Per meter
32 x 6	1/600 Kg Per meter
40 x 6	2 Kg Per meter
50 x 6	2/400 Kg Per meter
65 x 10	5/200 Kg Per meter
75 x 12	7/200 Kg Per meter

GI Earthing Plate:

Plate	Weight
600 x 600 x 3 mm	10 Kg App.
600 x 600 x 4 mm	12 Kg App.
600 x 600 x 5 mm	15 Kg App.
600 x 600 x 6 mm	18 Kg App.
600 x 600 x 12 mm	36 Kg App.
1200 x 1200 x 6 mm	70 Kg App.
1200 x 1200 x 12 mm	140 Kg App.

GI Earthing Pipe:

Pipe	Weight
3 meter Long BISE	5 Kg App.
3 meter r Long BISE	9 Kg App.
4.5 meter (15' Long BISE)	5 Kg App.
4.5 meter (15' Long BISE)	9 Kg App.
4.5 meter (15' Long BISE)	14 Kg App

GI Earthing Wire:

Plate	Weight
6 Swg	5 meter in 1 Kg
8 Swg	9 meter in 1 Kg

Chapter: 25 Calculate Qty of Chemical Earthing Material & Size of Earthing Rod

Calculate Qty of Chemical Earthing and size of Earthing Rod for following specification.

- Earthing Bore Hole (Auger) size is 150MM and Length is 3Meter.
- Chemical Earthing Material is available in Bag of 25Kg.Mixing Ratio of Earthing Compound and Water is 2:1.
- Earthing Rod Material is GI and length is 3 Meter.
- Size of Transformer for Upstream of Electrical Network is 2000KVA,430V,8%Impedance and consider Short Circuit Current is for 0.5Sec.

Calculation:

(A) Calculate Required Chemical Earthing Material

- Volume of Bore Hole = πr^2 x h
- Volume of Bore Hole = 3.14 x $(0.150/2)^2$ x 3.0
- **Volume of Bore Hole = 0.053 m3**
- Chemical Earthing in one Bag=25Kg
- Volume of Chemical Earthing material (Dry) in one Bag = Bag weight in kg x 0.00117 m3
- Volume of Chemical Earthing material (Dry) in one Bag = 25 x 0.00117 m3
- Volume of Chemical Earthing material (Dry) in one Bag = 0.02925 m3
- Mixing Ratio of Earthing Compound and Water is 2:1
- Hence Volume of Chemical Earthing material (Wet) in one Bag =0.02925x2 m3
- **Volume of Chemical Earthing material (Wet) in one Bag =0.0585 m3**
- Required Chemical Earthing material = Volume of Bore Hole x Bag Weight / Volume of Chemical Earthing material (Wet) in one Bag
- Required Chemical Earthing material = 0.053x25 / 0.0585 Kg
- **Required Chemical Earthing material =22.5 Kg**
- Required Chemical Earthing material = Volume of Bore Hole / Volume of Chemical Earthing material (Wet) in one Bag
- Required Chemical Earthing material = 0.053 / 0.0585
- **Required Chemical Earthing material = 0.9 Bag**

(B) Calculate Size of Earthing Rod

- Transformer Full Load Current= Size of Transformer/ 1.732XVolt
- Transformer Full Load Current= 2000x1000 /1.732x430
- Transformer Full Load Current=2685Amp
- Short Circuit Current = Transformer Full Load Current / Transformer Impedance
- Short Circuit Current = 2865 x100 / 8
- Short Circuit Current =33567.86 Amp
- **Short Circuit Current =33.6 KA**
- Earthing Rod Size= √ (Fault currentx2 x Fault Time) / k
- Where K for GI=80, Aluminium= 126, Copper=205
- Earthing Rod Size=√ (33567.86)2 x 0.5 / 80 (Sq.mm)
- Earthing Rod Size=296.70 Sq.mm
- Earthing Rod Size= πd^2 / 4 (mm)
- Diameter of Earthing Rod =√ Earthing Rod Size x 4 / 3.14
- **Diameter of Earthing Rod =19.4mm**
- **Length of Earthing Rod=3 Meter**

Chapter: 26 Calculate Size of Cable for Motor (As NEC)

NEC Code 430.22 (Size of Cable for Single Motor):

- Size of Cable for Branch circuit which has Single Motor connection is **125% of Motor Full Load Current Capacity.**
- **Example:** what is the minimum rating in amperes for Cables supplying 1 No of 5 hp, 415-volt, 3-phase motor at 0.8 Power Factor. Full-load currents for 5 hp = 7Amp.
- **Min Capacity of Cable= (7X125%) =8.75 Amp.**

NEC Code 430.6(A) (Size of Cable for Group of Motors or Elect. Load).

- Cables or Feeder which is supplying more than one motors other load(s), shall have an ampacity not less than 125 % of the full-load current rating of the highest rated motor plus the sum of the full-load current ratings of all the other motors in the group, as determined by 430.6(A).
- For Calculating minimum Ampere Capacity of Main feeder and Cable is **125% of Highest Full Load Current + Sum of Full Load Current of remaining Motors.**
- **Example:** what is the minimum rating in amperes for Cables supplying 1 No of 5 hp, 415-volt, 3-phase motor at 0.8 Power Factor, 1 No of 10 hp, 415-volt, 3-phase motor at 0.8 Power Factor, 1 No of 15 hp, 415-volt, 3-phase motor at 0.8 Power Factor and 1 No of 5hp, 230-volt, single-phase motor at 0.8 Power Factor?
- Full-load currents for 5 hp = 7Amp.
- Full-load currents for 10 hp = 13Amp.
- Full-load currents for 15 hp = 19Amp.
- Full-load currents for 10 hp (1 Ph) = 21Amp.
- Here Capacity wise Large Motor is 15 Hp but Highest Full Load current is 21Amp of 5hp Single Phase Motor so 125% of Highest Full Load current is 21X125%=26.25Amp
- **Min Capacity of Cable= (26.25+7+13+19) =65.25 Amp.**

NEC Code 430.24 (Size of Cable for Group of Motors or Electrical Load).

- As specified in 430.24, conductors supplying two or more motors must have an ampacity not less than 125 % of the full-load current rating of the highest rated motor + the sum of the full-load current ratings of all the other motors in the group or on the same phase.
- It may not be necessary to include all the motors into the calculation. It is permissible to balance the motors as evenly as possible between phases before performing motor-load calculations.
- **Example:**what is the minimum rating in amperes for conductors supplying 1No of 10 hp, 415-volt, 3-phase motor at 0.8 P.F and 3 No of 3 hp, 230-volt, single-phase motors at 0.8 P.F.
- The full-load current for a 10 hp, 415-volt, 3-phase motor is **13** amperes.
- The Full-load current for single-phase 3 hp motors is **12 amperes.**
- Here for Load Balancing one Single Phase Motor is connected on R Phase Second in B Phase and third is in Y Phase.Because the motors are balanced between phases, the full-load current on each phase is 25 amperes (13 + 12 = 25).
- Here multiply 13 amperes by 125 %=(13 × 125% = 16.25 Amp). Add to this value the full-load currents of the other motor on the same phase (16.25 + 12 = **28.25 Amp**).
- The minimum rating in amperes for conductors supplying these motors is 28 amperes.

NEC 430/32 Size of Overload Protection for Motor:

- Overload protection (Heater or Thermal cut out protection) would be a device that thermally protects a given motor from damage due to heat when loaded too heavy with work.
- All continuous duty motors rated more than 1HP must have some type of an approved overload device.
- An overload shall be installed on each conductor that controls the running of the motor rated more than one horsepower. NEC 430/37 plus the grounded leg of a three phase grounded system must contain an overload also. This Grounded leg of a three phase system is the only time you may install an overload or over – current device on a grounded conductor that is supplying a motor.
- To Find the motor running overload protection size that is required, you must multiply the F.L.C. (full load current) with the minimum or the maximum percentage ratings as follows;

Maximum Overload

- Maximum overload = F.L.C. (full load current of a motor) X allowable % of the maximum setting of an overload,
- 130% for motors, found in NEC Article 430/34.
- Increase of 5% allowed if the marked temperature rise is not over 40 degrees or the marked service factor is not less than 1.15.

Minimum Overload

- Minimum Overload = F.L.C. (full load current of a motor) X allowable % of the minimum setting of an overload,115% for motors found in NEC Article 430/32/B/1.
- Increase of 10% allowed to 125% if the marked temperature rise is not over 40 degrees or the marked service factor is not less than 1.15

Chapter: 27 Calculate Size of Contactor / Fuse / CB / OL Relay of DOL Starter

- Calculate Size of each Part of DOL starter for The System Voltage 415V ,5HP Three Phase House hold Application Induction Motor, Code A, Motor efficiency 80%,Motor RPM 750 ,Power Factor 0.8 , Overload Relay of Starter is Put before Motor.

Basic Calculation of Motor Torque & Current:

- **Motor Rated Torque (Full Load Torque) =5252xHPxRPM**
- Motor Rated Torque (Full Load Torque)=5252x5x750=35 lb-ft.
- **Motor Rated Torque (Full Load Torque) =9500xKWxRPM**
- Motor Rated Torque (Full Load Torque)=9500x(5x0.746)x750 =47 Nm
- If Motor Capacity is less than 30 KW than Motor Starting Torque is 3xMotor Full Load Current or 2X Motor Full Load Current.
- **Motor Starting Torque=3xMotor Full Load Current.**
- Motor Starting Torque==3x47=142Nm.
- **Motor Lock Rotor Current =1000xHPx figure from below Chart/1.732x415**

Locked Rotor Current		
Code	**Min**	**Max**
A	1	3.14
B	3.15	3.54
C	3.55	3.99
D	4	4.49
E	4.5	4.99
F	5	2.59
G	2.6	6.29
H	6.3	7.09
I	7.1	7.99
K	8	8.99
L	9	9.99
M	10	11.19
N	11.2	12.49
P	12.5	13.99
R	14	15.99
S	16	17.99
T	18	19.99
U	20	22.39
V	22.4	

- As per above chart Minimum Locked Rotor Current =1000x5x1/1.732x415=7 Amp
- Maximum Locked Rotor Current =1000x5x3.14/1.732x415=22 Amp.
- **Motor Full Load Current (Line) =KWx1000/1.732x415**
- Motor Full Load Current (Line) = (5x0.746)x1000/1.732x415=6 Amp.
- **Motor Full Load Current (Phase)=Motor Full Load Current (Line)/1.732**
- Motor Full Load Current (Phase)==6/1.732=4Amp
- **Motor Starting Current =6 to 7xFull Load Current.**
- Motor Starting Current (Line)=7x6=45 Amp

(1) Size of Fuse:

Fuse as per NEC 430-52		
Type of Motor	**Time Delay Fuse**	**Non-Time Delay Fuse**
Single Phase	300%	175%
3 Phase	300%	175%
Synchronous	300%	175%
Wound Rotor	150%	150%
Direct Current	150%	150%

- **Maximum Size of Time Delay Fuse =300% x Full Load Line Current.**
- Maximum Size of Time Delay Fuse =300%x6= 19 Amp.
- **Maximum Size of Non Time Delay Fuse =1.75% x Full Load Line Current.**
- Maximum Size of Non Time Delay Fuse=1.75%6=11 Amp.

(2) Size of Circuit Breaker:

Circuit Breaker as per NEC 430-52

Type of Motor	Instantaneous Trip	Inverse Time
Single Phase	800%	250%
3 Phase	800%	250%
Synchronous	800%	250%
Wound Rotor	800%	150%
Direct Current	200%	150%

- **Maximum Size of Instantaneous Trip Circuit Breaker =800% x Full Load Line Current.**
- Maximum Size of Instantaneous Trip Circuit Breaker =800%x6= 52 Amp.
- **Maximum Size of Inverse Trip Circuit Breaker =250% x Full Load Line Current.**
- Maximum Size of Inverse Trip Circuit Breaker =250%x6= 16 Amp.

(3) Thermal over Load Relay:

- **Thermal over Load Relay (Phase):**
- **Min Thermal Over Load Relay setting =70%xFull Load Current(Phase)**
- Min Thermal Over Load Relay setting =70%x4= 3 Amp
- **Max Thermal Over Load Relay setting =120%xFull Load Current(Phase)**
- Max Thermal Over Load Relay setting =120%x4= 4 Amp
- **Thermal over Load Relay (Phase):**
- **Thermal over Load Relay setting =100%xFull Load Current (Line).**
- Thermal over Load Relay setting =100%x6= 6 Amp

(4) Size and Type of Contactor:

Application	Contactor	Making Cap
Non-Inductive or Slightly Inductive ,Resistive Load	AC1	1.5
Slip Ring Motor	AC2	4
Squirrel Cage Motor	AC3	10
Rapid Start / Stop	AC4	12
Switching of Electrical Discharge Lamp	AC5a	3
Switching of Electrical Incandescent Lamp	AC5b	1.5
Switching of Transformer	AC6a	12
Switching of Capacitor Bank	AC6b	12
Slightly Inductive Load in Household or same type load	AC7a	1.5
Motor Load in Household Application	AC7b	8
Hermetic refrigerant Compressor Motor with Manual O/L Reset	AC8a	6
Hermetic refrigerant Compressor Motor with Auto O/L Reset	AC8b	6
Control of Restive & Solid State Load with upto coupler Isolation	AC12	6
Control of Restive Load and Solid State with T/C Isolation	AC13	10
Control of Small Electro Magnetic Load (<72VA)	AC14	6
Control of Small Electro Magnetic Load (>72VA)	AC15	10

- As per above Chart
- **Type of Contactor= AC7b**
- **Size of Main Contactor = 100%X Full Load Current (Line).**
- Size of Main Contactor =100%x6 = 6 Amp.
- **Making/Breaking Capacity of Contactor= Value above Chart x Full Load Current (Line).**
- Making/Breaking Capacity of Contactor=8x6= 52 Amp.

Chapter: 28 Calculate Size of Contactor / Fuse / CB / OL Relay of Star-Delta Starter

- Calculate Size of each Part of Star-Delta starter for 10HP, 415 Volt Three Phase Induction Motor having Non Inductive Type Load, Code A, Motor efficiency 80%, Motor RPM 600, Power Factor 0.8. Also Calculate Size of Overload Relay if O/L Relay Put in the windings (overload is placed after the Winding Split into main and delta Contactor) or in the line (Putting the overload before the motor same as in DOL).

Basic Calculation of Motor Torque & Current:

- **Motor Rated Torque (Full Load Torque) =5252xHPxRPM**
- Motor Rated Torque (Full Load Torque)=5252x10x600=88 lb-ft.
- **Motor Rated Torque (Full Load Torque) =9500xKWxRPM**
- Motor Rated Torque (Full Load Torque)=9500x(10x0.746)x600 =119 Nm
- If Motor Capacity is less than 30 KW than Motor Starting Torque is 3xMotor Full Load Current or 2X Motor Full Load Current.
- **Motor Starting Torque=3x Motor Rated Torque (Full Load Torque).**
- Motor Starting Torque==3x119=356 Nm.
- **Motor Lock Rotor Current =1000xHPx figure from below Chart/1.732x415**

Locked Rotor Current		
Code	**Min**	**Max**
A	1	3.14
B	3.15	3.54
C	3.55	3.99
D	4	4.49
E	4.5	4.99
F	5	2.59
G	2.6	6.29
H	6.3	7.09
I	7.1	7.99
K	8	8.99
L	9	9.99
M	10	11.19
N	11.2	12.49
P	12.5	13.99
R	14	15.99
S	16	17.99
T	18	19.99
U	20	22.39
V	22.4	

- As per above chart Minimum Locked Rotor Current =1000x10x1/1.732x415=14 Amp
- Maximum Locked Rotor Current =1000x10x3.14/1.732x415=44 Amp.
- **Motor Full Load Current (Line) =KWx1000/1.732x415**
- Motor Full Load Current (Line) = (10x0.746)x1000/1.732x415=13 Amp.
- **Motor Full Load Current (Phase) =Motor Full Load Current (Line)/1.732.**
- Motor Full Load Current (Phase) ==13/1.732=7 Amp.
- **Motor Starting Current (Star-Delta Starter) =3xFull Load Current.**
- Motor Starting Current (Line)=3x13=39 Amp

(1) Size of Fuse:

Fuse as per NEC 430-52		
Type of Motor	**Time Delay Fuse**	**Non-Time Delay Fuse**
Single Phase	300%	175%
3 Phase	300%	175%
Synchronous	300%	175%

Wound Rotor	150%	150%
Direct Current	150%	150%

- **Maximum Size of Time Delay Fuse =300% x Full Load Line Current.**
- Maximum Size of Time Delay Fuse =300%x13= 39 Amp.
- **Maximum Size of Non Time Delay Fuse =1.75% x Full Load Line Current.**
- Maximum Size of Non Time Delay Fuse=1.75%13=23 Amp.

(2) Size of Circuit Breaker:

Circuit Breaker as per NEC 430-52		
Type of Motor	**Instantaneous Trip**	**Inverse Time**
Single Phase	800%	250%
3 Phase	800%	250%
Synchronous	800%	250%
Wound Rotor	800%	150%
Direct Current	200%	150%

- **Maximum Size of Instantaneous Trip Circuit Breaker =800% x Full Load Line Current.**
- Maximum Size of Instantaneous Trip Circuit Breaker =800%x13= 104 Amp.
- **Maximum Size of Inverse Trip Circuit Breaker =250% x Full Load Line Current.**
- Maximum Size of Inverse Trip Circuit Breaker =250%x13= 32 Amp.

(3) Thermal over Load Relay:

Thermal over Load Relay (Phase):

- **Min Thermal Over Load Relay setting =70%xFull Load Current(Phase)**
- Min Thermal Over Load Relay setting =70%x7= 5 Amp
- **Max Thermal Over Load Relay setting =120%xFull Load Current(Phase)**
- Max Thermal Over Load Relay setting =120%x7= 9 Amp

Thermal over Load Relay (Line):

- For a star-delta starter we have the possibility to place the overload protection in two positions, in the line or in the windings.
- **If O/L Relay Placed in Line:** (Putting the O/L before the motor same as in DOL).Supply>Over Load Relay>Main Contactor
- If Over Load Relay supply the entire motor circuit and are located ahead of where the power splits to the Delta and Star contactors, so O/L Relay size must be based upon the entire motor Full Load Current.
- **Thermal over Load Relay setting =100%xFull Load Current (Line).**
- Thermal over Load Relay setting =100%x13= 13 Amp
- Disadvantage: O/L Relay will not give Protection while Motor runs in Delta (Relay Setting is too High for Delta Winding)
- **If O/L Relay Placed In the windings:** (overload is placed after the Winding Split into main and delta Contactor).Supply>Main Contactor-Delta Contactor>O/L Relay
- If overload is placed after the Point where the wiring Split into main and delta Contactor, Size of over load relay at 58% (1/1.732) of the motor Full Load Current because we use 6 leads going to the motor, and only 58% of the current goes through the main set of conductors (connected to the main contactor).
- The overload then always measures the current inside the windings, and is thus always correct. The setting must be x0.58 FLC (line current).
- **Thermal over Load Relay setting =58%xFull Load Current (Line).**
- Thermal over Load Relay setting =58%x13= 8 Amp.
- Disadvantage: We must use separate short-circuit and overload protections

(4) Size and Type of Contactor:

- **Main and Delta Contactor:**
- The Main and Delta contactors are smaller compared to single contactor used in a Direct on Line starter because they Main and Delta contactors in star delta starter are controlling winding currents only. **The currents through the winding are 1/√3 (58%) of the current in the line.** These two contactors (Main contactor and Delta Contactor) are close during run. These rated at 58% of the current rating of the motor.
- **Star Contactor:**

- The third contactor is the star contactor and that only carries star current while the motor is connected in star in starting. The current in star winding is 1/√3= (58%) of the current in delta, so this contactor can be rated at 1/3 (33%) of the motor rating. Star contactor can be selected smaller than the others, providing the star contactor pulls first before the main contactor. Then no current flows when third contactor pulls.
- In star connection at start, the motor draws and delivers 1/3 of its full rated power.
- When the starter switches over to Delta, the motor draws full power, but since the contactors and the overload relay are usually wired within the Delta, you need to use contcators and relay which are only rated 1/√3 =58% of the full rated power of the motor.

Application	Contactor	Making Cap
Non-Inductive or Slightly Inductive ,Resistive Load	AC1	1.5
Slip Ring Motor	AC2	4
Squirrel Cage Motor	AC3	10
Rapid Start / Stop	AC4	12
Switching of Electrical Discharge Lamp	AC5a	3
Switching of Electrical Incandescent Lamp	AC5b	1.5
Switching of Transformer	AC6a	12
Switching of Capacitor Bank	AC6b	12
Slightly Inductive Load in Household or same type load	AC7a	1.5
Motor Load in Household Application	AC7b	8
Hermetic refrigerant Compressor Motor with Manual O/L Reset	AC8a	6
Hermetic refrigerant Compressor Motor with Auto O/L Reset	AC8b	6
Control of Restive & Solid State Load with opto coupler Isolation	AC12	6
Control of Restive Load and Solid State with T/C Isolation	AC13	10
Control of Small Electro Magnetic Load (<72VA)	AC14	6
Control of Small Electro Magnetic Load (>72VA)	AC15	10

As per above Chart

- **Type of Contactor= AC1**
- **Making/Breaking Capacity of Contactor= Value above Chart x Full Load Current (Line).**
- Making/Breaking Capacity of Contactor=1.5x13= 19 Amp.
- **Size of Star Contactor (Starting Condition) = 33%X Full Load Current (Line).**
- Size of Star Contactor =33%x13 = 4 Amp.
- **Size of Main Contactor (Starting-Transition-Running) = 58%X Full Load Current (Line).**
- Size of Main Contactor =58%x13 = 8 Amp.
- **Size of Delta Contactor (Running Condition) = 58%X Full Load Current (Line).**
- Size of Delta Contactor =58%x13 = 8 Amp.

Summary:

- **Type of Contactor= AC1**
- **Making/Breaking Capacity of Contactor=19 Amp.**
- **Size of Star Contactor =4 Amp.**
- **Size of Main Contactor = 8 Amp.**
- **Size of Delta Contactor =8 Amp.**

Chapter: 29 Calculate IDMT Over Current Relay Setting (50/51)

- Calculate setting of IDMT over Current Relay for following Feeder and CT Detail
- **Feeder Detail**: Feeder Load Current 384 Amp, Feeder Fault current Min11KA and Max 22KA.
- **CT Detail:** CT installed on feeder is 600/1 Amp. Relay Error 7.5%, CT Error 10.0%, CT over shoot 0.05 Sec, CT interrupting Time is 0.17 Sec and Safety is 0.33 Sec.
- **IDMT Relay Detail:**
- **IDMT Relay Low Current setting:** Over Load Current setting is 125%, Plug setting of Relay is 0.8 Amp and Time Delay (TMS) is 0.125 Sec, Relay Curve is selected as Normal Inverse Type.
- **IDMT Relay High Current setting :**Plug setting of Relay is 2.5 Amp and Time Delay (TMS) is 0.100 Sec, Relay Curve is selected as Normal Inverse Type

Calculation of Over Current Relay Setting:

(1) Low over Current Setting: (I>)

- **Over Load Current (In) = Feeder Load Current X Relay setting = 384 X 125% =480 Amp**
- **Required Over Load Relay Plug Setting= Over Load Current (In) / CT Primary Current**
- Required Over Load Relay Plug Setting = 480 / 600= 0.8
- **Pick up Setting of Over Current Relay (PMS) (I>)= CT Secondary Current X Relay Plug Setting**
- Pick up Setting of Over Current Relay (PMS) (I>)= 1 X 0.8 = 0.8 Amp
- **Plug Setting Multiplier (PSM) = Min. Feeder Fault Current / (PMS X (CT Pri. Current / CT Sec. Current))**
- Plug Setting Multiplier (PSM) = 11000 / (0.8 X (600 / 1)) = 22.92
- Operation Time of Relay as per it's Curve
- Operating Time of Relay for Very Inverse Curve (t) =13.5 / ((PSM)-1).
- Operating Time of Relay for Extreme Inverse Curve (t) =80/ ((PSM)2 -1).
- Operating Time of Relay for Long Time Inverse Curve (t) =120 / ((PSM) -1).
- Operating Time of Relay for Normal Inverse Curve (t) =0.14 / ((PSM) 0.02 -1).
- Operating Time of Relay for Normal Inverse Curve (t)=0.14 / ((22.92)0.02-1) = 2.17 Amp
- Here Time Delay of Relay (TMS) is 0.125 Sec so
- **Actual operating Time of Relay (t>) = Operating Time of Relay X TMS =2.17 X 0.125 =0.271 Sec**
- **Grading Time of Relay = [((2XRelay Error)+CT Error)XTMS]+ Over shoot+ CB Interrupting Time+ Safety**
- Total Grading Time of Relay=[((2X7.5)+10)X0.125]+0.05+0.17+0.33 = 0.58 Sec
- **Operating Time of Previous upstream Relay = Actual operating Time of Relay+ Total Grading Time** Operating Time of Previous up Stream Relay = 0.271 + 0.58 = 0.85 Sec

(2) High over Current Setting: (I>>)

- **Pick up Setting of Over Current Relay (PMS) (I>>)= CT Secondary Current X Relay Plug Setting**
- Pick up Setting of Over Current Relay (PMS) (I>)= 1 X 2.5 = 2.5 Amp
- **Plug Setting Multiplier (PSM) = Min. Feeder Fault Current / (PMS X (CT Pri. Current / CT Sec. Current))**
- Plug Setting Multiplier (PSM) = 11000 / (2.5 X (600 / 1)) = 7.33
- Operation Time of Relay as per it's Curve
- Operating Time of Relay for Very Inverse Curve (t) =13.5 / ((PSM)-1).
- Operating Time of Relay for Extreme Inverse Curve (t) =80/ ((PSM)2 -1).
- Operating Time of Relay for Long Time Inverse Curve (t) =120 / ((PSM) -1).
- Operating Time of Relay for Normal Inverse Curve (t) =0.14 / ((PSM) 0.02 -1).
- **Operating Time of Relay for Normal Inverse Curve (t)=0.14 / ((7.33)0.02-1) = 3.44 Amp**
- Here Time Delay of Relay (TMS) is 0.100 Sec so
- **Actual operating Time of Relay (t>) = Operating Time of Relay X TMS =3.44 X 0.100 =0.34 Sec**
- **Grading Time of Relay = [((2XRelay Error)+CT Error)XTMS]+ Over shoot+ CB Interrupting Time+ Safety**
- Total Grading Time of Relay=[((2X7.5)+10)X0.100]+0.05+0.17+0.33 = 0.58 Sec
- **Operating Time of Previous upstream Relay = Actual operating Time of Relay+ Total Grading Time.**
- Operating Time of Previous up Stream Relay = 0.34 + 0.58 = 0.85 Sec

Conclusion of Calculation:

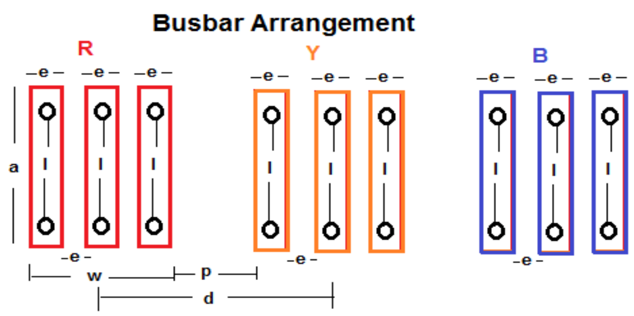
- Pickup Setting of over current Relay (PMS)(I>) should be satisfied following Two Condition.
- **(1)** Pickup Setting of over current Relay (PMS)(I>)>= Over Load Current (In) / CT Primary Current
- **(2)** TMS <= Minimum Fault Current / CT Primary Current

- For Condition (1) 0.8 > =(480/600) = 0.8 >= 0.8, Which found **OK**
- For Condition (2) 0.125 <= 11000/600 = 0.125 <= 18.33, Which found **OK**
- **Here Condition (1) and (2) are satisfied so**
- **Pickup Setting of Over Current Relay = OK**
- **Low Over Current Relay Setting: (I>) = 0.8A XIn Amp**
- **Actual operating Time of Relay (t>) = 0.271 Sec**
- **High Over Current Relay Setting: (I>>) = 2.5A XIn Amp**
- **Actual operating Time of Relay (t>>) = 0.34 Sec**

Chapter: 30 Calculate Bus bar Size for Panel

Example: Calculate Size of Bus bar having Following Details

- **Bus bar Current Details:**
- Rated Voltage = 415V,50Hz ,
- Desire Maximum Current Rating of Bus bar =630Amp.
- Fault Current (Isc)= 50KA ,Fault Duration (t) =1sec.
- **Bus bar Temperature details:**
- Operating Temperature of Bus bar (θ)=85°C.
- Final Temperature of Bus bar during Fault(θ1)=185°C.
- Temperature rise of Bus Bar Bar during Fault (θt=θ1-θ)=100°C.
- Ambient Temperature (θn) =50°C ., Maximum Bus Bar Temperature Rise=55°C.
- **Enclosure Details:**
- Installation of Panel=Indoors (well Ventilated)
- Altitude of Panel Installation on Site= 2000 Meter
- Panel Length= 1200 mm , Panel width= 600 mm,Panel Height= 2400 mm
- **Bus bar Details:**
- Bus bar Material= Copper
- Bus bar Strip Arrangements=Vertical
- Current Density of Bus Bar Material=1.6
- Temperature Co efficient of Material Resistance at 20°c(α20)=0.00403
- Material Constant(K)=1.166
- Bus bar Material Permissible Strength=1200 kg/cm2
- Bus bar Insulating Material=Bare
- Bus bar Position=Edge-mounted bars
- Bus bar Installation Media=Non-ventilated ducting
- Bus bar Artificial Ventilation Scheme=without artificial ventilation
- **Bus bar Size Details:**
- Busbar Width(e)= 75 mm
- Busbar Thickness(s)= 10 mm
- Number of Bus Bar per Phase(n)= 2 No
- Busbar Length per Phase(a)= 500 mm
- Distance between Two Bus Strip per Phase(e)= 75 mm
- Busbar Phase Spacing (p)= 400 mm
- Total No of Circuit= 3 No.
- **Busbar Support Insulator Detail:**
- Distance between insulators on Same Phase(l)= 500 mm
- Insulator Height (H)= 100 mm
- Distance from the head of the insulator to the busbar centreof gravity (h)= 5 mm
- Permissible Strength of Insulator (F')=1000 Kg/cm2



Calculation:

1) De rating Factor for Bus bar:

- **(1) Per Phase Bus Strip De rating Factor (K1):**

- Bus bar Width(e) is 75mm and Bus bar Length per Phase(a) is 500mm so e/a is 75/500=0.15
- No of Bus bar per phase is 2 No's.
- From following table value of de rating factor is 1.83

Number of Bus Bar Strip per Phase (K1)			
e/a	No of Bus Bar per Phase		
	1	2	3
0.05	1	1.63	2.4
0.06	1	1.73	2.45
0.08	1	1.76	2.5
0.1	1	1.8	2.55
0.12	1	1.83	2.6
0.14	1	1.85	2.63
0.16	1	1.87	2.65
0.18	1	1.89	2.68
0.2	1	1.91	2.7

- **(2) Busbar Insulating Material Derating Factor (K2)**
- Bus bar having No insulating material. It is Bare so following Table
- De rating Factor is 1.

Bus Bar Insulating Material (K2):	Derating Factor
Bare	1
PVC Sleeving	1.2
Painted	1.5

- **(3) Busbar Position Derating Factor (K3)**
- Bus bar Position is Edge-mounted bars so following Table
- De rating Factor is 1

Bus Bar Position(K3):	Derating Factor
Edge-mounted bars	1
1 bar base-mounted	0.95
several base-mounted bars	0.75

- **(4) Busbar Installation Media Derating Factor (K4)**
- Bus bar Installation Media is Non-ventilated ducting so following Table
- De rating Factor is 0.8

Bus Bar Installation Media(K4):	Derating Factor
Calm indoor atmosphere	1
Calm outdoor atmosphere	1.2
Non-ventilated ducting	0.8

- **(5) Bus bar Artificial Ventilation De rating Factor (K5)**
- Bus bar Installation Media is Non-ventilated ductingso following Table
- De rating Factor is 0.9

Bus Bar Artificial Ventilation Scheme (K5):	Derating Factor
without artificial ventilation	0.9
with artificial ventilation	1

- **(6) Enclosure & Ventilation De rating Factor (K6)**
- Bus bar Area per Phase = Bus width X Bus Thickness X Length of Bus X No of Bus bar per Phase
- Bus bar Area per Phase = 75x10xX500X2= 750000mm
- Total Bus bar Area for Enclosure= No of Circuit X(No of Phase + Neutral)XBus bar Area per Phase
- Here we used Size of Neutral Bus is equal to Size of Phase Bus
- Total Bus bar Area for Enclosure=3X(3+1)X750000mm
- Total Bus bar Area for Enclosure=9000000 Sq.mm
- Total Enclosure Area= width X Height X Length
- Total Enclosure Area=1200x600x2400=1728000000 Sq.mm
- Total Bus bar Area for Enclosure/ Total Enclosure Area =9000000/1728000000
- Total Bus bar Area for Enclosure/ Total Enclosure Area=0.53%

- Bus bar Artificial Ventilation Scheme iswithout artificial ventilation so following Table
- De rating Factor is 0.95

Volume of Enclosure & Ventilation Derating Factor (K6)			
cross Section area of Busbar/Total Bus Bar Area	Indoors (Panel is well Ventilated)	Indoors (Panel is Poorly Ventilated)	Outdoor
0%	0.95	0.85	0.65
1%	0.95	0.85	0.65
5%	0.9	0.7	0.6
10%	0.85	0.65	0.5

- **(7) Proxy Effect De rating Factor (K7)**
- Bus bar Phase Spacing (p) is 400mm.
- Bus bar Width (e) is 75mm and Space between each bus of Phase is 75mm so
- Total Bus length of Phase with spacing (w) =75+75+75+75+75=225mm
- Bus bar Phase Spacing (p) / Total Bus length of Phase with spacing (w) = 400 / 225 =2
- From following Table De rating factor is 0.82

Proxy Effect (K7):	Derating Factor
1	0.82
2	0.82
3	0.82
4	0.89
5	0.95
6	0.99
7	1

- **(8) Altitude of Bus Bar installation De rating Factor (K8)**
- Altitude of Panel Installation on Site is 2000 meter so following Table
- De rating Factor is 0.88

Altitude of installation site (Meter) (K8)	Derating Factor
2200	0.88
2400	0.87
2500	0.86
2700	0.85
2900	0.84
3000	0.83
3300	0.82
3500	0.81
4000	0.78
4500	0.76
5000	0.74

- Total De rating Factor= K1XK2XK3Xk4Xk5Xk6Xk7Xk8
- Total De rating Factor =1.83x1x1x0.8x0.9x0.95x0.82x0.88
- Total De rating Factor =0.90

2) Bus bar Size Calculation:

- Desire Current Rating of Busbar (I2) =630 Amp
- Current Rating of Busbar after Derating Factor (I1)= I2 X De rating Factor or I2 /De rating Factor
- Current Rating of Busbar after Derating Factor (I1)=630x0.9
- **Current Rating of Bus bar after De rating Factor (I1)=697Amp**
- Busbar Cross Section Area as per Current= Current Rating of Bus bar / Current Density of Material
- Busbar Cross Section Area as per Current= 697 / 1.6
- **Bus bar Cross Section Area as per Current= 436 Sq.mm**
- Busbar Cross Section Area as per Short Circuit= Isc X√ ((K/(θtx100)x(1+α20xθ) xt
- Busbar Cross Section Area as per Short Circuit=50000X√ ((1.166/(100x100)x(1+0.00403x85) x1
- **Bus bar Cross Section Area as per Short Circuit=626 Sq.mm**
- **Select Higher Size for Bus bar Cross section area between 436 Sq.mm and 626 Sq.mm**

- **Final Calculated Bus Bar Cross Section Area =626 Sq.mm**
- Actual Selected Bus bar size is 75x10=750 Sq.mm
- We have select 2 No's of Bus bar per Phase hence.
- Actual Bus bar cross section Area per Phase =750x2= 1500 Sq.mm
- **Actual Cross Section Area of Bus bar =1500 Sq.mm**
- **Actual Bus bar Size is Less than calculated Bus bar size.**

3) Forces generated on Bus Bar due to Short Circuit Current

- Peak electro-magnetic forces between phase conductors (F1) = 2X(l/d)X(2.5xIsc)2/100000000
- Total width of Bus bar per Phase(w)=75+75+75=225mm =2.25cm
- Bus bar Phase to Phase Distance (d)=400+225=625mm=6.25cm
- Peak electro-magnetic forces between phase conductors (F1) =2x(50/63)x(2.5x50000)2/100000000
- Peak electro-magnetic forces between phase conductors (F1)=250 Kg /cm2
- Peak electro-magnetic forces between phase conductors (F1)=2.5 Kg /mm2
- Actual Forces at the head of the Supports or Bus Bar (F)=F1X(H+h/H)
- Actual Forces at the head of the Supports or Bus Bar (F)=2.5x(100+5/100)
- **Actual Forces at the head of the Supports or Bus Bar (F)= 3 Kg /mm2**
- **Permissible Strength of Insulator (F') is 10 Kg/mm2**
- **Actual Forces at the head of the Supports or Bus Bar is less than Permissible Strength**
- **Forces on Insulation is in within Limits**

4) Mechanical strength of the busbars

- Mechanical strength of the busbars=(F1X i /12)x(1/ Modulus of inertia of a busbar)

Value of Modulus of inertia of a busbar or of a set of busbars (i/v)		
No of Bus Strip per Phase	**Vertical Bus Bar (cm3)**	**Horizontal Bus Bar (cm3)**
1	1.66	16.66
2	14.45	33.33
3	33	50

- From above table Value of Modulus of inertia of a busbar=14.45
- Mechanical strength of the bus bars=(250x50/12)X(1/14.45)
- Mechanical strength of the bus bars= 72 Kg/cm2
- **Mechanical strength of the bus bars= 0.72 Kg/mm2**
- **Permissible Bus bar Strength is 12 Kg/mm2**
- **Actual Mechanical Strength is less than Permissible Strength**
- **Mechanical strength of Bus bar is in within Limit**

5) Temperature Rise Calculation

- **Specified Maximum Temperature Rise (T1) is 35°c**
- Calculated Maximum Temperature Rise (T2)=T/(log(I1/I2)1.64)
- Calculated Maximum Temperature Rise (T2)=35/(Log(697/630)1.64)
- **Calculated Maximum Temperature Rise (T2)= 30°c**
- **Calculated Bus bar Temperature rise is less than Specified Max Temperature rise**
- **Temperature Rise is in within Limit**

Results:

- **Size of Bus bar = 2No's 75x10mm per Phase.**
- **Total No of Feeder =3 No's**
- **Total No's of Bus bar = 6 No's 75x10mm for Phase and 1No's 75x10mm for Neutral.**
- **Forces at the head of the Supports or Bus Bar (F)= 3kg/mm2**
- **Mechanical strength of the bus bars= 0.7 Kg/mm2**
- **Maximum Temperature Rise=30°c**

Chapter: 31 Calculate Size of Solar Panels

Calculate Size of Solar Panel, No of Solar Panel and Size of Inverter for following Electrical Load

Electrical Load Detail:

- 1 No's of 100W Computer use for 8 Hours/Day
- 2 No's of 60W Fan use for 8 Hours/Day
- 1 No's of 100W CFL Light use for 8 Hours/Day

Solar System Detail:

- Solar System Voltage (As per Battery Bank) = 48V DC
- Loose Wiring Connection Factor = 20%
- Daily Sunshine Hour in Summer = 6 Hours/Day
- Daily Sunshine Hour in Winter = 4.5 Hours/Day
- Daily Sunshine Hour in Monsoon = 4 Hours/Day

Inverter Detail:

- Future Load Expansion Factor = 10%
- Inverter Efficiency = 80%
- Inverter Power Factor =0.8

Calculation:

Step-1: Calculate Electrical Usages per Day

- Power Consumption for Computer = No x Watt x Use Hours/Day
- Power Consumption for Computer = 1x100x8 =**800-Watt Hr/Day**
- Power Consumption for Fan = No x Watt x Use Hours/Day
- Power Consumption for Fan = 2x60x8 = **960-Watt Hr/Day**
- Power Consumption for CFL Light = No x Watt x Use Hours/Day
- Power Consumption for CFL Light = 1x100x8 = **800-Watt Hr/Day**
- Total Electrical Load = 800+960+800 =**2560**-Watt **Hr/Day**

Step-2: Calculate Solar Panel Size

- Average Sunshine Hours = Daily Sunshine Hour in Summer+ Winter+ Monsoon /3
- Average Sunshine Hours = 6+4.5+4 / 3 =**4.8 Hours**
- Total Electrical Load =2560 Watt Hr/Day
- **Required Size of Solar Panel = (Electrical Load / Avg. Sunshine) X Correction Factor**
- Required Size of Solar Panel =(2560 / 4.8) x 1.2 **= 635.6 Watt**
- **Required Size of Solar Panel = 635.6 Watt**

Step-3: Calculate No of Solar Panel / Array of Solar Panel

If we Use 250 Watt, 24V Solar Panel in Series-Parallel Type Connection

- In Series-Parallel Connection Both Capacity (watt) and Volt are increases
- No of String of Solar Panel (Watt) = Total Size of Solar Panel / Capacity of Each Panel
- No of String of Solar Panel (Watt) = 635.6 / 250 = 2.5 No's Say **3 No's**
- **No of Solar Panel in Each String= Solar System Volt / Each Solar Panel Volt**
- No of Solar Panel in Each String= 48/24 =**2 No's**
- Total No of Solar Panel = No of String of Solar Panel x No of Solar Panel in Each String
- Total No of Solar Panel = 3x2 =**6 No's**
- **Total No of Solar Panel =6 No's**

Step-4: Calculate Electrical Load:

- Load for Computer = No x Watt
- Load for Computer = 1x100 =1**00 Watt**
- Load for Fan = No x Watt
- Load for Fan = 2x60 = **120 Watt**
- Load for CFL Light = No x Watt

- Load for CFL Light = 1x100 = **100 Watt**
- Total Electrical Load = 100+120+100 =**320 Watt**

Step-5: Calculate Size of Inverter:

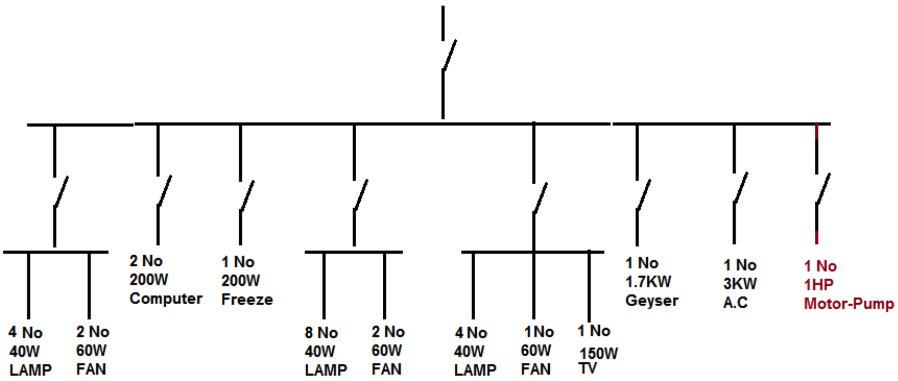
- Total Electrical Load in Watt = **320 Watt**
- **Total Electrical Load in VA= Watt /P.F**
- Total Electrical Load in VA =320/0.8 = **400VA**
- **Size of Inverter =Total Load x Correction Factor / Efficiency**
- Size of Inverter = 320 x 1.2 / 80% **=440 Watt**
- Size of Inverter =400 x 1.2 / 80% **=600 VA**
- **Size of Inverter = 440 Watt or 600 VA**

Summary:

- Required Size of Solar Panel = 635.6 Watt
- Size of Each Solar Panel = 250 Watt. 12 V
- No of String of Solar Panel = 3 No's
- No of Solar Panel in Each String = 2 No's
- **Total No of Solar Panel =6 No's**
- **Total Size of Solar Panel = 750 Watt**
- **Size of Inverter = 440 watt or 600 VA**

Chapter: 32 Calculate Size of Main ELCB / Branch MCB of Distribution Box

- Design Distribution Box of one House and Calculation of Size of Main ELCB and branch Circuit MCB as following Load Detail. Power Supply is 430V (P-P), 230 (P-N), 50Hz. Consider Demand Factor 0.6 for Non Continuous Load & 1 for Continuous Load for Each Equipment.
- **Branch Circuit-1**: 4 No of 1Ph, 40W, Lamp of Non Continues Load + 2 No's of1Phas 60W, Fan of Non Continues Load.
- **Branch Circuit-2**: 2 No of 1Ph, 200W, Computer of Non Continues Load.
- **Branch Circuit-3**: 1 No of 1Ph, 200W, Freeze of Continues Load.
- **Branch Circuit-4**: 8 No of 1Ph, 40W, Lamp of Non Continues Load + 2 No's of1Phas 60W, Fan of Non Continues Load.
- **Branch Circuit-5**: 4 No of 1Ph, 40W, Lamp of Non Continues Load + 1 No's of1Ph, 60W, Fan of Non Continues Load.+ 1 No's of1Ph, 150W, TV of Continues Load
- **Branch Circuit-6**: 1 No of 1Ph, 1.7KW, Geyser of Non Continues Load.
- **Branch Circuit-7**: 1 No of 1Ph, 3KW, A.C of Non Continues Load.
- **Branch Circuit-8**: 1 No of 3Ph, 1HP, Motor-Pump of Non Continues Load.



Fault Current (TABLE-A)	
Voltage	**Fault Current**
230V	6KA
430V	10KA
11KV	25KA

Class of MCB/ELCB/RCCB (TABLE-B)		
Type of Load	**Class**	**Sensitivity**
Lighting	B Class	IΔn:30ma
Heater	B Class	IΔn:30ma
Drive	C Class	IΔn:100ma
A.C	C Class	IΔn:30ma
Motor	C Class	IΔn:100ma
Ballast	C Class	IΔn:30ma
Induction Load	C Class	IΔn:100ma
Transformer	D Class	IΔn:100ma

Size of MCB/ELCB (TABLE-C)		
Current (Amp)	**Lighting Load MCB/ELCB (Amp)**	**Heating/Cooling/Motor-Pump Load MCB/ELCB (Amp)**
1.0 to 4.0	6	16
6.0	10	16
10.0	16	16
16.0	20	20
20.0	25	25
25.0	32	32
32.0	40	40

40.0	45	45
45.0	50	50
50.0	63	63
63.0	80	80
80.0	100	100
100.0	125	125
125.0	225	225
225.0	600	600
600.0	800	800
800.0	1600	1600
1600.0	2000	2000
2000.0	3000	3000

Calculation:

Size of MCB for Branch Circuit-1:

- Load Current of Lamp= (No X Watt X Demand Factor)/Volt =(4X40X0.6)/230=0.40Amp
- Load Current of Fan= (No X Watt X Demand Factor)/Volt =(2X60X0.6)/230=0.31Amp
- **Branch Circuit-1 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-1 Current as per NEC =(0.4+0.31)+125%(0) =0.73Amp
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-2:

- Load Current of Computer = (No X Watt X Demand Factor)/Volt =(2X200X0.6)/230=1.04Amp
- **Branch Circuit-2 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-2 Current as per NEC =(1.04)+125%(0) =1.04Amp
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-3:

- Load Current of Freeze= (No X Watt X Demand Factor)/Volt =(1X200X0.6)/230=0.87Amp
- **Branch Circuit-3 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-3 Current as per NEC =(0.87)+125%(0) =0.87Amp
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-4:

- Load Current of Lamp= (No X Watt X Demand Factor)/Volt =(8X40X0.6)/230=0.83Amp
- Load Current of Fan= (No X Watt X Demand Factor)/Volt =(2X60X0.6)/230=0.31Amp
- **Branch Circuit-4 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-4 Current as per NEC =(0.83+0.31)+125%(0) =1.15Amp
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-5:

- Load Current of Lamp= (No X Watt X Demand Factor)/Volt =(4X40X0.6)/230=0.42Amp
- Load Current of Fan= (No X Watt X Demand Factor)/Volt =(1X60X0.6)/230=0.16Amp
- Load Current of TV = (No X Watt X Demand Factor)/Volt =(1X150X1)/230=0.65Amp
- **Branch Circuit-5 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-5 Current as per NEC =(0.42+0.16)+125%(0.65) =0.57+0.82=1.39Amp
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-6:

- Load Current of Geyser= (No X Watt X Demand Factor)/Volt =(1X1700X0.6)/230=4.43Amp
- **Branch Circuit-6 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-6 Current as per NEC =(4.43)+125%(0) =4.43Amp
- Type of Load=Heating & Cooling Type
- Class of MCB=C Class
- Size of MCB=16 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-7:

- Load Current of A.C= (No X Watt X Demand Factor)/Volt =(1X3000X0.6)/230=7.83Amp
- **Branch Circuit-7 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-7 Current as per NEC =(7.83)+125%(0) =7.83Amp
- Type of Load=Heating & Cooling Type
- Class of MCB=C Class
- Size of MCB=16 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-8:

- Load Current of Motor-Pump = (No X Watt X Demand Factor)/(1.732XVolt) =(1X746X0.6)/(1.732X430)=0.60Amp
- **Branch Circuit-8 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-8 Current as per NEC =(0.60)+125%(0) =0.60Amp
- Type of Load=Motor-Pump Type
- Class of MCB=C Class
- Size of MCB=16 Amp
- Breaking Capacity: 10KA
- No of Pole of MCB= Three Pole

Size of Main ELCB/RCCB:

- Total Branch Circuit Load & MCB Detail is

Branch Circuit	**Total Current (Amp)**	**Size of MCB (Amp)**	**Class of MCB**	**Breaking Capacity of MCB**	**Pole of MCB**
Branch circuit-1	0.73	6 Amp	B Class	6KA	SP
Branch circuit-2	1.04	6 Amp	B Class	6KA	SP
Branch circuit-3	0.87	6 Amp	B Class	6KA	SP
Branch circuit-4	1.15	6 Amp	B Class	6KA	SP
Branch circuit-5	1.39	6 Amp	B Class	6KA	SP
Branch circuit-6	4.43	16 Amp	C Class	6KA	SP
Branch circuit-7	7.83	16 Amp	C Class	6KA	SP
Branch circuit-8	0.63	16 Amp	C Class	10KA	TP
Total	**18.04**				

- Total Load Current as per NEC= 18.04Amp--------(A)
- Max Size of Branch circuit MCB=16Amp

- **Total Load Current of Panel as per Branch Circuit= 2X Max Size of Branch circuit MCB**
- Total Load Current of Panel as per Branch Circuit =2X16=32Amp------(B)
- Total Load Current of Panel as per NEC = Maximum of (A) and (B)
- Total Load Current of Panel as per NEC=32Amp
- **Min Size of ELCB/RCCB as per NEC=40Amp**
- Class of ELCB/RCCB= B or C Class
- No of Pole of ELCB/RCCB=TP or FP
- Sensitivity(IΔn)=30ma
- Breaking Capacity=10KA

Size of Distribution Board:

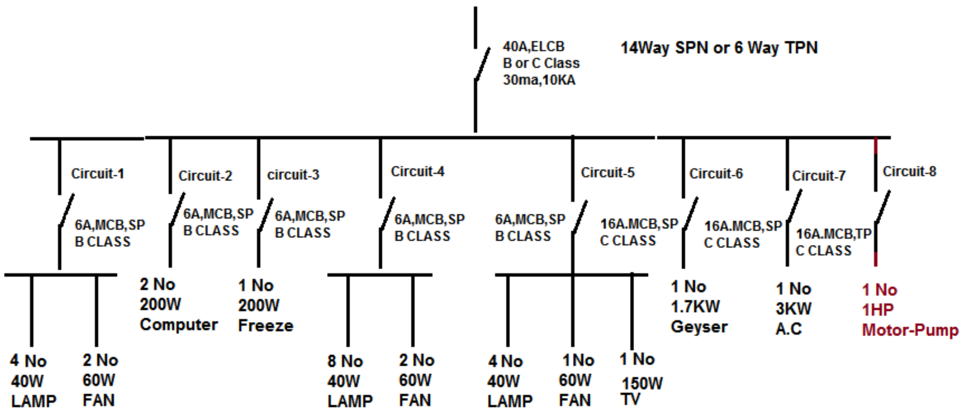
- No of Single Pole Branch Circuit MCB (SP)= 7 No's
- No of Three Pole Branch Circuit MCB (TP)= 1 No's
- Main ELCB (TP)=1 No's
- Total No of Way of D.B (SPN)= (SP)+3X(TP)=7+(3X2)=13Way SPN
- Total No of Way of D.B (TPN)= (SP)/3+ (TP)=(7/3)+(2)=4+2=6Way SPN
- Select Either 14Way SPN or 6 Way TPN

Load Balancing of Distribution Board:

- To Balance Load We need to try distribute Single Phase load on each Phase.
- Suppose We connect Branch Circuit load on following Phase

Branch Circuit	Current (Amp)	Type of Load	Connection on
Branch circuit-1	0.73	Single Phase	Y Phase
Branch circuit-2	1.04	Single Phase	B Phase
Branch circuit-3	0.87	Single Phase	Y Phase
Branch circuit-4	1.15	Single Phase	B Phase
Branch circuit-5	1.39	Single Phase	Y Phase
Branch circuit-6	4.43	Single Phase	B Phase
Branch circuit-7	7.83	Single Phase	R Phase
Branch circuit-8	0.63	Three Phase	RYB Phase
Summary of Load			
R Phase Load	**8.5**	**Amp**	
Y Phase Load	**3.5**	**Amp**	
B Phase Load	**7.23**	**Amp**	
Total Load	**18.04**	**Amp**	

Summary of Distribution Box:



- **Size of Distribution Box : 14Way SPN or 6 Way TPN**
- **Size of Main ELCB: 40A,B or C Class,30ma,10KA**
- **Size & No of Branch MCB: 5 No's of 6A,SP, B Class,6KA**
- **Size & No of Branch MCB: 2 No's of 16A,SP, C Class,6KA**
- **Size & No of Branch MCB: 1 No's of 16A,TP, C Class,10KA**

Chapter: 33 Calculate Dimension of Electrical Panel from SLD

Introduction:

- In Designing Stage , We need to calculate approximate Dimension of Electrical Panel to conclude Dimension of Electrical Room and Total Space requirement of Electrical Services.
- Dimension of Electrical Panel's is calculated from Electrical SLD.
- Dimension of Electrical Panel mainly depends on

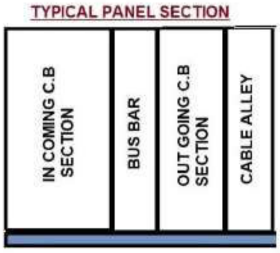
1. Size of Main Incoming and Outgoing Circuit Braker.
2. No of Outgoing Circuit Breakers.
3. Panel's Form Factor.
4. Type of Panel (Indoor / Outdoor).
5. Cable connection in Panel (Front Side / Back side of Panel).
6. Installation of Circuit Breaker (Horizontal / Vertical)
7. Height of Panel should not be more than 2200mm Due to Operation of Upmost Switchgear.

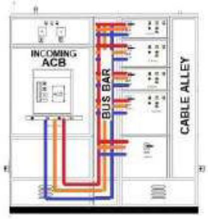
General Switchgear arrangements in Panel

- There are four compartments in Electrical Panel.

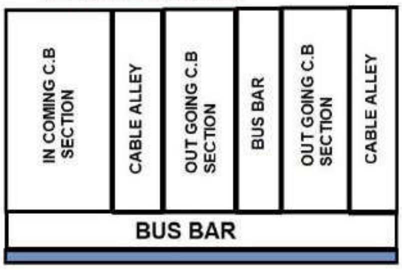
1. Incoming Section
2. Outgoing Section
3. Busbar Chamber
4. Cable Alley.

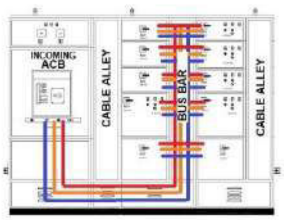
TYPICAL PANEL SECTION





TYPICAL PANEL SECTION





Factors needs to be considered to calculate Dimension of Panel:

- Dimension of Panel mainly depends on following factors.

1. Type of Panel (Indoor / Outdoor):

- Depth of Panel is depending on Type of Panel.
- If We have Indoor Type of Panel and there are no any issue regarding Water seepages near Panel than Double Door type of Panel is not required.
- In Out Door Type Panel construction is mostly Double Door Type.
- **For Double Door Construction required more 100mm Panel Depth than actual .**

INDOOR PANEL

OUT DOOR PANEL

OUT DOOR PANEL

2. Form Factor of Panel:

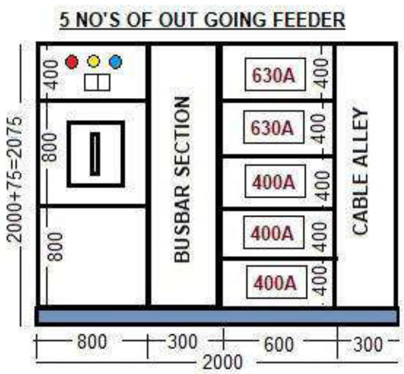
- Type of Form Factor decide Dimension of Panel.
- For Same type and same rating of Switchgear Form 1 required less space compared to Form 2A, 2B, 3A, 3B, 4A, 4B.

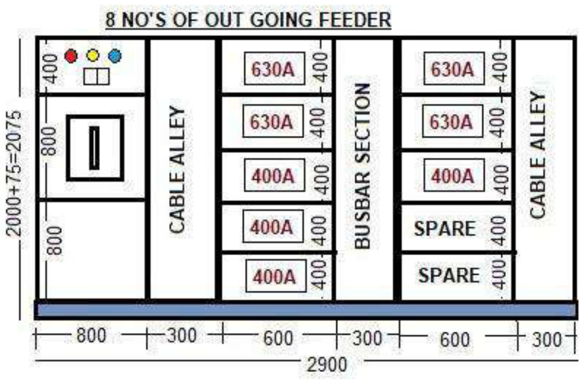
3. Position of Switch gear Installation

- Panel's Width and Height mostly depends on Position of Switchgear Installation.
- If we installed Switchgear in vertical Position than Height of Panel is increased.
- If we installed Switchgear in horizontal position than with of Panel is increased.
- Most of manufacture prefer Horizontal position of Switchgear to easy termination of Incoming and Outgoing of Switchgear to Busbar.

4. Height of Panel

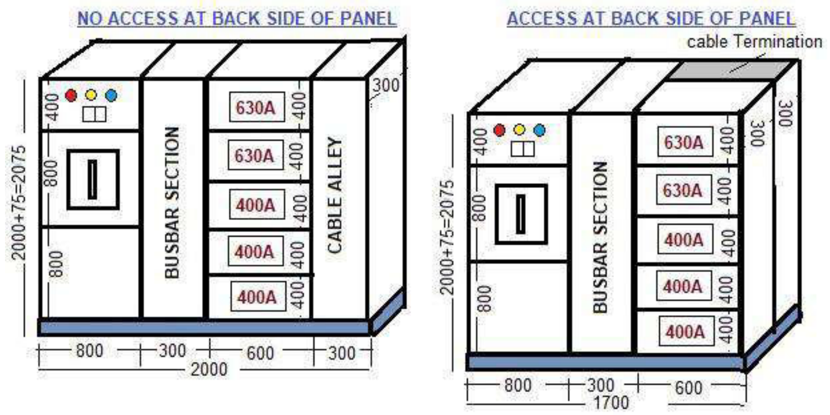
- **Height of Panel should not more than 2200mm for easy operation of upmost Switchgear in Panel.**
- This 2200MM height concert increase width of Panel if we have multiple number of outgoing.
- If we have 5 Nos of outgoing than it may require one No of Colum Section of Panel (400x5=2000mm).
- But if we have 8 No's of outgoing than we required two no of Colum Section in one Section 4 no of Outgoing Switchgear and in second Colum section for 3 no of Switch gear. 1 no of More cable alley section (300mm) required for cable termination.





5. Cale Termination in Panel (Front Side / Back Side)

- **Front Side Cable Termination:** If We Installed Panel Infront of wall than Panel Back Side is not accessible hence We need Cable Termination on front side of Panel for this we need Cable Alley of 300mm for Cable Termination.
- **This arrangement increase width of 300mm for panel but depth of panel will not increase.**
- **Back Side Cable Termination:** If We Installed Panel at some distance from wall than Panel Back Side is accessible hence, we may do Cable Termination on back side of Panel for this arrangement we need more 300mm depth for Cable Termination.
- **This arrangement will not increase width of panel but depth of panel will not increase 300mm.**



General Compartment Size for various Switchgear in Panel.

Size of MCB / MCCB Compartment (Cable Connections are in front of Panel)				
MCB / MCCB Size	Position	Width (mm)	Height (mm)	Depth (mm)
Up to 63A	Horizontal	300	275	300
63A to 100A	Horizontal	350	300	300
125A to 250A	Horizontal	350 to 400	300 to 350	300 to 350
400A to 630A	Horizontal	600	400	350 to 400
MCCB 800A	Horizontal	600	600	700
MCCB 1250A to 3200A	Horizontal	800	850	1000
* Cable Connections are in front side of Panel, If Cable Connection are in Back Side of Panel add 300mm in Depth of Panel				
* Cable Termination Space in Panel (From Cable Entry at Panel to Termination Location) Up to 800A =more than 400 mm, above 800A It should be more than 800mm.				

Size of ACB Compartment (Cable Connections are in front of Panel)				
ACB Size	Position	Width (mm)	Height (mm)	Depth (mm)
800A	Horizontal	700	800	800
1600A	Horizontal	800	800	850
ACB up to 3200A	Horizontal	800	850	1000
ACB Above 3200A	Horizontal	1400	1000	1200
For Cable Entry from Bottom of Panel=Min 700mm Height from Bottom to Cable Termination				
* Cable Termination Space in Panel (From Cable Entry at Panel to Termination Location) Up to 800A =more than 400 mm, Above 800A It should be more than 800mm.				

Size of SFU Compartment (Cable Connections are in front of Panel)				
SFU Size	Position	Width (mm)	Height (mm)	Depth (mm)
125A	Horizontal	400	350	300
200A	Horizontal	400	350	300
200A	Horizontal	400	400	300
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side of Panel add 300mm in Depth of Panel				

Size of ATS Compartment (Cable Connections are in front of Panel)				
ATS Size	Position	Width (mm)	Height (mm)	Depth (mm)
100A	Vertical	400	700	350
160A	Vertical	400	900	350
200A	Vertical	400	750	350
400A	Vertical	400	750	350
630A	Vertical	400	1000	350
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side of Panel add 300mm in Depth of Panel				

Size of Motorized MCCB Compartment (Cable Connections are in front of Panel)				
Motorized MCCB Size	Position	Width (mm)	Height (mm)	Width (mm)
125A	Vertical	500	500	300
200A	Vertical	500	500	300
400A	Vertical	500	500	300
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side of Panel add 300mm in Depth of Panel				

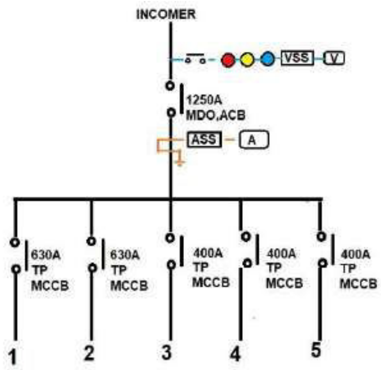
Size of Starter Compartment (Cable Connections are in front of Panel)				
Motor KW	Position	Width (mm)	Height (mm)	Depth (mm)
Up to 6KW	Horizontal	500	300	300
7.5KW to 11 KW	Horizontal	600	200	300
15KW to 30KW	Horizontal	600	300	450
37KW to 55KW	Horizontal	600	400	600
55KW to 132KW	Vertical	600	600	800
250KW to 300KW	Vertical	800	1500	1000
* Cable Connections are in front side of Panel , If Cable Connection are in Back Side of Panel add 300mm in Depth of Panel				

Size of BUSBAR & Cable Alley Compartment				
Type	Position	Width (mm)	Height (mm)	Depth (mm)
BUS BAR	Horizontal	-	300 to 400	300
BUS BAR	Vertical	300 to 400	-	300
CABLE ALLEY	Vertical	300 to 350	-	300

Size of MCB Compartment (For No's of MCB)				
MCB Size	Position	Width (mm)	Height (mm)	Depth (mm)
10A to 63A,4P MCB=5NO	Vertical	700	300	300
10A to 63A,4P MCB=5NO	Vertical	700	300	300
10A to 63A,4P MCB=3NO	Vertical	500	300	300
10A to 63A,4P RCCB=2NO+10A to 40A, SP MCB=20NO	Vertical	600	300	300
10A to 63A,4P RCCB=5NO+10A to 40A, DP MCB=2NO	Vertical	600	600	300
10A to 63A,4P MCB=2NO, ON/OFF	Vertical	350	300	300
*Required 25mm to 35mm for Each Pole, Ex for Four Pole MCB required 140mm Space				

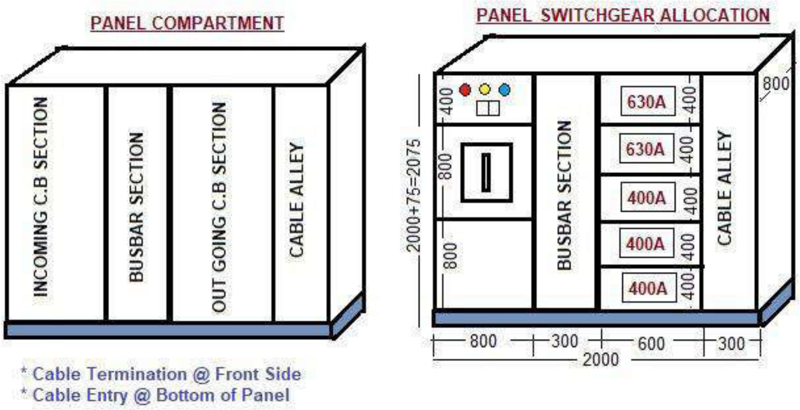
Calculation-1

- Calculate Dimension of Panel for following Electrical SLD
- Cable Termination are in front side of Panel ,Cable Entry are at bottom of the Panel ,Type of Panel is Indoor Type ,Switchgear will be installed in horizontal position.



Solution:

- Incoming Switchgear= 1250A,4P, ACB
- Outgoing Switchgear = 630A, TP, MCCB=2 No and 400A, TP, MCCB=3 No's.

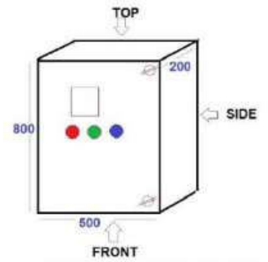


- **Height of Panel:**
- Height of Panel is decided from No of Outgoing Feeder and Switchgear Installation Position (Horizontal / Vertical). We will Installed Switchgear in horizontal position.
- From Above Tables Height for MCCB Compartment for 400A to 630A MCCB=400mm
- Total Height of panel for 5no of MCCB= 5x400=2000mm
- Panel Base Frame is 75mm
- Total Panel height is 2000+75=2075mm which is less than **2200mm**
- **Width of Panel:**
- Width of Panel is decided from Incoming and Out Going Switchgear Section, Cable Termination from Front / Back Side and Switchgear installation position (vertical /Horizontal).
- From above Table, Incoming Switchgear Compartment Size for 1250A,4P, ACB width is 800mm
- Size of Busbar compartment =300mm
- Size of Outgoing Switchgear compartment for 400A to 630A MCCB=600mm
- Size of Busbar alley compartment (Front Side Cable Termination) =300mm
- Total Width of Panel =800+300+600+300=**2000mm**
- **Depth of Panel:**
- Depth of Panel is decided from Incoming Switchgear (which has maximum depth) and Cable Termination in Panel (Front Side / Back Side)
- From Above Table Depth of Switchgear compartment for 1250A ,4P, ACB=800mm
- Total depth of panel=**800mm**
- We can also choose different depth for Incoming Switchgear compartment and Outgoing Switchgear compartment.
- In this example we can also choose depth of panel for incoming compartment=800mm and cable termination is front side of panel hence for Outgoing switchgear compartments=300mm.
- **Conclusion:**
- **Total Width of Panel is 2000mm, Height of Panel is 2075mm, Depth of Panel is 800mm**

Chapter: 34 Calculate Weight of Electrical Panel

EXAMPLE-1 (Single Compartment Panel):

- Calculate Electrical Panel Weight having height of 800mm, width of 200mm and depth of 500mm.
- The panel material is CRCA steel having 2mm thickness. CRCA Steel density is 7860 kg/m3.
- Panel is Mounted on MS Angle Stand of 25x25x4.5 mm, Height of Stand is 500mm, Weight of MS Angle is 1.6Kg/Meter



SINGLE COMPARTMENT PANEL

Calculation:

- We need to calculate Weight of CRCA Steel Sheet for Front, Top and Side of Panel.

Front Side (Front + Back):

- From Front side We can see either 3 no's of Plate (Front, Back and Switchgear Mounting Plate) or 2 no's of Plate (Front and Back) according to Type of Panel.
- **Front & Back Side Steel Sheet Weight = Height X Width X Density of Sheet X Thickness of Sheet X No of Sheet**
- Front & Back Side Steel Sheet Weight =0.8 x 0.5 x 7860 x 0.002 x 3
- **Front & Back Side Steel Sheet Weight =18.86 Kg**

Top Side (Top + Bottom):

- **Top Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Top Side Steel Sheet Weight =0.2 x 0.5 x 7860 x 0.002 x 2
- **Top Side Steel Sheet Weight =3.14 Kg**

Side (Left + Right):

- **Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Side Steel Sheet Weight =0.8 x 0.2 x 7860 x 0.002 x 2
- **Side Steel Sheet Weight = 5.03 Kg**

Panel MS Stand Weight.

- Total Peripheral Length of Panel = 500+500+200+200=1400 =1.4 Meter
- Height of Stand is 500mm, Length of MS Angle =500x4=2000=2 Meter
- Total Length of 25x25x4.5 mm MS Angle =1.4+2=3.4 Meter
- Weight of 25x25x4.5 mm MS Angle is 1.6 Kg/Meter
- **Total 75MM MS Base channel Weight =3.4 x 1.6 = 5.44 Kg**

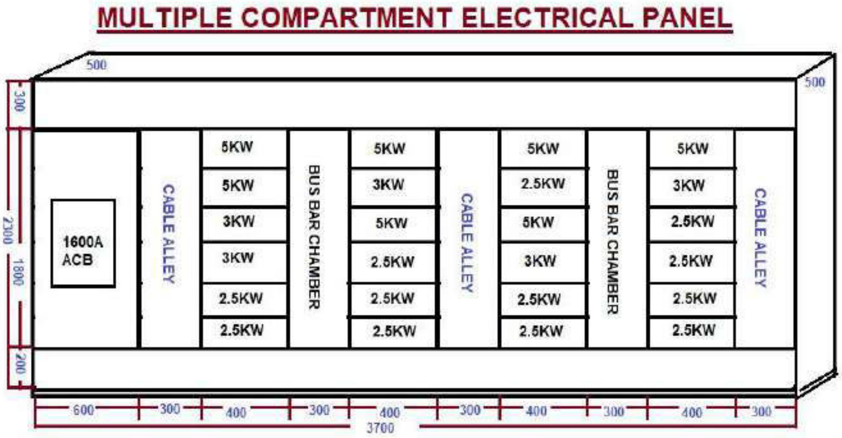
Total Panel Weight

- Total Electrical Panel Weight = Front Sheet Weight + Top Sheet Weight + Side Sheet Weight+ MS Stand
- Total Electrical Panel Weight = 18.86 +314 + 5.03 + 5.44 = 32.47 Kg
- Considering extra 20% weight for Hinges, Lock etc.
- Total Electrical Panel Weight =32.47 x 1.2 =38.97 Kg

Total Electrical Panel Weight =38.97 Kg

EXAMPLE-2 (Multi Compartment Panel):

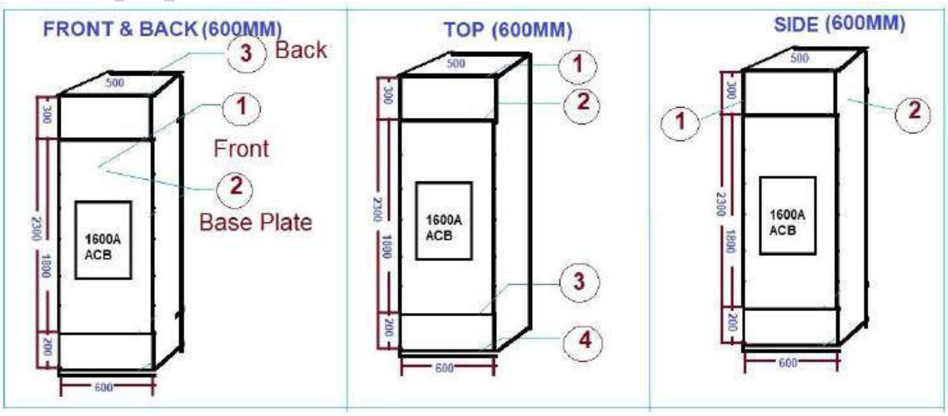
- Calculate Electrical Panel Weight having height of 2300mm, width of 3700mm and depth of 500mm.
- The panel material is CRCA steel having 2mm thickness. CRCA Steel density is 7860 kg/m3.
- The Panel Mounting Base Channel is 75MM.



Calculation:

- We need to calculate Weight of CRCA Steel Sheet for Front, Top and Side of Panel for Each Compartment of Panel.
- Here Main Size of Compartment is 600mm,300mm and 400mm

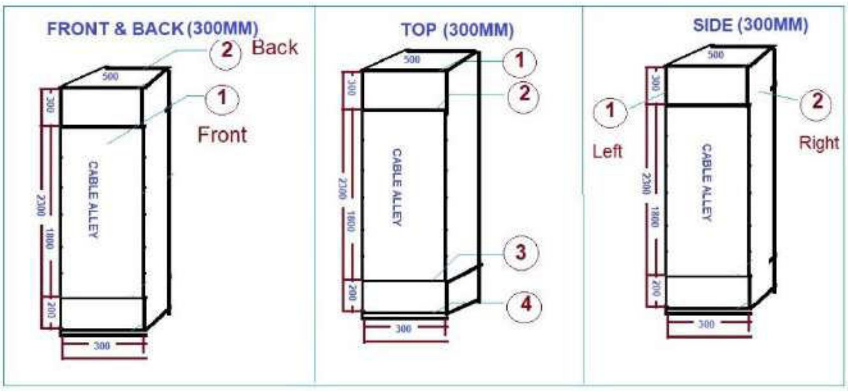
(1) For 600MM Compartment:



- **Front Side (Front + Back):**
- From Front side We can see 3 no's of Plate (Front, Back and Switchgear Mounting Plate).
- Total Height=300+1800+200=2300=2.3meter.
- **Front & Back Side Steel Sheet Weight = Height X Width X Density of Sheet X Thickness of Sheet X No of Sheet**
- Front & Back Side Steel Sheet Weight =2.3 x 0.6 x 7860 x 0.002 x 3

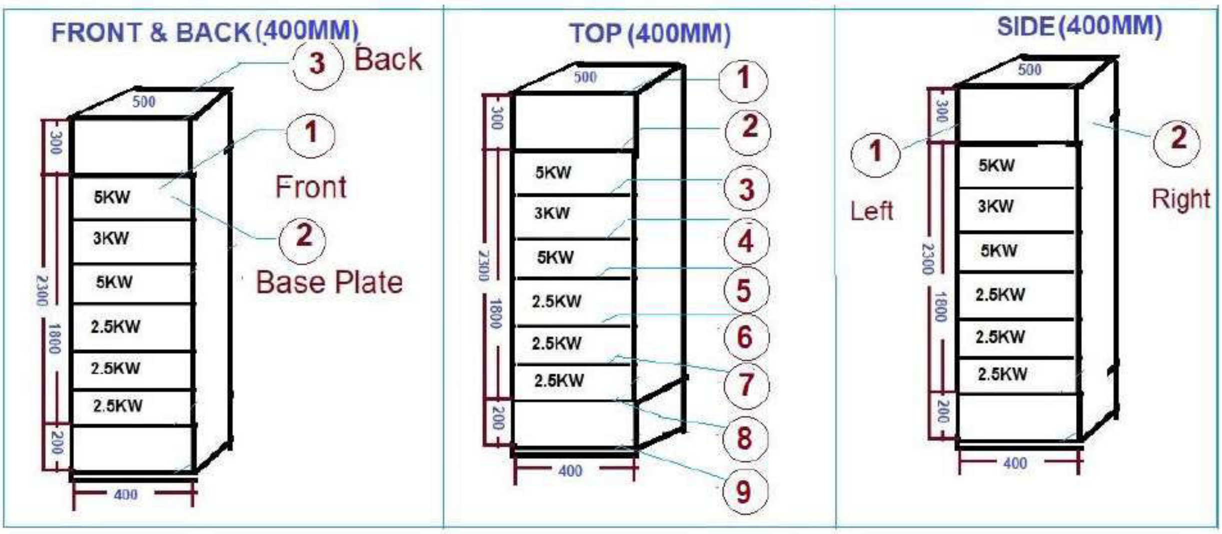
- Front & Back Side Steel Sheet Weight =65.08 Kg-------------------------(1)
- **Top Side (Top + Bottom):**
- **Top Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Top Side Steel Sheet Weight =0.6 x 0.5 x 7860 x 0.002 x 4
- Top Side Steel Sheet Weight =18.86 Kg-------------------------------(2)
- **Side (Left + Right):**
- **Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Side Steel Sheet Weight =2.3 x 0.5 x 7860 x 0.002 x 2
- Side Steel Sheet Weight = 36.15 Kg-------------------------------------(3)
- **Total 600MM Compartment Weight:**
- 600MM Compartment Weight= (1) + (2) + (3) =65.08+18.86+36.15=120.1Kg
- No of 600MM Compartment in Panel=1 No
- **TOTAL 600MM Compartment Weight =120.1x1=120.1 Kg---------(A)**

(2) For 300MM Compartment:



- **Front Side (Front + Back):**
- From Front side We can see 2 no's of Plate (Front and Back, In Busbar Chamber Base plate is not required).
- Total Height=300+1800+200=2300=2.3meter.
- **Front & Back Side Steel Sheet Weight = Height X Width X Density of Sheet X Thickness of Sheet X No of Sheet**
- Front & Back Side Steel Sheet Weight =2.3 x 0.3 x 7860 x 0.002 x 2
- Front & Back Side Steel Sheet Weight =21.69 Kg-------------------------(1)
- **Top Side (Top + Bottom):**
- **Top Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Top Side Steel Sheet Weight =0.3 x 0.5 x 7860 x 0.002 x 4
- Top Side Steel Sheet Weight =9.43 Kg-------------------------------(2)
- **Side (Left + Right):**
- **Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Side Steel Sheet Weight =2.3 x 0.5 x 7860 x 0.002 x 1 (We can see 2 No's of Plate but 1 No of Plate is already considered in adjoin 600MM Compartment)
- Side Steel Sheet Weight = 18.07 Kg-------------------------------------(3)
- **Total 300MM Compartment Weight:**
- 300MM Compartment Weight= (1) + (2) + (3) =21.69+9.43+18.07=49.20Kg
- No of 300MM Compartment in Panel=5 No
- **TOTAL 300MM Compartment Weight =49.20x5=246.01 Kg---------(B)**

(3) For 400MM Compartment:



- **Front Side (Front + Back):**
- From Front side We can see 3 no's of Plate (Front, Back and Switchgear Mounting Plate).
- Total Height=300+1800+200=2300=2.3meter.
- **Front & Back Side Steel Sheet Weight = Height X Width X Density of Sheet X Thickness of Sheet X No of Sheet**
- Front & Back Side Steel Sheet Weight =2.3 x 0.4 x 7860 x 0.002 x 3
- Front & Back Side Steel Sheet Weight =43.38 Kg-------------------------(1)
- **Top Side (Top + Bottom):**
- **Top Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Top Side Steel Sheet Weight =0.4 x 0.5 x 7860 x 0.002 x 9
- Top Side Steel Sheet Weight =28.29 Kg-------------------------------(2)
- **Side (Left + Right):**
- **Side Steel Sheet Weight = Height X Depth X Density of Sheet X Thickness of Sheet X No of Sheet**
- Side Steel Sheet Weight =2.3 x 0.5 x 7860 x 0.002 x 1 (We can see 2 No's of Plate but 1 No of Plate is already considered in adjoin 300MM Compartment)
- Side Steel Sheet Weight = 18.07 Kg-------------------------------------(3)
- **Total 400MM Compartment Weight:**
- 400MM Compartment Weight= (1) + (2) + (3) =43.38+28.29+18.07=89.76Kg
- No of 400MM Compartment in Panel=4 No
- **TOTAL 400MM Compartment Weight =89.76x4=359.04 Kg---------(C)**

(4) For 75MM MS Base Channel:

- Total Peripheral Length of Panel = 3700+500+3700+500=8400 =8.4 Meter
- Weight of 75MM MS channel is 7.14 Kg/Meter
- **Total 75MM MS Base channel Weight =8.4 x 7.14 = 59.97 Kg----------------(D)**

Total Panel Weight

- Total Electrical Panel Weight = 600MM Compartment Weight + 300MM Compartment Weight + 400MM Compartment Weight+ 75MM Panel Base Chanel Weight
- Total Electrical Panel Weight = 120.10 + 246.01 + 359.04 + 59.97
- Total Electrical Panel Weight = 785.13 Kg
- Considering extra 20% weight for Hinges, Lock etc.
- Total Electrical Panel Weight = 785.13 x 1.2 =942.16 Kg

Total Electrical Panel Weight =942.16 Kg

Chapter: 35 Calculate Size of Capacitor Bank / Annual Saving & Payback Period

- Calculate Size of Capacitor Bank Annual Saving in Bills and Payback Period for Capacitor Bank.
- Electrical Load of (1) 2 No's of 18.5KW,415V motor ,90% efficiency,0.82 Power Factor ,(2) 2 No's of 7.5KW,415V motor ,90% efficiency,0.82 Power Factor,(3) 10KW ,415V Lighting Load. The Targeted Power Factor for System is 0.98.
- Electrical Load is connected 24 Hours, Electricity Charge is 100Rs/KVA and 10Rs/KW.
- Calculate size of Discharge Resistor for discharging of capacitor Bank. Discharge rate of Capacitor is 50v in less than 1 minute.
- Also Calculate reduction in KVAR rating of Capacitor if Capacitor Bank is operated at frequency of 40Hz instead of 50Hz and If Operating Voltage 400V instead of 415V.
- Capacitor is connected in star Connection, Capacitor voltage 415V, Capacitor Cost is 60Rs/Kvar. Annual Deprecation Cost of Capacitor is 12%.

Calculation:

- For Connection (1):
- Total Load KW for Connection(1) =Kw / Efficiency=(18.5x2) / 90=41.1KW
- Total Load KVA (old) for Connection(1)= KW /Old Power Factor= 41.1 /0.82=50.1 KVA
- Total Load KVA (new) for Connection(1)= KW /New Power Factor= 41.1 /0.98= 41.9KVA
- Total Load KVAR= KWX([(√1-(old p.f)2) / old p.f]- [(√1-(New p.f)2) / New p.f])
- Total Load KVAR1=41.1x([(√1-(0.82)2) / 0.82]- [(√1-(0.98)2) / 0.98])
- **Total Load KVAR1=20.35 KVAR**
- OR
- tanØ1=Arcos(0.82)=0.69
- tanØ2=Arcos(0.98)=0.20
- Total Load KVAR1= KWX (tanØ1- tanØ2) =41.1(0.69-0.20)=20.35KVAR
- For Connection (2):
- Total Load KW for Connection(2) =Kw / Efficiency=(7.5x2) / 90=16.66KW
- Total Load KVA (old) for Connection(1)= KW /Old Power Factor= 16.66 /0.83=20.08 KVA
- Total Load KVA (new) for Connection(1)= KW /New Power Factor= 16.66 /0.98= 17.01KVA
- Total Load KVAR2= KWX([(√1-(old p.f)2) / old p.f]- [(√1-(New p.f)2) / New p.f])
- Total Load KVAR2=20.35x([(√1-(0.83)2) / 0.83]- [(√1-(0.98)2) / 0.98])
- **Total Load KVAR2=7.82 KVAR**
- For Connection (3):
- Total Load KW for Connection(2) =Kw =10KW
- Total Load KVA (old) for Connection(1)= KW /Old Power Factor= 10/0.85=11.76 KVA
- Total Load KVA (new) for Connection(1)= KW /New Power Factor= 10 /0.98= 10.20KVA
- Total Load KVAR3= KWX([(√1-(old p.f)2) / old p.f]- [(√1-(New p.f)2) / New p.f])
- Total Load KVAR3=20.35x([(√1-(0.85)2) / 0.85]- [(√1-(0.98)2) / 0.98])
- **Total Load KVAR1=4.17 KVAR**
- **Total KVAR=KVAR1+KVAR2+KVAR3**
- Total KVAR=20.35+7.82+4.17
- **Total KVAR=32Kvar**

Size of Capacitor Bank:

- **Site of Capacitor Bank=32 Kvar.**
- **Leading KVAR supplied by each Phase= Kvar/No of Phase**
- Leading KVAR supplied by each Phase =32/3=10.8Kvar/Phase
- **Capacitor Charging Current (Ic)= (Kvar/Phase x1000)/Volt**
- Capacitor Charging Current (Ic)= (10.8x1000)/(415/√3)
- Capacitor Charging Current (Ic)=44.9Amp
- **Capacitance of Capacitor = Capacitor Charging Current (Ic)/ Xc**
- Xc=2x3.14xfxv=2x3.14x50x(415/√3)=75362
- Capacitance of Capacitor=44.9/75362= 5.96µF
- **Required 3 No's of 10.8 Kvar Capacitors and**
- **Total Size of Capacitor Bank is 32Kvar**

Protection of Capacitor Bank

Size of HRC Fuse for Capacitor Bank Protection:

- **Size of the fuse =165% to 200% of Capacitor Charging current.**
- Size of the fuse=2x44.9Amp
- Size of the fuse=90Amp

Size of Circuit Breaker for Capacitor Protection:

- **Size of the Circuit Breaker =135% to 150% of Capacitor Charging current.**
- Size of the Circuit Breaker=1.5x44.9Amp
- Size of the Circuit Breaker=67Amp
- Thermal relay setting between 1.3 and 1.5of Capacitor Charging current.
- Thermal relay setting of C.B=1.5x44.9 Amp
- Thermal relay setting of C.B=67 Amp
- Magnetic relay setting between 5 and 10 of Capacitor Charging current.
- Magnetic relay setting of C.B=10x44.9Amp
- Magnetic relay setting of C.B=449Amp

Sizing of cables for capacitor Connection:

- Capacitors can withstand a permanent over current of 30% +tolerance of 10% on capacitor Current.
- Cables size for Capacitor Connection= 1.3 + 1.1 x nominal capacitor Current
- **Cables size for Capacitor Connection = 1.43 x nominal capacitor Current**
- Cables size for Capacitor Connection=1.43x44.9Amp
- Cables size for Capacitor Connection=64 Amp

Maximum size of discharge Resistor for Capacitor:

- Capacitors will be discharge by discharging resistors.
- After the capacitor is disconnected from the source of supply, discharge resistors are required for discharging each unit within 3 min to 75 V or less from initial nominal peak voltage (according IEC-standard 60831-1 + 2).
- Discharge resistors have to be connected directly to the capacitors. There shall be no switch, fuse cut-out or any other isolating device between the capacitor unit and the discharge resistors.
- **Max. Discharge resistance Value (Star Connection) = Ct / Cn x Log (Un x√2/ Dv).**
- **Max. Discharge resistance Value (Delta Connection)= Ct / 1/3xCn x Log (Un x√2/ Dv)**
- Where Ct =Capacitor Discharge Time (sec)
- Cn=Capacitance µ Farad.
- Un = Line Voltage
- Dv=Capacitor Discharge voltage.
- Maximum Discharge resistance =60 / ((5.96/1000000)x log (415x√2 /50)
- **Maximum Discharge resistance=4087 KΩ**

Effect of Decreasing Voltage & Frequency on Rating of Capacitor:

- The kvar of capacitor will not be same if voltage applied to the capacitor and frequency changes
- Reduced in Kvar size of Capacitor when operating 50 Hz unit at 40 Hz
- Actual KVAR = Rated KVAR x(Operating Frequency / Rated Frequency)
- Actual KVAR = Rated KVAR x(40/50)
- Actual KVAR = 80% of Rated KVAR
- **Hence 32 Kvar Capacitor works as 80%x32Kvar= 26.6Kvar**
- Reduced in Kvar size of Capacitor when operating 415V unit at 400V
- Actual KVAR = Rated KVAR x(Operating voltage / Rated voltage)^2
- Actual KVAR = Rated KVAR x(400/415)^2
- Actual KVAR=93% of Rated KVAR
- **Hence 32 Kvar Capacitor works as 93%x32Kvar= 230.6Kvar**

Annual Saving and Pay Back Period

Before Power Factor Correction:

- **Total electrical load KVA (old)= KVA1+KVA2+KVA3**
- Total electrical load= 50.1+20.08+11.76

- Total electrical load=82 KVA
- Total electrical Load KW=kW1+KW2+KW3
- Total electrical Load KW=37+15+10
- Total electrical Load KW =62kw
- Load Current=KVA/V=80x1000/(415/1.732)
- Load Current=114.1 Amp
- KVA Demand Charge=KVA X Charge
- KVA Demand Charge=82x60Rs
- KVA Demand Charge=8198 Rs
- Annual Unit Consumption=KWx Daily usesx365
- Annual Unit Consumption=62x24x365 =543120 Kwh
- Annual charges =543120x10=5431200 Rs
- Total Annual Cost= 8198+5431200
- **Total Annual Cost before Power Factor Correction= 5439398 Rs**

After Power Factor Correction:

- **Total electrical load KVA (new)= KVA1+KVA2+KVA3**
- Total electrical load= 41.95+17.01+10.20
- Total electrical load=69 KVA
- Total electrical Load KW=kW1+KW2+KW3
- Total electrical Load KW=37+15+10
- Total electrical Load KW =62kw
- Load Current=KVA/V=69x1000/(415/1.732)
- Load Current=96.2 Amp
- KVA Demand Charge=KVA X Charge
- KVA Demand Charge=69x60Rs =6916 Rs-------------(1)
- Annual Unit Consumption=KWx Daily usesx365
- Annual Unit Consumption=62x24x365 =543120 Kwh
- Annual charges =543120x10=5431200 Rs-----------------(2)
- Capital Cost of capacitor= Kvar x Capacitor cost/Kvar = 82 x 60= 4919 Rs---(3)
- Annual Interest and Deprecation Cost =4919 x 12%=590 Rs-----(4)
- Total Annual Cost= 6916+5431200+4919+590
- **Total Annual Cost After Power Factor Correction =5438706 Rs**

Pay Back Period:

- Total Annual Cost before Power Factor Correction= 5439398 Rs
- Total Annual Cost After Power Factor Correction =5438706 Rs
- Annual Saving= 5439398-5438706 Rs
- **Annual Saving= 692 Rs**
- Payback Period= Capital Cost of Capacitor / Annual Saving
- Payback Period= 4912 / 692
- **Payback Period = 7.1 Years**

Chapter: 36 Calculate Size of Diesel Generator Set

- Calculate Size of Diesel Generator having following Electrical Load. Consider Future Expansion ratio is 10%.Average use of Equipment is 0.8 (1 is Full Time Use)
- 4 No's of 1Ph, 230V, 80Watt CFL Bulbs, Diversity Factor is 0.8; Starting & Running P.F is 0.8.
- 2 No's of 1Ph, 230V, 3000Watt Air Condition, Diversity Factor is 1, Starting & Running P.F is 0.8.
- 2 No's of 1Ph, 230V, 500Watt Halogen Lights Diversity Factor is 0.8 Starting & Running P.F is 0.8.
- 1 No's of 1Ph,230V, 10KW Motor with Y-D Starter, Diversity Factor is 0.8,Starting P.F is 0.7 & Running P.F is 0.8
- 1 No's of 3Ph,430V, 130KW Motor with Soft Starter , Diversity Factor is 0.8,Starting P.F is 0.7 & Running P.F is 0.8

Calculation:

Type of Load	Equipment	Starting Current
Linear Load	General Equipments	100% of Full Load Current
Non-Linear Load	UPS, Inverter, Computer, Ballast	160% of Full Load Current

Type of Starter	Starting Current
DOL	6 X Full Load Current
Star-Delta	4 X Full Load Current
Auto Transformer	3 X Full Load Current
Soft Starter	2 X Full Load Current
VFD	1.5 X Full Load Current

Load Calculation-1:

- Full Load KW of CFL Bulb=(No X Watt X Diversity Factor) /1000
- Full Load KW of CFL Bulb=(4x80x0.8)/1000=0.3KW
- Full Load KVA of CFL Bulb=KW / P.F
- **Full Load KVA of CFL Bulb=0.3 / 0.8=0.4KVA------------(H)**
- Full Load current of CFL Bulb=(No X Watt X Diversity Factor) / (Volt x P.F)
- **Full Load current of CFL Bulb=(4x80x0.8) / (230x0.8) =2 Amp----(M)**
- Type of Load=Linear
- Starting KVA of CFL Bulb=1 X (KW / Starting P.F)
- **Starting KVA of CFL Bulb=0.3 / 0.8=0.4KVA---------------------(1)**
- Starting Current=100% of Full Load Current.
- **Starting Current=1 X 2= 2 Amp.--------------(A)**

Load Calculation-2:

- Total Full Load KW of A.C=(No X Watt X Diversity Factor) /1000
- Total Full Load KW of A.C =(2x3000x0.8)/1000=4.8KW
- Total Full Load KVA of A.C =KW / P.F
- **Total Full Load KVA of A.C =4.8 / 0.8=6KVA------------(I)**
- Total Full Load current of A.C =(No X Watt X Diversity Factor) / (Volt x P.F)
- **Total Full Load current of A.C =(2x3000x0.8) / (230x0.8) =26 Amp-------(N)**
- Type of Load=Non Linear
- Starting KVA of A.C=1.6 X (KW / Starting P.F)
- **Starting KVA of A.C =1.6 X (4.8 / 0.8)=9.6KVA---------------------(2)**
- Starting Current=160% of Full Load Current.
- **Starting Current=1.6 X 26= 42 Amp. --------------(B)**

Load Calculation-3:

- Full Load KW of Halogen Bulb=(No X Watt X Diversity Factor) /1000
- Full Load KW of Halogen Bulb=(2x500x0.8)/1000=0.8KW
- Full Load KVA of Halogen Bulb=KW / P.F
- **Full Load KVA of Halogen Bulb=0.8 / 0.8=1KVA------------(J)**
- Full Load current of Halogen Bulb=(No X Watt X Diversity Factor) / (Volt x P.F)

- **Full Load current of Halogen Bulb=(2x500x0.8) / (230x0.8) =4 Amp----(O)**
- Type of Load=Non Linear
- Starting KVA of Halogen Bulb =1.6 X (KW / Starting P.F) / Starting P.F
- **Starting KVA of Halogen Bulb =1.6 X (0.8 / 0.8)=1.6KVA----------------------(3)**
- Starting Current=160% of Full Load Current.
- **Starting Current=1.6 X 4= 7 Amp .--------------(C)**

Load Calculation-4:

- Full Load KW of Motor=(No X Watt X Diversity Factor) /1000
- Full Load KW of Motor =(1x10000x0.8)/1000=8KW
- Full Load KVA of Motor =KW / P.F
- **Full Load KVA of Motor =8 / 0.8=10KVA------------(K)**
- Full Load current of Motor =(No X Watt X Diversity Factor) / (Volt x P.F)
- **Full Load current of Motor =(1x10000x0.8) / (230x0.8) =43 Amp----(P)**
- Type of Starter=Star-Delta
- Starting KVA of Motor =4 X (KW / Starting P.F)
- **Starting KVA of Motor=4X (8 / 0.7)=45.7KVA------------------------(4)**
- Starting Current=4 X Full Load Current
- **Starting Current=4 X 11.4 = 174 Amp.--------------(D)**

Load Calculation-5:

- Full Load KW of Motor=(No X Watt X Diversity Factor) /1000
- Full Load KW of Motor =(1x120000x0.8)/1000=96KW
- Full Load KVA of Motor =KW / P.F
- **Full Load KVA of Motor =96 / 0.8=120KVA------------(L)**
- Full Load current of Motor =(No X Watt X Diversity Factor) / (Volt x P.F)
- **Full Load current of Motor =(1x120000x0.8) / (1.732x430x0.8) =167 Amp----(Q)**
- Type of Starter=Auto Transformer
- Starting KVA of Motor =3 X (KW / Starting P.F)
- **Starting KVA of Motor=3 X (96 / 0.7)=411.4KVA---------------(5)**
- Starting Current=3 X Full Load Current
- **Starting Current=3 X 167 = 501 Amp.--------------(E)**

Total Load Calculation:

- **Total Starting KVA =** (1) + (2) +(3) + (4) + (5)
- **Total Starting KVA** =0.4+9.6+1.6+45.7+411.4 =**468.7 KVA**
- **Total Starting Current =** (A) + (B) +(C) + (D) + E
- **Total Starting Current** =2+42+7+174+501= **725 Amp**
- **Total Running KVA =**(H)+(I)+(J)+(K)+(L)
- **Total Running KVA =**0.4+6+1+10+120= **137KVA**
- **Total Running Current=**(M)+(N)+(O)+(P)+(Q)
- **Total Running Current=**2+26+4+43+167**= 242 Amp**
- **Size of Diesel Generator= Starting KVA X Future Expansion X Average Use of Equipments**
- Size of Diesel Generator=468 X 1.1 X 0.8
- **Size of Diesel Generator= 412 KVA**

Summary:

- **Total Starting KVA =468.7 KVA**
- **Total Starting Current =725 Amp**
- **Total Running KVA = 137KVA**
- **Total Running Current= 242 Amp**
- **Size of Diesel Generator= 412 KVA**

Chapter: 37 Calculate Size of Inverter & Battery Bank

- Calculate Size of Inverter for following Electrical Load .Calculate Size of Battery Bank and decide Connection of Battery.

Electrical Load detail:

- 2 No of 60W,230V, 0.8 P.F Fan.
- 1 No of 200W,230V, 0.8 P.F Computer.
- 2 No of 30W,230V, 0.8 P.F Tube Light.

Inverter / Battery Detail:

- Additional Further Load Expansion (Af)=20%
- Efficiency of Inverter (Ie) = 80%
- Required Battery Backup (Bb) = 2 Hours.
- Battery Bank Voltage = 24V DC
- Loose Connection/Wire Loss Factor (LF) = 20%
- Battery Efficiency (n) = 90%
- Battery Aging Factor (Ag) =20%
- Depth of Discharge (DOD) =50%
- Battery Operating Temp =46ºC

Temp. °C	Factor
80	1.00
70	1.04
60	1.11
50	1.19
40	1.30
30	1.40
20	1.59

Calculation:

Step 1: Calculate Total Load:

- Fan Load= No x Watt =2x60=**120 Watt**
- Fan Load=(No x Watt)/P.F=(2x60)/0.8= **150VA**
- Computer Load= No x Watt =1x200=**200 Watt**
- Computer Load=(No x Watt)/P.F =(1x200)/0.8= **250VA**
- Tube Light Load= No x Watt =2x30=**60 Watt**
- Tube Light Load=(No x Watt)/P.F =(2x30)/0.8= **75VA**
- **Total Electrical Load=120+200+60 =380 Watt**
- **Total Electrical Load=150+250+75= 475VA**

Step 2: Size of Inverter:

- Size of Inverter=Total Load+(1+Af) / Ie VA
- Size of Inverter= 475+(1+20%) / 80%
- **Size of Inverter= 712 VA**

Step 3: Size of Battery:

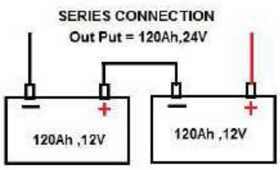
- Total Load of Battery Bank= (Total Load x Backup Capacity) / Battery Bank Volt
- Total Load of Battery Bank=(380 x 2) / 24 Amp Hr
- **Total Load of Battery Bank= 32.66 Amp Hr**
- Temperature Correction Factor for 46ºC (Tp)=1
- Size of Battery Bank=[(Load) x (1+LF) x (1+Ag) x Tp] / [n x DOD] Amp/Hr
- Size of Battery Bank= (32.66 x (1+20%) x (1+20%) x 1) / (90% x 50%)
- **Size of Battery Bank= 101.3 Amp/Hr**

Step 4: Connection of Battery:

If We Select 120 Amp Hr , 12V DC Battery for Battery Bank:

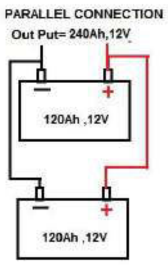
Series Connection:

- Series configurations will add the voltage of the two batteries but keep the amperage rating (Amp Hours) same.
- Condition-I :
- **Selection of Battery for Voltage = Volt of Each Battery <= Volt of Battery Bank**
- Selection of Battery for Voltage =12< 24
- **Condition-I is O.K**
- No of Battery for Voltage = Volt of Battery Bank / Volt of Each Battery
- No of Battery for Voltage =24/12 = **2 No's**
- Condition-II :
- **Selection of Battery for Amp Hr = Amp Hr of Battery Bank <= Amp Hr of Each Battery**
- Selection of Battery for Amp Hr =**101.3<=120**
- **Condition-II is O.K**
- We can use Series Connection for Battery & No of Battery required 2 No's



Parallel Configuration

- In Parallel connection, the current rating will increase but the voltage will be the same.
- More the number of batteries more will be the amp/hour. Two batteries will produce twice the amp/hour of a single battery.
- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Battery Bank / Amp Hr of Each Battery <=1
- Selection of Battery for Amp Hr =101/120 = 0.84=**1 No's**
- **Condition-I is O.K**
- Condition-II :
- **Selection of Battery for Voltage = Volt of Battery Bank = Volt of Each Battery**
- Condition-II :Selection of Battery for Voltage for Amp Hr = **24<=12**
- **Condition-II is Not Full Fill**
- We cannot use Parallel Connection for Battery as per our requirement But If We do Practically It is Possible and it will give more Hours of back



Series-Parallel Connection:

- Connecting the batteries up in series will increase both the voltage and the run time.
- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Each Battery <= Amp Hr of Battery Bank
- Selection of Battery for Amp Hr =120<=101
- **Condition-I is Not Full Fill**
- Condition-II :
- Selection of Battery for Voltage = Volt of Each Battery <= Volt of Battery Bank
- Selection of Battery for Voltage = 12<=24
- **Condition-II is OK**
- We cannot use Parallel Connection for Battery

If We Select 60 Amp Hr , 12V DC Battery for Battery Bank:

Series Connection:

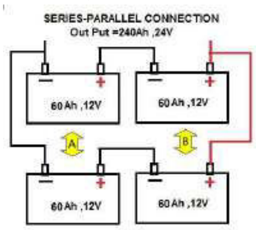
- **Selection of Battery for Voltage = Volt of Each Battery <= Volt of Battery Bank**
- Selection of Battery for Voltage =12< 24
- **Condition-I is O.K**
- No of Battery for Voltage = Volt of Battery Bank / Volt of Each Battery
- No of Battery for Voltage =24/12 = **2 No's**
- Condition-II :
- **Selection of Battery for Amp Hr = Amp Hr of Battery Bank <= Amp Hr of Each Battery**
- Selection of Battery for Amp Hr =**101.3<=60**
- **Condition-II is Not Full Fill**
- We can use Series Connection for Battery

Parallel Configuration

- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Battery Bank / Amp Hr of Each Battery <=1
- Selection of Battery for Amp Hr =101/60 = 1.63=**1 No's**
- **Condition-I is O.K**
- Condition-II :
- **Selection of Battery for Voltage = Volt of Battery Bank = Volt of Each Battery**
- Condition-II :Selection of Battery for Voltage for Amp Hr = **24=12**
- **Condition-II is Not Full Fill**
- We cannot use Parallel Connection for Battery as per our requirement.

Series-Parallel Connection:

- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Each Battery <= Amp Hr of Battery Bank
- Selection of Battery for Amp Hr =120<=60
- **Condition-I is OK**
- No of Battery for Amp Hr = Amp Hr of Battery Bank / Amp Hr of Each Battery
- No of Battery for Amp Hr = 120/60 =1.68 =**2 No's**
- Condition-II :
- Selection of Battery for Voltage = Volt of Each Battery <= Volt of Battery Bank
- Selection of Battery for Voltage = 12<=24
- **Condition-II is OK**
- No of Battery for Voltage = Volt of Battery Bank / Volt of Each Battery
- No of Battery for Voltage = 24 / 12 =**2 No's**
- No of Battery Required = No of Battery Amp Hr x No of Battery for Voltage
- No of Battery Required = 2 x 2= **4 No's**
- We can use Series-Parallel Connection for Battery



Summary

- Total Electrical Load=**380 Watt**
- Total Electrical Load=**475VA**
- **Size of Inverter= 712 VA**
- **Size of Battery Bank= 101.3 Amp/Hr**
- **For 120 Amp/Hr , 12V DC Battery : Series Connection & 2 No's of Battery or**
- **For 60 Amp/Hr , 12V DC Battery : Series-Parallel Connection & 4 No's of Battery**

Chapter: 38 Calculation of Crippling (Ultimate Transverse) Load on Electrical Pole

- Wind Speed = 89 Mile/Hr.
- Height of Pole=10 Meter
- Type of Pole =RCC
- Height of Pole in Ground=1.5 Meter.
- Pole Section on Bottom of Pole (Length x Width)=400mm x 150mm
- Pole Section on Top of Pole (Length x Width)=127mm x 150mm
- Conductor Mounting from top of Pole(g)=0.5 Meter.
- Distance between Two Pole(s) =20 Meter.
- No of Conductor on Pole(n)=3No's
- Size of Conductor(r)= 30mm

Calculations:

- Wind Pressure = 0.00256 x 2x Wind Speed
- Wind Pressure = 0.00256 x 2x 90 = 20.506 Pound /Sq.Foot
- Wind Pressure(Wp) =4.882x20.506 = 100 Kgf/M2
- Wind Load on Conductor/Span(ws)=2/3 x Wp x s x r x n
- Wind Load on Conductor/Span(ws)=2/3 x 100 x 20 x 30 x 3 =**120 Kg-----------(I)**
- Height of Pole Above Ground (h)= 10-1.5 =8.5 Meter
- Total Bending Movement at Ground Level due to Wind Load on All Conductor=ws x h
- Total Bending Movement at Ground Level due to Wind Load on All Conductor(b)=120 x 8.5= 960 Kg.Mt
- Equivalent Safe Working Load at said Meter from TOP of The Pole corresponding to Wind Load on All Conductors =b / (h- g) = 960 / 8.5-0.5 =120 Kg
- Wind Load on Pole Surface above Ground Level (p1)=Wp x h /((l1+w1)/(2x1000))
- Wind Load on Pole Surface above Ground Level (p1)=100x8.5/(400+150/2x1000) =233.75 Kg
- Centre of Gravity of Tapering rectangular section of Pole(p2)= (h/3)x((l2+(l1*2))/(l1+l2))
- Centre of Gravity of Tapering rectangular section of Pole(p2)= (8.5/3)x((127+(400x2)) /(127+400))=4.98Mt
- Bending Movement at Ground Level due to Wind Load on Pole(p) =p1 x p2
- Bending Movement at Ground Level due to Wind Load on Pole(p) =233.75x4.98=1164.98 Kg.Mt
- Equivalent Safe Working Load at said meter from Top of The Pole corresponding to Wind Load on Pole(wt) = p /(h-g) =1164.98 / (8.5-0.5) = **145.62 Kg-----------------------------(II)**
- Total Transverse Load at said meter from Top of The Pole (Due to wind Load on Conductors + Wind Load on Pole Surface) (T)=Ws + Wt = 120+145.62 =256.62 Kg

Type of Pole	Safety Factor
Wooden Pole	3.5
RCC Pole	2.5
PCC Pole	2.5
Steel Tubular Pole	2
Rail/RSJ Pole	2
Struts (Steel Pole)	2.5
Struts (RCC/PCC)	3
PCC Pole for 33 KV	2

- From Above Table Safety Factor=2.5
- Total Transverse Load (Crippling Load) of Pole = T x Safety Factor
- Total Transverse Load (Crippling Load) of Pole = 256 x 2.5 =664 Kg.
- **Total Transverse Load (Crippling Load) of Pole=664 Kg**

Max. Length of Pole (Meter)	Min. Ultimate Transverse Load from 0.6meter from Top (Kg)
17	3000
17	2300

17	2000
17	1400
16	1100
15	1050
14	1050
13	1000
12	800
11	600
10	500
9	300
8	200
7	200
6	200
5	150
4	150
3	150

- From Above Table Min. Ultimate **Transverse Load for 10 Meter Pole = 500 Kg and as per our calculation it is 664 Kg hence Selection of Pole if O.K**

Results:

- **Calculated Transverse Load (Crippling Load) of Pole = 664 Kg**

Chapter: 39 Calculate Size of Ventilation Fan:

- Calculate Size of Ventilation Fan for Bathroom of 10 Foot Long,15 Foot width and 10-foot height.

Calculation:

- Area of the Room=Length x Width x Height
- Area of the Room=10 x 15 x 10 =1500 Cub. Foot
- From the table Air Changing Rate (ACH) for Bathroom = 8 Times/Hour.
- **Size of Ventilation Fan = (Area of Room x ACH) / 60**
- Size of Ventilation Fan = (1500 x 8) / 60 = 200 CFM
- **Size of Ventilation Fan = 200 CFM**

Recommended Air Change Rates For Room (ACH)		
Type of Room	**Air Change Rate /Hour**	**Consider**
Shower Area	15 To 20	**20**
Bathroom & Shower Rooms	15 To 20	**15**
Bathroom	6 To 10	**8**
Bedrooms	2 To 4	**4**
Halls & Landings	4 To 6	**5**
Kitchens	10 To 20	**15**
Living & Other Domestic Rooms	4 To 6	**5**
Toilets - Domestic	6 To 10	**8**
Utility Rooms	15 To 20	**15**
Cafés	10 To 15	**15**
Canteens	8 To 12	**10**
Cellars	3 To 10	**6**
Changing Rooms with Showers	15 To 20	**15**
Conference Rooms	8 To 12	**8**
Garages	6 To 10	**8**
Hairdressing Salons	10 To 15	**13**
Hospital Wards	6 To 8	**7**
Laundries & Launderettes	10 To 15	**13**
Meeting Rooms	6 To 12	**7**
Offices	4 To 6	**6**
Restaurants & Bars	10 To 15	**12**
School Rooms	5 To 7	**6**
Shops	8 To 10	**9**
Sports Facilities	4 To 6	**6**
Store Rooms	3 To 6	**5**
Workshops	6 To 10	**8**
Assembly rooms	4 To 8	**8**
Bakeries	20 To 30	**25**
Banks/Building Societies	4 To 8	**5**
Billiard Rooms *	6 To 8	**5**
Boiler Rooms	15 To 30	**25**
Canteens	8 To 12	**10**
Changing Rooms Main area	6 To 10	**8**
Changing Rooms Shower area	15 To 20	**17**
Churches	1 To 3	**3**
Cinemas and theatres *	10 To 15	**12**
Club rooms	0.12	**0.12**
Compressor rooms	10 To 15	**15**

Conference rooms	8 To 12	**12**
Dairies	8 To 10	**10**
Dance halls	0.12	**0.12**
Dental surgeries	12 To 15	**15**
Dye works	20 - 30	**30**
Electroplating shops	10 To 12	
Engine rooms	15 To 30	**30**
Entrance halls & corridors	3 To 5	**5**
Factories and workshops	8 To 10	**10**
Foundries	15 To 30	**20**
Glasshouses	25 To 60	**50**
Gymnasiums	0.6	**0.6**
Hospitals - Sterilizing	15 To 25	**20**
Kitchens - Domestic	15 To 20	**15**
Kitchens - Commercial	0.3	**0.3**
Laboratories	6 To 15	**12**
Lavatories	6 To 15	**12**
Lecture theatres	5 To 8	**8**
Libraries	3 To 5	**4**
Mushroom houses	6 To 10	**8**
Paint shops (not cellulose)	10 To 20	**15**
Photo & X-ray darkrooms	10 To 15	**12**
Public house bars	0.12	**0.12**
Recording control rooms	15 To 25	**20**
Recording studios	10 To 12	**10**
Shops and supermarkets	8 To 15	**12**
Squash courts	0.04	**0.04**
Swimming baths	10 To 15	**12**
Welding shops	15 To 30	**20**

Chapter: 40 Calculate Motor-Pump Size:

- Calculate Size of Pump having following Details
- Static Suction Head(h2)=0 Meter
- Static Discharge Head (h1)=50 Meter.
- Required Amount of Water (Q1)=300 Liter/Min.
- Density of Liquid (D) =1000 Kg/M3
- Pump Efficiency (pe)=80%
- Motor Efficiency(me)= 90%
- Friction Losses in Pipes (f)=30%

Calculations:

- Flow Rate (Q) =Q1x1.66/100000 =300x1.66/100000= 0.005 M3/Sec
- Actual Total Head (After Friction Losses) (H) = (h1+h2)+((h1+h2)xf)
- Actual Total Head (After Friction Losses) (H)=50+(50x30%)= 65 Meter.
- **Pump Hydraulic Power (ph) = (D x Q x H x9.87)/1000**
- Pump Hydraulic Power (ph) = (1000 x 0.005 x 65 x9.87)/1000 =**3KW**
- Motor/ Pump Shaft Power (ps)= ph / pe = 3 / 80% = **4KW**
- Required Motor Size: ps / me =4 / 90% = **4.5 KW**
- **Required Size of Motor Pump = 4.5 HP or 6 HP**

Chapter: 41 Calculate Size of Anchor Fastener:

Calculate Size of Anchor fastener for Cable Tray Support having following Details

- **CABLE TRAY DETAIL:**
- Size of Cable Tray=600mm Ladder Type Cable Tray
- Weight of Cable Tray=120 kg/meter
- **CABLE DETAILS (LAID IN CABLE TRAY)**
- Size of Cable =3.5Cx300 Sq.mm, Alu, XLPE, Armored Cable
- No of Cable / Cable tray= 6 No's
- Weight of Cable = 5.9 Kg/meter
- Size of Cable =3.5Cx150 Sq.mm, Alu, XLPE, Armored Cable
- No of Cable / Cable tray= 2 No's
- Weight of Cable = 4.5 Kg/meter.
- **CABLE TRAY SUPPORT DETAILS**
- Cable Tray Support installed at 1 Meter of Cable Tray
- Weight of Cable Tray Support =5.8 Kg/meter
- Safety Factor=5

CALCULATIONS

- Weight of Cable Tray Support = No of Support X Weight of Support
- Weight of Cable Tray Support =1x5.8 Kg/Meter
- Weight of Cable Tray Support =5.8 Kg/Meter---------(A)
- Weight of Cable Tray = No of Cable Tray X Weight of Tray
- Weight of Cable Tray =1x120
- Weight of Cable Tray =120 Kg/Meter---------(B)
- Weight of 3.5Cx300 Sq.mm Cable = No of Cable X Weight of Cable
- Weight of 3.5Cx300 Sq.mm Cable =6x5.9
- Weight of 3.5Cx300 Sq.mm Cable =35.4 Kg/Meter---------(C1)
- Weight of 3.5Cx150 Sq.mm Cable = No of Cable X Weight of Cable
- Weight of 3.5Cx150 Sq.mm Cable =2x4.5
- Weight of 3.5Cx150 Sq.mm Cable =9 Kg/Meter---------(C2)
- Total Weight =Safety Factor X (Weight of Cable Tray support + Weight of Cable Tray + Weight of Cables)
- Total Weight =5X (5.8+120+35.4+9) Kg/Meter
- Total Weight=851 Kg/Meter-----------------(1)
- Consider 4 No of 10mm size of Anchor Fastner having Basic Tensile Load Capacity of 5KN at each Support.
- Total Tensile Load= No of Anchor Fastner X 101.97XAnchor Tensile Load Capacity (KN)
- Total Tensile Load=4x101.97x5
- Total Tensile Load=1876 Kg/Meter------------(2)

Here Total Tensile Load Capacity of Anchor Fastner (1876 Kg/Meter) > Total Weight (851 Kg/Meter) hence Size of Anchor Fastner is OK

Chapter: 42 Calculate Size of Diesel Generator:

Calculate Size of Diesel Generator set for following types of various equipment's

D.G Set Detail:

- D.G Set Phase-Phase Voltage=415V, Phase-Neutral Voltage=230V, Future Load expansion=10%, D.G overload capacity =130%.

Connected Load:

- Fire Fighting Pump: 1No,3 Phase, 90KW, starting P.F is 0.7 & running P.F is 0.8, Soft Starter, Continuous use.
- HVAC Load: 1No, 3 Phase, 20KW, starting P.F is 0.7 & running P.F is 0.8, Intermediate use.
- UPS Load: 1No, 3 Phase, 7KW, starting P.F is 0.7 & running P.F is 0.8, Continuous use.
- Lighting Load: 10No, 1Phase ,400Watt, starting P.F is 0.7 & running P.F is 0.8, Continuous use.
- Linear Load =General Electrical equipment, Heater
- Non-Linear Load = UPS, Inverter, Ballast, Drives

CALCULATION:

LOAD NO:1 (MOTOR LOAD)

- **Total Load (KW)= No of Equipment X Size of Equipment**
- Total Load (KW)=01x90 =90KW
- **Diversify Load (KW)= Total Load X Duty factor (0=Stand by Load,1=continuous Load, 0 to 1 =Intermediate Load)**
- Diversify Load (KW) = 90x1= 90KW-------------------------------------(1)
- Running KVA = Diversify Load (KW) / Running P.F
- Running KVA = 90 x 0.8
- Running KVA =113 KVA-------------------------------------(2)
- Running Amp (Amp) = Diversify Load (KW) / 1.732 x Volt x Running P.F
- Running Amp (Amp) =90x1000 / 1.732 x 415 x 0.8
- Running Amp (Amp) =156.7 Amp
- Starting Amp = Running Amp X Multiplying Factor of Starter
- Multiplying Factor of Starter is as under.

Starter Starting current	
Method	**Starting current**
Direct-on-Line (DOL)	5 to 10 times the full load current
Star-Delta Starter	3 to 4 times the full load current
Auto-transformer	2 to 3 times the full load current
Soft starter	1.1 to 2 times full load current
Variable Speed drive	1.1 to 1.5 times full load current

- Considering Multiplying Factor for Soft Starter is 2
- Starting Amp = 156.7 X 2
- Starting Amp =313Amp
- Starting KVA = (Diversify Load (KW) / Starting P.F) X Multiplying Factor of Starter
- Starting KVA = (90/0.7) X 2
- **Starting KVA = 257 KVA---(3)**

LOAD NO:2 (HVAC LOAD)

- **Total Load (KW)= No of Equipment X Size of Equipment**
- Total Load (KW)=01x20 =20KW
- **Diversify Load (KW)= Total Load X Duty factor (0=Stand by Load,1=continuous Load, 0 to 1 =Intermediate Load)**
- Diversify Load (KW) = 20x0.8= 16KW-------------------------------------(4)
- Running KVA = Diversify Load (KW) / Running P.F
- Running KVA = 16 x 0.8
- Running KVA =20 KVA-------------------------------------(5)
- Running Amp (Amp) = Diversify Load (KW) / 1.732 x Volt x Running P.F
- Running Amp (Amp) =16x1000 / 1.732 x 415 x 0.8

- Running Amp (Amp) =28 Amp
- Starting Amp = Running Amp X Multiplying Factor of HVAC
- Multiplying Factor of Starting Current for various type of Load is as under.

Starting current	
Type of Load	**Starting current for Load**
Linear	1 time the full load current
Non-Linear	1.2 to 1.6 times the full load current
HVAC	1.2 to 1.5 times the full load current

- Considering Multiplying Factor of HVAC is 1.3
- Starting Amp = 28X 1.3
- Starting Amp =36Amp
- Starting KVA = (Diversify Load (KW) / Starting P.F) X Multiplying Factor of HVAC
- Starting KVA = (16/0.7) X1.3
- **Starting KVA = 30 KVA--(6)**

LOAD NO:3 (NON-LINEAR LOAD)

- **Total Load (KW)= No of Equipment X Size of Equipment**
- Total Load (KW)=01x7 =7KW
- **Diversify Load (KW)= Total Load X Duty factor (0=Stand by Load,1=continuous Load, 0 to 1 =Intermediate Load)**
- Diversify Load (KW) = 7x1= 7KW-----------------------------------(7)
- Running KVA = Diversify Load (KW) / Running P.F
- Running KVA = 7 x 0.8
- Running KVA =9 KVA------------------------------------(8)
- Running Amp (Amp) = Diversify Load (KW) / 1.732 x Volt x Running P.F
- Running Amp (Amp) =7x1000 / 1.732 x 415 x 0.8
- Running Amp (Amp) =12 Amp
- Starting Amp = Running Amp X Multiplying Factor of Non-Linear Load
- Multiplying Factor of Starting Current for various type of Load is as under.

Starting current	
Type of Load	**Starting current for Load**
Linear	1 time the full load current
Non-Linear	1.2 to 1.6 times the full load current
HVAC	1.2 to 1.5 times the full load current

- Considering Multiplying Factor of Non-Linear Load (UPS) is 1.6
- Starting Amp = 12X 1.6
- Starting Amp =19Amp
- Starting KVA = (Diversify Load (KW) / Starting P.F) X Multiplying Factor of HVAC
- Starting KVA = (7/0.7) X1.6
- **Starting KVA = 16 KVA--(9)**

LOAD NO:4 (LINEAR LOAD)

- **Total Load (KW)= No of Equipment X Size of Equipment**
- Total Load (KW)=10x0.4 =4KW
- **Diversify Load (KW)= Total Load X Duty factor (0=Stand by Load,1=continuous Load, 0 to 1 =Intermediate Load)**
- Diversify Load (KW) = 4x1= 4KW-----------------------------------(10)
- Running KVA = Diversify Load (KW) / Running P.F
- Running KVA = 4 x 0.8
- Running KVA =5 KVA------------------------------------(11)
- Running Amp (Amp) = Diversify Load (KW) / 1.732 x Volt x Running P.F
- Running Amp (Amp) =4x1000 / 230 x 0.8
- Running Amp (Amp) =22 Amp
- Starting Amp = Running Amp X Multiplying Factor of Linear Load

- Multiplying Factor of Starting Current for various type of Load is as under.

Starting current	
Type of Load	**Starting current for Load**
Linear	1 time the full load current
Non-Linear	1.6 times the full load current
HVAC	1.2 to 1.5 times the full load current

- Considering Multiplying Factor of Linear Load is 1
- Starting Amp =22x1
- Starting Amp =22Amp
- Starting KVA = (Diversify Load (KW) / Starting P.F)
- Starting KVA = (4/0.7)
- **Starting KVA = 6 KVA---(12)**

TOTAL LOAD CALCULATION:

- Total Starting KVA= Starting KVA of (Load 1+ Load 2+ Load 3 +Load 4)
- Total Starting KVA= 257+30+16+6
- **Total Starting KVA= 309 KVA------------------------------------(A)**
- Total Running KVA =Running KVA of (Load 1+ Load 2+ Load 3 +Load 4)
- Total Running KVA =113+20+9+5
- **Total Running KVA = 146 KVA----------------------------(B)**
- **D.G set Size (KVA) = Total Starting KVA x Future Load Expansion.**
- D.G set Size (KVA) = 309x1.1 (10% Future expansion)
- **D.G set Size (KVA) = 339 KVA--(C)**

CONDITION FOR SELECTING D.G SET:

- **CONDITION-1:**
- **Total Non-Linear Load < 30% of D.G Size**
- Here Value no (9) < Value no (C)
- 16 KVA < 102 KVA
- Condition-1 is full fill
- **CONDITION-2:**
- **Overloads withstand Capacity of D.G > Total Required starting KVA**
- **Overload withstand capacity of D. G= D.G size X D.G over Load Capacity**
- Overload withstand capacity of D. G= 339 x 130%
- Overload withstand capacity of D. G= 401 KVA-------------------(D)
- **Total Required starting KVA = Total Load (KVA) -Largest Motor rating (KVA)+ Largest Motor starting (KVA)**
- Total Required starting KVA =146 -113+257
- Total Required starting KVA =291 KVA ------------------------(E)
- Here Value no (D) > Value no (E)
- 401 KVA > 291 KVA
- Condition-2 is full fill

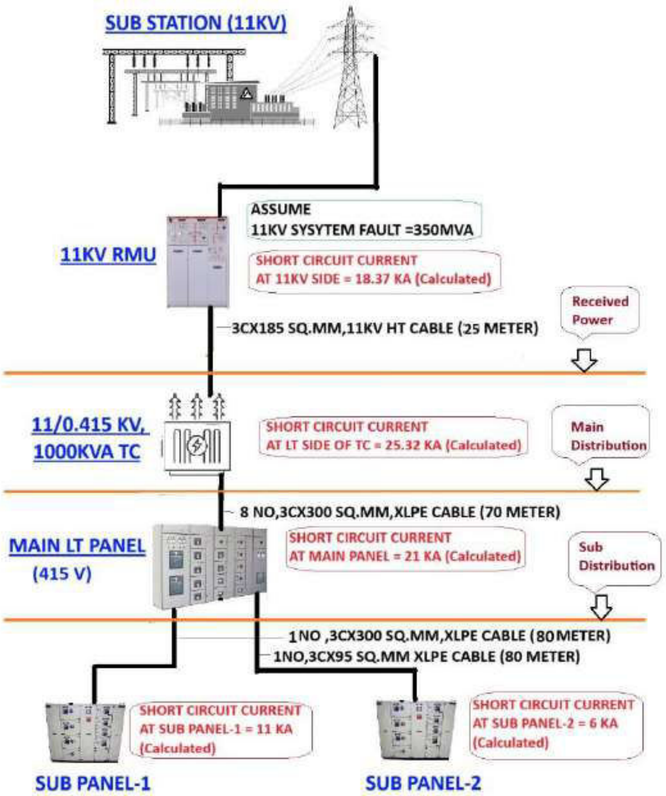
CONCLUSION:

- Here Condition-1 & Condition-2 is full fill hence selected D.G Size is OK.
- **Hence D.G size is 339 KVA or near its 380 KVA**

Chapter: 43 Calculate Short Circuit Current at Sub Panel (End User)

EXAMPLE:

- Calculate short circuit current at Electrical Equipment Panel / Distribution Board at end user side.
- HT Power is received by 11KV RMU and given to 11/0.415KV,1000KVA Transformer by 1 no of 3Cx185 Sq.mm 11KV HT Cable of 25 Meter Length.
- Resistance and Reactance of HT cable are 0.21 Ω / KM and 0.1 Ω / KM
- Transformer impedance is 6.25%.
- LT Side of Transformer is connected to Main LT Panel by 8 no of 3.5Cx300 Sq.mm, XLPE cable of 70 Meter.
- Resistance and Reactance of 3.5Cx300 Sq.mm, XLPE cable are 0.129 Ω / KM and 0.071 Ω / KM.
- Main LT Panel is connected to Sub Panel-1 by 1 no of 3.5Cx300 Sq.mm, XLPE cable of 80 Meter.
- Resistance and Reactance of 3.5Cx300 Sq.mm, XLPE cable are 0.129 Ω / KM and 0.071 Ω / KM.
- Main LT Panel is connected to Sub Panel-2 by 1 no of 3.5Cx95 Sq.mm, XLPE cable of 80 Meter.
- Resistance and Reactance of 3.5Cx95 Sq.mm, XLPE cable are 0.409 Ω / KM and 0.072 Ω / KM.
- Calculate Short circuit Current at Sub Panel-1 & Sub Panel-2.



CALCUALTION

- Short Circuit Current is calculated at various points of Power Distribution Networks, At Power Receiving Point (11KV), At Main Panel Point (0.415V) and At Sub Distribution Point (0.415V)

(1) SHORT CIRCUIT CURRENT AT 11 KV PANEL / RMU:

- Assume that 11KV Side System Fault MVA is 350 MVA.
- **Shor Circuit Current at 11KV System = Fault MVA / 1.732 x System Voltage at Fault Point.**
- Shor Circuit Current at 11KV System = 350 / 1.732 x 11.
- **Shor Circuit Current at 11KV System = 18.37 KA.**

(2) SHORT CIRCUIT CURRENT AT TRANSFORMER:

- To calculate Short Circuit Current at Transformer Side, First We need to sum Impedance of the system up to Transformer (Impedance of HT Source +Impedance of HT Cable + Impedance of Transformer).
- Transformer Capacity is 1000 KVA
- Base MVA = TC Size / 1000
- Base MVA = 1000 / 1000

- Base MVA = 1 MVA or
- **Base KVA = 1000 KVA**
- % Impedance of Source = Base MVA x100 / System Fault MVA
- % Impedance of Source = 1 x100 / 350
- % Impedance of Source = 0.29 Ώ / KM.-------------------------------(A)
- **CALCULATE % RESISTANCE & REACTANCE OF CABLE (185 SQ.MM HT CABLE)**
- **% Resistance of Cable =Base KVA (TC Capacity) x Cable Resistance x No of Run x Length of Cable / System Voltagex2x10.**
- % Resistance of Cable =1000 x 0.21 x 1 x 25 / 11x2x10
- % Resistance of Cable =0.004339 % Ώ
- **% Reactance of Cable =Base KVA (TC Capacity) x Cable Reactance x No of Run x Length of Cable / System Voltagex2x10.**
- % Reactance of Cable =1000 x 0.1 x 1 x 25 / 11x2x10
- % Reactance of Cable =0.002066 % Ώ
- **% Impedance of Cable =$\sqrt{}$ $R^2 + X^2$**
- % Impedance of Cable =$\sqrt{}$ $(0.004339)^2 + (0.002066)^2$
- % Impedance of Cable =0.00481 % Ώ.
- Considering 10% Tolerance in Transformer Impedance
- **% Impedance of Transformer = Impedance of Transformer – 10% Variation of Transformer Impedance**
- % Impedance of Transformer = 6.25 -(6.25X10%)
- % Impedance of Transformer =5.63 % Ώ.
- **Total % Impedance up to Transformer = % Impedance of Source +%Cable Impedance + % Transformer Impedance**
- Total % Impedance up to Transformer = 0.29+0.00481+5.63 % Ώ.
- Total % Impedance up to Transformer = 5.92% Ώ. -------------------------(A)
- **Fault KVA on LT Side of Transformer = Base MVA of Transformer x100 / Total % Impedance up to Transformer.**
- Fault KVA on LT Side of Transformer = 1 x100 / 5.92.
- Fault KVA on LT Side of Transformer = 16.9 KVA.
- **Short Circuit Current at Transformer LT Side= Fault KVA / 1.732 x System Voltage at Fault Point.**
- Short Circuit Current at Transformer LT Side= 16.9 / 1.732 x 0.415
- **Short Circuit Current at Transformer LT Side= 25.32 KA**

(3) SHORT CIRCUIT CURRENT AT MAIN LT PANEL:

- To calculate Short Circuit Current at Main LT Panel, we need to sum Impedance of the system up to Main LT Panel (Total Impedance up to Transformer LT Side + Impedance of LT Cable).
- Total % Impedance up to Transformer LT Side= 5.92% Ώ.
- **CALCULATE % RESISTANCE & REACTANCE OF CABLE (300 SQ.MM)**
- **% Resistance of Cable =Base KVA (TC Capacity) x Cable Resistance x Length of Cable / System Voltagex2x10.**
- % Resistance of Cable =1000 x 0.129 x 1 x 70 / 0.415 x 2 x10
- % Resistance of Cable =0.66 % Ώ
- **% Reactance of Cable =Base KVA (TC Capacity) x Cable Reactance x No of Run x Length of Cable / System Voltage x 2 x10.**
- % Reactance of Cable =1000 x 0.071 x 8 x 70 / 0.415x2x10
- % Reactance of Cable =0.36 % Ώ
- **% Impedance of Cable =$\sqrt{}$ $R^2 + X^2$**
- % Impedance of Cable =$\sqrt{}$ $(0.66)^2 + (0.36)^2$
- % Impedance of Cable =0.747 % Ώ.-------------------------------(B)
- **Total % Impedance up to Main LT Panel = % Impedance up Transformer +%Cable Impedance**
- Total % Impedance up to Main LT Panel = = 5.92+0.747 % Ώ.
- Total % Impedance up to Main LT Panel = = 6.662% Ώ. -------------------------(B)
- **Fault KVA on Main LT Panel= Base MVA x100 / Total % Impedance.**
- Fault KVA on LT Side of Transformer = 1 x100 / 6.662.
- Fault KVA on LT Side of Transformer = 15.01 KVA.
- **Short Circuit Current at Main LT Panel = Fault KVA / 1.732 x System Voltage at Fault Point.**
- Short Circuit Current at Main LT Panel = 15.01 / 1.732 x 0.415
- Short Circuit Current at Main LT Panel = 20.88 KA.
- **Short Circuit Current at Main LT Panel = 21 KA**

(4) SHORT CIRCUIT CURRENT AT SUB PANEL-1:

- To calculate Short Circuit Current at Sub Panel-1, We need to sum Total Impedance of the system up to Sub Panel-1 (Total Impedance up to Main LT Panel + Impedance of LT Cable-1).
- Total % Impedance up to Main LT Panel= 6.662 % Ώ. (Calculated as per (B))
- **CALCULATE % RESISTANCE & REACTANCE OF CABLE-1 (300 SQ.MM)**
- **% Resistance of Cable =Base KVA (TC Capacity) x Cable Resistance x Length of Cable / System Voltagex2x10.**
- % Resistance of Cable =1000 x 0.129 x 1 x 80 / 0.415 x 2 x10
- % Resistance of Cable =5.99 % Ώ
- **% Reactance of Cable =Base KVA (TC Capacity) x Cable Reactance x No of Run x Length of Cable / System Voltage x 2 x10.**
- % Reactance of Cable =1000 x 0.071 x 1 x 80 / 0.415x2x10
- % Reactance of Cable =3.27 % Ώ
- **% Impedance of Cable =$\sqrt{R^2 + X^2}$**
- % Impedance of Cable =$\sqrt{(5.99)^2 + (3.27)^2}$
- % Impedance of Cable =6.82 % Ώ.--------------------------------(B)
- **Total % Impedance up to Sub Panel-1 = % Impedance up Main LT Panel +%Cable Impedance**
- Total % Impedance = 5.92+6.82 % Ώ.
- Total % Impedance = 13.49% Ώ.
- **Fault KVA on Sub Panel-1= Base MVA x100 / Total % Impedance.**
- Fault KVA on Sub Panel-1 = 1 x100 / 13.49.
- Fault KVA on Sub Panel-1 = 7.41 KVA.
- **Short Circuit Current at Sub Panel-1 = Fault KVA on Sub Panel-1 / 1.732 x System Voltage at Fault Point.**
- Short Circuit Current at Sub Panel-1 = 7.41 / 1.732 x0.415.
- Short Circuit Current at Sub Panel-1 = 10.33 KA.
- **Short Circuit Current at Sub Panel-1 = 11 KA**

(5) SHORT CIRCUIT CURRENT AT SUB PANEL-2:

- To calculate Short Circuit Current at Sub Panel-2, We need to sum Total Impedance of the system up to Sub Panel-2 (Total Impedance up to Main LT Panel + Impedance of LT Cable-2).
- Total % Impedance up to Main LT Panel= 6.662 % Ώ. (Calculated as per (B))
- **CALCULATE % RESISTANCE & REACTANCE OF CABLE-2 (95 SQ.MM)**
- **% Resistance of Cable =Base KVA (TC Capacity) x Cable Resistance x Length of Cable / System Voltagex2x10.**
- % Resistance of Cable =1000 x 0.409 x 1 x 80 / 0.415 x 2 x10
- % Resistance of Cable =19 % Ώ
- **% Reactance of Cable =Base KVA (TC Capacity) x Cable Reactance x No of Run x Length of Cable / System Voltage x 2 x10.**
- % Reactance of Cable =1000 x 0.072 x 1 x 80 / 0.415x2x10
- % Reactance of Cable =3.36 % Ώ
- **% Impedance of Cable =$\sqrt{R^2 + X^2}$**
- % Impedance of Cable =$\sqrt{(19)^2 + (3.36)^2}$
- % Impedance of Cable =19.294 % Ώ.
- **Total % Impedance up to Sub Panel-2 = % Impedance up Main LT Panel +%Cable Impedance**
- Total % Impedance up to Sub Panel-2 = 6.662+19.294 % Ώ.
- Total % Impedance up to Sub Panel-2 = 25.956% Ώ.
- **Fault KVA on Sub Panel-2 = Base MVA x100 / Total % Impedance up to Sub Panel-2.**
- Fault KVA on Sub Panel-2 = 1 x100 / 25.956.
- Fault KVA on Sub Panel-2 = 3.85 KVA.
- **Short Circuit Current at Sub Panel-2 = Fault KVA on Sub Panel-2 / 1.732 x System Voltage at Fault Point.**
- Short Circuit Current at Sub Panel = 3.85 / 1.732 x 415.
- Short Circuit Current at Sub Panel = 5.36 KA.
- **Short Circuit Current at Sub Panel-2 = 6 KA**

CONCLUSION:

- Shor Circuit Current at 11KV System = 18.37 KA.
- Short Circuit Current at Transformer LT Side= 25.32 KA
- Short Circuit Current at Main LT Panel = 21 KA
- Short Circuit Current at Sub Panel-1 = 11 KA
- Short Circuit Current at Sub Panel-2 = 6 KA

Chapter: 44 Calculate Diesel Generator Protection Setting

Generator Protection

- Recommended Generator Protection are

Recommended Generator Protection	
ANSI Code	**Protection Function**
27	Under Voltage
32	Reverse Power
37	Under Power
40	Loss of Excitation
46	Negative Phase Sequence /Un Balance Load
49T	Thermal Overload
50	Instantaneous Over Current
51	Time grade Over Current
51G	Earth Fault Time Overcurrent
50/51V	Voltage Restrained Overcurrent
59	Over voltage
60G	Fuse Failure Monitor
64S	Stator Earth Fault Protection
81	Under / Over Frequency
87	Three Phase Current Differential
87N	Neutral Current Differential
87G	Generator Differential Protection
24G	Over excitation (Volt/Hertz) Protection
21G	Impedance Protection
59N or 64G1	Stator EF protection (0-95%)
27TN or 64G2	Stator EF protection (100%)
50BF	Breaker Failure Protection
24G	Over excitation (Volt/Hertz) Protection
78G	Pole slip protection

Protection Setting Calculation:

(1) Under Voltage Relay (27):

- The Under Voltage Relay measure either phase-to-phase (Ph-Ph) or phase-to-neutral (Ph-N) fundamental RMS voltage depending on the input voltage setting. If the value of measured voltages deviates from the setting values, then these relays will give a trip indication.
- **Reason:**
- An under-voltage condition in a diesel generator can occur due to several reasons, overloading the generator beyond its capacity, faulty Automatic Voltage Regulator (AVR), issues with the stator windings, problems with the voltage sampling line, loose connections, low engine speed, fuel problems, and issues with the excitation system
- **Setting:**
- The Typical under-voltage setting is usually **80 % of the normal rated voltage.** If the voltage falls below this level for the set amount of time, then the tripping command is issued by the relay and hence the system is isolated. The time setting is used to avoid tripping due to any transient disturbances. the exact setting can vary depending on the specific generator and system requirements.
- Usually, motors stall at below 80% of their rated voltage. An under-voltage element can be set to trip motor circuits once fall below 80% so that on the restoration of supply an overload is not caused by the simultaneous starting of all the motors.
- Normally Generators are designed to operate continuously at minimum voltage of 95% of its rated voltage.
- Two levels of tripping are provided depending on the severity of the condition, these under voltage elements are blocked from tripping when the generator breaker is open to allow for startup conditions.
- **Calculation:**
- For 415V Diesel Generator
- Level 1 (Slow)= 80% of Rated Voltage
- Level 1 (Slow)= 80% x 415V =**332 V**
- Time Delay = 2.5 sec.
- Level 2 (Fast): 70% of Rated Voltage
- Level 2 (Fast)= 70% x 415V =**290 V**
- Time Delay = 1.0 sec.

(2) Over Voltage Protection [59]:

- The Over Voltage Relay measure either phase-to-phase (Ph-Ph) or phase-to-neutral (Ph-N) fundamental RMS voltage depending on the input voltage setting. If the value of measured voltages deviates from the setting values, then these relays will give a trip indication.
- **Reason:**
- System over voltages can damage the insulation of components. Over voltages occur due to sudden loss of load, improper working of tap changer, Generator AVR malfunction, Reactive component malfunctions, etc.
- **Setting:**
- The Overvoltage setting is usually **110 to 130 % of the normal operating voltage** depending on the system requirement.
- If the voltage rises above this level for the set amount of time then the tripping command issued by the relay and hence the system is isolated. The time setting is used to avoid tripping due to any transient disturbances.
- **Calculation:**
- For 415V Diesel Generator
- Level 1 (Slow)= 110% of Rated Voltage
- Level 1 (Slow)= 110% x 415V =**456 V**
- Time Delay = 2.5 sec.
- Level 2 (Fast): 130% of Rated Voltage
- Level 2 (Fast)= 130% x 415V =**539 V**
- Time Delay = 1.0 sec.

(3) Reverse Power Protection [32R]:

- Reverse power relay is an electronic, microprocessors-based protection device which is used for monitoring and stopping the power supply flowing grid side to the DG side or generator running in parallel with another generator. If accidentally leakage current is received by generator, then it can start to running as motor. This situation may be very dangerous for generator set.

- The function of the reverse power relay is to prevent a reverse power condition in which power flows from the bus bar into the generator.
- This condition can occur when there is a failure in the prime mover such as an engine or a turbine which drives the generator.
- Relay detects the reverse flow of power from the load back to the generator, which can occur during system faults or abnormal operating conditions. By sensing this reverse power flow, the relay triggers a protective action, typically disconnecting the generator to prevent further issues.
- The generator are classified by their Prime Mover which determine the amount of Reverse power they can motor.

Sr. No	Prime Mover	Motorizing Power in % of Unit Rating
1	Gas Turbine (single shaft)	100%
2	Gas Turbine (Double Shaft)	10-15%
3	4 Cycle Diesel	15%
4	2 Cycle Diesel	25%
5	Hydraulic Turbine	2-100
6	Steam Turbine (Conventional)	1-4%
7	Steam Turbine (Cond Cooled)	0.5 to 1.0%

- **Reason:**
- When Two or more unit running in parallel
- In LT panel if the DG supply is running then grid supply should be switched off and if the grid supply is running then DG supply should be switched off. When one source is on then second source accidentals starts to leakage current resultant a large fault may be occurred and system can be failed. So, for prevention of other source leakage the RPR relay is used.
- **Failure of Speed controller or another breakdown**. When the prime mover of a generator running in a synchronized condition fails. There is a condition known as motoring, where the generator draws power from the bus bar, runs as a motor and drives the prime mover. This happens as in a synchronized condition all the generators will have the same frequency. Any drop in frequency in one generator will cause the other power sources to pump power into the generator. The flow of power in the reverse direction is known as the reverse power relay.
- **Synchronization.** If the frequency of the machine to be synchronized is slightly lesser than the bus bar frequency and the breaker is closed, power will flow from the bus bar to the machine. Hence, during synchronization(forward), frequency of the incoming machine is kept slight higher than that of the bus bar i.e. the synchroscope is made to rotate in the "Too fast" direction. This ensures that the machine takes on load as soon as the breaker is closed.
- Loss of excitation:
- Failure of AVR
- **Setting:**
- A generator reverse power relay setting is typically set between **2% and 8%** of the generator's rated power, depending on the type of prime mover (like a diesel engine or steam turbine), with diesel engines generally requiring a higher setting (around 8%) compared to turbines (around 2 to 5%) to prevent unnecessary tripping during transient conditions; this setting essentially determines the threshold at which the relay will activate to protect the generator from reverse power flow, which can damage the machine if it becomes too significant.
- **Calculation:**
- Generator capacity :500KVA ,415V,0.9 Power factor
- Full Load Current =500x1000/(1.732*415)
- Full Load Current =695A

- Setting at 5%
- Reverse Power = -5%*500*0.9 = -22.5KW
- Relay Setting= Reverse Power / Real Power =-22.5 / 500 =-4.50%
- Relay Setting =-4.50%
- Time delay proposed=5 sec

(4) Negative Phase Sequence (Unbalance Phase) Relay (46):

- The Negative Sequence Overcurrent function provides protection against possible rotor overheating and damage due to unbalanced faults or other system conditions which can cause unbalanced three phase currents in the generator.
- Negative Phase Sequence detects imbalances in the network that does not cause energy loss out of the system.
- **Reason:**
- Generator or Motor are design to operate in balance three phase loading.
- Generator negative phase sequence currents can result from any unbalance condition on the system including un transposed lines, single phase loads, unbalanced type line faults and open conductors. the unbalance condition leads negative sequence currents having opposite rotation that of power system in generator leads. This reversed rotating current produce double frequency current in rotor structure. This resulting over heating of rotor.
- **Setting:**
- A generator Negative Phase Sequence (NPS) relay setting is typically set between **2 to 10% of the full load current** depending on the specific generator design and manufacturer's recommendations, aiming to detect significant unbalances in the power system while avoiding unnecessary tripping due to normal load variations; this setting should be based on the generator's maximum allowable negative sequence I^2 (current squared) value to prevent excessive rotor heating.
- Generator withstand limit against negative sequence overcurrent (K) = 10 (As per IEC-60034-1)
- Normally Generator continuous withstand limit: 8 %
- **Calculation:**
- Generator capacity :500KVA ,415V , CT is 800/1
- Full Load Current =500x1000/(1.732*415)
- Full Load Current =695A
- Setting at 10% .
- Desired pickup current = 10% of rated current
- Relay setting = (0.1 x Rated Current) / CT ratio
- Relay setting =(0.1x695) / 800
- Relay setting =0.0868A

(5) Thermal Overload Relay (49T):

- In general, generators can operate successfully at rated kVA, frequency, and power factor for a voltage variation of 5% above or below rated voltage. Under emergency condition, it is possible to exceed the continuous output capability for a short time.
- The stator overload function provides protection against possible damage during overload conditions.
- **Reason:**
- A generator becomes overloaded when too many appliances or devices are plugged in and drawing power simultaneously, exceeding the generator's rated capacity, often happening when attempting to power heavy appliances like air conditioners, heaters, or electric stoves at the same time; essentially, drawing more power than the generator can supply.
- **Peak usage times:** Running multiple high-power appliances simultaneously.
- **Damaged components:** Faulty electrical components within the generator can contribute to overload issues.
- **Improper load management:** Not prioritizing which appliances to run on the generator.
- **Adding new equipment:** Plugging in additional appliances without considering the generator's capacity.
- **Setting:**
- A generator thermal overload relay setting is typically based on a percentage of the motor's full load current.

- Common settings are:
- **For motors with Service Factor (SF) ≥ 1.15, Set to 125% of FLA.**
- **For motors with Service Factor (SF) < 1.15, Set to 115% of FLA**
- As per IEEE Generator short time thermal capability for balanced three-phase loading diagram (Short time capability curve) the wining will withstand **117% rated current for 120 second.**
- **Calculation:**
- Generator capacity :500KVA ,415V , CT is 800/1
- Full Load Current =500x1000/(1.732*415)
- Full Load Current =695A
- Setting at 117% .
- Desired pickup current = 117% of rated current
- Relay setting = (1.17 x Rated Current) / CT ratio
- Relay setting =(1.17x695) / 800
- Relay setting =1.016A

(6) Generator Under Frequency Protection (81 G):

- Prevents the steam turbine and generator from exceeding the permissible operating time at reduced frequencies.
- Ensures that the generating unit is separated from the network at a preset value of frequency.
- Prevent over fluxing (v/f) of the generator (large over fluxing for short times).
- The stator under frequency relay measures the frequency of the stator terminal voltage.
- **Setting Recommendations:**
- within 0.2 to 0.5Hz below the nominal frequency
- For Alarm: 48.0 Hz, 2.0 Sec. time delay.
- For Trip: 47.5 Hz, 1.0 Sec. or as recommended by Generator Manufacturers.

(7) Instantaneous Over Current Relay (50):

- Instantaneous overcurrent protection is where a protective relay initiates a breaker trip based on current exceeding a pre-programmed "pickup" value for any length of time.
- **Setting:**
- A generator phase instantaneous overcurrent relay setting is typically set between **1.2 to 1.5 times the full load current (FLA)** of the generator, ensuring quick tripping in case of a severe fault while avoiding unnecessary trips due to momentary current surges during starting or load fluctuations; this setting is usually referred to as the "pickup current" of the relay.
- This is back up protection for Generator. To avoid unnecessary trip of the generator we recommend making OFF this function in generator protection.
- **Calculation:**
- Generator full Load Current = 130A & CT is 300/5 =60
- Setting =1.5 times of Full Load Current
- Setting= 1.5x130 =195A
- 51 Current Setting = Setting / CT Ratio = 195/60 =3.25A.
- Time setting =5 Second.
- The proposed above setting is coordinated with other O/C protection setting.

(8) Time grade Over Current Relay (51):

- Time overcurrent protection is where a protective relay initiates a breaker trip based on the combination of overcurrent magnitude and overcurrent duration, the relay tripping sooner with greater current magnitude. This is a more sophisticated form of overcurrent protection than instantaneous.
- **Setting:**
- This is back-up protection of the generator, for better time gradings the overcurrent setting should be co-ordinate with load connected feeder overcurrent setting.
- A generator Phase Overcurrent (51) setting is typically set between **125% and 150%** of the generator's full load current; however, the exact setting depends on the specific application and should be coordinated with other system protections.
- **Calculation:**

- Generator full Load Current = 130A & CT is 300/5 =60
- Setting =150% of Full Load Current
- Setting= 1.5x130 =195A
- 51 Current Setting = Setting / CT Ratio = 195/60 =3.25A.
- Time setting =5 Second.
- The proposed above setting is coordinated with other O/C protection setting.

(9) Earth Fault Time Overcurrent (51G)

- This is back-up protection in Earth Fault of generator, for better time gradings the overcurrent setting should be co-ordinate with load connected feeder setting.
- **Setting:**
- Earth Fault Relay setting shall be **10 to 20 % Full Load Current**
- **Calculation:**
- Generator full Load Current = 130A & CT is 300/5 =60
- Setting =20% of Full Load Current
- Setting= 0.2x130 =26A
- 51G Current Setting = Setting / CT Ratio = 26/60 =0.43A.
- Time setting =5 Second.
- The proposed above setting is coordinated with other O/C protection setting.

(9) Ground Differential (87 N)

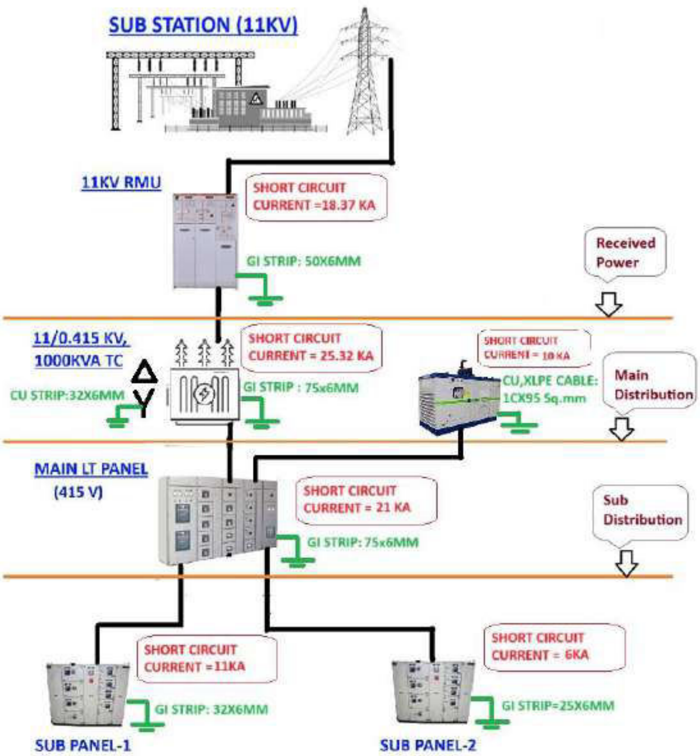
- The ground differential element (87N) that operates based on the difference between the measured neutral current and the sum of the three-phase current inputs.
- The 87N element provides sensitive ground fault detection on resistance-grounded particularly where multiple generators are connected directly to a load bus.
- The relay provides two definite-time delayed ground current differential elements designed to detect ground faults on resistance grounded generator.
- The relay uses the neutral CT connected to the relay input to measure the generator neutral current. It then calculates the residual current, which is the sum of the three phase current inputs (from CTs located at generator terminals).
- The relay adjusts the residual current by the ratio of the CTR and CTRN settings to scale the residual current in terms of the secondary neutral current. It then calculates the difference. Normally, under balanced load or external ground fault conditions, the difference current should be zero. In the event of an internal ground fault, the difference current is nonzero. If the difference current magnitude is greater than the element pickup setting, the element picks up and begins to operate the definite time-delay.
- **Setting:**
- Earth Fault Relay setting shall be **10 to 20 % Maximum Ground Fault Current**
- **Calculation:**
- Generator grounded through 39.8 Ohms Resistance.
- Generator rated Voltage=13800V, Current 130A
- Maximum Earth Fault Current =(138000 / 1.732) / 39.8
- Maximum Earth Fault Current =7967.4 / 39.8
- Maximum Earth Fault Current = 200 A
- 87N pickup current setting = 10% x 200 / CT Ratio
- 87N pickup current setting = 20 / 60
- 87N pickup current setting = 0.3
- 87N Time delay =0.2s

Chapter: 45 Calculate Earthing Strip Size for Electrical Equipment's in Power Distribution Network

EXAMPLE:

Calculate Earthing Strip / Cable Size for Electrical Equipment's / Panels in Power Distribution Networks.

1) At RMU
2) At Transformer
3) At D.G Set
4) At Main Distribution Panel
5) At Sub Panel-1
6) At Sub Panel-2



CALCULATION:

(1) Earthing Strip Size at RMU:

- Shot circuit capacity at RMU is 18.37 KA for 1 Second.
- Corrosion in Strip is 1% per year
- Earthing Strip shall be replaced after 25 Years.
- Safety Factor for Strip is 1.5
- Earthing Strip Material is GI

Calculation

- As per IS: 3043, clause 12.2.2.1:
- Cross section area of Earthing Strip (A) =(Isc x√t)/k
- Where Isc= Shot circuit current capacity in Ampere.
- t= Time for Shot circuit current in Second.
- K= Material Constant

Bare Conductor Material with No Risk of Fire or Danger to any Other Touching or Surrounding Material
TABLE 11A (IS:3043)

Material	K value (1 second)	K value (2 second)
Steel	80	46
Aluminum	126	73
Copper	205	118

- Cross section area of Earthing Strip (A) = (Isc x√t)/k
- Cross section area of Earthing Strip (A) = (18.37x1000 x√1)/80
- **Cross section area of Earthing Strip (A) = 229.69 Sq.mm**
- Allowable corrosion =1% per Year
- No of Year for replacement = 25 Year
- Allowable corrosion in 25 Years = 229.69x1x25% =57.40 Sq.mm
- Allowable Safety Factor = 229.69x1.5%=3.44 Sq.mm
- Required Earthing Strip size = Cross sectional area + Total Corrosion allowance + Safety factor
- Required Earthing Strip size=229.69+57.40+3.44 Sq.mm
- **Required Earthing Strip size=290.47 Sq.mm**
- **Proposed GI Earthing Strip shall be 50x6 mm = 300 Sq.mm.**
- Here Proposed Earthing Strip Size > Required Earthing Strip Size
- Proposed Earthing Strip is OK

(2) Earthing Strip Size at Transformer:

- Shot circuit capacity at Transformer is 25.32 KA for 1 Second.
- Corrosion in Strip is 1% per year
- Earthing Strip shall be replaced after 25 Years.
- Safety Factor for Strip is 1.5
- Earthing Strip Material for Transformer Neutral is Copper
- Earthing Strip Material for Transformer Body is GI

Calculation

- **For Neutral**
- As per IS: 3043, clause 12.2.2.1:
- Cross section area of Earthing Strip (A) =(Isc x√t)/k
- Where Isc= Shot circuit current capacity in Ampere.
- t= Time for Shot circuit current in Second.
- K= Material Constant

Bare Conductor Material with No Risk of Fire or Danger to any Other Touching or Surrounding Material		
TABLE 11A (IS:3043)		
Material	**K value (1 second)**	**K value (2 second)**
Steel	80	46
Aluminum	126	73
Copper	205	118

- Cross section area of Earthing Strip (A) = (Isc x√t)/k
- Cross section area of Earthing Strip (A) = (25.32x1000 x√1)/205
- **Cross section area of Earthing Strip (A) = 125.51 Sq.mm**
- Allowable corrosion =1% per Year
- No of Year for replacement = 25 Year
- Allowable corrosion in 25 Years = 125.51 x1x25% =30.87 Sq.mm
- Allowable Safety Factor = 125.51 x1.5%=1.85 Sq.mm
- Required Earthing Strip size = Cross sectional area + Total Corrosion allowance + Safety factor
- Required Earthing Strip size=125.51+30.87+1.85 Sq.mm

- **Required Earthing Strip size=156.24 Sq.mm**
- **Proposed Cu Earthing Strip shall be 32x6 mm = 192 Sq.mm.**
- Here Proposed Earthing Strip Size > Required Earthing Strip Size
- Proposed Earthing Strip is OK
- **For Body**
- As per IS: 3043, clause 12.2.2.1:
- Cross section area of Earthing Strip (A) =(Isc x√t)/k
- Where Isc= Shot circuit current capacity in Ampere.
- t= Time for Shot circuit current in Second.
- K= Material Constant

Bare Conductor Material with No Risk of Fire or Danger to any Other Touching or Surrounding Material		
TABLE 11A (IS:3043)		
Material	**K value (1 second)**	**K value (2 second)**
Steel	80	46
Aluminum	126	73
Copper	205	118

- Cross section area of Earthing Strip (A) = (Isc x√t)/k
- Cross section area of Earthing Strip (A) = (25.32 x1000 x√1)/80
- **Cross section area of Earthing Strip (A) = 316.5 Sq.mm**
- Allowable corrosion =1% per Year
- No of Year for replacement = 25 Year
- Allowable corrosion in 25 Years = 316.5 x1x25% =79.12 Sq.mm
- Allowable Safety Factor = 316.5 x1.5%=4.74 Sq.mm
- Required Earthing Strip size = Cross sectional area + Total Corrosion allowance + Safety factor
- Required Earthing Strip size=316.5+79.12+4.74 Sq.mm
- **Required Earthing Strip size=400.37 Sq.mm**
- **Proposed GI Earthing Strip shall be 75x6 mm = 450 Sq.mm.**
- Here Proposed Earthing Strip Size > Required Earthing Strip Size
- Proposed Earthing Strip is OK

(3) Earthing Cable Size at D.G Set:

- Shot circuit capacity at D.G Set is 10KA for 1 Second.
- Corrosion in Strip is 1% per year
- Earthing Strip shall be replaced after 25 Years.
- Safety Factor for Strip is 1.5
- Earthing Wire Material is Copper, XLPE Insulated

Calculation

- As per IS: 3043, clause 12.2.2.1:
- Cross section area of Earthing Strip (A) =(Isc x√t)/k
- Where Isc= Shot circuit current capacity in Ampere.
- t= Time for Shot circuit current in Second.
- K= Material Constant

Insulated Protective Conductors Not Incorporated in Cables or Bare Conductors Touching Other Insulated Cables		
TABLE 11B (IS:3043)		
Material	**K value (1 second)**	**K value (3 second)**

Copper , PVC Insulated	136	79
Copper, Rubber Insulated	150	92
Copper, XLPE Insulated	170	98
Aluminum, PVC Insulated	90	52
Aluminum, Rubber Insulated	106	61
Aluminum, XLPE Insulated	112	65
Steel, PVC Insulated	49	28
Steel, Rubber Insulated	58	33
Steel, XLPE Insulated	62	36

- Cross section area of Earthing Strip (A) = (Isc x√t)/k
- Cross section area of Earthing Strip (A) = (10x1000 x√1)/170
- **Cross section area of Earthing Strip (A) = 58.82 Sq.mm**
- Allowable corrosion =1% per Year
- No of Year for replacement = 25 Year
- Allowable corrosion in 25 Years = 58.82x1x25% =14.70 Sq.mm
- Allowable Safety Factor = 58.82 x1.5%=0.88 Sq.mm
- Required Earthing Strip size = Cross sectional area + Total Corrosion allowance + Safety factor
- Required Earthing Strip size=58.82+14.7+0.88 Sq.mm
- **Required Earthing Strip size=74.41 Sq.mm**
- **Proposed Earthing Single Core Copper, XLPE Cable=95 Sq.mm**
- Here Proposed Earthing Cable Size > Required Earthing Cable Size
- Proposed Earthing Cable is OK

(4) Earthing Strip Size at Main Panel :

- Shot circuit capacity at Main Panel is 21 KA for 1 Second.
- Corrosion in Strip is 1% per year
- Earthing Strip shall be replaced after 25 Years.
- Safety Factor for Strip is 1.5
- Earthing Strip Material is GI

Calculation

- As per IS: 3043, clause 12.2.2.1:
- Cross section area of Earthing Strip (A) =(Isc x√t)/k
- Where Isc= Shot circuit current capacity in Ampere.
- t= Time for Shot circuit current in Second.
- K= Material Constant

Bare Conductor Material with No Risk of Fire or Danger to any Other Touching or Surrounding Material		
TABLE 11A (IS:3043)		
Material	**K value (1 second)**	**K value (2 second)**
Steel	80	46
Aluminum	126	73
Copper	205	118

- Cross section area of Earthing Strip (A) = (Isc x√t)/k
- Cross section area of Earthing Strip (A) = (21 x1000 x√1)/80

- **Cross section area of Earthing Strip (A) = 262.5 Sq.mm**
- Allowable corrosion =1% per Year
- No of Year for replacement = 25 Year
- Allowable corrosion in 25 Years = 262.5 x1x25% =65.62 Sq.mm
- Allowable Safety Factor = 262.5 x1.5%=3.93 Sq.mm
- Required Earthing Strip size = Cross sectional area + Total Corrosion allowance + Safety factor
- Required Earthing Strip size=262.5+65.62+3.93 Sq.mm
- **Required Earthing Strip size=332.06 Sq.mm**
- **Proposed GI Earthing Strip shall be 75x6 mm = 450 Sq.mm.**
- Here Proposed Earthing Strip Size > Required Earthing Strip Size
- Proposed Earthing Strip is OK

(5) Earthing Strip Size at Sub Panel-1 :

- Shot circuit capacity at Sub Panel-1 is 11 KA for 1 Second.
- Corrosion in Strip is 1% per year
- Earthing Strip shall be replaced after 25 Years.
- Safety Factor for Strip is 1.5
- Earthing Strip Material is GI

Calculation

- As per IS: 3043, clause 12.2.2.1:
- Cross section area of Earthing Strip (A) =(Isc x√t)/k
- Where Isc= Shot circuit current capacity in Ampere.
- t= Time for Shot circuit current in Second.
- K= Material Constant

Bare Conductor Material with No Risk of Fire or Danger to any Other Touching or Surrounding Material		
TABLE 11A (IS:3043)		
Material	**K value (1 second)**	**K value (2 second)**
Steel	80	46
Aluminum	126	73
Copper	205	118

- Cross section area of Earthing Strip (A) = (Isc x√t)/k
- Cross section area of Earthing Strip (A) = (11 x1000 x√1)/80
- **Cross section area of Earthing Strip (A) = 137.5 Sq.mm**
- Allowable corrosion =1% per Year
- No of Year for replacement = 25 Year
- Allowable corrosion in 25 Years = 137.5 x1x25% =34.37 Sq.mm
- Allowable Safety Factor = 137.5 x1.5%=2.06 Sq.mm
- Required Earthing Strip size = Cross sectional area + Total Corrosion allowance + Safety factor
- Required Earthing Strip size=137.5+34.37+2.06 Sq.mm
- **Required Earthing Strip size=173.93 Sq.mm**
- **Proposed GI Earthing Strip shall be 32x6 mm = 192 Sq.mm.**
- Here Proposed Earthing Strip Size > Required Earthing Strip Size
- Proposed Earthing Strip is OK

(5) Earthing Strip Size at Sub Panel-2 :

- Shot circuit capacity at Sub Panel-2 is 6 KA for 1 Second.
- Corrosion in Strip is 1% per year
- Earthing Strip shall be replaced after 25 Years.
- Safety Factor for Strip is 1.5
- Earthing Strip Material is GI

Calculation

- As per IS: 3043, clause 12.2.2.1:
- Cross section area of Earthing Strip (A) =(Isc x√t)/k
- Where Isc= Shot circuit current capacity in Ampere.
- t= Time for Shot circuit current in Second.
- K= Material Constant

Bare Conductor Material with No Risk of Fire or Danger to any Other Touching or Surrounding Material		
TABLE 11A (IS:3043)		
Material	**K value (1 second)**	**K value (2 second)**
Steel	80	46
Aluminum	126	73
Copper	205	118

- Cross section area of Earthing Strip (A) = (Isc x√t)/k
- Cross section area of Earthing Strip (A) = (6 x1000 x√1)/80
- **Cross section area of Earthing Strip (A) = 75.0 Sq.mm**
- Allowable corrosion =1% per Year
- No of Year for replacement = 25 Year
- Allowable corrosion in 25 Years = 75 x1x25% =18.75 Sq.mm
- Allowable Safety Factor = 75 x1.5%=1.12 Sq.mm
- Required Earthing Strip size = Cross sectional area + Total Corrosion allowance + Safety factor
- Required Earthing Strip size=75+18.75+1.12 Sq.mm
- **Required Earthing Strip size=94.87 Sq.mm**
- **Proposed GI Earthing Strip shall be 25x6 mm = 150 Sq.mm.**
- Here Proposed Earthing Strip Size > Required Earthing Strip Size
- Proposed Earthing Strip is OK

CONCLUSION:

- At RMU=GI Earthing Strip: 50x6MM
- At Transformer Neutral=CU Earthing Strip: 32x6MM
- At Transformer Body=GI Earthing Strip: 75x6MM
- At D.G Set=CU, XLPE Earthing Cable: 1Cx95 SQ.MM
- At Main Distribution Panel=GI Earthing Strip: 75x6MM
- At Sub Panel=1=GI Earthing Strip: 32x6MM
- At Sub Panel-2=GI Earthing Strip: 25x6MM

Chapter: 46 Calculate Main Fire Pump Capacity with Head and other Characteristic as per NBC 2016 / IS 12469 / IS 15301.

EXAMPLE:

- Calculate Main Fire Pump Capacity with Head and other characteristic as per NBC 2016 / IS 12469 / IS 15301 for following Details.
- **Type of Hazard:**
- Fire Type is Light hazard
- **Fire Protection Area (Building) Detail:**
- There are 4 Nos of Residency Building having 12 Nos floor and each floor have of 3.2 Meter height. (Building Height 38.40 Meter).
- **Fire Fighting Pipe Network Detail:**
- The maximum horizontal length of fire System header is 50 Meter.
- Up to Furthest Location in Fire Network System, the maximum bend in Horizontal Line are 6 Nos and Vertical Line /Header are 2 No. The Losses on each bend is 1.5 to 2 Meter.
- The Water Friction losses are approximately 3%

CALCULATION:

- We will derive calculation as per following sequence.
  1) Calculate Size of Main Fire Pump.
  2) Calculate Head of Fire Pump.
  3) Calculate RPM of Pump.
  4) Calculate Pump Pressure.
  5) Check Pump Characteristic as per Clauses.

(1) Calculate Size of Main Fire Pump:

- Type of Building occupancy is Residency and type of hazard is Light. The Building Height is 38.40 Meter.
- **AS PER NBC-2016:**
- As per NBC 2016, Table-7, Note No 10 , The Main Fire Pump Capacity will be **2850 Liter/Min.**

NBC -2016 Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Extinguisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm² at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm²
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
2)	15 m and above but not exceeding 35 m in height	R	R	NR	R	NR	R (*see* Note 4)	R (*see* Note 8)	NR	NR	25 000	NR	900
3)	Above 35 m but not exceeding 45 m in height	R	R	R	NR	NR	R (*see* Note 4 and Note 9)	R	NR	75 000	5 000	(*see* Note 10)	NR
4)	Above 45 m in height but not exceeding 60 m in height	R	R	R	NR	R	R	R	NR	150 000	10 000	(*see* Note 11)	NR
5)	Above 60 m in height	R	R	R	NR	R	R	R	R	200 000	10 000	(*see* Note 12 & Note 13)	NR

Table 7 — (*Concluded*)

6 Additional value given in parenthesis shall be added if basement area exceeds 200 m².
7 Required to be provided for buildings with more than two storeys (Ground + One).
8 Required to be provided for buildings with height above 15 m and above.
9 Sprinklers shall be fed water from both underground static water storage tank and terrace tank.
10 Provide required number of sets of pumps each consisting of one electric and one diesel pump (stand by) of capacity 2 280 litre/min and one electric pump of capacity 180 litre/min (*see* Fig. 11) (*see also* notes 22 and 23).
11 Provide required number of sets of pumps each consisting of two electric and one diesel pump (stand by) of capacity 2 280 litre/min and two electric pump of capacity 180 litre/min (*see* Fig. 12) (*see also* Notes 22 and 23).
12 Provide required number of sets of pumps each consisting of two electric and one diesel pump (stand by) of capacity 2 850 litre/min and two electric pump of capacity 180 litre/min (*see* Fig. 12) (*see also* Notes 22 and 23).
13 Lower levels in high rise buildings 60 m or above in height are likely to experience high pressure and therefore, it is recommended to consider multi-stage, multi-outlet pumps (creating pressure zones) or variable frequency drive pumps or any other equivalent arrangement.
14 Provide required number of sets of pumps each consisting of one electric and one diesel pump (stand by) of capacity 1 620 litre/min and one electric pump of capacity 180 litre/min (*see* Fig. 11) (*see also* Notes 22 and 23).
15 Required to be provided for buildings with more than one storey.
16 Buildings above 30 m in height not to be permitted for Group B, Group C, Group D and Group F occupancies.
17 The requirements given in this table for Group G Industrial Buildings are for small scale industry units. For other industries the requirements will have to be worked out on the basis of relevant Indian Standards and also in consultation with the local fire authorities.
18 Buildings above 18 m in height not to be permitted for G-1 and G-2 occupancies.
19 Buildings above 15 m in height not to be permitted for G-3 occupancies.
20 Buildings above 15 m in height not to be permitted for Group H and Group J occupancies. However, buildings above 45 m in height shall not be permitted for multi-level car parking (MLCP) occupancy.
21 Pump capacity shall be based on the covered area of the building.
22 One set of pumps shall be provided for each 100 hydrants or part thereof, with a maximum of two sets. In case of more than one pump set installation, both pump sets shall be interconnected at their delivery headers.
23 Alternative to provisions of additional set of pumps, the objective can be met by providing additional diesel pump of the same capacity and doubling the water tank capacity as required for one set of pumps.
24 As per the requirement of local authority dry riser may be used in hilly areas, industrial areas or as required.

- **AS PER IS: 12469:**
- Total No of Hydrant for Building = 1 No for Each Floor, hence approximate 1x12 (Floor) x4 (Tower) =49 No's,
- As per IS 12469 , Fire Pump Capacity Shall be 137 M3/Hour = **2282 Liter / Min**

IS : 12469 - 1988

TABLE 1 CLASS OF OCCUPANCY AND SIZE OF INSTALLATION

(*Clauses* 3.1.2 *and* 3.1.4)

Sl No.	Nature of Risk	Number of Hydrants	Pump Capacity in l/s (m³/h)	Delivery Pressure at Rated Capacity kg/cm²
1.	Light Hazard	a) Not exceeding 20	27 (96)	5.6
		b) Exceeding 20 but not exceeding 55	38 (137)	7.0
		c) Exceeding 55 but not exceeding 100	47 (171)	7.0
		*d) Exceeding 100	47 (171) plus 47 (171) for every additional 125 hydrants or a part thereof	7/8.8

Note — The total pumping capacity need not be greater than 190 (683) irrespective of the number of hydrant points.

- **From Above consideration Capacity Main Fire Pump Shall be 2850 Liter /Min.**

(2) Calculate Head of Main Fire Pump:

Vertical Head

- Vertical Head =No floor x Floor Height
- Vertical Head =12 x 3.2 = 38.40 Meter.

- Head Losses due to Bend= 2 x Head Losses of Each Bend
- Head Losses due to Bend= 2 x 1.5 = 2.06 Meter.
- Equivalent Vertical Head=Vertical Head+ Head Loss due to bend
- Equivalent Vertical Head=38.40+2.06 =40.46 Meter.
- Total Vertical head= Equivalent Vertical Head x Friction Losses.
- **Total Vertical head= =40.46 x 1.03= 41.67 Meter-------(A)**

Horizontal Head

- Horizontal Head=Maximum Horizontal Length
- Horizontal Head=50 Meter
- Head Losses due to Bend= 6x Head Losses of Each Bend
- Head Losses due to Bend= 6 x 1.5 = 9 Meter.
- Equivalent Horizontal Head= Horizontal Head+ Head Loss due to bend
- Equivalent Horizontal Head=50+9 =59 Meter.
- Total Horizontal head= Equivalent Horizontal Head x Friction Losses.
- **Total Horizontal head= =59 x 1.03= 60.77 Meter-------(B)**

Total Head:

- Total Head =Horizontal Head + Vertical Head
- Total Head =41.67+60.77= 102 Meter.
- **As per above Calculation Head for Fire Pump shall be 110 Meter.**

(3) Calculate Speed of Main Fire Pump:

- **As per IS 15301:**
- As per IS 15301 (Clause 6.2) , Electric motors required to feed the pump up to 2280 Liter/Min are usually running at 2900 RPM and the pumps required to match the motors must also run at the same revolutions per minute.
- **As per above Consideration Fire Pump speed shall be 2900 RPM.**

(4) Calculate Main Fire Pump Pressure:

- **As per IS 12469:**
- As per IS 15301 (Clause 6.2) , Fire Pump Delivery Pressure shall be 7.0 Kg/cm2
- **As per above Consideration Fire Pump speed shall be 7.0 Kg/cm2.**

IS : 12469 - 1988

TABLE 1 CLASS OF OCCUPANCY AND SIZE OF INSTALLATION

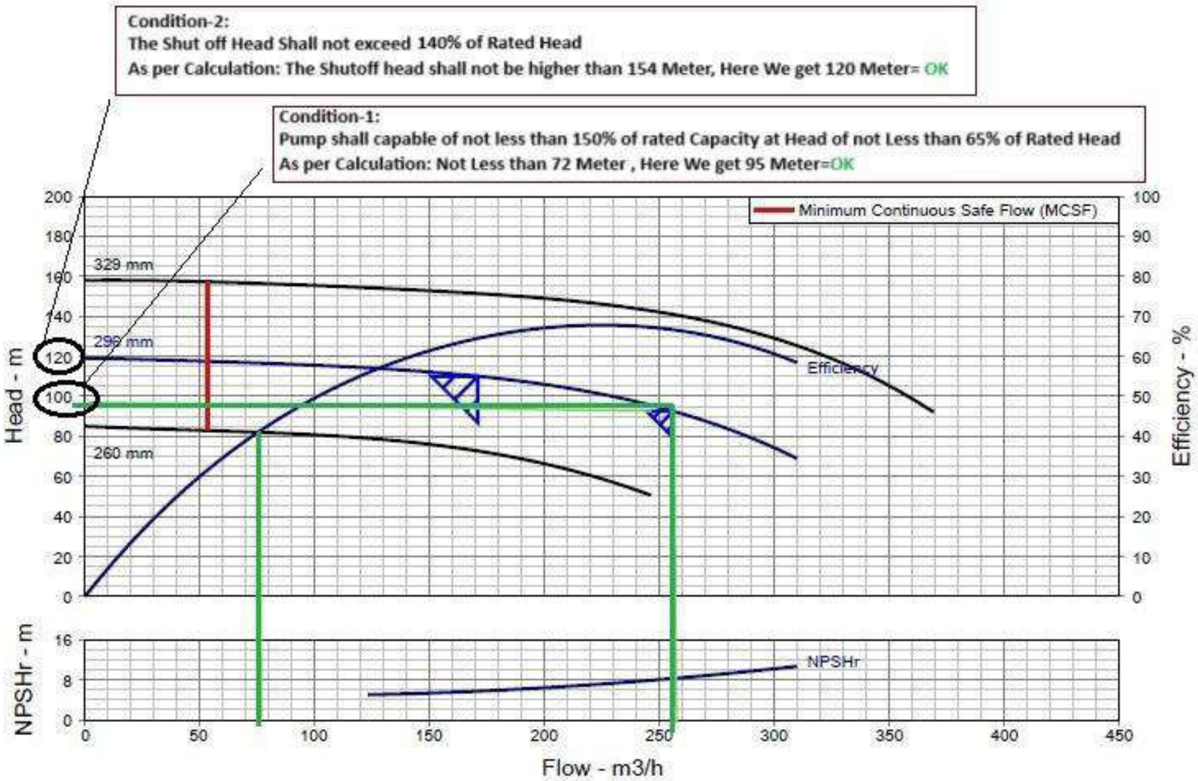
(*Clauses* 3.1.2 *and* 3.1.4)

SI No.	Nature of Risk	Number of Hydrants	Pump Capacity in l/s (m^3/h)	Delivery Pressure at Rated Capacity kg/cm^2
1.	Light Hazard	a) Not exceeding 20	27 (96)	5.6
		b) Exceeding 20 but not exceeding 55	38 (137)	7.0
		c) Exceeding 55 but not exceeding 100	47 (171)	7.0
		*d) Exceeding 100	47 (171) plus 47 (171) for every additional 125 hydrants or a part thereof	7/8.8

Note — The total pumping capacity need not be greater than 190 (683) irrespective of the number of hydrant points.

(5) Check Pump Characteristic as per Clauses.

- **As per IS 12469:**
- For Calculation consider Pump Flow rate 171 M3/Hour and head is 110 Meter.
- Following Two Condition shall be satisfied for Fire Main Pump.
- Pump shall be capable of not less than 150% of rated Capacity at Head of not Less than 65% of Rated Head.
- The Shut off Head Shall not exceed 140% of Rated Head.
- Pump Graph is as per following.



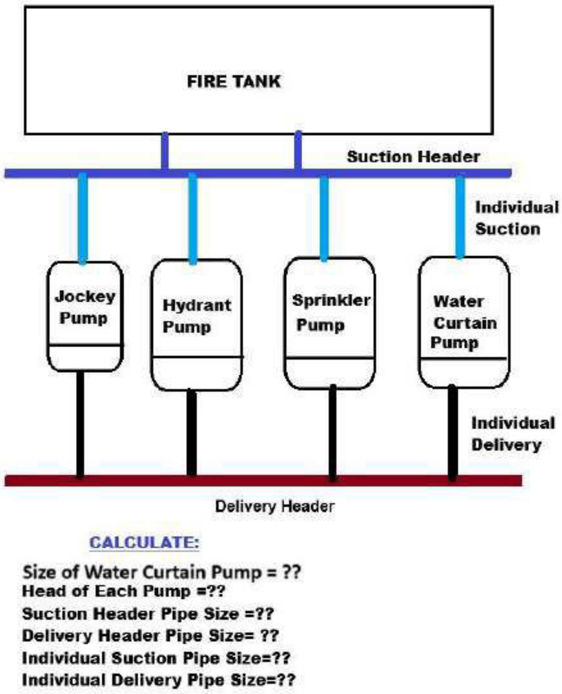
- **Condition-1:**
- **Pump shall be capable of not less than 150% of rated Capacity at Head of not Less than 65% of Rated Head.**
- Pump Shall be capable to supply =150% of rated Capacity
- Pump Shall be capable to supply =150% x 171 = 256.5 M3/Hour.
- Pump shall capable of Head not less than=65% of Rated Head
- Pump shall capable of Head not less than=65% x 110 = 72 Meter
- As per Graph for flow rate of 256.5 M3/Hour Pump head is 95 Meter (Which is less than 72 Meter)
- **Condition-1 is satisfied.**
- **Condition-2:**
- **The Shut off Head Shall not exceed 140% of Rated Head.**
- The Shut off Head Shall not higher =110x1.40 =154 Meter.
- As per Graph for flow rate of 256.5 M3/Hour, shut off Pump head is 120 Meter (Which is less than 154 Meter)
- **Condition-2 is satisfied.**

CONCLUSION:

- Size of Main Fire Pump: 2850 Liter/Min
- Head of Fire Pump: 110 Meter.
- RPM of Pump & Motor: 2900 RPM
- Calculate Pump Pressure: 7.0 Kg/cm2
- Check Pump Characteristic as per Clauses: Satisfied.

Chapter: 47 Calculate Size of Water Curtain Pump / Head of all Fire Pumps / Pipe Size of Suction & Delivery Header.

- Calculate Pump Head of following size of Pumps along with Pipe size of Suction & Delivery Header.



Calculate Size of Water Curtain Pump:

- As Per water curtain requirement, required minimum pressure of 1.6 kg/sq.cm at the last nozzle of water curtain.
- Total Length of Pipe Network for water curtain in one zone = 84 meter.
- Spacing between Open Nozzle =2.5-meter Nozzle to Nozzle
- **Calculation:**
- No of Nozzle = Total Length of Pipe / Spacing between Nozzle
- No of Nozzle = 84 / 2.5 = 34 Nos.
- **The flow through each nozzle Q = K x P (As per IS: 9972/ NFPA 13)**
- Where
- Q = Flow in lpm flowing through nozzle
- K = Nozzle Factor = 45 (As per manufacturer)
- P = Total Pressure in Bar at flow Q = 1.6 bar
- The flow through each nozzle Q = K x P =45 x 1.6
- The flow through each nozzle Q =56.92 LPM
- Total Flow rate required= No Nozzle x Flow on Each Nozzle
- Total Flow rate required= 34 x 56.92
- Total Flow rate required= 1935 LPM or 116.11 m3 /Hour
- Maximum water curtain Pump capacity required= **2280 LPM or 137 m3/hour**

Calculate Pump Head for Water Curtain Pump:

- Head requirement for Fire Pump has been decided as below
- As Per water curtain requirement, required minimum pressure of 1.6 kg/sq.cm at the last nozzle of water curtain.

(A) Calculate Total Length of Pipe:

- Note: Considering that basement shall be provided the water curtain system:
- Total Vertical Length of Pipe from Plant Room to remotest water curtain = 10 meter
- Total Horizontal Length of Pipe from Plant Room to remotest water curtain= 50 meter
- Total Length of Pipe from Plant Room to remotest water curtain = 50+10=60 meter
- Equivalent Length of Pipe Due to Fittings @ 10 %= 6 meter
- Total Length of Pipe = **65 meters**

(B) Calculate residual Head:

- Required Residual head= Required minimum Pressure at last Point

- Required Residual head= 1.6kg/sq.cm = 1.6x10.00=**16 meters.**

(C) Calculate Head loss in Pipe:

- Head Loss in bar (As per Hazen William's formula) **(H) = $(6.05 \times 10^{5} \times Q^{1.85} \times L) / (C^{1.85} \times d^{4.87})$**
- Where L = Length of pipe in meters
- Q = Discharge in Lpm
- C = Hazen-Williams roughness coefficients
- D = Dia. of pipe in mm
- H = Head loss in bar.

Pipe Material	Hazen-Williams roughness coefficients (C)
Cast Iron (unlined)	**100 to 120**
Cast Iron (lined)	130
Ductile Iron (cement lined)	140
Steel (new)	140
Steel (galvanized)	120
Copper	140 to 150
PVC and Plastic	140 to 150
Asbestos Cement	140 to 150
Concrete	100 to 140
Corrugated Metal	60 to 150
Riveted Steel	90 to 110
Vitrified Clay	110 to 140

- Here L = 65 m
- Q = 1280 Lpm
- C = 120 (As per Table)
- D = 150 mm
- Head Loss in bar (H) = $6.05 \times 10^{5} \times 2280^{1.85} \times 65 / 120^{1.85} \times 150^{4.87}$
- Head Loss in bar (H) = 0.23 bar or **2 meters**

(D) Calculate Total Head of Water Curtain Pump:

- Total Head of Pump = Static Head (Vertical) + Residual Head + Head loss in Pipe
- Total Head of Pump = 10+16 + 2 =28 meter
- **Total Head of Pump =30 meter**

Calculate Pump Head for Hydrant Pump:

- Head requirement for Fire Pump has been decided as below
- As Per NBC Rule, there shall be minimum pressure of 3.5kg/sq.cm at the highest Fire Hydrant

(A) Calculate Total Length of Pipe:

- Total Vertical Length of Pipe from Plant Room to remotest Fire Hydrant = 64 meter
- Total Horizontal Length of Pipe from Plant Room to remotest Fire Hydrant= 80 meter
- Total Length of Pipe from Plant Room to remotest Fire Hydrant = 64+80=144meter
- Equivalent Length of Pipe Due to Fittings @ 10 %= 158.4 meter
- Total Length of Pipe = **159 meters**

(B) Calculate residual Head:

- Required Residual head= Required minimum Pressure at last Point
- Required Residual head= 3.5kg/sq.cm = **35 meters.**

(C) Calculate Head loss in Pipe:

- Head Loss in bar (As per Hazen William's formula) **(H) = $(6.05 \times 10^{5} \times Q^{1.85} \times L) / (C^{1.85} \times d^{4.87})$**
- Where L = Length of pipe in meters
- Q = Discharge in Lpm

- C = Hazen-Williams roughness coefficients
- D = Dia. of pipe in mm
- H = Head loss in bar.

Pipe Material	Hazen-Williams roughness coefficients (C)
Cast Iron (unlined)	100 to 120
Cast Iron (lined)	130
Ductile Iron (cement lined)	140
Steel (new)	140
Steel (galvanized)	120
Copper	140 to 150
PVC and Plastic	140 to 150
Asbestos Cement	140 to 150
Concrete	100 to 140
Corrugated Metal	60 to 150
Riveted Steel	90 to 110
Vitrified Clay	110 to 140

- Here L = 159 m
- Q = 2850 Lpm
- C = 120 (As per Table)
- D = 150 mm
- Head Loss in bar (H) = 6.05 x 10^^{5} x 2850^$^{1.85}$ x 159/ 120^$^{1.85}$ x 150^$^{4.87}$
- Head Loss in bar (H) = 0.85 bar or **9 meter**

(D) **Calculate Total Head of Fire Pump:**

- Total Head of Pump = Static Head (Vertical) + Residual Head + Head loss in Pipe
- Total Head of Pump = 64+35 + 9 =108 meter
- **Total Head of Pump =110 meter**

Calculate Size of Common Suction Header:

- There are 4 Nos of Pumps connected to Suction Header in Pump Room
- Fire Hydrant Pump of 2850 LPM = 1 no
- Sprinkler Pump of 2850 LPM = 1 no
- Water Curtain Pump of 2280 LPM = 1 no
- Jockey Pump of 2850 LPM = 1 no
- Flow Rate of Fire Hydrant Pump =2850 LPM= 171 M3/Hr =0.0475 M3/Sec
- Flow Rate of Sprinkler Pump =2850 LPM= 171 M3/Hr =0.0475 M3/Sec
- Flow Rate of Water Curtain Pump =2280 LPM= 136.8 M3/Hr =0.0377 M3/Sec
- Flow Rate of Jockey Pump =180 LPM= 10.8 M3/Hr =0.003 M3/Sec
- Total Flow Rate (Q) =(0.0475x1)+ (0.0475x1)+ (0.0377x1)+ (0.003x1) =**0.1357 M3/sec**
- **No of Suction Pipes shall be 2 no's**
- **Total Flow Rate (Q) =0.1357 /2 = 0.0675 M3/sec**
- Consider Water velocity (V) = 1.5 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.0675/3.14x1.5
- Dia of Pipe = 0.239 meter = 239 mm
- Dia of Pipe = **250mm of 2 Nos**

Calculate Size of Common Delivery Header:

- There are 4 Nos of Pumps connected to Delivery Header
- Fire Hydrant Pump of 2850 LPM = 1 no
- Sprinkler Pump of 2850 LPM = 1 no
- Water Curtain Pump of 2280 LPM = 1 no
- Jockey Pump of 180 LPM = 1 no
- Flow Rate of Fire Hydrant Pump =2850 LPM= 171 M3/Hr =0.0475 M3/Sec
- Flow Rate of Sprinkler Pump =2850 LPM= 171 M3/Hr =0.0475 M3/Sec
- Flow Rate of Water Curtain Pump =2280 LPM= 136.8 M3/Hr =0.0377 M3/Sec
- Flow Rate of Jockey Pump =180 LPM= 10.8 M3/Hr =0.003 M3/Sec
- Total Flow Rate (Q) =(0.0475x1)+ (0.0475x1)+ (0.0377x1)+ (0.003x1) =**0.1357 M3/sec**
- Consider Water velocity (V) = 3 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.1357/3.14x3
- Dia of Pipe = 0.239 meters = 239 mm
- Dia of Pipe = **250mm of 1 Nos**

Calculate Size of Individual Suction Header of Each Pump:

(A) Calculate Individual Suction Header of Water Curtain Pump:

- Water curtain Pump Flow Rate (Q) =2280 LPM = 136.8 M3/Hr = 0.038 M3/Sec
- Consider Water velocity (V) = 1.5 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.038/3.14x1.5
- Dia of Pipe = 0.180 meter = 180 mm
- Dia of Pipe = **200mm**

(B) Calculate Individual Delivery Header of Fire Hydrant Pump / Sprinkler Pump:

- Fire Pump Flow Rate (Q) =2850 LPM = 171 M3/Hr = 0.0475 M3/Sec
- Consider Water velocity (V) = 1.5 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.0475/3.14x1.5
- Dia of Pipe = 0.200 meters = 200 mm
- Dia of Pipe = **200mm**

(C) Calculate Individual Delivery Header of Jockey Pump:

- Water curtain Pump Flow Rate (Q) =180 LPM = 10.8 M3/Hr =0.003 M3/Sec
- Consider Water velocity (V) = 1.5 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.003/3.14x1.5
- Dia of Pipe = 0.050 meter = 50 mm
- Dia of Pipe = **50mm**

Calculate Size of Individual Delivery Header of Each Pump:

(A) Calculate Individual Delivery Header of Water Curtain Pump:

- Water curtain Pump Flow Rate (Q) =2280 LPM = 136.8 M3/Hr = 0.0377 M3/Sec
- Consider Water velocity (V) = 3 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.0377/3.14x3
- Dia of Pipe = 0.128 meters = 128 mm
- Dia of Pipe = **150mm**

(B) Calculate Individual Delivery Header of Fire Hydrant Pump / Sprinkler Pump:

- Fire Pump Flow Rate (Q) =2850 LPM = 171 M3/Hr = 0.0475 M3/Sec
- Consider Water velocity (V) = 3 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.0475/3.14x3

- Dia of Pipe = 0.142 meters = 142 mm
- Dia of Pipe = **150mm**

(C) Calculate Individual Delivery Header of Jockey Pump:

- Water curtain Pump Flow Rate (Q) =180 LPM = 10.8 M3/Hr =0.003 M3/Sec
- Consider Water velocity (V) = 3 m/sec
- **Flow Rate (Q) = Area x Velocity**
- Dia of Pipe =√4Q/3.14xV
- Dia of Pipe =√4x0.003/3.14x3
- Dia of Pipe = 0.036 meters = 36 mm
- Dia of Pipe = **40mm**

Conclusion:

- Water curtain Pump capacity = 2280 LPM or 137 m3/hour
- Head of Hydrant / Sprinkler Pump =110 meter
- Size of Common Suction Header=2 Nos of 250mm Pipes
- Size of Common Delivery Header=1 Nos of 250mm Pipe
- Individual Suction Header of Water Curtain Pump=200mm Pipe
- Individual Delivery Header of Fire Hydrant Pump / Sprinkler Pump=200mm Pipe
- Individual Delivery Header of Jockey Pump=50mm Pipe
- Individual Delivery Header of Water Curtain Pump=150mm Pipe
- Individual Delivery Header of Fire Hydrant Pump / Sprinkler Pump=150mm Pipe
- Individual Delivery Header of Jockey Pump=40mm Pipe

PART-3

Electrical Notes

Chapter: 1 Direct Online Starter (DOL)

Introduction:

- Different starting methods are employed for starting induction motors because Induction Motor draws more starting current during starting. To prevent damage to the windings due to the high starting current flow, we employ different types of starters.
- The simplest form of motor starter for the induction motor is the **D**irect **O**n**L**ine starter. The DOL starter consist a MCCB or Circuit Breaker, Contactor and an overload relay for protection. Electromagnetic contactor which can be opened by the thermal overload relay under fault conditions.
- Typically, the contactor will be controlled by separate start and stop buttons, and an auxiliary contact on the contactor is used, across the start button, as a hold in contact. I.e. the contactor is electrically latched closed while the motor is operating.

Principle of DOL:

- To start, the contactor is closed, applying full line voltage to the motor windings. The motor will draw a very high inrush current for a very short time, the magnetic field in the iron, and then the current will be limited to the Locked Rotor Current of the motor. The motor will develop Locked Rotor Torque and begin to accelerate towards full speed.
- As the motor accelerates, the current will begin to drop, but will not drop significantly until the motor is at a high speed, typically about 85% of synchronous speed. The actual starting current curve is a function of the motor design, and the terminal voltage, and is totally independent of the motor load.
- The motor load will affect the time taken for the motor to accelerate to full speed and therefore the duration of the high starting current, but not the magnitude of the starting current.
- Provided the torque developed by the motor exceeds the load torque at all speeds during the start cycle, the motor will reach full speed. If the torque delivered by the motor is less than the torque of the load at any speed during the start cycle, the motor will stops accelerating. If the starting torque with a DOL starter is insufficient for the load, the motor must be replaced with a motor which can develop a higher starting torque.
- The acceleration torque is the torque developed by the motor minus the load torque, and will change as the motor accelerates due to the motor speed torque curve and the load speed torque curve. The start time is dependent on the acceleration torque and the load inertia.
- **DOL starting have a maximum start current and maximum start torque.** This may cause an electrical problem with the supply, or it may cause a mechanical problem with the driven load. So this will be inconvenient for the users of the supply line, always experience a voltage drop when starting a motor. But if this motor is not a high power one it does not affect much.

Parts of DOL Starters:

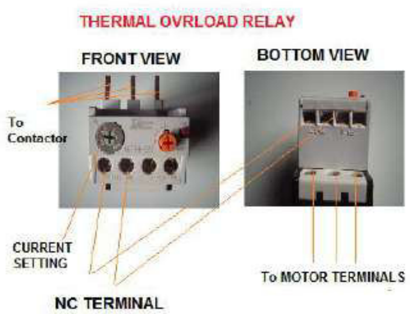
(1) Contactors & Coil.

- Magnetic contactors are electromagnetically operated switches that provide a safe and convenient means for connecting and interrupting branch circuits.
- Magnetic motor controllers use electromagnetic energy for closing switches. The electromagnet consists of a coil of wire placed on an iron core. When a current flow through the coil, the iron of the magnet becomes magnetized, attracting an iron bar called the armature. An interruption of the current flow through the coil of wire causes the armature to drop out due to the presence of an air gap in the magnetic circuit.

- Line-voltage magnetic motor starters are electromechanical devices that provide a safe, convenient, and economical means of starting and stopping motors, and have the advantage of being controlled remotely. The great bulk of motor controllers sold are of this type.
- Contactors are mainly used to control machinery which uses electric motors. It consists of a coil which connects to a voltage source. Very often for Single phase Motors, 230V coils are used and for three phase motors, 415V coils are used. The contactor has three main NO contacts and lesser power rated contacts named as Auxiliary Contacts [NO and NC] used for the control circuit. A contact is conducting metal parts which completes or interrupt an electrical circuit.
- NO-normally open
- NC-normally closed

(2) Overload Relay (Overload protection).

- Overload protection for an electric motor is necessary to prevent burnout and to ensure max operating life. Under any condition of overload, a motor draws excessive current that causes overheating. Since motor winding insulation deteriorates due to overheating, there are established limits on motor operating temperatures to protect a motor from overheating. Overload relays are employed on a motor control to limit the amount of current drawn.
- **The overload relay does not provide short circuit protection. This is the function of over current protective equipment like fuses and circuit breakers, generally located in the disconnecting switch enclosure.**
- The ideal and easiest way for overload protection for a motor is an element with current-sensing properties very similar to the heating curve of the motor which would act to open the motor circuit when full-load current is exceeded. The operation of the protective device should be such that the motor is allowed to carry harmless over-loads but is quickly removed from the line when an overload has persisted too long.
- Normally fuses are not designed to provide overload protection. Fuse is protecting against short circuits (over current protection). Motors draw a high inrush current when starting and conventional fuses have no way of distinguishing between this temporary and harmless inrush current and a damaging overload. Selection of Fuse is depend on motor full-load current, would "blow" every time the motor is started. On the other hand, if a fuse were chosen large enough to pass the starting or inrush current, it would not protect the motor against small, harmful overloads that might occur later.
- The overload relay is the heart of motor protection. It has inverse-trip-time characteristics, permitting it to hold in during the accelerating period (when inrush current is drawn), yet providing protection on small overloads above the full-load current when the motor is running. Overload relays are renewable and can withstand repeated trip and reset cycles without need of replacement. Overload relays cannot, however, take the place of over current protection equipment.
- The overload relay consists of a current-sensing unit connected in the line to the motor, plus a mechanism, actuated by the sensing unit, which serves, directly or indirectly, to break the circuit. Overload relays can be classified as being thermal, magnetic, or electronic.
- **(1) Thermal Relay**: As the name implies, thermal overload relays rely on the rising temperatures caused by the overload current to trip the overload mechanism. Thermal overload relays can be further subdivided into two types: melting alloy and bimetallic.
- **(2) Magnetic Relay:** Magnetic overload relays react only to current excesses and are not affected by temperature.
- **(3) Electronic Relay:** Electronic or solid-state overload relays, provide the combination of high-speed trip, adjustability, and ease of installation. They can be ideal in many precise applications.



Wiring of DOL Starter:

(1) Main Contact:

- Contactor is connecting among Supply Voltage, Relay Coil and Thermal Overload Relay.
- L1 of Contactor Connect (NO) to R Phase through MCCB
- L2 of Contactor Connect (NO) to Y Phase through MCCB
- L3 of Contactor Connect (NO) to B Phase through MCCB.
- **NO Contact (-||-):**
- (13-14 or 53-54) is a normally Open NO contact (closes when the relay energizes)
- Contactor Point 53 is connecting to Start Button Point (94) and 54 Point of Contactor is connected to Common wire of Start/Stop Button.
- **NC Contact (-|/|-):**
- (95-96) is a normally closed NC contact (opens when the thermal overloads trip if associated with the overload block)

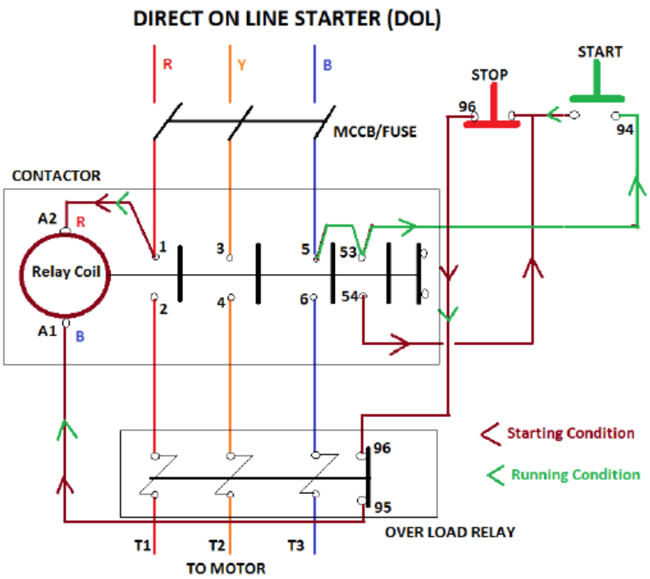
(2) Relay Coil Connection:

- A1 of Relay Coil is connecting to any one Supply Phase and A2 is connecting to Thermal over Load Relay's NC Connection (95).

(3) Thermal Overload Relay Connection:

- T1,T2,T3 are connect to Thermal Overload Relay
- Overload Relay is Connecting between Main Contactor and Motor
- NC Connection (95-96) of Thermal Overload Relay is connecting to Stop Button and Common Connection of Start/Stop Button.

Wiring Diagram of DOL Starter:



Control Circuit of DOL Starter:

- The main heart of DOL starter is Relay Coil. Normally it gets one phase constant from incoming supply Voltage (A1).when Coil gets second Phase relay coil energizes and Magnet of Contactor produce electromagnetic field and due to this Plunger of Contactor will move and Main Contactor of starter will closed and Auxiliary will change its position NO become NC and NC become (shown Red Line in Diagram)
- **Pushing Start Button:**
- When We Push the start Button Relay Coil will get second phase from Supply Phase-Main contactor (5)-Auxiliary Contact (53)-Start button-Stop button-96-95-To Relay Coil (A2).Now Coil energizes and Magnetic field produce by Magnet and Plunger of Contactor move. Main Contactor closes and Motor gets supply at the same time Auxiliary contact become (53-54) from NO to NC.
- **Release Start Button:**

- Relay coil gets supply even though we release Start button. When We release Start Push Button Relay Coil gets Supply phase from Main contactor (5)-Auxiliary contactor (53) - Auxiliary contactor (54)-Stop Button-96-95-Relay coil (shown Red / Blue Lines in Diagram).
- In Overload Condition of Motor will be stopped by intermission of Control circuit at Point 96-95.
- **Pushing Stop Button:**
- When we push Stop Button Control circuit of Starter will be break at stop button and Supply of Relay coil is broken, Plunger moves and close contact of Main Contactor becomes Open, Supply of Motor is disconnected.

Motor Starting Characteristics on DOL Starter:

- Available starting current: 100%.
- Peak starting current: 6 to 8 Full Load Current.
- Peak starting torque: 100%

Advantages:

1. Most Economical and Cheapest Starter
2. Simple to establish, operate and maintain
3. Simple Control Circuitry
4. Easy to understand and trouble-shoot.
5. It provides 100% torque at the time of starting.
6. Only one set of cable is required from starter to motor.
7. Motor is connected in delta at motor terminals.

Disadvantages:

1. **Not Reduce Starting Current:** It does not reduce the starting current of the motor.
2. **High Starting Current:** Very High Starting Current (Typically 6 to 8 times the FLC of the motor).
3. **Mechanically Harsh:** Thermal Stress on the motor, thereby reducing its life.
4. **Voltage Dip:** There is a big voltage dip in the electrical installation because of high in-rush current affecting other customers connected to the same lines and therefore not suitable for higher size squirrel cage motors
5. **High starting Torque:** Unnecessary high starting torque, even when not required by the load, thereby increased mechanical stress on the mechanical systems such as rotor shaft, bearings, gearbox, coupling, chain drive, connected equipments, etc. leading to premature failure and plant downtimes.

Features of DOL starting

- For low- and medium-power three-phase motors
- Three connection lines (circuit layout: star or delta)
- High starting torque
- Very high mechanical load
- High current peaks
- Voltage dips
- Simple switching devices

DOL is Suitable for:

- A direct on line starter can be used if the high inrush current of the motor does not cause excessive voltage drop in the supply circuit. The maximum size of a motor allowed on a direct on line starter may be limited by the supply utility for this reason. For example, a utility may require rural customers to use reduced-voltage starters for motors larger than 10 kW.
- DOL starting is sometimes used to start small water pumps, compressors, fans and conveyor belts.

DOL is not suitable for:

- The peak starting current would result in a serious voltage drop on the supply system
- The equipment being driven cannot tolerate the effects of very high peak torque loadings
- The safety or comfort of those using the equipment may be compromised by sudden starting as, for example, with escalators and lifts.

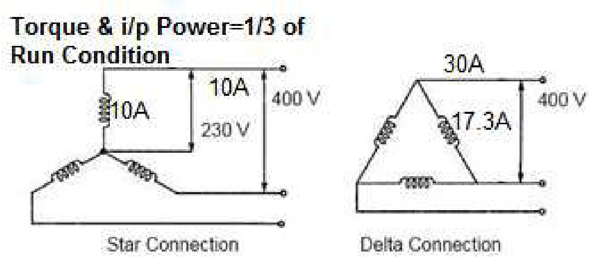
Chapter: 2 Star-Delta Starter

Introduction:

- Most induction motors are started directly on line, but when very large motors are started that way, they cause a disturbance of voltage on the supply lines due to large starting current surges. To limit the starting current surge, large induction motors are started at reduced voltage and then have full supply voltage reconnected when they run up to near rotating speed. Two methods are used for reduction of starting voltage are star delta starting and autotransformer stating.

Working Principal of Star-Delta Starter:

- This is the reduced voltage starting method. Voltage reduction during star-delta starting is achieved by physically reconfiguring the motor windings as illustrated in the figure below. During starting the motor windings are connected in star configuration and this reduces the voltage across each winding 3. This also reduces the torque by a factor of three. After a period of time the winding are reconfigured as delta and the motor runs normally.



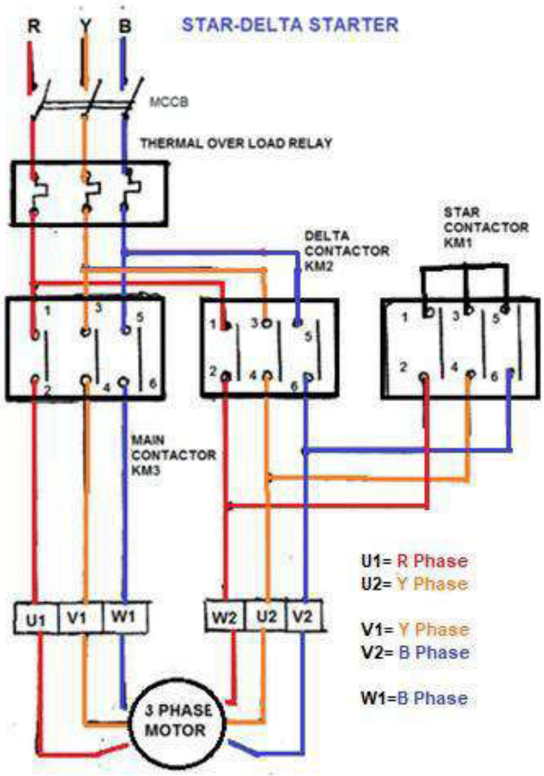
- Star/Delta starters are probably the most common reduced voltage starters. They are used in an attempt to reduce the start current applied to the motor during start as a means of reducing the disturbances and interference on the electrical supply.
- Traditionally in many supply regions, there has been a requirement to fit a reduced voltage starter on all motors greater than 5HP (4KW). The Star/Delta (or Wye/Delta) starter is one of the lowest cost electromechanical reduced voltage starters that can be applied.
- The Star/Delta starter is manufactured from three contactors, a timer and a thermal overload. The contactors are smaller than the single contactor used in a Direct on Line starter as they are controlling winding currents only. The currents through the winding are 1/root 3 (58%) of the current in the line.
- There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor. The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is one third of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.

Star-delta Starter Consists following units:

1) Contactors (Main, star and delta contactors) 3 No's (For Open State Starter) or 4 No's (Close Transient Starter).
2) Time relay (pull-in delayed) 1 No.
3) Three-pole thermal over current release 1No.
4) Fuse elements or automatic cut-outs for the main circuit 3 Nos.
5) Fuse element or automatic cut-out for the control circuit 1No.

Power Circuit of Star Delta Starter:

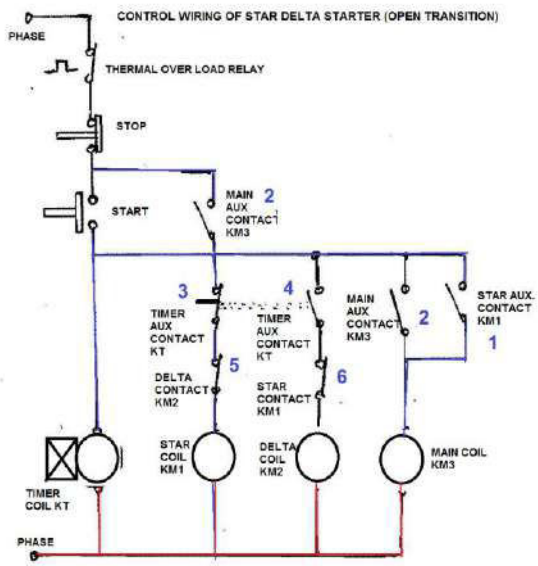
- The main circuit breaker serves as the main power supply switch that supplies electricity to the power circuit.
- The main contactor connects the reference source voltage R, Y, B to the primary terminal of the motor U1, V1, W1.
- In operation, the Main Contactor (KM3) and the Star Contactor (KM1) are closed initially, and then after a period of time, the star contactor is opened, and then the delta contactor (KM2) is closed. The control of the contactors is by the timer (K1T) built into the starter. The Star and Delta are electrically interlocked and preferably mechanically interlocked as well. In effect, there are four states.



- The star contactor serves to initially short the secondary terminal of the motor U2, V2, W2 for the start sequence during the initial run of the motor from standstill. This provides one third of DOL current to the motor, thus reducing the high inrush current inherent with large capacity motors at start-up.

Control Circuit of Star-Delta Starter (Open Transition):

- Controlling the interchanging star connection and delta connection of an AC induction motor is achieved by means of a star delta or wye delta control circuit. The control circuit consists of push button switches, auxiliary contacts and a timer.



- The **ON** push button starts the circuit by initially energizing Star Contactor Coil (KM1) of star circuit and Timer Coil (KT) circuit.
- When Star Contactor Coil (KM1) energized, Star Main and Auxiliary contactor change its position from NO to NC.
- When Star Auxiliary Contactor (1)(which is placed on Main Contactor coil circuit)became NO to NC it's complete The Circuit of Main contactor Coil (KM3) so Main Contactor Coil energized and Main Contactor's Main and Auxiliary Contactor Change its Position from NO To NC. This sequence happens in a friction of time.
- After pushing the **ON** push button switch, the auxiliary contact of the main contactor coil (2) which is connected in parallel across the ON push button will become NO to NC, thereby providing a latch to hold the main contactor

coil activated which eventually maintains the control circuit active even after releasing the ON push button switch.

- When Star Main Contactor (KM1) close its connect Motor connects on STAR and it's connected in STAR until Time Delay Auxiliary contact KT (3) become NC to NO.
- Once the time delay is reached its specified Time, the timer's auxiliary contacts (KT)(3) in Star Coil circuit will change its position from NC to NO and at the Same Time Auxiliary contactor (KT) in Delta Coil Circuit(4) change its Position from NO To NC so Delta coil energized and Delta Main Contactor becomes NO To NC. Now Motor terminal connection change from star to delta connection.
- A normally close auxiliary contact from both star and delta contactors (5&6)are also placed opposite of both star and delta contactor coils, these interlock contacts serves as safety switches to prevent simultaneous activation of both star and delta contactor coils, so that one cannot be activated without the other deactivated first. Thus, the delta contactor coil cannot be active when the star contactor coil is active, and similarly, the star contactor coil cannot also be active while the delta contactor coil is active. The control circuit above also provides two interrupting contacts to shutdown the motor. The OFF push button switch break the control circuit and the motor when necessary. The thermal overload contact is a protective device which automatically opens the STOP Control circuit in case when motor overload current is detected by the thermal overload relay, this is to prevent burning of the motor in case of excessive load beyond the rated capacity of the motor is detected by the thermal overload relay.

Open or Closed Transition Starting

- At some point during starting, it is necessary to change from a star connected winding to a delta connected winding. Power and control circuits can be arranged to this in one of two ways - open transition or closed transition.

(1) Open Transition Starters.

- Discuss mention above is called open transition switching because there is an open state between the star state and the delta state. In open transition the power is disconnected from the motor while the winding are reconfigured via external switching. When a motor is driven by the supply, either at full speed or at part speed, there is a rotating magnetic field in the stator. This field is rotating at line frequency. The flux from the stator field induces a current in the rotor and this in turn results in a rotor magnetic field.
- When the motor is disconnected from the supply (open transition) there is a spinning rotor within the stator and the rotor has a magnetic field. Due to the low impedance of the rotor circuit, the time constant is quite long and the action of the spinning rotor field within the stator is that of a generator which generates voltage at a frequency determined by the speed of the rotor. When the motor is reconnected to the supply, it is reclosing onto an unsynchronized generator and **this result in a very high current and torque transient. The magnitude of the transient is dependent on the phase relationship between the generated voltage and the line voltage at the point of closure** can be much higher than DOL current and torque and can result in electrical and mechanical damage.
- Open transition starting is the easiest to implement in terms or cost and circuitry and if the timing of the changeover is good, this method can work well. In practice though it is difficult to set the necessary timing to operate correctly and disconnection/reconnection of the supply can cause significant voltage/current transients.
- In Open transition there are Four states:

1. **OFF State**: All Contactors are open.
2. **Star State:** The Main [KM3] and the Star [KM1] contactors are closed and the delta [KM2] contactor is open. The motor is connected in star and will produce one third of DOL torque at one third of DOL current.
3. **Open State:** This type of operation is called open transition switching because there is an open state between the star state and the delta state. The Main contractor is closed and the Delta and Star contactors are open. There is voltage on one end of the motor windings, but the other end is open so no current can flow. The motor has a spinning rotor and behaves like a generator.
4. **Delta State:** The Main and the Delta contactors are closed. The Star contactor is open. The motor is connected to full line voltage and full power and torque are available

(2) Closed Transition Star/Delta Starter.

- There is a technique to reduce the magnitude of the switching transients. This requires the use of a fourth contactor and a set of three resistors. The resistors must be sized such that considerable current is able to flow in the motor windings while they are in circuit. The auxiliary contactor and resistors are connected across the delta contactor. In operation, just before the star contactor opens, the auxiliary contactor closes resulting in current flow via the resistors into the star connection. Once the star contactor opens, current is able to flow round through the motor windings to the supply via the resistors. These resistors are then shorted by the delta contactor. If the resistance of the resistors is too high, they will not swamp the voltage generated by the motor and will serve no purpose.

- **In closed transition the power is maintained to the motor at all times.** This is achieved by introducing resistors to take up the current flow during the winding changeover. A fourth contractor is required to place the resistor in circuit before opening the star contactor and then removing the resistors once the delta contactor is closed. These resistors need to be sized to carry the motor current. In addition to requiring more switching devices, the control circuit is more complicated due to the need to carry out resistor switching
- In Close transition there are Four states:

1. **OFF State.** All Contactors are open
2. **Star State.** The Main [KM3] and the Star [KM1] contactors are closed and the delta [KM2] contactor is open. The motor is connected in star and will produce one third of DOL torque at one third of DOL current.
3. **Star Transition State.** The motor is connected in star and the resistors are connected across the delta contactor via the aux [KM4] contactor.
4. **Closed Transition State.** The Main [KM3] contactor is closed and the Delta [KM2] and Star [KM1] contactors are open. Current flows through the motor windings and the transition resistors via KM4.
5. **Delta State.** The Main and the Delta contactors are closed. The transition resistors are shorted out. The Star contactor is open. The motor is connected to full line voltage and full power and torque are available.

Effect of Change over Transient in Open Transient Star-Delta starter:

- It is Important the pause between star contactor switch off and Delta contactor switch is on correct. This is because Star contactor must be reliably disconnected before Delta contactor is activated. It is also important that the **switch over pause is not too long.**
- For 415v Star Connection voltage is effectively reduced to 58% or 240v. The equivalent of 33% that is obtained with Direct Online (DOL) starting.
- If Star connection has sufficient torque to run up to 75% or %80 of full load speed, then the motor can be connected in Delta mode.
- When connected to Delta configuration the phase voltage increases by a ratio of V3 or 173%. The phase currents increase by the same ratio. The line current increases three times its value in star connection.
- During transition period of switchover, the motor must be free running with little deceleration. While this is happening "Coasting" it may generate a voltage of its own, and on connection to the supply this voltage can randomly add to or subtract from the applied line voltage. This is known as transient current. Only lasting a few milliseconds it causes voltage surges and spikes. Known as a changeover transient.

Size of each part of Star-Delta starter

(1) Size of Overload Relay:

- For a star-delta starter there is a possibility to place the overload protection in two positions, in the line or in the windings.
- **Overload Relay in Line:** In the line is the same as just putting the overload before the motor as with a DOL starter.
- **The rating of Overload (In Line) = FLC of Motor.**
- Disadvantage: If the overload is set to FLC, then it is not protecting the motor while it is in delta (setting is x1.732 too high).
- **Overload Relay in Winding:** In the windings means that the overload is placed after the point where the wiring to the contactors are split into main and delta. The overload then always measures the current inside the windings.
- **The setting of Overload Relay (In Winding) =0.58XFLC (line current).**
- Disadvantage: We must use separate short circuit and overload protections.

(2) Size of Main and Delta Contractor:

- There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor.
- **Size of Main Contactor= IFL x 0.58**

(3) Size of Star Contractor:

- The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is 1/ √3= (58%) of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.
- **Size of Star Contactor= IFL x 0.33**

Motor Starting Characteristics of Star-Delta Starter:

- Available starting current: 33% Full Load Current.
- Peak starting current: 1.3 to 2.6 Full Load Current.
- Peak starting torque: 33% Full Load Torque.

Advantages of Star-Delta starter:

- The operation of the star-delta method is simple and rugged
- It is relatively cheap compared to other reduced voltage methods.
- Good Torque/Current Performance.
- It draws 2 times starting current of the full load ampere of the motor connected

Disadvantages of Star-Delta starter:

- Low Starting Torque (Torque = (Square of Voltage) is also reduce).
- Break In Supply - Possible Transients
- Six Terminal Motor Required (Delta Connected).
- It requires 2 set of cables from starter to motor.
- It provides only 33% starting torque and if the load connected to the subject motor requires higher starting torque at the time of starting than very heavy transients and stresses are produced while changing from star to delta connections, and because of these transients and stresses many electrical and mechanical break-down occurs. In this method of starting initially motor is connected in star and then after change over the motor is connected in delta. The delta of motor is formed in starter and not on motor terminals.
- **High transmission and current peaks:** When starting up pumps and fans for example, the load torque is low at the beginning of the start and increases with the square of the speed. When reaching approx. 80-85 % of the motor rated speed the load torque is equal to the motor torque and the acceleration ceases. To reach the rated speed, a switch over to delta position is necessary, and this will very often result in high transmission and current peaks. In some cases the current peak can reach a value that is even bigger than for a D.O.L start.
- Applications with a load torque higher than 50 % of the motor rated torque will not be able to start using the start-delta starter.
- **Low Starting Torque:** The star-delta (wye-delta) starting method controls whether the lead connections from the motor are configured in a star or delta electrical connection. The initial connection should be in the star pattern that results in a reduction of the line voltage by a factor of 1/√3 (57.7%) to the motor and the current is reduced to 1/3 of the current at full voltage, but the starting torque is also reduced 1/3 to 1/5 of the DOL starting torque. The transition from star to delta transition usually occurs once nominal speed is reached, but is sometimes performed as low as 50% of nominal speed which make transient Sparks.

Features of star-delta starting

- For low- to high-power three-phase motors.
- Reduced starting current
- Six connection cables
- Reduced starting torque
- Current peak on changeover from star to delta
- Mechanical load on changeover from star to delta

Application of Star-Delta Starter:

- The star-delta method is usually only applied to **low to medium voltage and light starting Torque** motors. The received starting current is about **30 %** of the starting current during direct online start and the starting torque is reduced to about **25 %** of the torque available at a D.O.L start. This starting method only works when the application is light loaded during the start. If the motor is too heavily loaded, there will not be enough torque to accelerate the motor up to speed before switching over to the delta position.

General Terminology

(1) Service Factor:

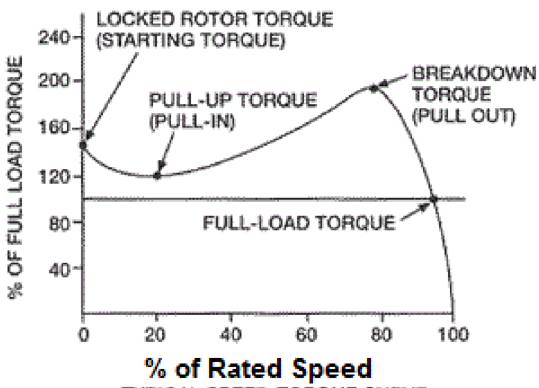
- The service factor is a multiplier that indicates the amount of overload a motor can be expected to handle. If a motor with a 1.15 service factor can be expected to safely handle intermittent loads amounting to 15% beyond its nameplate horsepower.
- For example, many motors will have a service factor of 1.15, meaning that the motor can handle a 15% overload. The service factor amperage is the amount of current that the motor will draw under the service factor load condition.

(2) Slip:

- Slip is used in two forms. One is the slip RPM which is the difference between the synchronous speed and the full load speed. When this slip RPM is expressed as a percentage of the synchronous speed, then it is called percent slip or just "slip". Most standard motors run with a full load slip of 2% to 5%.

(3) Synchronous Speed:

- This is the speed at which the magnetic field within the motor is rotating. It is also approximately the speed that the motor will run under no load conditions. For example, a 4 pole motor running on 60 cycles would have a magnetic field speed of 1800 RPM. The no load speed of that motor shaft would be very close to 1800, probably 1798 or 1799 RPM. The full load speed of the same motor might be 1745 RPM. The difference between the synchronous speed and the full load speed is called the slip RPM of the motor.



TYPICAL SPEED-TORQUE CURVE

(4) Motor Torque:

a) Pull Up Torque:

- When the motor starts and begins to accelerate the torque in generally decrease until it reach a low point at a certain speed it called the pull-up torque.
- The Pull-up Torque is the minimum torque developed by the electrical motor when it runs from zero to full-load speed (before it reaches the break-down torque point).
- Pull-up torque is the minimum torque developed during the period of acceleration from locked-rotor to the speed at which breakdown torque occurs.
- Some motor designs do not have a value of pull up torque because the lowest point may occur at the locked rotor point. In this case, pull up torque is the same as locked rotor torque.
- For motors which do not have a definite breakdown torque (such as NEMA design D) pull-up torque is the minimum torque developed up to rated full-load speed. It is usually expressed as a percentage of full-load torque.

b) Starting Torque (Locked Rotor Torque):

- The amount of torque the motor produces when it is energized at full voltage and with the shaft locked in place is called starting torque.
- The Locked Rotor Torque or Starting Torque is the torque the electrical motor develop when its starts at rest or zero speed.
- It is the amount of torque available when power is applied to break the load away and start accelerating it up to speed.

- A high Starting Torque is more important for application or machines hard to start - as positive displacement pumps, cranes etc. A lower Starting Torque can be accepted in applications as centrifugal fans or a pump where the start loads is low or close to zero.
- Operating a motor in a locked-rotor condition in excess of 20 seconds can result in insulation failure due to the excessive heat generated in the stator.

c) Full Load Torque:

- Full load torque is the rated continuous torque that the motor can support without overheating within its time rating.
- In imperial units the Full-load Torque can be expressed as
- T full-load torque (lb ft) = (Rated horsepower of Motor X 5252) / Rated rotational speed (rpm)
- In metric units the rated torque can be expressed as
- **Full-load torque (Nm) = (Rated KW of Motor X 9550) / Rated rotational speed (rpm)**
- Example: The torque of a 60 hp motor rotating at 1725 rpm can be expressed as
- T full-load torque = 60 X 5,252 / 1725 (rpm)
- T full-load torque = 182.7 lb

d) Peak Torque:

- Many types of loads such as reciprocating compressors have cycling torques where the amount of torque required varies depending on the position of the machine.
- The actual maximum torque requirement at any point is called the peak torque requirement.
- Peak torques is involved in things such as punch presses and other types of loads where an oscillating torque requirement occurs.

e) Pull out Torque (Breakdown Torque):

- Breakdown torque is the maximum torque the motor will develop with rated voltage applied at rated frequency without an abrupt drop in speed. Breakdown torque is usually expressed as a percentage of full-load torque.
- The load is then increased until the maximum point is reached.

(5) Motor Current:

a) Full Load Amps:

- The amount of current the motor can be expected to draw under full load (torque) conditions is called Full Load Amps. It is also known as nameplate amps.

b) Locked Rotor Amps:

- Also known as starting inrush, this is the amount of current the motor can be expected to draw under starting conditions when full voltage is applied.

c) Code Letter:

- The code letter is an indication of the amount of inrush or locked rotor current that is required by a motor when it is started

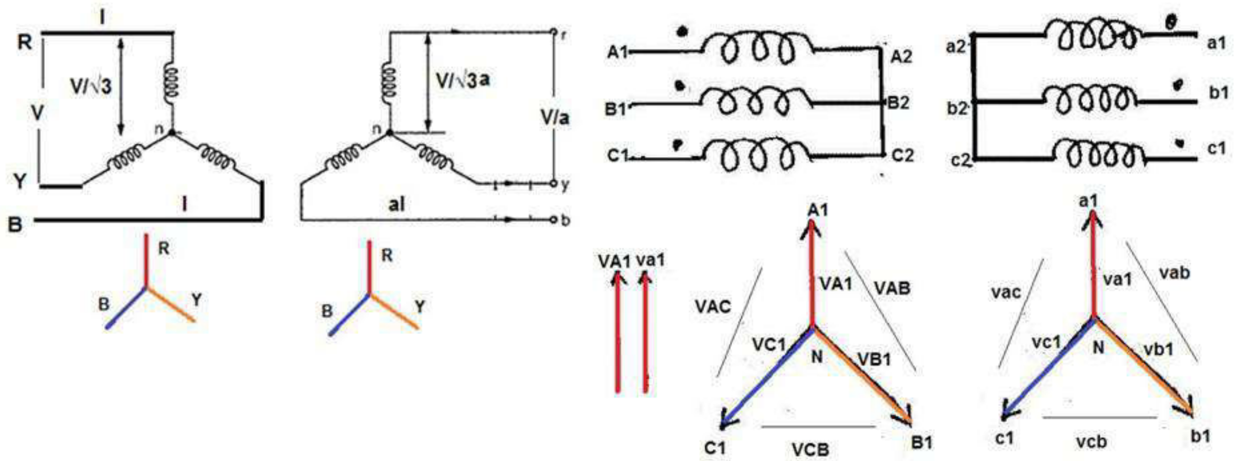
Chapter: 4 Three Phase Transformer Connection

Introduction:

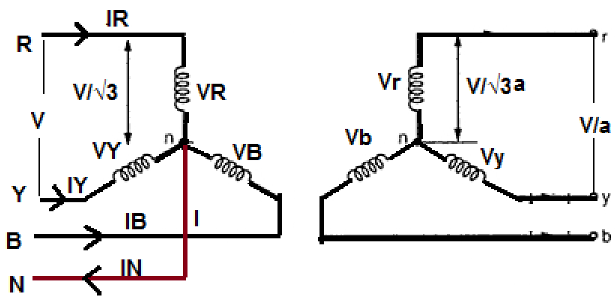
- The windings of three phase transformers may be connected in by Y or Δ in the same manner as for three single phase transformers. Since the secondary's may be connected either in Y or Δ regardless of which connection is used on the primaries, there must be four ways of connecting the windings of a 3-phase transformer for transformation of 3-phase voltages, namely Y-y,Δ -Δ, Y-Δ, and Δ -y. The inter-connections are made inside of the case so that only the terminal leads need to be brought outside the case

1. Star – Star Transformer (Yy0 or Yy6)
2. Delta – Delta Transformer (Dd0 or Dd6)
3. Delta – Star Transformer (Dy)
4. Star – Delta Transformer Yd) (Grounding Transformer).
5. Zig-zag Transformer (Yz, Dz) (Grounding Transformer)
6. Scott ("T" Type) Transformer (Grounding Transformer).
7. Auto Transformer.

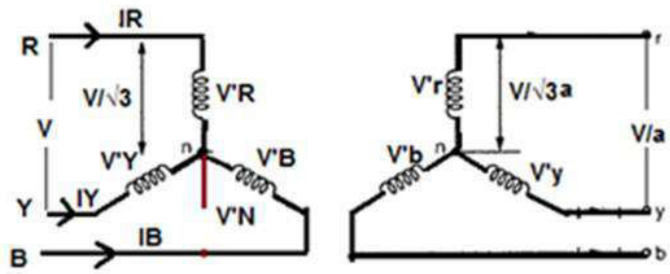
(1) Star-Star (Y-y) Connection:



- In Primary Winding Each Phase is120°electrical degrees out of phase with the other two phases.
- In Secondary Winding Each Phase is120°electrical degrees out of phase with the other two phases.
- Each primary winding is magnetically linked to one secondary winding through a common core leg. Sets of windings that are magnetically linked are drawn parallel to each other in the vector diagram. In the Y-Y connection, each primary and secondary winding is connected to a neutral point.
- The neutral point may or may not be brought out to an external physical connection and the neutral may or may not be grounded
- Transformer magnetizing currents are not purely sinusoidal, even if the exciting voltages are sinusoidal. The magnetizing currents have significant quantities of odd-harmonic components. If three identical transformers are connected to each phase and are excited by 60 Hz voltages of equal magnitude, the 60 Hz fundamental components of the exciting currents cancel out each other at the neutral. This is because the 60 Hz fundamental currents of A, B, and C phase are 120° out of phase with one another and the vector sum of these currents is zero.
- The third, ninth, fifteenth and other so-called zero-sequence harmonic currents are in phase with each other; therefore, these components do not cancel out each other at the neutral but add in phase with one another to produce a zero-sequence neutral current, provided there is a path for the neutral current to flow.
- Due to the nonlinear shape of the B-H curve, odd-harmonic magnetizing currents are required to support sinusoidal induced voltages. If some of the magnetizing current harmonics are not present, then the induced voltages cannot be sinusoidal.
- **Y-Y Connection with Grounded Neutral :**
- Figure Show the situation where the primary neutral is returned to the voltage source in a four-wire three-phase circuit. Each of the magnetizing currents labeled IR, IY, and IB contain the 60 Hz fundamental current and all of the odd harmonic currents necessary to support sinusoidal induced voltages.



- The zero-sequence magnetizing currents combine to form the neutral current IN, which returns these odd harmonics to the voltage source. Assuming that the primary voltage is sinusoidal, the induced voltages VR, VY, and VB (in both the primary and secondary) are sinusoidal as well.
- The connection of primary neutral to the neutral of generator has an add advantage that it eliminates distortion in the secondary phase voltages. If the flux in the core has sinusoidal waveform then it will give sinusoidal waveform for the voltage. But due to characteristic of iron, a sinusoidal waveform of flux requires a third harmonic component in the exciting current. As the frequency of this component is thrice the frequency of circuit at any given constant. It will try to flow either towards or away from the neutral point in the transformer windings. With isolated neutral, the triple frequency current cannot flow so the flux in the core will not be a sine wave and the voltages are distorted. If primary neutral is connected to generator neutral the triple frequency currents get the path to solve the difficulty. The alternative way of overcoming with this difficulty is the use of tertiary winding of low KVA rating. These windings are connected in delta and provide a circuit in which triple frequency currents can flow. Thus sinusoidal voltage on primary will give sinusoidal voltage on secondary side.
- This situation changes if the neutrals of both sets of the primary and secondary windings are not grounded.
- **Y-Y Connection without Grounded Neutral:**
- If the neutrals of both the primary and the secondary are open-circuited and so there is no path for the zero-sequence harmonic currents to flow and theinduced voltages will not be sinusoidal.



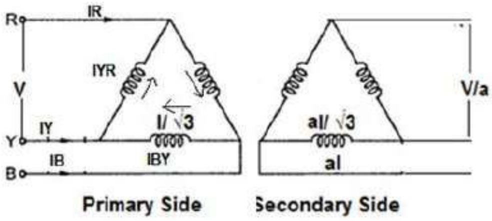
- V'R, V'Y, and V'B will not be sinusoidal. This results in distortions of the secondary voltages. The resulting voltage distortion is equivalent to a Y-Y transformer with zero-sequence currents allowed to flow in the primary neutral with an imaginary superimposed primary winding carrying only the zero-sequence currents 180° out of phase with the normal zero-sequence currents.
- Analysis of the voltages induced by the "primary windings" is greatly complicated by the fact that the core is highly nonlinear so that each of the individual zero-sequence harmonics currents carried by the phantom primary windings will induce even higher-order harmonic voltages as well.
- Fourier analysis can be used to arrive at an approximation of the secondary voltages with an open primary neutral. Taking one phase at a time, the normal magnetizing current for a sinusoidal exciting voltage is plotted from the B-H curve of the transformer. The normal magnetizing current is converted to a Fourier series and then it is reconstructed by removing all of the zero-sequence harmonics. The resulting exciting current will have a shape different from the normal exciting current, which is then used to construct an induced voltage using the B-H curve in there verse manner that was used to construct the original exciting current. This process is rather laborious, so suffice it to say that if a Y-Y transformer does not have a neutral path for zero-sequence exciting currents, there will be harmonic voltages induced in the secondary even if the exciting voltage is purely sinusoidal.
- **Advantage of Y-Y Connection:**
- **No Phase Displacement:**

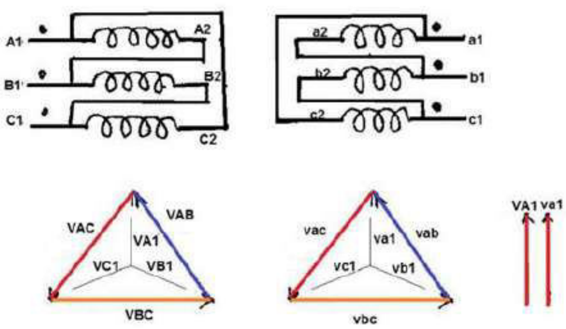
- The primary and secondary circuits are in phase; i.e., there are no phase angle displacements introduced by the Y-Y connection. This is an important advantage when transformers are used to interconnect systems of different voltages in a cascading manner. For example, suppose there are four systems operating at 800, 440, 220, and 66 kV that need to be interconnected. Substations can be constructed using Y-Y transformer connections to interconnect any two of these voltages. The 800 kV systems can be tied with the 66 kV systems through a single 800 to 66 kV transformation or through a series of cascading transformations at 440,220 and 66 kV.
- **Required Few Turns for winding:**
- Due to star connection, phase voltages is (1/√3) times the line voltage. Hence less number of turns is required. Also the stress on insulation is less. This makes the connection economical for small high voltage purposes.
- **Required Less Insulation Level:**
- If the neutral end of a Y-connected winding is grounded, then there is an opportunity to use reduced levels of insulation at the neutral end of the winding. A winding that is connected across the phases requires full insulation throughout the winding.
- **Handle Heavy Load:**
- Due to star connection, phase current is same as line current. Hence windings have to carry high currents. This makes cross section of the windings high. Thus the windings are mechanically strong and windings can bear heavy loads and short circuit current.
- **Use for Three phases Four Wires System:**
- As neutral is available, suitable for three phases four wire system.
- **Eliminate Distortion in Secondary Phase Voltage:**
- The connection of primary neutral to the neutral of generator eliminates distortion in the secondary phase voltages by giving path to triple frequency currents toward to generator.
- **Sinusoidal voltage on secondary side:**
- Neutral give path to flow Triple frequency current to flow Generator side thus sinusoidal voltage on primary will give sinusoidal voltage on secondary side.
- **Used as Auto Transformer:**
- A Y-Y transformer may be constructed as an autotransformer, with the possibility of great cost savings compared to the two-winding transformer construction.
- **Better Protective Relaying:**
- The protective relay settings will be protecting better on the line to ground faults when the Y-Y transformer connections with solidly grounded neutrals are applied.
- **Disadvantage of Y-Y Connection:**
- **The Third harmonic issue:**
- The voltages in any phase of a Y-Y transformer are 1200 apart from the voltages in any other phase. However, the third-harmonic components of each phase will be in phase with each other. Nonlinearities in the transformer core always lead to generation of third harmonic. These components will add up resulting in large (can be even larger than the fundamental component) third harmonic component.
- **Overvoltage at Lighting Load:**
- The presence of third (and other zero-sequence) harmonics at an ungrounded neutral can cause overvoltage conditions at light load. When constructing a Y-Y transformer using single-phase transformers connected in a bank, the measured line-to-neutral voltages are not 57.7% of the system phase-to-phase voltage at no load but are about 68% and diminish very rapidly as the bank is loaded. The effective values of voltages at different frequencies combine by taking the square root of the sum of the voltages squared. With sinusoidal phase-to-phase voltage, the third-harmonic component of the phase-to-neutral voltage is about 60%.
- **Voltage drops at Unbalance Load:**
- There can be a large voltage drop for unbalanced phase-to-neutral loads. This is caused by the fact that phase-to-phase loads cause a voltage drop through the leakage reactance of the transformer whereas phase-to-neutral loads cause a voltage drop through the magnetizing reactance, which is 100 to 1000 times larger than the leakage reactance.
- **Overheated Transformer Tank:**

- Under certain circumstances, a Y-Y connected three-phase trans- can produce severe tank overheating that can quickly destroy the transformer. This usually occurs with an open phase on the primary circuit and load on the secondary.
- **Over Excitation of Core in Fault Condition:**
- If a phase-to-ground fault occurs on the primary circuit with the primary neutral grounded, then the phase-to-neutral voltage on the un faulted phases increases to 173% of the normal voltage. This would almost certainly result in over excitation of the core, with greatly increased magnetizing currents and core losses
- If the neutrals of the primary and secondary are both brought out, then a phase-to-ground fault on the secondary circuit causes neutral fault current to flow in the primary circuit. Ground protection re- laying in the neutral of the primary circuit may then operate for faults on the secondary circuit
- **Neutral Shifting:**
- If the load on the secondary side unbalanced, then the performance of this connection is not satisfactory then the shifting of neutral point is possible. To prevent this, star point of the primary is required to be connected to the star point of the generator.
- **Distortion of Secondary voltage:**
- Even though the star or neutral point of the primary is earthed, the third harmonic present in the alternator voltage may appear on the secondary side. This causes distortion in the secondary phase voltages.
- **Over Voltage at Light Load:**
- The presence of third (and other zero-sequence) harmonics at an ungrounded neutral can cause overvoltage conditions at light load.
- **Difficulty in coordination of Ground Protection:**
- In Y-Y Transformer, a low-side ground fault causes primary ground fault current, making coordination more difficult.
- **Increase Healthy Phase Voltage under Phase to ground Fault:**
- If a phase-to-ground fault occurs on the primary circuit with the primary neutral grounded, then the phase-to-neutral voltage on the UN faulted phase's increases to 173% of the normal voltage. If the neutrals of the primary and secondary are both brought out, then a phase-to-ground fault on the secondary circuit causes neutral fault current to flow in the primary circuit.
- **Trip the T/C in Line-Ground Fault:**
- All harmonics will propagate through the transformer, zero-sequence current path is continuous through the transformer and one line-to-ground fault will trip the transformer.
- **Suitable for Core Type Transformer:**
- The third harmonic voltage and current is absent in such type of connection with three phase wire system. or shell type of three phase units, the third harmonic phase voltage may be high. This type of connection is more suitable for core type transformers.
- **Application:**
- This Type of Transformer is rarely used due to problems with unbalanced loads.
- It is economical for small high voltage transformers as the number of turns per phase and the amount of insulation required is less.

(2) Delta-Delta Connection:

- In this type of connection, both the three phase primary and secondary windings are connected in delta as shown in the Fig.

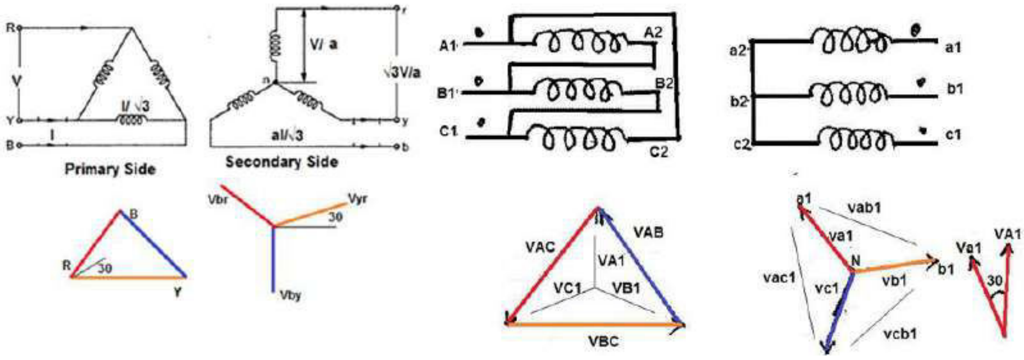




- The voltages on primary and secondary sides can be shown on the phasor diagram.
- This connection proves to be economical for large low voltage transformers as it increases number of turns per phase.
- **Key point:**
- Primary Side Line Voltage = Secondary Side Line Voltage.
- Primary Side Phase Voltage= Secondary Side Phase Voltage.
- No phase shift between primary and secondary voltages
- **Advantage of Delta-Delta Connection:**
- **Sinusoidal Voltage at Secondary:**
- In order to get secondary voltage as sinusoidal, the magnetizing current of transformer must contain a third harmonic component. The delta connection provides a closed path for circulation of third harmonic component of current. The flux remains sinusoidal which results in sinusoidal voltages.
- **Suitable for Unbalanced Load:**
- Even if the load is unbalanced the three phase voltages remains constant. Thus, it suitable for unbalanced loading also.
- **Carry 58% Load if One Transfer is Faulty in Transformer Bank:**
- If there is bank of single phase transformers connected in delta-delta fashion and if one of the transformers is disabled then the supply can be continued with remaining tow transformers of course with reduced efficiency.
- **No Distortion in Secondary Voltage:**
- There is no any phase displacement between primary and secondary voltages. There is no distortion of flux as the third harmonic component of magnetizing current can flow in the delta connected primary windings without flowing in the line wires .there is no distortion in the secondary voltages.
- **Economical for Low Voltage:**
- Due to delta connection, phase voltage is same as line voltage hence winding have more number of turns. But phase current is (1/√3) times the line current. Hence the cross-section of the windings is very less. This makes the connection economical for low voltages transformers.
- **Reduce Cross section of Conductor:**
- The conductor is required of smaller Cross section as the phase current is 1/√3 times of the line current. It increases number of turns per phase and reduces the necessary cross sectional area of conductors thus insulation problem is not present.
- **Absent of Third Harmonic Voltage:**
- Due to closed delta, third harmonic voltages are absent.
- The absence of star or neutral point proves to be advantageous in some cases.
- **Disadvantage of Delta-Delta Connection:**
- Due to the absence of neutral point it is not suitable for three phase four wire system.
- More insulation is required and the voltage appearing between windings and core will be equal to full line voltage in case of earth fault on one phase.
- **Application:**
- Suitable for large, low voltage transformers.
- This Type of Connection is normally uncommon but used in some industrial facilities to reduce impact of SLG faults on the primary system
- It is generally used in systems where it need to be carry large currents on low voltages and especially when continuity of service is to be maintained even though one of the phases develops fault.

(3) Delta-Star Connection of Transformer

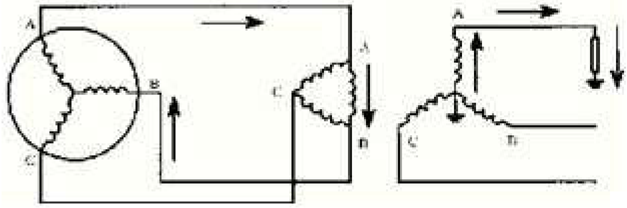
- In this type of connection, the primary connected in delta fashion while the secondary current is in star.



- The main use of this connection is to step up the voltage i.e. at the begining of high-tension transmission system. It can be noted that there is a phase shift of 30° between primary line voltage and secondary line voltage as leading.
- **Key point:**
- As primary in delta connected:
- Line voltage on primary side = Phase voltage on Primary side.
- Now Transformation Ration (K) = Secondary Phase Voltage / Primary Phase Voltage
- Secondary Phase Voltage = K X Primary Phase Voltage.
- As Secondary in Star connected
- Line voltage on Secondary side = √3 X Phase voltage on Secondary side. So,
- **Line voltage on Secondary side = √3 X K X Primary Phase Voltage.**
- **Line voltage on Secondary side = √3 X K X Primary Line Voltage.**
- **There is s +30 Degree or -30 Degree Phase Shift between Secondary Phase Voltage to Primary Phase Voltage.**
- **Advantages of Delta-Star Connection:**
- **Cross section area of winding is less at Primary side:**
- On primary side due to delta connection winding cross-section required is less.
- **Used at Three phase four wire System:**
- On secondary side, neutral is available, due to which it can be used for 3-phase, 4 wire supply system.
- **No distortion of Secondary Voltage:**
- No distortion due to third harmonic components.
- **Handled large, unbalanced Load:**
- Large, unbalanced loads can be handled without any difficulty.
- **Grounding Isolation between Primary and Secondary:**
- Assuming that the neutral of the Y-connected secondary circuit is grounded, a load connected phase-to-neutral or a phase-to-ground fault produces two equal and opposite currents in two phases in the primary circuit without any neutral ground current in the primary circuit. Therefore, in contrast with the Y-Y connection, phase-to-ground faults or current unbalance in the secondary circuit will not affect ground protective relaying applied to the primary circuit. This feature enables proper coordination of protective devices and is a very important design consideration.
- The neutral of the Y grounded is sometimes referred to as a grounding bank, because it provides a local source of ground current at the secondary that is isolated from the primary circuit.
- **Harmonic Suppression:**
- The magnetizing current must contain odd harmonics for the induced voltages to be sinusoidal and the third harmonic is the dominant harmonic component. In a three-phase system the third harmonic currents of all three phases are in phase with each other because they are zero-sequence currents. In the Y-Y connection, the only path for third harmonic current is through the neutral. In the Δ -Y connection, however, the third harmonic currents, being equal in amplitude and in phase with each other, are able to circulate around the path formed by the Δ connected winding. The same thing is true for the other zero-sequence harmonics.
- **Grounding Bank:**
- It provides a local source of ground current at the secondary that is isolated from the primary circuit. For suppose an ungrounded generator supplies a simple radial system through Δ-Y transformer with grounded Neutral at

secondary as shown Figure. The generator can supply a single-phase-to-neutral load through the -grounded Y transformer.

- Let us refer to the low-voltage generator side of the transformer as the secondary and the high-voltage load side of the transformer as the primary. Note that each primary winding is magnetically coupled to a secondary winding The magnetically coupled windings are drawn in parallel to each other.



- Through the second transformer law, the phase-to-ground load current in the primary circuit is reflected as a current in the A-C secondary winding. No other currents are required to flow in the A-C or B-C windings on the generator side of the transformer in order to balance ampere-turns.
- **Easy Relaying of Ground Protection:**
- Protective relaying is MUCH easier on a delta-wye transformer because ground faults on the secondary side are isolated from the primary, making coordination much easier. If there is upstream relaying on a delta-wye transformer, any zero-sequence current can be assumed to be from a primary ground fault, allowing very sensitive ground fault protection. On a wye-wye, a low-side ground fault causes primary ground fault current, making coordination more difficult. Actually, ground fault protection is one of the primary advantages of delta-wye units

Disadvantages of Delta-Star Connection:

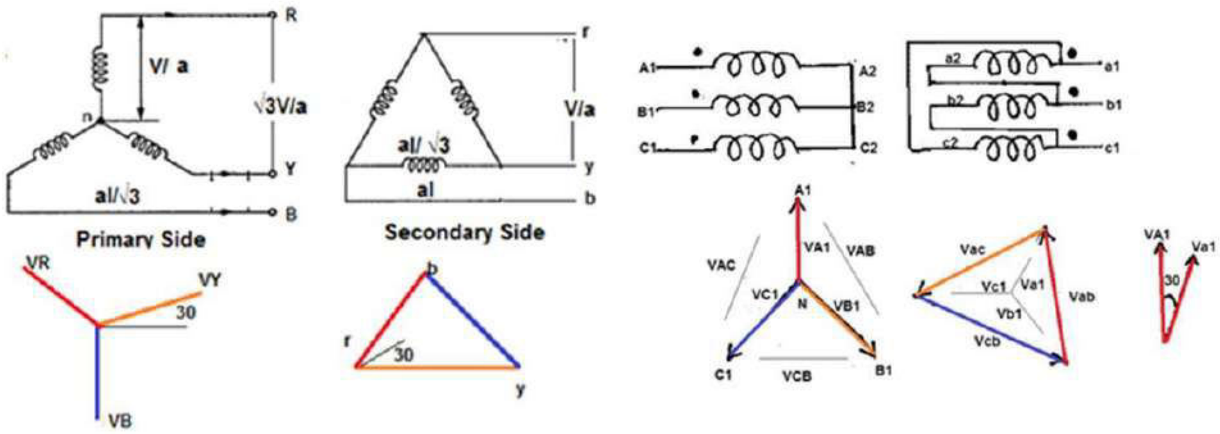
- In this type of connection, the secondary voltage is not in phase with the primary. Hence it is not possible to operate this connection in parallel with star-star or delta-delta connected transformer.
- One problem associated with this connection is that the secondary voltage is shifted by 30^0 with respect to the primary voltage. This can cause problems when paralleling 3-phase transformers since transformers secondary voltages must be in-phase to be paralleled. Therefore, we must pay attention to these shifts.
- If secondary of this transformer should be paralleled with secondary of another transformer without phase shift, there would be a problem.

Applications:

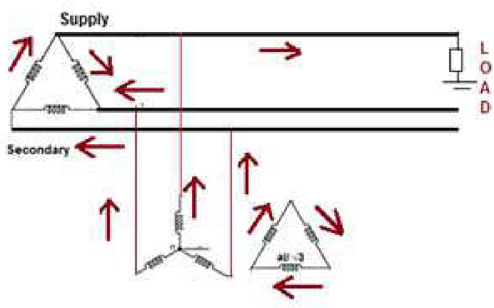
- **Commonly used in a step-up transformer:**
- As for example, at the beginning of a HT transmission line. In this case neutral point is stable and will not float in case of unbalanced loading. There is no distortion of flux because existence of a Δ -connection allows a path for the third-harmonic components. The line voltage ratio is √3 times of transformer turn-ratio and the secondary voltage leads the primary one by 30°. In recent years, this arrangement has become very popular for distribution system as it provides 3- Ø, 4-wire system.
- **Commonly used in commercial, industrial, and high-density residential locations:**
- To supply three-phase distribution systems. An example would be a distribution transformer with a delta primary, running on three 11kV phases with no neutral or earth required, and a star (or wye) secondary providing a 3-phase supply at 400 V, with the domestic voltage of 230 available between each phase and an earthed neutral point.
- **Used as Generator Transformer:**
- The Δ-Y transformer connection is used universally for connecting generators to transmission systems because of two very important reasons. First of all, generators are usually equipped with sensitive ground fault relay protection. The Δ-Y transformer is a source of ground currents for loads and faults on the transmission system, yet the generator ground fault protection is completely isolated from ground currents on the primary side of the transformer. Second, rotating machines can literally be

(4) Star-Delta Connection:

- In this type of connection, then primary is connected in star fashion while the secondary is connected in delta fashion as shown in the Fig.



- The voltages on primary and secondary sides can be represented on the phasor diagram as shown in the Fig.
- **Key point:**
- As Primary in Star connected
- Line voltage on Primary side = √3 X Phase voltage on Primary side. So
- Phase voltage on Primary side = Line voltage on Primary side / √3
- Now Transformation Ration (K) = Secondary Phase Voltage / Primary Phase Voltage
- Secondary Phase Voltage = K X Primary Phase Voltage.
- As Secondary in delta connected:
- Line voltage on Secondary side = Phase voltage on Secondary side.
- Secondary Phase Voltage = K X Primary Phase Voltage. =K X (Line voltage on Primary side / √3)
- **Secondary Phase Voltage = (K/√3) X Line voltage on Primary side.**
- **There is s +30 Degree or -30 Degree Phase Shift between Secondary Phase Voltage to Primary Phase Voltage**
- **Advantages of Star Delta Connection:**
- The primary side is star connected. Hence fewer numbers of turns are required. This makes the connection economical for large high voltage step down power transformers.
- The neutral available on the primary can be earthed to avoid distortion.
- The neutral point allows both types of loads (single phase or three phases) to be met.
- Large, unbalanced loads can be handled satisfactory.
- The Y-D connection has no problem with third harmonic components due to circulating currents inD. It is also more stable to unbalanced loads since the D partially redistributes any imbalance that occurs.
- The delta connected winding carries third harmonic current due to which potential of neutral point is stabilized. Some saving in cost of insulation is achieved if HV side is star connected. But in practice the HV side is normally connected in delta so that the three phase loads like motors and single phase loads like lighting loads can be supplied by LV side using three phase four wire system.
- **As Grounding Transformer:**
- In Power System Mostly grounded Y- Δ transformer is used for no other purpose than to provide a good ground source in ungrounded Delta system. Take, for example, a distribution system supplied by Δ connected (i.e., un-grounded) power source. If it is required to connect phase-to-ground loads to this system a grounding bank is connected to the system, as shown in Figure

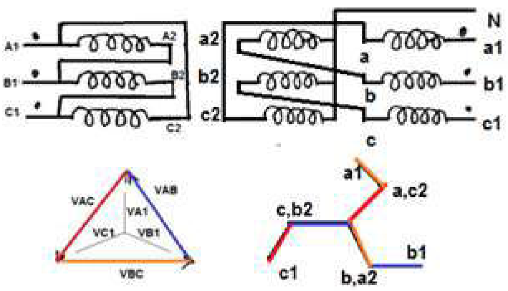


Y-D Grounding Transformer

- This system a grounding bank is connected to the system, as shown in Figure. Note that the connected winding is not connected to any external circuit in Figure.
- With a load current equal to 3 times i, each phase of the grounded Y winding provides the same current i, with the -connected secondary winding of the grounding bank providing the ampere-turns required to cancel the ampere-turns of the primary winding. Note that the grounding bank does not supply any real power to the load; it is there merely to provide a ground path. All the power required by the load is supplied by two phases of the ungrounded supply.
- **Disadvantages of Star-Delta Connection:**
- In this type of connection, the secondary voltage is not in phase with the primary. Hence it is not possible to operate this connection in parallel with star-star or delta-delta connected transformer.
- One problem associated with this connection is that the secondary voltage is shifted by 300 with respect to the primary voltage. This can cause problems when paralleling 3-phase transformers since transformers secondary voltages must be in-phase to be paralleled. Therefore, we must pay attention to these shifts.
- If secondary of this transformer should be paralleled with secondary of another transformer without phase shift, there would be a problem
- **Application:**
- It is commonly employed for power supply transformers.
- This type of connection is commonly employed at the substation end of the transmission line. The main use with this connection is to step down the voltage. The neutral available on the primary side is grounded. It can be seen that there is phase difference of 30° between primary and secondary line voltages.
- Commonly used in a step-down transformer, Y connection on the HV side reduces insulation costs the neutral point on the HV side can be grounded, stable with respect to unbalanced loads. As for example, at the end of a transmission line. The neutral of the primary winding is earthed. In this system, line voltage ratio is 1/√3 Times of transformer turn-ratio and secondary voltage lags behind primary voltage by 30°. Also third harmonic currents flow in theto give a sinusoidal flux.

(5) The Zigzag Connection:

- The zigzag connection is also called the interconnected star connection. This connection has some of the features of the Y and the Δ connections, combining the advantages of both.
- The zigzag transformer contains six coils on three cores. The first coil on each core is connected contrariwise to the second coil on the next core. The second coils are then all tied together to form the neutral and the phases are connected to the primary coils. Each phase, therefore, couples with each other phase and the voltages cancel out. As such, there would be negligible current through the neutral pole and it can be connected to ground
- One coil is the outer coil and the other is the inner coil. Each coil has the same number of windings turns (Turns ratio=1:1) but they are wound in opposite directions. The coils are connected as follows:
- The outer coil of phase a1-a is connected to the inner coil of phase c2-N.
- The outer coil of phase b1-b is connected to the inner coil of phase a2-N.
- The outer coil of phase c1-c is connected to the inner coil of phase b2-N.
- The inner coils are connected together to form the neutral and our tied to ground.
- The outer coils are connected to phase’s a1, b1, c1 of the existing delta system.



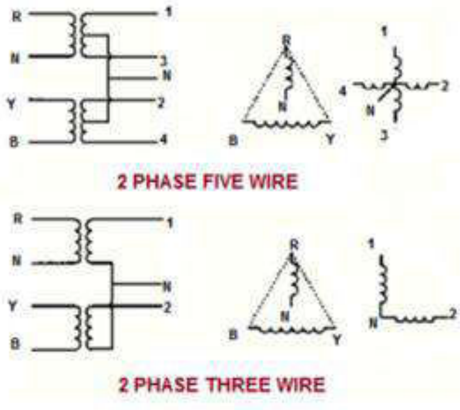
- If three currents, equal in magnitude and phase, are applied to the three terminals, the ampere-turns of the a2-N winding cancel the ampere-turns of the b1-b winding, the ampere-turns of the b2-N winding cancel the ampere turns of the c1-c winding, and the ampere-turns of the c2-N winding cancel the ampere turns of the a1-a winding. Therefore, the transformer allows the three in-phase currents to easily flow to neutral.

- If three currents, equal in magnitude but 120° out of phase with each other, are applied to the three terminals, the ampere-turns in the windings cannot cancel and the transformer restricts the current flow to the negligible level of magnetizing current. Therefore, the zigzag winding provides an easy path for in-phase currents but does not allow the flow of currents that are 120°out of phase with each other.
- Under normal system operation the outer and inner coil winding's magnetic flux will cancel each other and only negligible current will flow in the in the neutral of the zig –zag transformer.
- During a phase to ground fault the zig-zag transformer's coils magnetic flux are no longer equal in the faulted line. This allows zero sequence.
- If one phase, or more, faults to earth, the voltage applied to each phase of the transformer is no longer in balance; fluxes in the windings no longer oppose. (Using symmetrical components, this is Ia0 = Ib0 = Ic0.) Zero sequence (earth fault) current exists between the transformers' neutral to the faulting phase. Hence, the purpose of a zigzag transformer is to provide a return path for earth faults on delta connected systems. With negligible current in the neutral under normal conditions, engineers typically elect to under size the transformer; a short time rating is applied. Ensure the impedance is not too low for the desired fault limiting. Impedance can be added after the secondary's are summed (the 3Io path)
- The neutral formed by the zigzag connection is very stable. Therefore, this type of transformer, or in some cases an auto transformer, lends itself very well for establishing a neutral for an ungrounded 3 phase system.
- Many times this type of transformer or auto transformer will carry a fairly large rating, yet physically be relatively small. This particularly applies in connection with grounding applications. The reason for this small size in relation to the nameplate KVA rating is due to the fact that many types of grounding auto transformers are rated for 2 seconds. This is based on the time to operate an over current protection device such as a breaker. Zigzag transformers used to be employed to enable size reductions in drive motor systems due to the stable wave form they present. Other means are now more common, such as 6 phase star.
- **Advantages of Zig-Zag Transformer:**
- The Δ -zigzag connection provides the same advantages as the Δ-Y connection.
- **Less Costly for grounding Purpose:**
- It is typically the least costly than Y-D and Scott Transformer.
- **Third harmonic suppression:**
- The zigzag connection in power systems to trap triple harmonic (3rd, 9th, 15th, etc.) currents. Here, We install zigzag units near loads that produce large triple harmonic currents. The windings trap the harmonic currents and prevent them from traveling upstream, where they can produce undesirable effects.
- **Ground current isolation:**
- If we need a neutral for grounding or for supplying single-phase line to neutral loads when working with a 3-wire, ungrounded power system, a zigzag connection may be the better solution. Due to its composition, a zigzag transformer is more effective for grounding purposes because it has less internal winding impedance going to the ground than when using a Star type transformer.
- **No Phase Displacement:**
- There is no phase angle displacement between the primary and the secondary circuits with this connection; therefore, the Δ-zigzag connection can be used in the same manner as Y-Y and Δ- Δ transformers without introducing any phase shifts in the circuits.
- **Application:**
- **An Earthing Reference:**
- Occasionally engineers use a combination of YD and zigzag windings to achieve a vector phase shift. For example, an electrical network may have a transmission network of 220 kV/66 kV star/star transformers, with 66 kV/11 kV delta/star for the high voltage distribution network. If a transformation is required directly between the 220 kV/11 kV network the most obvious option is to use 220 kV/11 kV star/delta. The problem is that the 11 kV delta no longer has an earth reference point. Installing a zigzag transformer near the secondary side of the 220 kV/11 kV transformer provides the required earth reference point.
- **As a Grounding Transformer:**
- The ability to provide a path for in-phase currents enables us to use the zigzag connection as a grounding bank, which is one of the main applications for this connection.
- We rarely use zigzag configurations for typical industrial or commercial use, because they are more expensive to construct than conventional Star connected transformers. But zigzag connections are useful in special applications where conventional transformer connections aren't effective.

- D or Y / Zig-zag are used in unbalanced low voltage system – mostly with single phase appliances

(6) Scott-T Connection of Transformer (Transforming 3 Ph to 2 Ph):

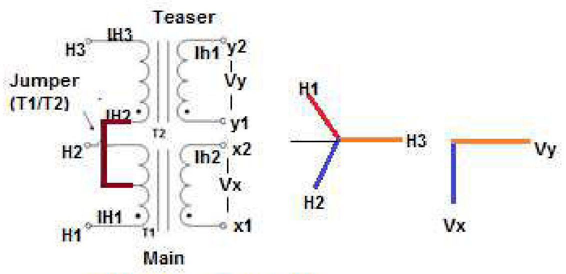
- **There are two main reasons for the need to transform from three phases to two phases.**
- To give a supply to an existing two-phase system from a three phase supply.
- To supply two phase furnace transformers from a three-phase source.
- Two-phase systems can have 3-wire, 4-wire, or 5-wire circuits. It is needed to be considering that a two-phase system is not 2/3 of a three-phase system. Balanced three-wire, two-phase circuits have two phase wires, both carrying approximately the same amount of current, with a neutral wire carrying 1.414 times the currents in the phase wires. The phase-to-neutral voltages are 90° out of phase with each other.
- Two phase 4-wire circuits are essentially just two ungrounded single-phase circuits that are electrically 90° out of phase with each other. Two phase 5-wire circuits have four phase wires plus a neutral; the four phase wires are 90° out of phase with each other.



- The easiest way to transform three-phase voltages into two-phase voltages is with two conventional single-phase transformers. The first transformer is connected phase-to-neutral on the primary (three-phase) side and the second transformer is connected between the other two phases on the primary side.
- The secondary windings of the two transformers are then connected to the two-phase circuit. The phase-to-neutral primary voltage is 90° out of phase with the phase-to-phase primary voltage, producing a two-phase voltage across the secondary windings. This simple connection, called the T connection, is shown in Figure
- The main advantage of the T connection is that it uses transformers with standard primary and secondary voltages. The disadvantage of the T connection is that a balanced two-phase load still produces unbalanced three-phase currents; i.e., the phase currents in the three-phase system do not have equal magnitudes, their phase angles are not 120° apart, and there is a considerable amount of neutral current that must be returned to the source.

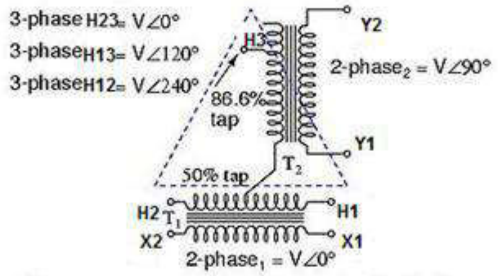
- ### The Scott Connection of Transformer:

- A Scott-T transformer (also called a Scott connection) is a type of circuit used to derive two-phase power from a three-phase source or vice-versa. The Scott connection evenly distributes a balanced load between the phases of the source.
- Scott T Transformers require a three phase power input and provide two equal single phase outputs called Main and Teaser. The MAIN and Teaser outputs are 90 degrees out of phase. The MAIN and the Teaser outputs must not be connected in parallel or in series as it creates a vector current imbalance on the primary side.
- MAIN and Teaser outputs are on separate cores. An external jumper is also required to connect the primary side of the MAIN and Teaser sections.
- The schematic of a typical Scott T Transformer is shown below



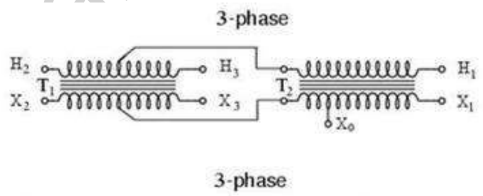
Scott T Connection

- Scott T Transformer is built with two single phase transformers of equal power rating. The MAIN and Teaser sections can be enclosed in a floor mount enclosure with MAIN on the bottom and Teaser on top with a connecting jumper cable. They can also be placed side by side in separate enclosures.
- Assuming the desired voltage is the same on the two and three phase sides, the Scott-T transformer connection consists of a center-tapped 1:1 ratio main transformer, T1, and an 86.6% (0.5√3) ratio teaser transformer, T2. The center-tapped side of T1 is connected between two of the phases on the three-phase side. Its center tap then connects to one end of the lower turn count side of T2, the other end connects to the remaining phase. The other side of the transformers then connects directly to the two pairs of a two-phase four-wire system.



SCOTT-T CONNECTION CONVERT 3PHAS to 2 PHASE

- The Scott-T transformer connection may be also used in a back to back T to T arrangement for a three-phase to 3 phase connection. This is a cost saving in the smaller kVA transformers due to the 2 coil T connected to a secondary 2 coil T in-lieu of the traditional three-coil primary to three-coil secondary transformer. In this arrangement the Neutral tap is part way up on the secondary teaser transformer . The voltage stability of this T to T arrangement as compared to the traditional 3 coil primary to three-coil secondary transformer is questioned



SCOOT-T CONNECTION 3 PHASE to 3 PHASE

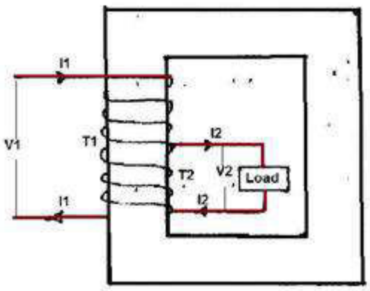
- **Key Point:**
- If the main transformer has a turn's ratio of 1: 1, then the teaser transformer requires a turn's ratio of 0.866: 1 for balanced operation. The principle of operation of the Scott connection can be most easily seen by first applying a current to the teaser secondary windings, and then applying a current to the main secondary winding, calculating the primary currents separately and superimposing the results.
- **Load connected between phaseY1 and phase Y2 of the secondary:**
- Secondary current from the teaser winding into phase X1 =1.0 <90°
- Secondary current from the teaser winding into phase X2 =-1.0< 90°
- Primary current from H3 phase into the teaser winding= 1.1547< 90°
- Primary current from H2 phase into the main winding= 0.5774 <90°
- Primary current from H1 phase into the main winding= -0.5774< 90°
- The reason that the primary current from H3 phase into the teaser winding is 1.1547 due to 0.866: 1 turn's ratio of the teaser, transforming 1/0.866= 1.1547 times the secondary current. This current must split in half at the center tap of the main primary winding because both halves of the main primary winding are wound on the same core and the total ampere-turns of the main winding must equal zero.

- **Load connected between phase X2 and phase X1 of the secondary:**
- Secondary current from the main winding into phase X2 =1.0< 0°
- Secondary current from the main winding into phase X4= -1.0 <0°
- Primary current from H2 phase into the main winding =1.0 <0°
- Primary current from H1 phase into the main winding=- 1.0 <0°
- Primary current from H3 phase into the teaser winding= 0
- **Superimpose the two sets of primary currents:**
- I H3= 1.1547 <90° +0= 1.1547 <90°
- I H2 =0.5774 <90° +1.0< 0°= 1.1547 < 30°
- I H1 =0.5774 <90°+ 1.0 <0°=1.1547 <210°
- Notice that the primary three-phase currents are balanced, i.e., the phase currents have the same magnitude and their phase angles are 120° apart. The apparent power supplied by the main transformer is greater than the apparent power supplied by the teaser transformer. This is easily verified by observing that the primary currents in both transformers have the same magnitude; however, the primary voltage of the teaser transformer is only 86.6% as great as the primary voltage of the main transformer. **Therefore, the teaser transforms only 86.6% of the apparent power transformed by the main.**
- We also observe that while the total real power delivered to the two-phase load is equal to the total real power supplied from the three-phase system, the total apparent power transformed by both transformers is greater than the total apparent power delivered to the two-phase load.
- The apparent power transformed by the teaser is 0.866 X IH1= 1.0 and the apparent power transformed by the main is 1.0X IH2 =1.1547 for a total of 2.1547 of apparent power transformed.
- The additional 0.1547 per unit of apparent power is due to parasitic reactive power owing between the two halves of the primary winding in the main transformer.
- Single-phase transformers used in the Scott connection are specialty items that are virtually impossible to buy "off the shelf" nowadays. In an emergency, standard distribution transformers can be used
- **Advantages of the Scott T Connection:**
- If desired, a three phase, two phase, or single-phase load may be supplied simultaneously
- The neutral points can be available for grounding or loading purposes
- **Disadvantages when used for 3 Phase Loading**
- This type of asymmetrical connection (3 phases, 2 coils) reconstructs three phases from 2 windings. This can cause unequal voltage drops in the windings, resulting in potentially unbalanced voltages to be applied to the load.
- The transformation ratio of the coils and the voltage obtained may be slightly unbalanced due to manufacturing variances of the interconnected coils.
- This design's neutral has to be solidly grounded. If it is not grounded solidly, the secondary voltages could become unstable.
- Since this design will have a low impedance, special care will have to be taken on the primary protection fault current capacity. This could be an issue if the system was designed for a Delta-Star connection.
- The inherent single phase construction and characteristics of this connection produces a comparatively bulky and heavier transformer when compared with a normal three phase transformer of the same rating.
- **Application:**
- For Industrial Furnace Transformer.
- **For Traction Purpose:**
- The power is obtained from the 220 kV or 132 kV or 110 kV or 66 kV, three-phase, effectively earthed transmission network of the State Electricity Board, through single-phase transformers or Scott connected transformer installed at the Traction Substation. The primary winding of the single-phase transformer is connected to two phases of the transmission network or Where Scott-connected transformer is used, the primary windings are connected to the three phases of the transmission network.
- The single-phase transformers at a Traction Substation are connected to the same two phases of the transmission network (referred as single-phase connection), or alternatively to different pairs of phases- the three single phase transformers forming a delta-connection on the primary side. Out of three single-phase transformers, one transformer feeds the overhead equipment (OHE) on one side of the Traction Substation, another feeds the OHE on the other side of the Traction Substation, and the third remains as standby. Thus the two single-phase

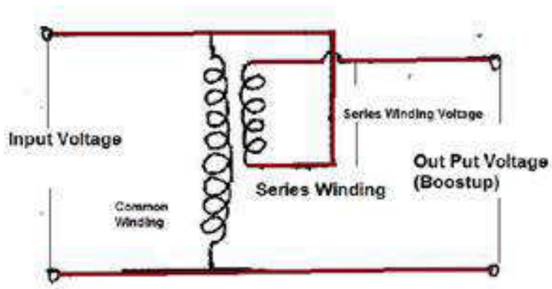
transformers which feed the OHE constitute an open-delta connection (alternatively, referred as V-connection) on the three-phase transformers network. The Scott-connected transformer and V-connected single-phase transformers are effective in reducing voltage imbalance on the transmission network. The spacing between adjacent substations is normally between 70 and 100 km.

(7) Auto Transformer Connection:

- An Ordinary Transformer consists of two windings called primary winding and secondary winding. These two windings are magnetically coupled and electrically isolated. But the transformer in which a part of windings is common to both primary and secondary is called Auto Transformer.
- In Auto Transformer two windings are not only magnetically coupled but also electrically coupled. The input to the transformer is constant but the output can be varied by varying the tapings.
- The autotransformer is both the most simple and the most fascinating of the connections involving two windings. It is used quite extensively in bulk power transmission systems because of its ability to multiply the effective KVA capacity of a transformer. Autotransformers are also used on radial distribution feeder circuits as voltage regulators. The connection is shown in Figure



- The primary and secondary windings of a two winding transformer have induced emf in them due to a common mutual flux and hence are in phase. The currents drawn by these two windings are out of phase by 180 ◦ . This prompted the use of a part of the primary as secondary. This is equivalent to common the secondary turns into primary turns.
- The common section need to have a cross sectional area of the conductor to carry (I2−I1) ampere.
- Total number of turns between A and C are T1. At point B a connection is taken. Section AB has T2 turns. As the volts per turn, which is proportional to the flux in the machine, is the same for the whole winding, V1 : V2 = T1 : T2
- When the secondary winding delivers a load current of I2 Ampere the demagnetizing ampere turns is I2T2. This will be countered by a current I1 flowing from the source through the T1 turns such that, I1T1 = I2T2
- A current of I1 ampere flows through the winding between B and C. The current in the winding between A and B is (I2 − I1) ampere. The cross section of the wire to be selected for AB is proportional to this current assuming a constant current density for the whole winding. Thus some amount of material saving can be achieved compared to a two winding transformer. The magnetic circuit is assumed to be identical and hence there is no saving in the same. To quantify the saving the total quantity of copper used in an auto transformer is expressed as a fraction of that used in a two winding transformer As
- copper in auto transformer / copper in two winding transformer =((T1 − T2)I1 + T2(I2 − I1))/T1I1 + T2I2
- copper in auto transformer / copper in two winding transformer = 1 −(2T2I1 / (T1I1 + T2I2))
- But T1I1 = T2I2 so
- The Ratio = 1 −(2T2I1 / 2T1I1) = 1 −(T2/T1)
- This means that **an auto transformer requires the use of lesser quantity of copper given by the ratio of turns. This ratio therefore the savings in copper.**
- As the space for the second winding need not be there, the window space can be less for an auto transformer, giving some saving in the lamination weight also. The larger the ratio of the voltages, smaller is the savings. As T2 approaches T1 the savings become significant. Thus, auto transformers become ideal choice for close ratio transformations



- The auto transformer shown in Figure is connected as a boosting auto transformer because the series winding boosts the output voltage. Care must be exercised when discussing "primary" and "secondary" voltages in relationship to windings in an auto transformer.
- In two-winding transformers, the primary voltage is associated with the primary winding, the secondary voltage is associated with the secondary winding, and the primary voltage is normally considered to be greater than the secondary voltage. In the case of a boosting autotransformer, however, the primary (or high) voltage is associated with the series winding, and the secondary (or low) voltage is associated with the common winding; but the voltage across the common winding is higher than across the series winding.
- **Limitation of the autotransformer**
- One of the limitations of the autotransformer connection is that not all types of three-phase connections are possible. For example, the Δ-Y and Y- Δ connections are not possible using the autotransformer. The Y-Y connection must share a common neutral between the high-voltage and low-voltage windings, so the neutrals of the circuits connected to these windings cannot be isolated.
- A Δ- Δ autotransformer connection is theoretically possible; however, this will create a peculiar phase shift. The phase shift is a function of the ratio of the primary to secondary voltages and it can be calculated from the vector diagram. This phase shift cannot be changed or eliminated and for this reason, autotransformers are very seldom connected as Δ – Δ transformers.
- **Advantages of the autotransformer**
- There are considerable savings in size and weight.
- There are decreased losses for a given KVA capacity.
- Using an autotransformer connection provides an opportunity for achieving lower series impedances and better regulation. Its efficiency is more when compared with the conventional one.
- Its size is relatively very smaller.
- Voltage regulation of autotransformer is much better.
- Lower cost
- Low requirements of excitation current.
- Less copper is used in its design and construction.
- In conventional transformer the voltage step up or step down value is fixed while in autotransformer, we can vary the output voltage as per out requirements and can smoothly increase or decrease its value as per our requirement.
- **Disadvantages of the autotransformer:**
- The autotransformer connection is not available with certain three-phase connections.
- Higher (and possibly more damaging) short-circuit currents can result from a lower series impedance.
- Short circuits can impress voltages significantly higher than operating voltages across the windings of an autotransformer.
- For the same voltage surge at the line terminals, the impressed and induced voltages are greater for an autotransformer than for a two-winding transformer.
- Autotransformer consists of a single winding around an iron core, which creates a change in voltage from one end to the other. In other words, the self-inductance of the winding around the core changes the voltage potential, but there is no isolation of the high and low voltage ends of the winding. So any noise or other voltage anomaly coming in on one side is passed through to the other. For that reason, Autotransformers are typically only used where there is already some sort of filtering or conditioning ahead of it, as in electronic applications, or the downstream device is unaffected by those anomalies, such as an AC motor during starting
- **Applications:**
- Used in both Synchronous motors and induction motors.

- Used in electrical apparatus testing labs since the voltage can be smoothly and continuously varied.
- They find application as boosters in AC feeders to increase the voltage levels.
- **Used in HV Substation due to following reasons.**

1. If we use normal transformer the size of transformer will be very high which leads to heavy weight, more copper and high cost.
2. The tertiary winding used in Auto transformer balances single phase unbalanced loads connected to secondary and it does not pass on these unbalanced currents to Primary side. Hence Harmonics and voltage unbalance are eliminated.
3. Tertiary winding in the Auto Transformer balances amp turns so that Auto transformer achieves magnetic separation like two winding transformers.

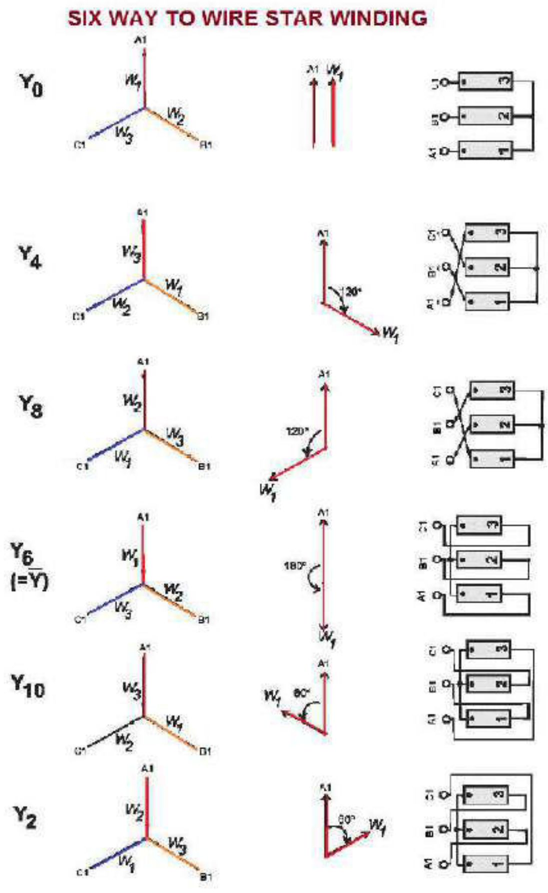
Chapter: 5 Vector Group of Transformer

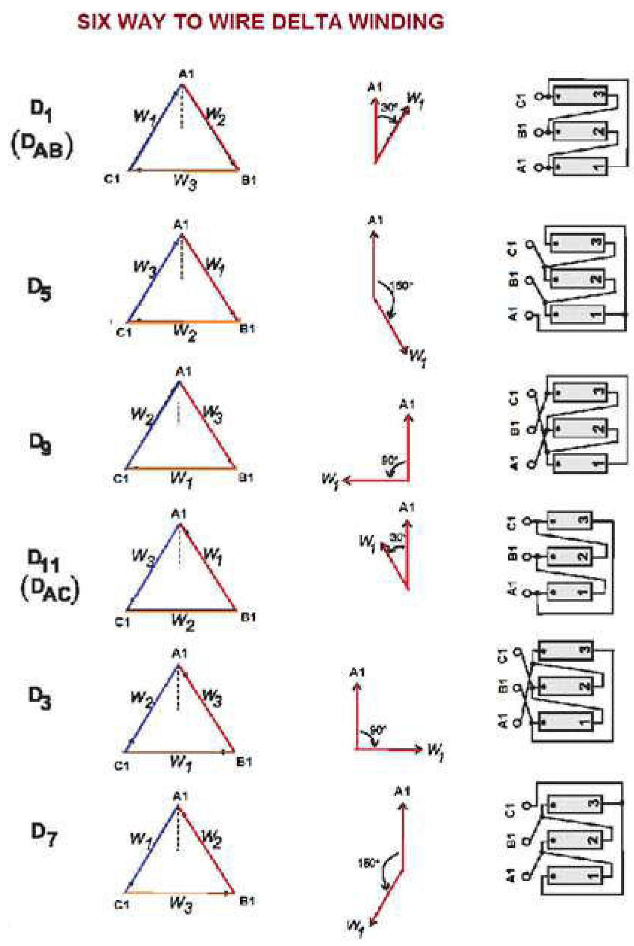
Introduction:

- Three phase transformer consists of three sets of primary windings, one for each phase, and three sets of secondary windings wound on the same iron core. Separate single-phase transformers can be used and externally interconnected to yield the same results as a 3-phase unit.
- The primary windings are connected in one of several ways. The two most common configurations are the delta, in which the polarity end of one winding is connected to the non-polarity end of the next, and the star, in which all three non-polarities (or polarity) ends are connected together. The secondary windings are connected similarly. This means that a 3-phase transformer can have its primary and secondary windings connected the same (delta-delta or star-star), or differently (delta-star or star-delta).
- It's important to remember that the secondary voltage waveforms are in phase with the primary waveforms when the primary and secondary windings are connected the same way. This condition is called "no phase shift." But when the primary and secondary windings are connected differently, the secondary voltage waveforms will differ from the corresponding primary voltage waveforms by 30 electrical degrees. This is called a 30 degree phase shift. When two transformers are connected in parallel, their phase shifts must be identical; if not, a short circuit will occur when the transformers are energized."

Basic Idea of Winding:

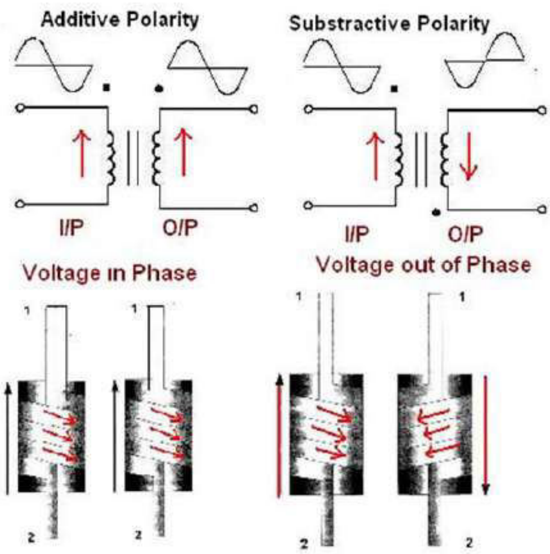
- An ac voltage applied to a coil will induce a voltage in a second coil where the two are linked by a magnetic path. The phase relationship of the two voltages depends upon which ways round the coils are connected. The voltages will either be in-phase or displaced by 180 deg
- When 3 coils are used in a 3 phase transformer winding a number of options exist. The coil voltages can be in phase or displaced as above with the coils connected in star or delta and, in the case of a star winding, have the star point (neutral) brought out to an external terminal or not.





Polarity:

- An ac voltage applied to a coil will induce a voltage in a second coil where the two are linked by a magnetic path. The phase relationship of the two voltages depends upon which way round the coils are connected. The voltages will either be in-phase or displaced by 180 deg.
- When 3 coils are used in a 3 phase transformer winding a number of options exist. The coil voltages can be in phase or displaced as above with the coils connected in star or delta and, in the case of a star winding, have the star point (neutral) brought out to an external terminal or not.



- When Pair of Coil of Transformer have same direction than voltage induced in both coil are in same direction from one end to other end.
- When two coil have opposite winding direction than Voltage induced in both coil are in opposite direction.

Winding connection designations:

- **First Symbol:** for High Voltage: Always capital letters.
- D=Delta, S=Star, Z=Interconnected star, N=Neutral
- **Second Symbol:** for Low voltage: Always Small letters.
- d=Delta, s=Star, z=Interconnected star, n=Neutral.
- Third Symbol: Phase displacement expressed as the clock hour number (1,6,11)
- **Example - Dyn11**
- Transformer has a delta connected primary winding (D) a star connected secondary (y) with the star point brought out (n) and a phase shift of 30 deg leading (11).
- The point of confusion is occurring in notation in a step-up transformer. As the IEC60076-1 standard has stated, the notation is HV-LV in sequence. For example, a step-up transformer with a delta-connected primary, and star-connected secondary, is not written as 'dY11', but 'Yd11'. The 11 indicates the LV winding leads the HV by 30 degrees.
- Transformers built to ANSI standards usually do not have the vector group shown on their nameplate and instead a vector diagram is given to show the relationship between the primary and other windings.

Vector Group of Transformer:

- The three phase transformer windings can be connected several ways. Based on the windings' connection, the vector group of the transformer is determined.
- The transformer vector group is indicated on the Name Plate of transformer by the manufacturer. The vector group indicates the phase difference between the primary and secondary sides, introduced due to that particular configuration of transformer windings connection.
- The Determination of vector group of transformers is very important before connecting two or more transformers in parallel. If two transformers of different vector groups are connected in parallel then phase

difference exist between the secondary of the transformers and large circulating current flows between the two transformers which is very detrimental.

Phase Displacement between HV and LV Windings:

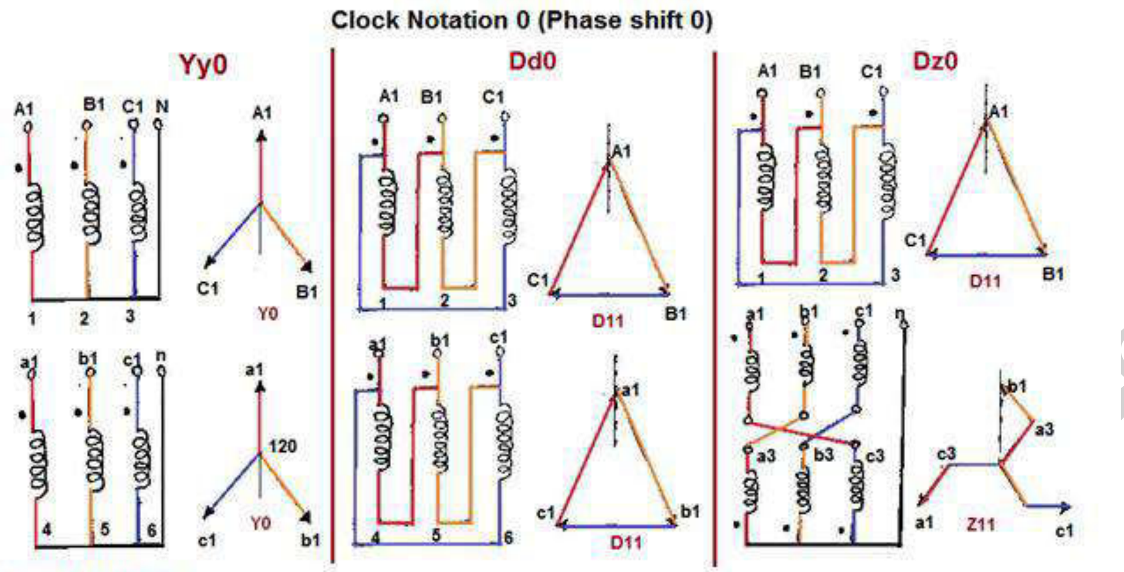
- The vector for the high voltage winding is taken as the reference vector. Displacement of the vectors of other windings from the reference vector, with anticlockwise rotation, is represented by the use of clock hour figure.
- IS: 2026 (Part 1V)-1977 gives 26 sets of connections star-star, star-delta, and star zigzag, delta-delta, delta star, delta-zigzag, zigzag star, zigzag-delta. Displacement of the low voltage winding vector varies from zero to -330° in steps of -30°, depending on the method of connections.
- Hardly any power system adopts such a large variety of connections. Some of the commonly used connections with phase displacement of 0, -300, -180" and -330° (clock-hour setting 0, 1, 6 and 11).
- Symbol for the high voltage winding comes first, followed by the symbols of windings in diminishing sequence of voltage. For example a 220/66/11 kV Transformer connected star, star and delta and vectors of 66 and 11 kV windings having phase displacement of 0° and -330° with the reference (220 kV) vector will be represented As **Yy0 - Yd11.**
- The digits (0, 1, 11 etc) relate to the phase displacement between the HV and LV windings using a clock face notation. The phasor representing the HV winding is taken as reference and set at 12 o'clock. Phase rotation is always anti-clockwise. (International adopted).
- Use the hour indicator as the indicating phase displacement angle. Because there are 12 hours on a clock, and a circle consists out of 360°, each hour represents 30°.Thus 1 = 30°, 2 = 60°, 3 = 90°, 6 = 180° and 12 = 0° or 360°.
- The minute hand is set on 12 o'clock and replaces the line to neutral voltage (sometimes imaginary) of the HV winding. This position is always the reference point.
- **Example:**
- Digit 0 =0° that the LV phasor is in phase with the HV phasor
  Digit 1 =30° lagging (LV lags HV with 30°) because rotation is anti-clockwise.
- Digit 11 = 330° lagging or 30° leading (LV leads HV with 30°)
- Digit 5 = 150° lagging (LV lags HV with 150°)
- Digit 6 = 180° lagging (LV lags HV with 180°)
- When transformers are operated in parallel it is important that any phase shift is the same through each. Paralleling typically occurs when transformers are located at one site and connected to a common bus bar (banked) or located at different sites with the secondary terminals connected via distribution or transmission circuits consisting of cables and overhead lines.

Phase Shift (Deg)	Connection		
0	Yy0	Dd0	Dz0
30 lag	Yd1	Dy1	Yz1
60 lag		Dd2	Dz2
120 lag		Dd4	Dz4
150 lag	Yd5	Dy5	Yz5
180 lag	Yy6	Dd6	Dz6
150 lead	Yd7	Dy7	Yz7
120 lead		Dd8	Dz8
60 lead		Dd10	Dz10
30 lead	Yd11	Dy11	Yz11

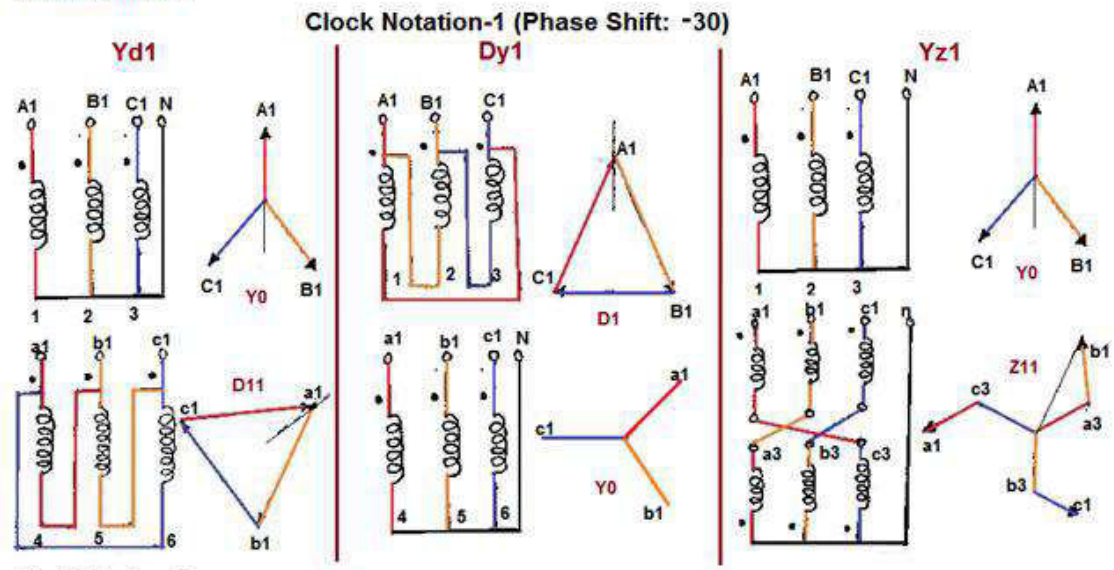
- The phase-bushings on a three phase transformer are marked either ABC, UVW or 123 (HV-side capital, LV-side small letters). Two winding, three phase transformers can be divided into four main categories

Group	O'clock	TC
Group I	0 o'clock, 0°	delta/delta, star/star
Group II	6 o'clock, 180°	delta/delta, star/star
Group III	1 o'clock, -30°	star/delta, delta/star
Group IV	11 o'clock, +30°	star/delta, delta/star
Minus indicates LV lagging HV, plus indicates LV leading HV		

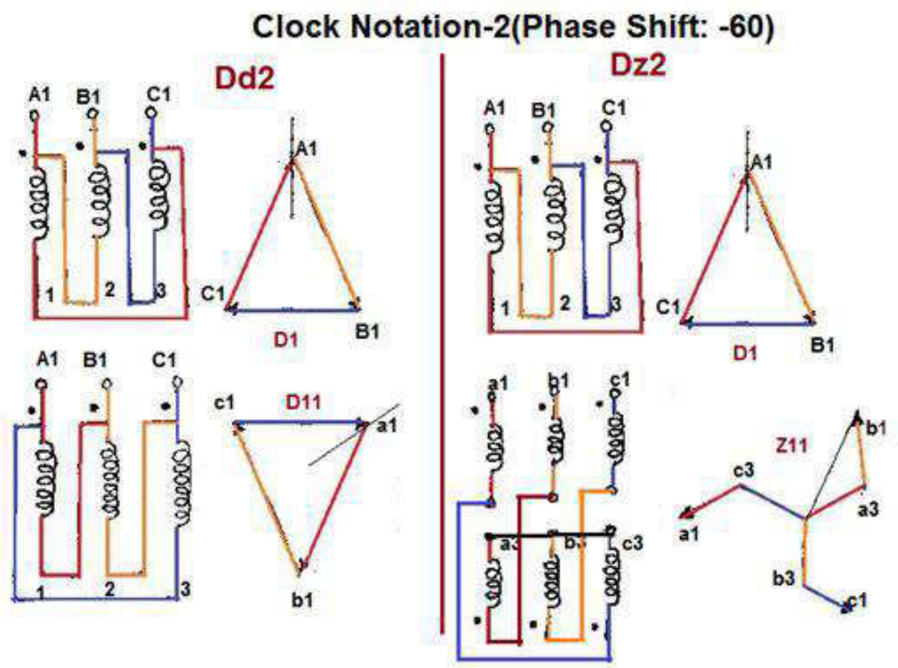
Clock Notation: 0



Clock Notation: 1

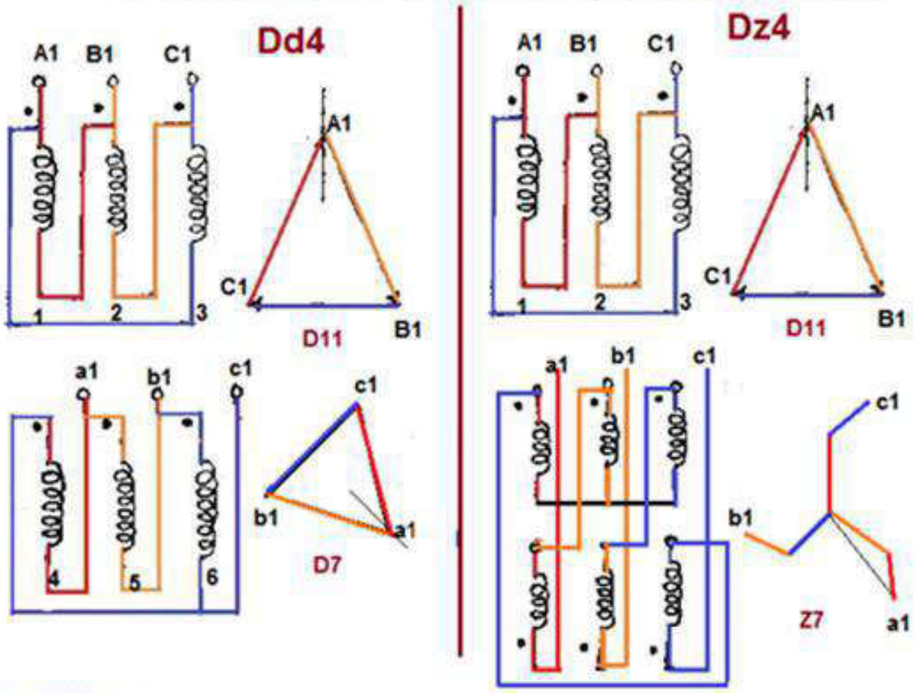


Clock Notation: 2



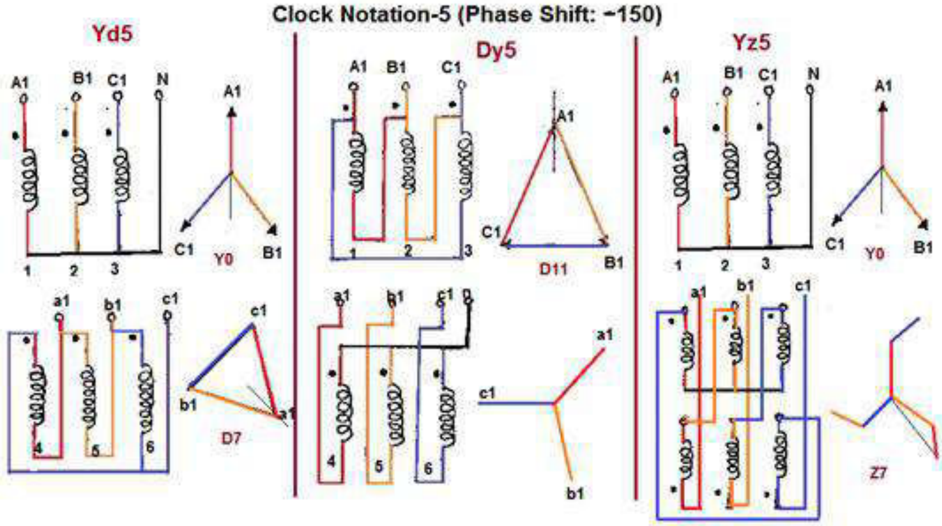
Clock Notation: 4

Clock Notation-4 (Phase Displacement -120)



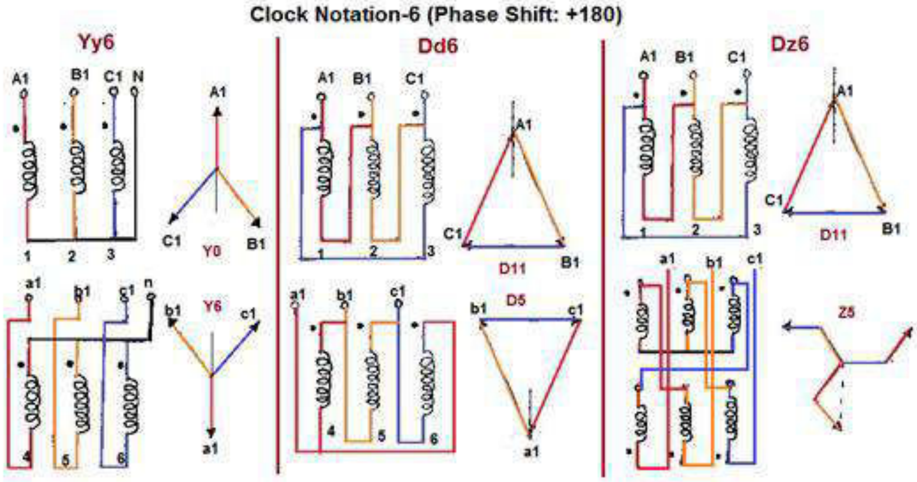
Clock Notation: 5

Clock Notation-5 (Phase Shift: -150)

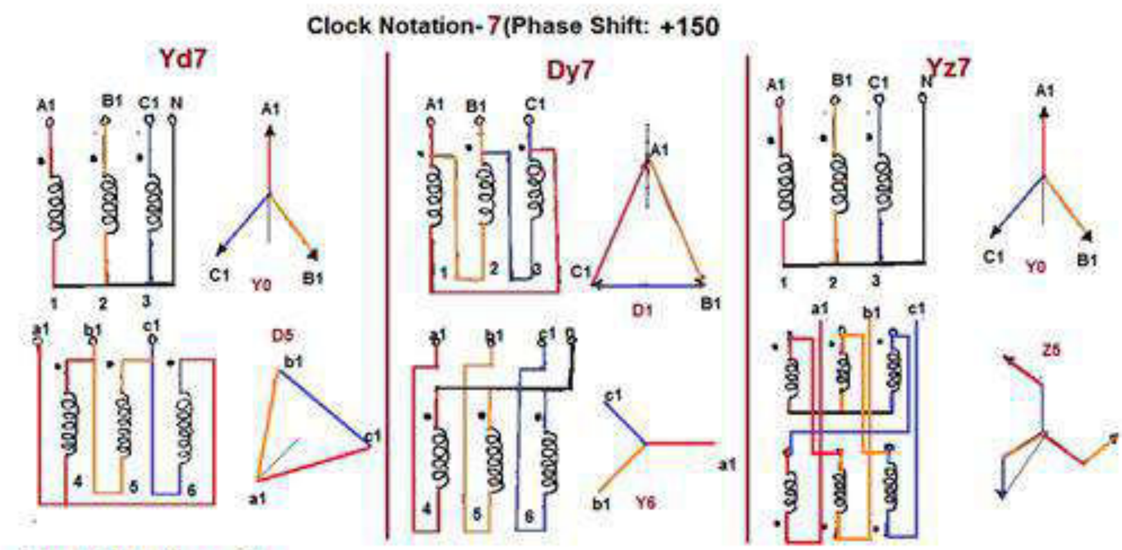


Clock Notation: 6

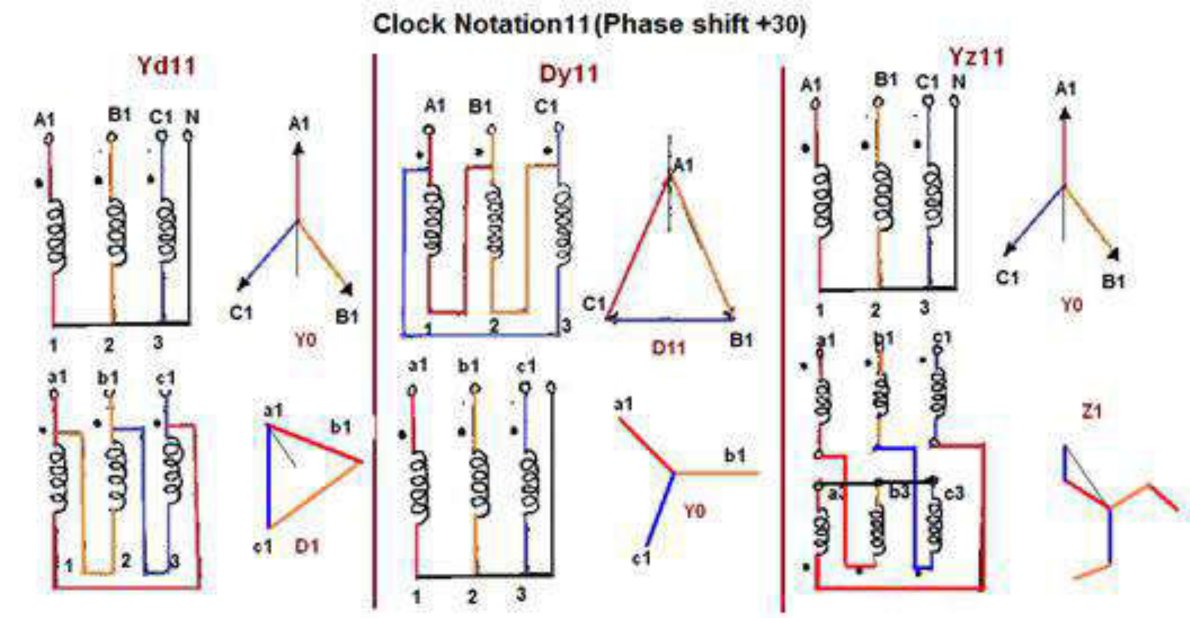
Clock Notation-6 (Phase Shift: +180)



Clock Notation: 7



Clock Notation: 11



Points to be consider while selecting of Vector Group:

- Vector Groups are the IEC method of categorizing the primary and secondary winding configurations of 3-phase transformers. Windings can be connected as delta, star, or interconnected-star (zigzag). Winding polarity is also important, since reversing the connections across a set of windings affects the phase-shift between primary and secondary. Vector groups identify the winding connections and polarities of the primary and secondary. From a vector group one can determine the phase-shift between primary and secondary.
- Transformer vector group depends upon

1. **Removing harmonics:** Dy connection - y winding nullifies 3rd harmonics, preventing it to be reflected on delta side.
2. **Parallel operations:** All the transformers should have same vector group & polarity of the winding.
3. **Earth fault Relay:** A Dd transformer does not have neutral. To restrict the earth faults in such systems, we may use zig zag wound transformer to create a neutral along with the earth fault relay.
4. Type of Non Liner Load: systems having different types of harmonics & non linear Types of loads e.g. furnace heaters, VFDS etc for that we may use Dyn11, Dyn21, Dyn31 configuration, wherein, 30 deg. shifts of voltages nullifies the 3rd harmonics to zero in the supply system.
5. **Type of Transformer Application:** Generally, for Power export transformer i.e. generator side is connected in delta and load side is connected in star. For Power export import transformers i.e. in Transmission Purpose

Transformer star star connection may be preferred by some since this avoids a grounding transformer on generator side and perhaps save on neutral insulation. Most of systems are running in this configuration. May be less harmful than operating delta system incorrectly. Yd or Dy connection is standard for all unit connected generators.

6. There are several factors associated with transformer connections and may be useful in designing a system, and the application of the factors therefore determines the best selection of transformers. For example:

For selecting Star Connection:

- A star connection presents a neutral. If the transformer also includes a delta winding, that neutral will be stable and can be grounded to become a reference for the system. A transformer with a star winding that does NOT include a delta does not present a stable neutral.
- Star-star transformers are used if there is a requirement to avoid a 30deg phase shift, if there is a desire to construct the three-phase transformer bank from single-phase transformers, or if the transformer is going to be switched on a single-pole basis (ie, one phase at a time), perhaps using manual switches.
- Star-star transformers are typically found in distribution applications, or in large sizes interconnecting high-voltage transmission systems. Some star-star transformers are equipped with a third winding connected in delta to stabilize the neutral.

For selecting Delta Connection:

- A delta connection introduces a 30 electrical degree phase shift.
- A delta connection 'traps' the flow of zero sequence currents.

For selecting Delta-Star Connection:

- Delta-star transformers are the most common and most generally useful transformers.
- Delta-delta transformers may be chosen if there is no need for a stable neutral, or if there is a requirement to avoid a 30 electrical degree phase shift. The most common application of a delta-delta transformer is as tan isolation transformer for a power converter.

For selecting Zig zag Connection:

- The Zig Zag winding reduces voltage unbalance in systems where the load is not equally distributed between phases, and permits neutral current loading with inherently low zero-sequence impedance. It is therefore often used for earthing transformers.
- Provision of a neutral earth point or points, where the neutral is referred to earth either directly or through impedance. Transformers are used to give the neutral point in the majority of systems. The star or interconnected star (Z) winding configurations give a neutral location. If for various reasons, only delta windings are used at a particular voltage level on a particular system, a neutral point can still be provided by a purpose-made transformer called a 'neutral earthing.

For selecting Distribution Transformer:

- The first criterion to consider in choosing a vector group for a distribution transformer for a facility is to know whether we want a delta-star or star-star. Utilities often prefer star-star transformers, but these require 4-wire input feeders and 4-wire output feeders (i.e. incoming and outgoing neutral conductors).
- For distribution transformers within a facility, often delta-star are chosen because these transformers do not require 4-wire input; a 3-wire primary feeder circuit suffices to supply a 4-wire secondary circuit. That is because any zero sequence current required by the secondary to supply earth faults or unbalanced loads is supplied by the delta primary winding, and is not required from the upstream power source. The method of earthing on the secondary is independent of the primary for delta-star transformers.
- The second criterion to consider is what phase-shift you want between primary and secondary. For example, Dy11 and Dy5 transformers are both delta-star. If we don't care about the phase-shift, then either transformer will do the job. Phase-shift is important when we are paralleling sources. We want the phase-shifts of the sources to be identical.
- If we are paralleling transformers, then you want them to have the same the same vector group. If you are replacing a transformer, use the same vector group for the new transformer, otherwise the existing VTs and CTs used for protection and metering will not work properly.
- There is no technical difference between the one vector groups (i.e. Yd1) or another vector group (i.e. Yd11) in terms of performance. The only factor affecting the choice between one or the other is system phasing, ie whether parts of the network fed from the transformer need to operate in parallel with another source. It also matters if you have an auxiliary transformer connected to generator terminals. Vector matching at the auxiliary bus bar

Application of Transformer according to Vector Group:

(1) Delta-Star (Dyn11, Dyn1, YNd1, YNd11)

- Common for distribution transformers.
- Normally Dyn11 vector group using at distribution system. Because Generating Transformer are YNd1 for neutralizing the load angle between 11 and 1.
- We can use Dyn1 at distribution system, when we are using Generator Transformer are YNd11.
- In some industries 6 pulse electric drives are using due to this 5thharmonics will generate if we use Dyn1 it will be suppress the 5th harmonics.
- Star point facilitates mixed loading of three phase and single phase consumer connections.
- The delta winding carry third harmonics and stabilizes star point potential.
- A delta-Star connection is used for step-up generating stations. If HV winding is star connected there will be saving in cost of insulation.
- But delta connected HV winding is common in distribution network, for feeding motors and lighting loads from LV side.

(2) Star-Star (Yy0 or Yy6)

- Mainly used for large system tie-up Transformer.
- Most economical connection in HV power system to interconnect between two delta systems and to provide neutral for grounding both of them.
- Tertiary winding stabilizes the neutral conditions. In star connected transformers, load can be connected between line and neutral, only if
  (a) the source side transformers is delta connected or
  (b) the source side is star connected with neutral connected back to the source neutral.
- In This Transformers. Insulation cost is highly reduced. Neutral wire can permit mixed loading.
- Triple harmonics are absent in the lines. These triple harmonic currents cannot flow, unless there is a neutral wire. This connection produces oscillating neutral.
- Three phase shell type units have large triple harmonic phase voltage. However three phase core type transformers work satisfactorily.
- A tertiary mesh connected winding may be required to stabilize the oscillating neutral due to third harmonics in three phase banks.

(3) Delta - Delta (Dd 0 or Dd 6)

- This is an economical connection for large low voltage transformers.
- Large unbalance of load can be met without difficulty.
- Delta permits a circulating path for triple harmonics thus attenuates the same.
- It is possible to operate with one transformer removed in open delta or" V" connection meeting 58 percent of the balanced load.
- Three phase units cannot have this facility. Mixed single phase loading is not possible due to the absence of neutral.

(4) Star-Zig-zag or Delta-Zig-zag (Yz or Dz)

- These connections are employed where delta connections are weak. Interconnection of phases in zigzag winding effects a reduction of third harmonic voltages and at the same time permits unbalanced loading.
- This connection may be used with either delta connected or star connected winding either for step-up or step-down transformers. In either case, the zigzag winding produces the same angular displacement as a delta winding, and at the same time provides a neutral for earthing purposes.
- The amount of copper required from a zigzag winding in 15% more than a corresponding star or delta winding. This is extensively used for earthing transformer.
- Due to zigzag connection (interconnection between phases), third harmonic voltages are reduced. It also allows unbalanced loading. The zigzag connection is employed for LV winding. For a given total voltage per phase, the zigzag side requires 15% more turns as compared to normal phase connection. In cases where delta connections are weak due to large number of turns and small cross sections, then zigzag star connection is preferred. It is also used in rectifiers.

(5) Zig- zag / star (ZY1 or Zy11)

- Zigzag connection is obtained by inter connection of phases.4-wire system is possible on both sides. Unbalanced loading is also possible. Oscillating neutral problem is absent in this connection.
- This connection requires 15% more turns for the same voltage on the zigzag side and hence costs more. Hence a bank of three single phase transformers cost about 15% more than their 3-phase counterpart. Also, they occupy more space. But the spare capacity cost will be less and single phase units are easier to transport.
- Unbalanced operation of the transformer with large zero sequence fundamental mmf content also does not affect its performance. Even with Yy type of poly phase connection without neutral connection the oscillating neutral does not occur with these cores. Finally, three phase cores themselves cost less than three single phase units due to compactness.

(6) Star- Delta (Yd5):

- Mainly used for machine and main Transformer in large Power Station and Transmission Substation.
- The Neutral point can be loaded with rated Current.

(7) Star / Zigzag (Yz-5):

- For Distribution Transformer up to 250MVA for local distribution system.
- The Neutral point can be loaded with rated Current.

Application of Transformer according according to Uses:

- **Step up Transformer:** It should be Yd1 or Yd11.
- **Step down Transformer:** It should be Dy1 or Dy11.
- **Grounding purpose Transformer:** It should be Yz1 or Dz11.
- **Distribution Transformer:** We can consider vector group of Dzn0 which reduce the 75% of harmonics in secondary side.
- **Power Transformer:** Vector group is deepen on application for Example: Generating Transformer : Dyn1 , Furnace Transformer: Ynyn0.

Convert One Group of Transformer to Other Group by Channing External Connection:

a) Group I: Example: Dd0 (no phase displacement between HV and LV).

- The conventional method is to connect the red phase on A/a, Yellow phase on B/b, and the Blue phase on C/c.
- Other phase displacements are possible with unconventional connections (for instance red on b, yellow on c and blue on a) By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd0 transformer can be changed either to a Dd4(-120°) or Dd8(+120°) connection. The same is true for internal connected Dd4 or Dd8 transformers.

b) Group II: Example: Dd6 (180° displacement between HV and LV).

- By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd6 transformer can be changed either to a Dd2(-60°) or Dd10(+60°) connection.

c) Group III: Example: Dyn1 (-30° displacement between HV and LV).

- By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn1 transformer can be changed either to a Dyn5(-150°) or Dyn9(+90°) connection.

d) Group IV: Example: Dyn11 (+30° displacement between HV and LV).

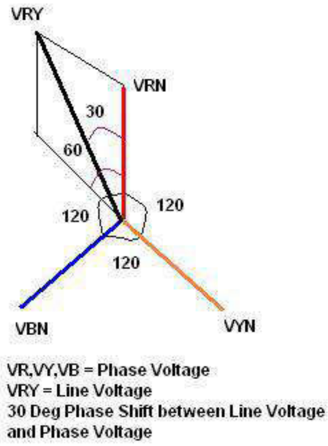
- By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn11 transformer can be changed either to a Dyn7(+150°) or Dyn3(-90°) connection.

Point to be remembered:

- **For Group-III & Group-IV:** By doing some unconventional connections externally on both sides of the Transformer, an internal connected Group-III or Group-IV transformer can be changed to any of these two groups.
- Thus by doing external changes on both sides of the Transformer an internal connected Dyn1 transformer can be changed to either a: Dyn3, Dyn5, Dyn7, Dyn9 or Dyn11 transformer, This is just true for star/delta or delta/star connections.
- **For Group-I & Group-II:** Changes for delta/delta or star/star transformers between Group-I and Group-III can just be done internally.

Why 30°phase shift occur in star-delta transformer between primary and secondary?

- The phase shift is a natural consequence of the delta connection. The currents entering or leaving the star winding of the transformer are in phase with the currents in the star windings. Therefore, the currents in the delta windings are also in phase with the currents in the star windings and obviously, the three currents are 120 electrical degrees apart.
- But the currents entering or leaving the transformer on the delta side are formed at the point where two of the windings comprising the delta come together - each of those currents is the phasor sum of the currents in the adjacent windings.
- When you add together two currents that are 120 electrical degrees apart, the sum is inevitably shifted by degree



- The Main reason for this phenomenon is that the phase voltage lags line current by 30degrees.consider a delta/star transformer. The phase voltages in three phases of both primary and secondary. you will find that in primary the phase voltage and line voltages are same, let it be VRY(take one phase).but, the corresponding secondary will have the phase voltage only in its phase winding as it is star connected. the line voltage of star connected secondary and delta connected primary won't have any phase differences between them. so this can be summarized that "the phase shift is associated with the wave forms of the three phase windings.

Why Generating Transformer is Yd1 and Distribution Transformer is Dy11:

- This is the HV Side or the Switchyard side of the Generator Transformer is connected in Delta and the LV Side or the generator side of the GT is connected in Star, with the Star side neutral brought out.The LV side voltage will "lag" the HV side voltage by 30 degrees.
- Thus, in a generating station we create a 30 degrees lagging voltage for transmission, with respect to the generator voltage.
- As we have created a 30 degrees lagging connection in the generating station, it is advisable to create a 30 degrees leading connection in distribution so that the user voltage is "in phase" with the generated voltage. And, as the transmission side is Delta and the user might need three phase, four-wire in the LV side for his single phase loads, the distribution transformer is chosen as Dyn11.
- There is magnetic coupling between HT and LT. When the load side (LT) suffers some dip the LT current try to go out of phase with HT current, so 30 degree phase shift in Dyn-11 keeps the two currents in phase when there is dip.
- So the vector group at the generating station is important while selecting distribution Transformer.

Vector Group in Generating-Transmission-Distribution System:

- Generating TC is Yd1 transmitted power at 400KV, for 400KV to 220KV Yy is used and by using **Yd** between e.g. 220 and 66 kV, then **Dy** from 66 to 11 kV so that their phase shifts can be cancelled out. And for LV (400/230V) supplies at 50 Hz are usually 3 phase, earthed neutral, so a "Dyn" LV winding is needed. Here GT side -30lag (Yd1) can be nullify +30 by using distribution Transformer of Dy11.
- A reason for using **Yd** between e.g. 220 and 66 kV, then **Dy** from 66 to 11 kV is that their phase shifts can cancel out and It is then also possible to parallel a 220/11 kV YY transformer, at 11 kV, with the 66/11 kV (a YY transformer often has a third, delta, winding to reduce harmonics). If one went Dy11 - Dy11 from 220 to 11 kV,

there would be a 60 degree shift, which is not possible in one transformer. The "standard" transformer groups in distribution avoid that kind of limitation, as a result of thought and experience leading to lowest cost over many years.

Generator Transformer is Yd1, Can we use Distribution Transformer Dy5 instead of Dy11.

- With regards to theory, there are no special advantages of Dyn11 over Dyn5.
- **In Isolation Application:** In isolated applications there is no advantage or disadvantage by using Dy5 or Dy11. If however we wish to interconnect the secondary sides of different Dny transformers, we must have compatible transformers, and that can be achieved if you have a Dyn11 among a group of Dyn5's and vice versa.
- **In Parallel Connection:** Practically, the relative places of the phases remain same in Dyn11 compared to Dyn5.
- If we use Yd1 Transformer on Generating Side and Distribution side Dy11 transformer than -30 lag of generating side (Yd1) is nullify by +30 Lead at Receiving side Dy11) so no phase difference respect to generating Side and if we are on the HV side of the Transformer, and if we denote the phases as R- Y-B from left to right, the same phases on the LV side will be R- Y -B, but from left to Right.
- This will make the Transmission lines have same color (for identification) whether it is input to or output from the Transformer.
- If we use Yd1 Transformer on Generating Side and Distribution side Dy5 transformer than -30 lag of generating side (Yd1) is more lag by -150 Lag at Receiving side (Dy5) so Total phase difference respect to generating Side is 180 deg (-30+-150=-180) and if we are on the HV side of the Transformer, and if we denote the phases as R- Y-B from left to right, the same phases on the LV side will be R- Y -B, but from Right to Left.
- This will make the Transmission lines have No same color (for identification) whether it is input to or output from the Transformer.
- The difference in output between the Dyn11 and Dny5 and is therefore 180 degrees.

Chapter: 6 Difference between Power Transformer & Distribution Transformer

Difference between Power Transfomer & Distribution Transformer:

1) Transformer Application:

- Power transformers are used in transmission network of higher voltages for step-up and step down application (400 kV, 200 kV, 110 kV, 66 kV, 33kV) and are generally rated above 200MVA.
- Distribution transformers are used for lower voltage distribution networks as a means to end user connectivity. (11kV, 6.6 kV, 3.3 kV, 440V, 230V) and are generally rated less than 200 MVA.

2) Transformer Size / Insulation Level:

- Power transformer is used for the transmission purpose at heavy load, high voltage greater than 33 KV & 100% efficiency. It also having a big in size as compare to distribution transformer, it used in generating station and Transmission substation .high insulation level.
- The distribution transformer is used for the distribution of electrical energy at low voltage as less than 33KV in industrial purpose and 440v-220v in domestic purpose. It work at low efficiency at 50-70%, small size, easy in installation, having low magnetic losses & it is not always fully loaded.

3) Iron Loss & Copper Loss:

- Power Transformers are used in Transmission network so they do not directly connect to the consumers, so load fluctuations are very less. These are loaded fully during 24 hr's a day, so cu losses & iron losses takes place throughout day the specific weight i.e. (iron weight)/(cu weight) is very less .the average loads are nearer to full loaded or full load and these are designed in such a way that maximum efficiency at full load condition. These are independent of time so in calculating the efficiency only power basis is enough.
- Power Transformers are used in Distribution Network so directly connected to the consumer so load fluctuations are very high. these are not loaded fully at all time so iron losses takes place 24hr a day and cu losses takes place based on load cycle. the specific weight is more i.e. (iron weight)/(cu weight).average loads are about only 75% of full load and these are designed in such a way that max efficiency occurs at 75% of full load.
- Power transformers are used for transmission as a step up devices so that the I2r loss can be minimized for a given power flow. These transformers are designed to utilize the core to maximum and will operate very much near to the knee point of B-H curve (slightly above the knee point value).This brings down the mass of the core enormously. Naturally these transformers have the matched iron losses and copper losses at peak load (i.e. the maximum efficiency point where both the losses match).
- Distribution transformers obviously cannot be designed like this. Hence the all-day-efficiency comes into picture while designing it. It depends on the typical load cycle for which it has to supply. Definitely Core design will be done to take care of peak load and as well as all-day-efficiency. It is a bargain between these two points.
- Power transformer generally operated at full load. Hence, it is designed such that copper losses are minimal. However, a distribution transformer is always online and operated at loads less than full load for most of time. Hence, it is designed such that core losses are minimal.
- In Power Transformer the flux density is higher than the distribution transformer.

4) Maximum Efficiency:

- The main difference between power and distribution transformer is distribution transformer is designed for maximum efficiency at 60% to 70% load as normally doesn’t operate at full load all the time. Its load depends on distribution demand. Whereas power transformer is designed for maximum efficiency at 100% load as it always runs at 100% load being near to generating station.
- Distribution Transformer is used at the distribution level where voltages tend to be lower .The secondary voltage is almost always the voltage delivered to the end consumer. Because of voltage drop limitations, it is usually not possible to deliver that secondary voltage over great distances. As a result, most distribution systems tend to involve many 'clusters' of loads fed from distribution transformers, and this in turn means that the thermal rating of distribution transformers doesn't have to be very high to support the loads that they have to serve.
- All day efficiency = (Output in KWhr) / (Input in KWhr) in 24 hrs which is always less than power efficiency

Chapter: 7 Parallel Operation of Transformer

Introduction:

- For supplying a load in excess of the rating of an existing transformer, two or more transformers may be connected in parallel with the existing transformer. The transformers are connected in parallel when load on one of the transformers is more than its capacity. The reliability is increased with parallel operation than to have single larger unit. The cost associated with maintaining the spares is less when two transformers are connected in parallel.
- It is usually economical to install another transformer in parallel instead of replacing the existing transformer by a single larger unit. The cost of a spare unit in the case of two parallel transformers (of equal rating) is also lower than that of a single large transformer. In addition, it is preferable to have a parallel transformer for the reason of reliability. With this at least half the load can be supplied with one transformer out of service.

Condition for Parallel Operation of Transformer:

- For parallel connection of transformers, primary windings of the Transformers are connected to source bus-bars and secondary windings are connected to the load bus-bars.
- Various conditions that must be fulfilled for the successful parallel operation of transformers:

1. Same voltage Ratio & Turns Ratio (both primary and secondary Voltage Rating is same).
2. Same Percentage Impedance and X/R ratio.
3. Identical Position of Tap changer.
4. Same KVA ratings.
5. Same Phase angle shift (vector group are same).
6. Same Frequency rating.
7. Same Polarity.
8. Same Phase sequence.

- Some of these conditions are convenient and some are mandatory.
- The convenient are: Same voltage Ratio & Turns Ratio, Same Percentage Impedance, Same KVA Rating, Same Position of Tap changer.
- The mandatory conditions are: Same Phase Angle Shift, Same Polarity, Same Phase Sequence and Same Frequency.
- When the convenient conditions are not met paralleled operation is possible but not optimal.

(1) Same voltage Ratio & Turns Ratio (on each tap):

- If the transformers connected in parallel have slightly different voltage ratios, then due to the inequality of induced emfs in the secondary windings, a circulating current will flow in the loop formed by the secondary windings under the no-load condition, which may be much greater than the normal no-load current.
- The current will be quite high as the leakage impedance is low. When the secondary windings are loaded, this circulating current will tend to produce unequal loading on the two transformers, and it may not be possible to take the full load from this group of two parallel transformers (one of the transformers may get overloaded).
- If two transformers of different voltage ratio are connected in parallel with same primary supply voltage, there will be a difference in secondary voltages.
- Now when the secondary of these transformers are connected to same bus, there will be a circulating current between secondary's and therefore between primaries also. As the internal impedance of transformer is small, a small voltage difference may cause sufficiently high circulating current causing unnecessary extra I^2R loss.
- The ratings of both primaries and secondary's should be identical. In other words, the transformers should have the same turn ratio i.e. transformation ratio.

(2) Same percentage impedance and X/R ratio:

- If two transformers connected in parallel with similar per-unit impedances they will mostly share the load in the ration of their KVA ratings. Here Load is mostly equal because it is possible to have two transformers with equal per-unit impedances but different X/R ratios. In this case the line current will be less than the sum of the transformer currents and the combined capacity will be reduced accordingly.
- A difference in the ratio of the reactance value to resistance value of the per unit impedance results in a different phase angle of the currents carried by the two paralleled transformers; one transformer will be working with a

higher power factor and the other with a lower power factor than that of the combined output. Hence, the real power will not be proportionally shared by the transformers.

- **The current shared by two transformers running in parallel should be proportional to their MVA ratings.**
- **The current carried by these transformers are inversely proportional to their internal impedance.**
- From the above two statements it can be said that impedance of transformers running in parallel are inversely proportional to their MVA ratings. In other words percentage impedance or per unit values of impedance should be identical for all the transformers run in parallel.
- When connecting single-phase transformers in three-phase banks, proper impedance matching becomes even more critical. In addition to following the three rules for parallel operation, it is also a good practice to try to match the *X/R* ratios of the three series impedances to keep the three-phase output voltages balanced.
- When single-phase transformers with the same KVA ratings are connected in a Y-Δ Bank, impedance mismatches can cause a significant load unbalance among the transformers
- Let's examine following different type of case among Impedance, Ratio and KVA.
- If single-phase transformers are connected in a Y-Y bank with an isolated neutral, then the magnetizing impedance should also be equal on an ohmic basis. Otherwise, the transformer having the largest magnetizing impedance will have a highest percentage of exciting voltage, increasing the core losses of that transformer and possibly driving its core into saturation.

- ## Case 1: Equal Impedance, Ratios and Same kVA:
- The standard method of connecting transformers in parallel is to have the same turn ratios, percent impedances, and kVA ratings.
- Connecting transformers in parallel with the same parameters results in equal load sharing and no circulating currents in the transformer windings.
- **Example:** Connecting two 2000 kVA, 5.75% impedance transformers in parallel, each with the same turn ratios to a 4000 kVA load.
- Loading on the transformers-1 =KVA1=[(KVA1 / %Z) / ((KVA1 / %Z1)+ (KVA2 / %Z2))]X KVAl
- kVA1 = 348 / (348 + 348) x 4000 kVA = 2000 kVA.
- Loading on the transformers-2 =KVA1=[(KVA2 / %Z) / ((KVA1 / %Z1)+ (KVA2 / %Z2))]X KVAl
- kVA2 = 348 / (348 + 348) x 4000 kVA = 2000 kVA
- **Hence KVA1=KVA2=2000KVA**

- ## Case 2: Equal Impedances, Ratios and Different kVA:
- This Parameter is not in common practice for new installations, sometimes two transformers with different kVAs and the same percent impedances are connected to one common bus. In this situation, the current division causes each transformer to carry its rated load. There will be no circulating currents because the voltages (turn ratios) are the same.
- **Example:** Connecting 3000 kVA and 1000 kVA transformers in parallel, each with 5.75% impedance, each with the same turn ratios, connected to a common 4000 kVA load.
- Loading on Transformer-1=kVA1 = 522 / (522 + 174) x 4000 = 3000 kVA
- Loading on Transformer-1=kVA2 = 174 / (522 + 174) x 4000 = 1000 kVA
- From above calculation it is seen that different kVA ratings on transformers connected to one common load, that current division causes each transformer to only be loaded to its kVA rating. The key here is that the percent impedance are the same.

- ## Case 3: Unequal Impedance but Same Ratios & kVA:
- Mostly used this Parameter to enhance plant power capacity by connecting existing transformers in parallel that have the same kVA rating, but with different percent impedances.
- This is common when budget constraints limit the purchase of a new transformer with the same parameters.
- We need to understand is that the current divides in inverse proportions to the impedances, and larger current flows through the smaller impedance. Thus, the lower percent impedance transformer can be overloaded when subjected to heavy loading while the other higher percent impedance transformer will be lightly loaded.
- **Example:** Two 2000 kVA transformers in parallel, one with 5.75% impedance and the other with 4% impedance, each with the same turn ratios, connected to a common 3500 kVA load.
- **Loading on Transformer-1**=kVA1 = 348 / (348 + 500) x 3500 = **1436 kVA**
- **Loading on Transformer-2=**kVA2 = 500 / (348 + 500) x 3500 = **2064 kVA**

- It can be seen that because transformer percent impedances do not match, they cannot be loaded to their combined kVA rating. Load division between the transformers is not equal. At below combined rated kVA loading, the 4% impedance transformer is overloaded by 3.2%, while the 5.75% impedance transformer is loaded by 72%.
- ## Case 4: Unequal Impedance & KVA Same Ratios:
- This particular of transformers used rarely in industrial and commercial facilities connected to one common bus with different kVA and unequal percent impedances. However, there may be that one situation where two single-ended substations may be tied together via bussing or cables to provide better voltage support when starting large Load.
- If the percent impedance and kVA ratings are different, care should be taken when loading these transformers.
- **Example:** Two transformers in parallel with one 3000 kVA (kVA1) with 5.75% impedance, and the other a 1000 kVA (kVA2) with 4% impedance, each with the same turn ratios, connected to a common 3500 kVA load.
- **Loading on Transformer-1=**kVA1 = 522 / (522 + 250) x 3500 = 2366 kVA
- **Loading on Transformer-2=**kVA2 = 250 / (522 + 250) x 3500 = 1134 kVA
- Because the percent impedance is less in the 1000 kVA transformer, it is overloaded with a less than combined rated load.
- ## Case 5: Equal Impedance & KVA Unequal Ratios:
- Small differences in voltage cause a large amount of current to circulate. It is important to point out that paralleled transformers should always be on the same tap connection.
- Circulating current is completely independent of the load and load division. If transformers are fully loaded there will be a considerable amount of overheating due to circulating currents.
- The Point which should be Remember that circulating currents do not flow on the line, they cannot be measured if monitoring equipment is upstream or downstream of the common connection points.
- **Example:** Two 2000 kVA transformers connected in parallel, each with 5.75% impedance, same X/R ratio (8), transformer 1 with tap adjusted 2.5% from nominal and transformer 2 tapped at nominal. What is the percent circulating current (%IC)
- %Z1 = 5.75, So %R' = %Z1 / √[(X/R)2 + 1)] = 5.75 / √((8)2 + 1)=0.713
- %R1 = %R2 = 0.713
- %X1 = %R x (X/R)=%X1= %X2= 0.713 x 8 = 5.7
- Let %e = difference in voltage ratio expressed in percentage of normal and k = kVA1/ kVA2
- **Circulating current %IC = %eX100 / √ (%R1+k%R2)2 + (%Z1+k%Z2)2.**
- %IC = 2.5X100 / √ (0.713 + (2000/2000)X0.713)2 + (5.7 + (2000/2000)X5.7)2
- %IC = 250 / 11.7 = 21.7
- The circulating current is 21.7% of the full load current.
- ## Case 6: Unequal Impedance, KVA & Different Ratios:
- This type of parameter would be unlikely in practice.
- If both the ratios and the impedance are different, the circulating current (because of the unequal ratio) should be combined with each transformer's share of the load current to obtain the actual total current in each unit.
- For unity power factor, 10% circulating current (due to unequal turn ratios) results in only half percent to the total current. At lower power factors, the circulating current will change dramatically.
- **Example:** Two transformers connected in parallel, 2000 kVA1 with 5.75% impedance, X/R ratio of 8, 1000 kVA2 with 4% impedance, X/R ratio of 5, 2000 kVA1 with tap adjusted 2.5% from nominal and 1000 kVA2 tapped at nominal.
- %Z1 = 5.75, So %R' = %Z1 / √[(X/R)2 + 1)] = 5.75 / √((8)2 + 1)=0.713
- %X1= %R x (X/R)=0.713 x 8 = 5.7
- %Z2= 4, So %R2 = %Z2 /√ [(X/R)2 + 1)]= 4 / √((5)2 + 1) =0.784
- %X2 = %R x (X/R)=0.784 x 5 = 3.92
- Let %e = difference in voltage ratio expressed in percentage of normal and k = kVA1/ kVA2
- **Circulating current %IC = %eX100 / √ (%R1+k%R2)2 + (%Z1+k%Z2)2.**
- %IC = 2.5X100 / √ (0.713 + (2000/2000)X0.713)2 + (5.7 + (2000/2000)X5.7)2
- %IC = 250 / 13.73 = 18.21.
- The circulating current is 18.21% of the full load current.

(3) Same polarity:

- Polarity of transformer means the instantaneous direction of induced emf in secondary. If the instantaneous directions of induced secondary emf in two transformers are opposite to each other when same input power is fed to the both of the transformers, the transformers are said to be in opposite polarity.
- The transformers should be properly connected with regard to their polarity. If they are connected with incorrect polarities then the two emfs, induced in the secondary windings which are in parallel, will act together in the local secondary circuit and produce a short circuit.
- Polarity of all transformers run in parallel should be same otherwise huge circulating current flows in the transformer but no load will be fed from these transformers.
- If the instantaneous directions of induced secondary emf in two transformers are same when same input power is fed to the both of the transformers, the transformers are said to be in same polarity.

(4) Same phase sequence:

- The phase sequence of line voltages of both the transformers must be identical for parallel operation of three-phase transformers. If the phase sequence is an incorrect, in every cycle each pair of phases will get short-circuited.
- **This condition must be strictly followed for parallel operation of transformers.**

(5) Same phase angle shift :(zero relative phase displacement between the secondary line voltages):

- The transformer windings can be connected in a variety of ways which produce different magnitudes and phase displacements of the secondary voltage. All the transformer connections can be classified into distinct vector groups.
- Group 1: Zero phase displacement (Yy0, Dd0, Dz0)
  Group 2:180° phase displacement (Yy6, Dd6, Dz6)
  Group 3: -30° phase displacement (Yd1, Dy1, Yz1)
  Group 4: +30° phase displacement (Yd11, Dy11, Yz11)
- In order to have zero relative phase displacement of secondary side line voltages, the transformers belonging to the same group can be paralleled. For example, two transformers with Yd1 and Dy1 connections can be paralleled.
- The transformers of groups 1 and 2 can only be paralleled with transformers of their own group. However, the transformers of groups 3 and 4 can be paralleled by reversing the phase sequence of one of them. For example, a transformer with Yd1 1 connection (group 4) can be paralleled with that having Dy1 connection (group 3) by reversing the phase sequence of both primary and secondary terminals of the Dy1 transformer.
- We can only parallel Dy1 and Dy11 by crossing two incoming phases and the same two outgoing phases on one of the transformers, so if we have a DY11 transformer we can cross B&C phases on the primary and secondary to change the +30 degree phase shift into a -30 degree shift which will parallel with the Dy1, assuming all the other points above are satisfied.

(6) Same KVA ratings:

- If two or more transformer is connected in parallel, then load sharing % between them is according to their rating. If all are of same rating, they will share equal loads
- Transformers of unequal kVA ratings will share a load practically (but not exactly) in proportion to their ratings, providing that the voltage ratios are identical and the percentage impedances (at their own kVA rating) are identical, or very nearly so in these cases a total of than 90% of the sum of the two ratings is normally available.
- It is recommended that transformers, the kVA ratings of which differ by more than 2:1, should not be operated permanently in parallel.
- Transformers having different kva ratings may operate in parallel, with load division such that each transformer carries its proportionate share of the total load To achieve accurate load division, it is necessary that the transformers be wound with the same turns ratio, and that the percent impedance of all transformers be equal, when each percentage is expressed on the kva base of its respective transformer. It is also necessary that the ratio of resistance to reactance in all transformers be equal. For satisfactory operation the circulating current for any combinations of ratios and impedances probably should not exceed ten percent of the full-load rated current of the smaller unit.

(7) Identical tap changer and its operation:

- The only important point to be remembered is the tap changing switches must be at same position for all the three transformers and should check and confirm that the secondary voltages are same. When the voltage tap need change all three tap changing switches should be operated identical for all transformers. The OL settings of the SF6 also should be identical. If the substation is operating on full load condition, tripping of one transformer can cause cascade tripping of all three transformers.

- In transformers Output Voltage can be controlled either by Off Circuit Tap Changer (Manual tap changing) or By On – Load Tap Changer-OLTC (Automatic Changing).
- In the transformer with OLTC, it is a closed loop system, with following components:
- (1) AVR (Automatic Voltage Regulator- an electronic programmable device). With this AVR we can set the Output Voltage of the transformers. The Output Voltage of the transformer is fed into the AVR through the LT Panel. The AVR Compares the SET voltage & the Output Voltage and gives the error signals, if any, to the OLTC through the RTCC Panel for tap changing. This AVR is mounted in the RTCC.
- (2) RTCC (Remote Tap Changing Cubicle): This is a panel consisting of the AVR, Display for Tap Position, Voltage, and LEDs for Raise & Lower of Taps relays, Selector Switches for Auto Manual Selection… In AUTO MODE the voltage is controlled by the AVR. In manual Mode the operator can Increase / decrease the voltage by changing the Taps manually through the Push Button in the RTCC.
- (3) OLTC is mounted on the transformer. It consists of a motor, controlled by the RTCC, which changes the Taps in the transformers.
- Both the Transformers should have same voltage ratio at all the taps & when you run transformers in parallel, it should operate as same tap position. If we have OLTC with RTCC panel, one RTCC should work as master & other should work as follower to maintain same tap positions of Transformer.
- However, a circulating current can be flown between the two tanks if the impedances of the two transformers are different or if the taps of the on-load tap changer (OLTC) are mismatched temporarily due to the mechanical delay. The circulating current may cause the malfunction of protection relays.

Other necessary condition for parallel operation:

1. All parallel units must be supplied from the same network.
2. Secondary cabling from the transformers to the point of paralling has approximately equal length and characteristics.
3. Voltage difference between corresponding phase must not exceed 0.4%
4. When the transformers are operated in parallel, the fault current would be very high on the secondary side. Supposing percentage impedance of one transformer is say 6.25 %, the short circuit MVA would be 25.6 MVA and short circuit current would be 35 kA.
5. If the transformers are of same rating and same percentage impedance, then the downstream short circuit current would be 3 times (since 3 transformers are in Parallel) approximately 105 kA. This means all the devices like ACBs, MCCBs, switch boards should withstand the short-circuit current of 105 kA. This is the maximum current. This current will get reduced depending on the location of the switch boards, cables and cable length etc. However this aspect has to be taken into consideration.
6. There should be Directional relays on the secondary side of the transformers.
7. The percent impedance of one transformer must be between 92.5% and 107.5% of the other. Otherwise, circulating currents between the two transformers would be excessive.

Summary of Parallel Operation of Transformer:

Transformer Parallel Connection Types	Equal Loading	Unequal Loading	Over loading	Circulating Current	Recomm. connection
Equal Impedance & Ratio, Same KVA	Yes	No	No	No	Yes
Equal Impedance & Ratio But different KVA	No	Yes	No	No	Yes
Unequal Impedance But Same Ratio& KVA	No	Yes	Yes	No	No
Unequal Impedance & KVA But Same Ratio	No	Yes	Yes	No	No
Unequal Impedance & Ratio but Same KVA	Yes	No	Yes	Yes	No
Unequal Impedance & Ratio & different KVA	No	No	Yes	Yes	No

The combinations that will operate in parallel:

- Following Vector group of Transformer will operate in parallel.

Operative Parallel Operation		
Sr.No	Transformer-1	Transformer-2
1	ΔΔ	ΔΔ or Yy

2	Yy	Yy or ΔΔ
3	Δy	Δy or YΔ
4	YΔ	YΔ or Δy

- Single-phase transformers can be connected to form 3-phase transformer banks for 3-phase Power systems.
- Four common methods of connecting three transformers for 3-phase circuits are Δ-Δ, Y-Y, Y-Δ, and Δ-Y connections.
- An advantage of Δ-Δ connection is that if one of the transformers fails or is removed from the circuit, the remaining two can operate in the open-Δ or V connection. This way, the bank still delivers 3-phase currents and voltages in their correct phase relationship. However, the capacity of the bank is reduced to 57.7 % (1 3) of its original value.
- In the Y-Y connection, only 57.7% of the line voltage is applied to each winding but full line current flows in each winding. The Y-Y connection is rarely used.
- The Δ-Y connection is used for stepping up voltages since the voltage is increased by the transformer ratio multiplied by 3.

The combinations that will not operate in parallel:

- Following Vector group of Transformer will not operate in parallel.

Inoperative Parallel Operation		
Sr.No	**Transformer-1**	**Transformer-2**
1	ΔΔ	Δy
2	Δy	ΔΔ
3	YΔ	Yy
4	Yy	YΔ

To check Synchronization of Transformers:

- Synchronization of Transformer can be checked by either of following steps:
- Checked by synchronizing relay & synchro scope.
- If Secondary of Transformer is not LT Then we must use check synchronizing relay & Commission the system properly. After connecting relay. Relay must be charges with only 1 supply & check that relay is functioning properly.
- Synchronizing should be checked of both the supply voltages. This can be checked directly with millimeter between L1 phases of Transformer 1 and L1 phase of Transformer 2. Then L2 Phase of Transformer 1 and L2 Phase of Transformer 2. Then L3 Phase of Transformer 1 and L3 Phase of Transformer 2. In all the cases MultiMate should show 0 voltages theoretically. These checks must be done at synchronizing breakers only. We have to also check that breaker out going terminals are connected in such a way that L1 Terminals of both the Breakers comes to same Main Bus bar of panel. Same for L2 & L3.
- Best way to check synchronization on LT is charge complete panel with 1 source up to outgoing terminals of another incoming breaker terminal. Then just measure Voltage difference on Incoming & out going terminals of Incoming Breaker. It should be near to 0.
- To check circulating current Synchronize both the transformer without outgoing load. Then check current. It will give you circulating current.

Advantages of Transformer Parallel Operation:

1) Maximize electrical system efficiency:

- Generally electrical power transformer gives the maximum efficiency at full load. If we run numbers of transformers in parallel, we can switch on only those transformers which will give the total demand by running nearer to its full load rating for that time.
- When load increases, we can switch no one by one other transformer connected in parallel to fulfil the total demand. In this way we can run the system with maximum efficiency.

2) Maximize electrical system availability:

- If numbers of transformers run in parallel, we can take shutdown any one of them for maintenance purpose. Other parallel transformers in system will serve the load without total interruption of power.

3) Maximize power system reliability:

- If nay one of the transformers run in parallel, is tripped due to fault other parallel transformers is the system will share the load hence power supply may not be interrupted if the shared loads do not make other transformers overloaded.

4) Maximize electrical system flexibility:

- There is a chance of increasing or decreasing future demand of power system. If it is predicted that power demand will be increased in future, there must be a provision of connecting transformers in system in parallel to fulfil the extra demand because it is not economical from business point of view to install a bigger rated single transformer by forecasting the increased future demand as it is unnecessary investment of money.
- Again, if future demand is decreased, transformers running in parallel can be removed from system to balance the capital investment and its return.

Disadvantages of Transformer Parallel Operation:

- Increasing short-circuit currents that increase necessary breaker capacity.
- The risk of circulating currents running from one transformer to another Transformer. Circulating currents that diminish load capability and increased losses.
- The bus ratings could be too high.
- Paralleling transformers reduces the transformer impedance significantly, i.e. the parallel transformers may have very low impedance, which creates the high short circuit currents.
  Therefore, some current limiters are needed, e.g. reactors, fuses, high impedance buses, etc
- The control and protection of three units in parallel is more complex.
- It is not a common practice in this industry, since Main-tie-Main is very common in this industry.

Conclusions:

- Loading con
- siderations for paralleling transformers are simple unless kVA, percent impedances, or ratios are different. When paralleled transformer turn ratios and percent impedances are the same, equal load division will exist on each transformer. When paralleled transformer kVA ratings are the same, but the percent impedances are different, then unequal load division will occur.
- The same is true for unequal percent impedances and unequal kVA. Circulating currents only exist if the turn ratios do not match on each transformer. The magnitude of the circulating currents will also depend on the X/R ratios of the transformers. Delta-delta to delta-wye transformer paralleling should not be attempted.

References

- Say, M.G. The performance and design of alternating current machines.
- Application Guide, Loading of Transformer, Nashville, TN, USA.
- Toro, V.D. Principles of electrical engineering.
- Stevenson, W.D. Elements of power system analysis.
- MIT Press, Magnetic circuits and transformers, John Wiley and Sons.

Chapter: 8 Various Routine Test of Power Transformer

Introduction:

- There are various Test required on Transformer to conform performance of Transformer.
- Mainly two types of transformers are done by manufacturer before dispatching the transformer mainly

(a) Type test of transformer and
(b) Routine test.

- In addition, some other tests are also carried out by the consumer at site before commissioning and also periodically on a regular & emergency basis throughout its life.
- Transformer Testing mainly classified in
- **Transformer Tests done by Manufacturer**

(a) Routine Tests
(b) Type Tests
(c) Special Tests

- **Transformer Tests done at Site**

(a) Pre-Commissioning Tests
(b) Periodic/Condition Monitoring Tests
(c) Emergency Tests

Tests of Transformer:

(A) Routine tests:

- A Routine test of transformer is mainly for confirming operational performance of individual unit in a production lot. Routine tests are carried out on every unit manufactured.
- All transformers are subjected to the following Routine tests:
  (1) Insulation resistance Test.
  (2) Winding resistance Test.
  (3) Turns Ration / Voltage ratio Test
  (4) Polarity / Vector group Test.
  (5) No-load losses and current Test.
  (6) Short-circuit impedance and load loss Test.
  (7) Continuity Test
  (8) Magnetizing Current Test
  (9) Magnetic Balance Test
  (10) High Voltage Test.
  (11) Dielectric tests
  - Separate source AC voltage.
  - Induced overvoltage.
  - Lightning impulse tests.

  (12) Test on On-load tap changers, where appropriate.

(B) Type tests

- Type tests are tests made on a transformer which is representative of other transformers to demonstrate that they comply with specified requirements not covered by routine tests:

(1) Temperature rise test (IEC 60076-2).
(2) Dielectric type tests (IEC 60076-3).

(C) Special tests

- Special tests are tests, other than routine or type tests, agreed between manufacturer and purchaser.

(1) Dielectric special tests.
(2) Zero-sequence impedance on three-phase transformers.
(3) Short-circuit test.
(4) Harmonics on the no-load current.
(5) Power taken by fan and oil-pump motors.
(6) Determination of sound levels.

(7) Determination of capacitances between windings and earth, and between windings.
(8) Determination of transient voltage transfer between windings.
(9) Tests intended to be repeated in the field to confirm no damage during shipment, for example frequency response analysis (FRA).

(D) Pre commissioning Tests

- The Test performed before commissioning the transformer at site is called pre commissioning test of transformer. These tests are done to assess the condition of transformer after installation and compare the test results of all the low voltage tests with the factory test reports.
- All transformers are subjected to the following Pre commissioning tests:

(1) IR value of transformer and cables
(2) Winding Resistance
(3) Transformer Turns Ratio
(4) Polarity Test
(5) Magnetizing Current
(6) Vector Group
(7) Magnetic Balance
(8) Bushing & Winding Tan Delta (HV)
(9) Protective relay testing
(10) Transformer oil testing
(11) Hipot test

(A) Various Routine tests of Transformer

(1) Insulation Resistance Test:

- **Test Purpose:**
- Insulation resistance test of transformer is essential to ensure the healthiness of overall insulation of an electrical power transformer.
- **Test Instruments:**
- For LT System: Use 500V or 1000V Megger.
- For MV / HV System: Use 2500V or 5000V Megger.
- **Test Procedure:**
- First disconnect all the line and neutral terminals of the transformer.
- Megger leads to be connected to LV and HV bushing studs to measure Insulation Resistance (IR) value in between the LV and HV windings.
- Megger leads to be connected to HV bushing studs and transformer tank earth point to measure Insulation Resistance IR value in between the HV windings and earth.
- Megger leads to be connected to LV bushing studs and transformer tank earth point to measure Insulation Resistance IR value in between the LV windings and earth.
- NB: It is unnecessary to perform insulation resistance test of transformer per phase wise in three phase transformers. IR values are taken between the windings collectively as because all the windings on HV side are internally connected to form either star or delta and also all the windings on LV side are internally connected together to form either star or delta.
- Measurements are to be taken as follows:

Type of Transformer	Testing-1	Testing-2	Testing-3
Auto Transformer	HV-LV to LV	HV-IV to E	LV to E
Two Winding Transformer	HV to LV	HV to E	LV to E
Three Winding Transformers	HV to LV	LV to LV	HV to E & LV to E

- Oil temperature should be noted at the time of insulation resistance test of transformer. Since the IR value of transformer insulating oil may vary with temperature.
- IR values to be recorded at intervals of 15 seconds, 1 minute and 10 minutes.
- With the duration of application of voltage, IR value increases. The increase in IR is an indication of dryness of insulation.
- **Absorption Coefficient = 1 minute value/ 15 second value.**
- **Polarization Index = 10 minutes value / 1 minute value**

- **Tests can detect:**
- Weakness of Insulation.

(2) D.C. Resistance or Winding Resistance Test

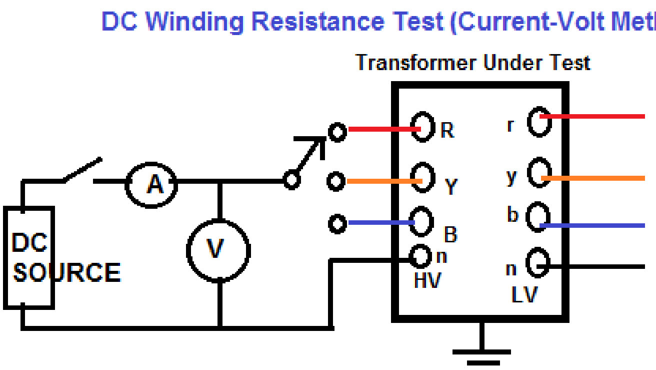
- **Test Purpose:**
- Transformer winding resistance is measured
- To check any abnormalities like Loose connections, broken strands and High contact resistance in tap changers
- To Calculation of the I2R losses in transformer.
- To Calculation of winding temperature at the end of temperature rise test of transformer.
- **Test Instrument:**
- The Resistance of HV winding LV winding between their terminals are to be measured with
- Precision milliohm meter/ micro–ohm meter / Transformer Ohmmeter. OR
- Wheatstone bridge or DC resistance meter.

Method No: 1 (Kelvin Bridge Method for measurement of winding resistance)

- **Test Procedure:**
- The main principle of bridge method is based on comparing an unknown resistance with a known resistance.
- When electric currents flowing through the arms of bridge circuit become balanced, the reading of galvanometer shows zero deflection that means at balanced condition no electric current will flow through the galvanometer.

- Very small value of resistance (in milliohms range) can be accurately measured by Kelvin Bridge method whereas for higher value Wheatstone bridge method of resistance measurement is applied. In bridge method of measurement of winding resistance, the error is minimized.
- All other steps to be taken during transformer winding resistance measurement in these methods are similar to that of current voltage method of measurement of winding resistance of transformer

Method No: 2 (current voltage method of measurement of winding resistance)



- **Test Procedure:**
- The resistance of each transformer winding is measured using DC current and recorded at a ambient temp.
- In this test resistance of winding is measurement by applying a small DC voltage to the winding and measuring the current through the same
- The measured resistance should be corrected to a common temperature such as 75°C or 85°C using the formula:

  RC=RM x ((CF+CT)/(CF+WT))
- where
- RC is the corrected resistance, RM is the measured resistance
- CF is the correction factor for copper (234.5) or aluminum (225) windings
- CT is the corrected temperature (75°C or 85°C)
- WT is the winding temperature (°C) at time of test

- Before measurement the transformer should be kept in OFF condition at least for 3 to 4 hours so in this time the winding temperature will become equal to its oil temperature.
- To minimize observation errors, polarity of the core magnetization shall be kept constant during all resistance readings.
- Voltmeter leads shall be independent of the current leads to protect it from high voltages which may occur during switching on and off the current circuit.
- The readings shall be taken after the electric current and voltage have reached steady state values. In some cases this may take several minutes depending upon the winding impedance.
- The test current shall not exceed 15% of the rated current of the winding. Large values may cause inaccuracy by heating the winding and thereby changing its resistance.
- For Calculating resistance, the corresponding temperature of the winding at the time of measurement must be taken along with resistance value.
- **Required Precaution:**
- According to IEC 60076-1 to reduce measurement errors due to changes in temperature, some precautions should be taken before the measurement is made.
- **For Delta connected Winding:**
- for delta-connected transformer, the resistance should be measured for each phase (i.e. R-Y , Y-B & B-R) .Delta is composed of parallel combination of the winding under test and the series combination of the remaining winding .It is therefore recommended to make three measurements for each phase to-phase winding in order obtain the most accurate results.
- For Delta connected windings, such tertiary winding of auto-transformers measurement shall be done between pairs of line terminals and resistance per winding shall be calculated as per the formula: Resistance per Winding = 1.5 X Measured Value
- **For Star connected winding:**
- The neutral brought out, the resistance shall be measured between the line and neutral terminal (i.e. R-N , Y-N,B-N) and average of three sets of reading shall be the tested value. For Star connected auto transformers the resistance of the HV side is measured between HV terminal and IV terminal, then between IV terminal and the neutral.
- **For Dry type transformers:**
- The transformer shall be at rest in a constant ambient temperature for at least three hours.
- For Oil immersed transformers:
- The transformers should be under oil and without excitation for at least three hours. In case of tapped windings, above readings are recorded at each tap. In addition, it is important to ensure that the average oil temperature (average of the top and bottom oil temperatures) is approximately the same as the winding temperature. Average oil temperature is to be recorded. Measured values are to be corrected to required temperatures.
- As the measurement current increases, the core will be saturated and inductance will decrease. In this way, the current will reach the saturation value in a shorter time.
- After the current is applied to the circuit, it should be waited until the current becomes stationary (complete saturation) before taking measurements, otherwise, there will be measurement errors.
- The values shall be compared with original test an result which varies with the transformer ratings.
- **Test Acceptance criteria:**
- DC Resistance Should be<=2% Factory Test.
- Test Current <10% Rated Current
- **Test can detect:**
- Short Turns
- Loose Connection of bushing
- Loose Connection or High Contact Resistance on Tap Changer.
- Broken winding stands

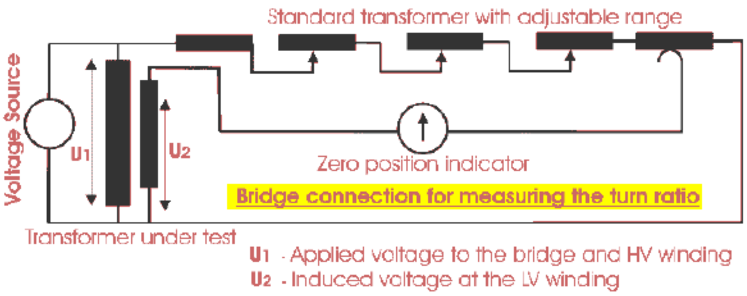
(3) Turns Ratio / Voltage Ratio Test:

- **Test Purpose:**
- Turns Ratio Test / Voltage Ratio Test are done in Transformer to find out Open Circuited turns, Short Circuited turns in Transformer winding.

- The voltage ratio is equal to the turn's ratio in a transformer (V1/V2=N1/N2). Using this principle, the turn's ratio is measured with the help of a turn's ratio meter. If it is correct , then the voltage ratio is assumed to be correct
- This test should be made for any new high-voltage power transformer at the time it is being installed.
- With use of Turns Ratio meter (TTR), turns Ratio between HV & LV windings at various taps to be measured & recorded.
- The turn's ratio is measure of the RMS voltage applied to the primary terminals to the RMS Voltage measured at the secondary terminals.
- **R= Np / Ns**
- Where,
- R=Voltage ratio
- Np=Number of turns at primary winding.
- Ns= Number of turns at secondary Winding.
- The voltage ratio shall be measured on each tapping in the no-load condition.
- **Test Instruments:**
- Turns Ratio meter (TTR) to energies the transformer from a low-voltage supply and measure the HV and LV voltages.
- Wheatstone Bridge Circuit

Method No1: Turns Ratio Testing:

- **Test Procedure:**
- **Transformer Turns Ratio Meter (TTR):**
- Transformer ratio test can be done by Transformer Turns Ratio (TTR) Meter. It has in built power supply, with the voltages commonly used being very low, such as 8, 10 V and 50 Hz.
- The HV and LV windings of one phase of a transformer (i.e. R-Y & r-n) are connected to the instrument, and the internal bridge elements are varied to produce a null indication on the detector.
- Values are recorded at each tap in case of tapped windings and then compared to calculated ratio at the same tap.
- The ratio meter gives accuracy of 0.1 per cent over a ratio range up to 1110:1. The ratio meter is used in a 'bridge' circuit where the voltages of the windings of the transformer under test are balanced against the voltages developed across the fixed and variable resistors of the ratio meter.
- Adjustment of the calibrated variable resistor until zero deflection is obtained on the galvanometer then gives the ratio to unity of the transformer windings from the ratio of the resistors.
- **Bridge Circuit:**
- A phase voltage is applied to the one of the windings by means of a bridge circuit and the ratio of induced voltage is measured at the bridge. The accuracy of the measuring instrument is < 0.1 %



- This theoretical turn ratio is adjusted on the transformer turn ratio tested or TTR by the adjustable transformer as shown in the figure above and it should be changed until a balance occurs in the percentage error indicator. The reading on this indicator implies the deviation of measured turn ratio from expected turn ratio in percentage.
- **Theoretical Turns Ratio = HV winding Voltage / LV Winding Voltage**
- **% Deviation = (Measured Turn Ratio – Expected Turns Ration) / Expected Turns Ration**
- Out-of-tolerance, ratio test of transformer can be due to shorted turns, especially if there is an associated high excitation current.
- Open turns in HV winding will indicate very low exciting current and no output voltage since open turns in HV winding causes no excitation current in the winding means no flux hence no induced voltage.

- But open turn in LV winding causes, low fluctuating LV voltage but normal excitation current in HV winding. Hence open turns in LV winding will be indicated by normal levels of exciting current, but very low levels of unstable output voltage.
- The turn ratio test of transformer also detects high resistance connections in the lead circuitry or high contact resistance in tap changers by higher excitation current and a difficulty in balancing the bridge.
- **Test Caution:**
- Disconnect all transformer terminals from line or load.
- Neutrals directly grounded to the grid can remain connected

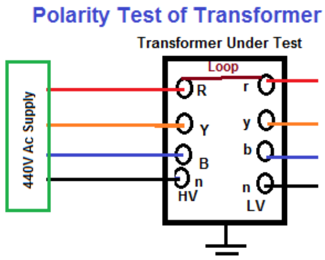
Method No 2: Voltage Ratio Testing:

- This test is done to check both the transformer voltage ratio and tap changer.
- When "Turns Ratio meter" is not available, Voltage Ratio Test is done at various tap position by applying 3 phases LT (415V) supply on HT side of Power transformer. In order to obtain the required accuracy it is usual to use a ratio meter rather than to energies the transformer from a low-voltage supply and measure the HV and LV voltages.
- At Various taps applied voltage and Resultant voltages LV side between various Phases and phases& neutral measured with precision voltmeter & noted.
- **Test Procedure:**
- With 415 V applied on high voltage side, measure the voltage between all phases on the low voltage side for every tap position.
- First, the tap changer of transformer is kept in the lowest position and LV terminals are kept open.
- Then apply 3-phase 415 V supply on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV and induced voltages at LV terminals simultaneously.
- After measuring the voltages at HV and LV terminals, the tap changer of transformer should be raised by one position and repeat test.
- Repeat the same for each of the tap position separately.
- At other taps values will be as per the percentage raise or lower at the respective tap positions.
- In case of Delta/Star transformers the ratio measure between RY-rn, YB-yn and BR-bn.
- Being Delta/Star transformers the voltage ratio between HV winding and LV winding in each phase limb at normal tap is 33 KV OR 33x√3 = 5.196 ,11 KV / √3 11
- At higher taps (i-e high voltage steps) less number of turns is in circuit than normal. Hence ratio values increase by a value equal to.5.196 + {5.196 x (no. of steps above normal) x (% rise per each tap)} 100
- Similarly for lower taps than normal the ratio is equal to 5.196 - {5.196 x (no. of steps above normal) x (% rise per each tap)}100
- **Test Acceptance Criteria:**
- Range of measured ratio shall be equal to the calculated ratio ±0.5%.
- Phase displacement is identical to approved arrangement and transformer's nameplate.
- The IEEE standard (IEEE Standard 62) states that when rated voltage is applied to one winding of the transformer, all other rated voltages at no load shall be correct within one half of one percent of the nameplate readings. It also states that all tap voltages shall be correct to the nearest turn if the volts per turn exceed one half of one percent desired voltage .The ratio test verifies that these conditions are met.
- The IEC60076-1 standard defines the permissible deviation of the actual to declared ratio
- Principal tapping for a specified first winding pair: the lesser ±0.5% of the declared voltage ratio or 0.1 times the actual short circuit impedance. Other taps on the first winding pair and other winding pair must be agreed upon, and must be lower than the smaller of the two values stated above.
- Measurements are typically made by applying a known low voltage across the high voltage winding so that the induced voltage on the secondary is lower, thereby reducing hazards while performing the test .For three phase delta/wye or wye/delta transformer, a three phase equivalency test is performed, i.e. the test is performed across corresponding single winding.
- **Test can detect:**
- Shorted turns or open circuits in the windings.
- Incorrect winding connections ,and other internal faults or defects in tap changer

(4) Polarity / Vector Group Test

- **Purpose of Test:**

- The vector group of transformer is an essential property for successful parallel operation of transformers. Hence every electrical power transformer must undergo through vector group test of transformer at factory site for ensuring the customer specified vector group of transformer.
- **Test Instruments:**
- Ratio meter.
- Voltmeter. A Ratio meter may not always be available and this is usually the case on site so that the polarity may be checked by voltmeter.
- **Test Circuit Diagram:**



- **Test Procedure:**
- The primary and secondary windings are connected together at one point.
- Connect neutral point of star connected winding with earth.
- Low-voltage three-phase supply (415 V) is then applied to the HV terminals.
- Voltage measurements are then taken between various pairs of terminals as indicated in the diagram and the readings obtained should be the phasor sum of the separate voltages of each winding under consideration.
- **Condition: (HV side R-Y-B-N and LV Side r-y-b-n)**
- R and r should be shorted.
- Apply 415 Volt to R-Y-B
- Measure Voltage between Following Phase and Satisfy Following Condition

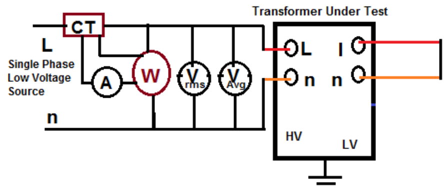
Vector Group	Satisfied Following Condition	Vector Group	Satisfied Following Condition
Dyn1	Rb=Rn+Bn	Ynd1	RN=Ry+Yn
	Bb=By		By=Yy
	Yy<Yb		Yy<Yb
Dyn11	Ry=Rn+Yn	Ynyn0	Bb=Yy
	Yb=Yy		Bn=Yn
	Bb<By		RN=Rn+Nn

(5) Short Circuit Test

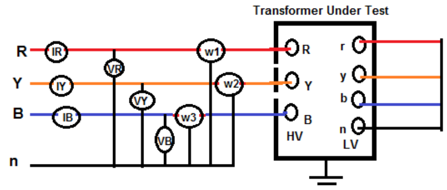
- **Test Purpose:**
- The value of the short circuit impedance Z% and the load (copper) losses (I2R) are obtained.
- This test should be performed before the impulse test-if the later will be performed as a routine test- in order to avoid readings errors
- **Test Instrument:**
- Megger or
- Multi meter.
- CT ,PT
- **Test Procedure:**
- Suitable Low Voltage (3-phase 415V, 50Hz)will be applied to the terminals of one winding (usually the H.V.) with the other winding short circuited with 50 sq. mm. Copper cable. (Usually the L.V.)
- The applied voltage is adjusted to pass the needed current in the primary/secondary. In order to simulate conditions nearest to full load, it is customary to pass 100%, 50% or at least 25% of full load current.
- Voltage to be increased gradually till the current in the energized winding reaches the required value (50% to 100% rated current).
- Measure the 3 Phase line currents at all tap position. If the tap-switch is an Off-Circuit tap-switch, the supply has to be disconnected before changing the tap. A consistent trend in the increase or decrease of current, as the case may be, confirms the healthiness of the transformer.
- If transformer is equipped with a tap changer, tapping regulations are applied.

- (1) If tapping range within±5% and rated power less than 2500kAV, load loss guarantee refer to the principal tap only.
- (2) If tapping range exceeds±5% or rated power above 2500kAV, it shall be stated for which tapping beside the principal tap the load losses will be guaranteed by the manufacturer.
- Three phase LT supply is applied on HV side of power transformer at normal tap with rated current on HV side and currents measured in all the phases on HV side and phases & neutral on LV side values noted.
- Readings to be taken as quickly as possible as the windings warm up and the winding resistance increases. Hence, the losses value will increase accordingly.
- Using appropriate instruments (conventional three wattmeter method or digital wattmeter with ammeters & voltmeters) measurements of voltage, currents and power can be recorded.

Short Circuit Test (Single Phase TC)

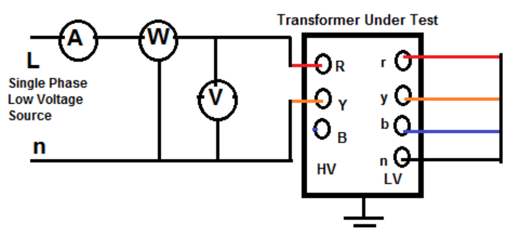


Short Circuit Test (Three Phase TC)



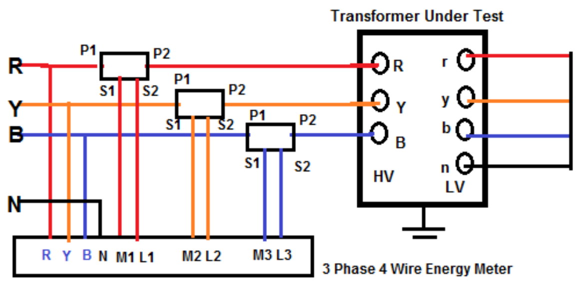
- **Short Circuit Test (Without using CT, PT)**
- To avoid CT's and PT's, this method can be used at current levels of 2 to 5 A and measurement of load losses is done at this condition. This measured load loss is then extrapolated to actual load currents to obtain load losses at the operating current.
- **Example: -** 11 kV/433 V, 1000 kVA transformer with 5% impedance, the voltage to be applied on H.V. side during load test is estimated below.
- H.V. side full load current (I1) = (KVAx1000/1.732xLine Voltage)
- H.V. side full load current (I1) =(1000x1000/1.732x11000)=52.5 Amp
- Line to line voltage to be applied on H.V side for getting 5 A on H.V. side,
- Line to line voltage to be applied on H.V side Visc= (Line Voltagex1000xZx5/0.866xI1x100)
- Line to line voltage to be applied on H.V side Visc=(11x1000x5xx/x0.866x52.5x100)=60.5 volts.
- Since the current drawn on H.V. side is only about 5A in this test, CT's can be avoided and hence phase angle error is not applicable.

Short Circuit Test (Without CT)



- **Short Circuit Test (With using CT, PT)**

Short Circuit Test (With CT)



- **Acceptance Criteria:**
- Measured impedance to be within guaranteed value and nameplate value.
- Load losses to be within guaranteed values.
- **Test can detect:**
- Winding deformation.
- Deviation in name plate value.

(6) Open Circuit / No Load Test

- **Test Purpose:**
- In this test, the value of No-Load power (Po) & the No-Load current (Io) are measured at rated voltage & frequency.
- **Test Instruments:**
- Watt meters.
- Ammeter , Voltmeter or
- Power analyser
- **Test Procedure:**
- Test is performed at rated frequency.
- Three phase LT Voltage of 415 V applied on HV side of Power transformer keeping LT open
- Two voltmeters are connected to the energized winding, one is measuring the voltage mean value and the other is for the Voltage R.M.S value.
- Voltage applied to winding (usually to H.V. windings).It will be in a range from 90% of winding rated voltage to 110% of the same in steps, each of 5% (i.e. for a 33/11kV transformer, applied voltage values will be 29.7kV, 31.35kV,36.3kV)
- Readings of watt meters, Voltmeters & Ammeters are recorded to obtain the values of V (r.m.s), Vmean, Po and Io at each voltage step.
- Test results are considered satisfactory if the readings of the two are equal within 3%. If it's more than 3%, the validity of the test is subjected to agreement.
- Measured value of power loss is corrected according to the following formula:
- Pc=Pm (1+d)
- D= (Vmean - Vr.m.s) / Vmean
- Measure the loss in all the three phases with the help of 3 watt meter method. Total no load loss or iron loss of the trf = W1 + W2 +W3
- **Test Caution:**
- This test should be performed before the impulse test-if the later will be performed as a routine test- in order to avoid readings errors

Acceptance Criteria:

- No Load losses to be within guaranteed values.

(7) Continuity test:

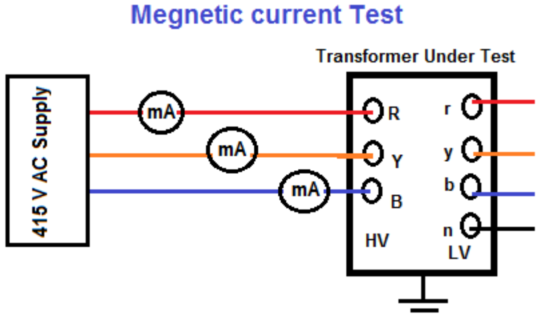
- **Purpose of Test:**
- To know the continuity of windings of the transformer.
- **Test Instruments:**
- Megger or
- Multi meter.
- **Test Procedure:**
- Check Continuity of Transformer by using multi meter or by Megger between following Terminals

Transformer	P-P	P-P	P-P	Result
HV Side	R-Y	Y-B	B-R	Zero Mega ohm or continuity
LV Side	r-y	y-b	b-r	Zero Mega ohm or continuity

- **Test can detect:**
- Open circuit / loose connection of winding

(8) Magnetic Current Test

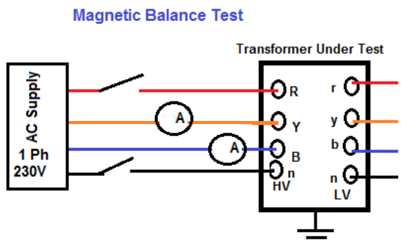
- **Test Purpose:**
- Magnetizing current test of transformer locates the defects in the magnetic core structure, shifting of windings, failure in turn to turn insulation or problem in tap changers.
- These conditions change the effective reluctance of the magnetic circuit, thus affecting the electric current required to establish flux in the core.
- **Test Instrument:**
- Multi meter.
- Mill Ammeter
- **Test Circuit Diagram:**



- Three phases LT Voltage of 415 V applied on HV side of Power transformer and currents are to be measured with mill ammeter.
- The value shall be = (1 to 2 percent of rated full load current of TC / HT KV) X Voltage Applied
- **Test Procedure:**
- First of all keep the tap changer in the lowest position and open all IV & LV terminals.
- Then apply three phase 415V supply on the line terminals for three phase transformers and single phase 230V supply on single phase transformers.
- Measure the supply voltage and electric current in each phase.
- Now repeat the magnetizing current test of transformer test with keeping tap changer in normal position.
- And repeat the test with keeping the tap at highest position.
- Generally there are two similar higher readings on two outer limb phases on transformer core and one lower reading on the centre limb phase, in case of three phase transformers.
- An agreement to within 30 % of the measured exciting current with the previous test is usually considered satisfactory. If the measured exciting current value is 50 times higher than the value measured during factory test, there is likelihood of a fault in the winding which needs further analysis.
- **Test Caution:**
- This magnetizing current test of transformer is to be carried out before DC resistance measurement.

(9) Magnetic Balance Test

- **Test Purpose:**
- Magnetic balance test of transformer is conducted only on three phase transformers to check the imbalance in the magnetic circuit.
- **Test Instrument:**
- Multi meter.
- Mill Ammeter
- **Test Circuit Diagram:**

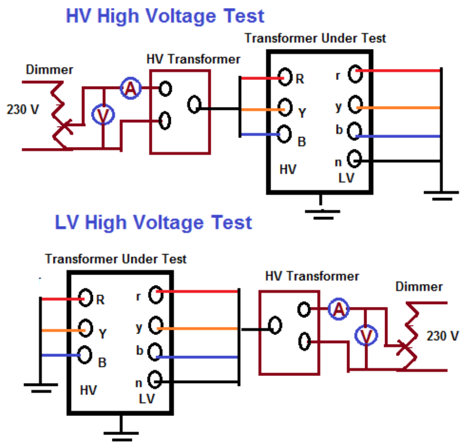


- **Test Procedure:**
- First keep the tap changer of transformer in normal position.
- Now disconnect the transformer neutral from ground.
- Then apply single phase 230V AC supply across one of the HV winding terminals and neutral terminal.
- Measure the voltage in two other HV terminals in respect of neutral terminal.
- Repeat the test for each of the three phases.
- In case of auto transformer, magnetic balance test of transformer should be repeated for IV winding also.
- There are three limbs side by side in a core of transformer. One phase winding is wound in one limb. The voltage induced in different phases depends upon the respective position of the limb in the core.
- The voltage induced in different phases of transformer in respect to neutral terminals given in the table below.
- 415V, Two phase supply is to be applied to any two phases terminals on HV side of Power transformer and voltages in other two phase combination are to be measured with LT open.
- Sum of the Resultant two values shall be equal to the voltage applied.

Applied Voltage (415V)	Measured Voltage(V1)	Measured Voltage(V2)	Result
RY	YB	BR	V=V1+V2
YB	RY	BR	V=V1+V2
BR	YB	RY	V=V1+V2

(10) High Voltage tests on HV & LV Winding:

- **Purpose:**
- To checks the insulation property between Primary to earth, Secondary to earth and between Primary & Secondary.
- **Test Instrument:**
- High Voltage tester (100KV & 3KV)
- **Test Circuit Diagram:**

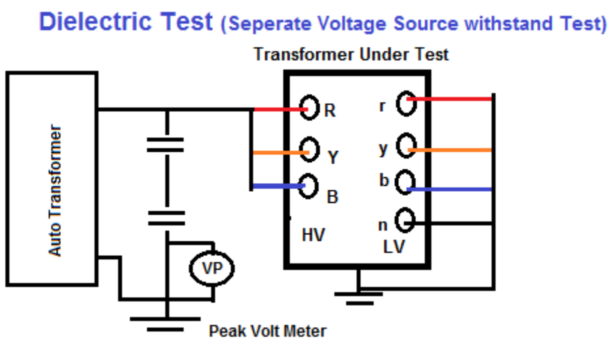


- **Test Procedure:**
- HV high voltage test: LV winding connected together and earthed. HV winding connected together and given Following HV Supply for 1 minute.
- LV high Voltage test: HV winding connected together and earthed. LV winding connected together and given Following HV Supply for 1 minute.
- 433V Winding =3KV High Voltage
- 11KV Winding =28KV High Voltage
- 22KV Winding =50KV High Voltage
- 33KV Winding =70KV High Voltage.

(11) Di electrical Test:

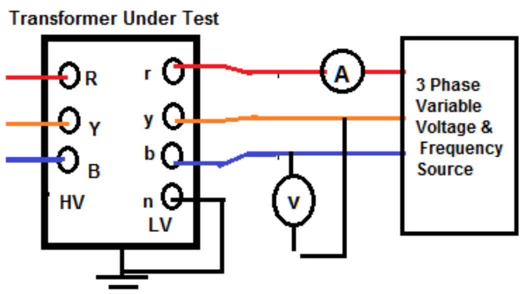
- **Test Purpose:**
- To check the ability of main insulation to earth and between winding
- To checks the insulation property between Primary to earth, Secondary to earth and between Primary & Secondary.

- **Test Instruments:**
- 3 Phase Variable Voltage & Frequency Source.
- Auto Transformer.
- **Test Procedure:**
- The following Dielectric tests are performed in order to meet the transformer insulation strength expectations.
- **Switching impulse test:** to confirm the insulation of the transformer terminals and windings to the earthed parts and other windings, and to confirm the insulation strength in the windings and through the windings.
- Lightning impulse test : to confirm the transformer insulation strength in case of a lightning hitting the connection terminals
- **Separate source AC withstand voltage test:** to confirm the insulation strength of the transformer line and neutral connection terminals and the connected windings to the earthed parts and other windings.
- **Induced AC voltage test (short duration ACSD and long duration ACLD) :** to confirm the insulation strength of the transformer connection terminals and the connected windings to the earthed parts and other windings, both between the phases and through the winding.
- Partial discharge measurement: to confirm the "partial discharge below a determined level" property of the transformer insulation structure under operating conditions.
- **Method No 1: (separate source voltage withstand test)**
- All the terminals of the winding under test should be connected together and the voltage should be applied.
- The secondary windings of bushing type current transformers should be connected together and earthed. The current should be stable during test and no surges should occur.



- A single phase power frequency voltage of shape approximately sinusoidal is applied for 60 seconds to the terminals of the winding under test.
- The test shall be performed on all the windings one by one.
- The test is successful if no breakdown in the dielectric of the insulation occurs during test.
- During the Separate source AC withstand voltage test, the frequency of the test voltage should be equal to the transformer's rated frequency or should be not less than 80% of this frequency. In this way, 60 Hz transformers can also be tested at 50 Hz. The shape of the voltage should be single phase and sinusoidal as far as possible.
- This test is applied to the star point (neutral point) of uniform insulated windings and gradual (non-uniform) insulation windings. Every point of the winding which test voltage has been applied is accepted to be tested with this voltage.
- The test voltage is measured with the help of a voltage divider. The test voltage should be read from voltmeter as peak value divided by2. Test period is 1 minute.
- **Method No 2: (Induced source voltage withstand test)**
- The aim of this test is to check the insulation both between phases and between turns of the windings and also the insulation between the input terminals of the graded insulation windings and earth

Dielectric Test(Induced Voltage Test)



- During test, normally the test voltage is applied to the low voltage winding. Meanwhile HV windings should be keeping open and earthed from a common point.
- Since the test voltage will be much higher than the transformer's rated voltage, the test frequency should not be less than twice the rated frequency value, in order to avoid oversaturation of the transformer core.
- The test shall start with a voltage lower than 1/3 the full test voltage and it shall be quickly increased up to desired value.
- The test voltage can either be measured on a voltage divider connected to the HV terminal or on a voltage transformer and voltmeter which have been set together with this voltage divider at the LV side. Another method is to measure the test voltage with a peak-value measuring instrument at the measuring-tap end of the capacitor type bushing (if any).
- Test period which should not be less than 15 seconds.
- It is calculated according ,Test period=120 seconds x (Rated frequency / Test frequency)
- The duration of the test shall be 60 second.
- The test is accepted to be successful if no surges, voltage collapses or extreme increases in the current have occurred.
- **Acceptance Criteria:**
- The test is successful if no break down occurs at full test voltage during test.
- **Method No 3: Lighting Impulse Test:**
- All the dielectric tests check the insulation level of the Transformer.
- Impulse generator is used to produce the specified voltage impulse wave of 1.2/50 micro seconds wave
- One impulse of a reduced voltage between 50 to 75% of the full test voltage and subsequent three impulses at full voltage.
- For a three-phase transformer, impulse is carried out on all three phases in succession.
- The voltage is applied on each of the line terminal in succession, keeping the other terminals earthed.
- The current and voltage wave shapes are recorded on the oscilloscope and any distortion in the wave shape is the criteria for failure.

Chapter: 9 Standard Transformer Accessories

Standard Transformer Fittings:

(1) Standard Fittings

1. Rating and terminal marking plate.
2. Tap Changing arrangement
3. Off – circuit tap changing switch
4. Off – circuit tap changing link
5. On Load tap changer
6. Two earthing terminals
7. Lifting Lugs
8. Drain – cum filter valve
9. Pressure Relief Device
10. Silica gel dehydrating breather.
11. Oil Level Indicator.
12. Thermometer Pocket.
13. Conservator with drain plug and filling hole.
14. Air Release plug.
15. Jacking lugs (above 1600 KVA)
16. Filter valve (top tank)
17. Under base unidirectional flat rollers.

(2) Terminal Arrangement:

1. Bare Bushings orCable box.
2. Compound filled for PVC cables (up to 33000 Volts) orAir filled for PVC cable s (Upto 11000 Volts) or
3. Bus Duct (Bare bushing enclosed in housing upto 600 Volts)
4. Disconnection chamber between cable box and transformer tank.
5. Additional bare neutral terminal.

(3) Optional Fittings:

1. These are optional fittings provided at an extra cost, if customer specifically orders them.
2. Winding temperature indicator
3. Oil temperature indicator
4. Gas and oil actuated (Buchholz) relay
5. Conservators drain valve
6. Shut off valve between conservator and tank.
7. Magnetic oil level gauge
8. Explosion vent
9. Filter valve (Bottom of tank)
10. Skid under base with haulage holes
11. Junction box.

Standard Transformer Accessories:

(1) Thermometer Pockets:

- This pocket is provided to measure temperature of the top oil in tank with a mercury in glass type thermometer. It is essential to fill the pocket with transformer oil before inserting the thermometer, to have uniform and correct reading. One additional pocket is provided for dial type thermometer (OTI) with contacts

(2) Air release plug:

- Air release plug is normally provided on the tank cover for transformer with conservator.
- Space is provided in the plug which allows air to be escaped without removing the plug fully from the seat.
- Plug should be unscrewed till air comes out from cross hole and as soon as oil flows out it should be closed. Air release plugs are also provided on radiator headers and outdoor bushings.

(3) Winding temperature Indicator

- The windings temperature indicator indicates '' Hot spot'' temperature of the winding. This is a ''Thermal Image type'' indicator. This is basically an oil temperature indicator with a heater responsible to raise the temperature equal to the ''Hot spot'' gradient between winding and oil over the oil temperature. Thus, this instrument indicates the ''Hot Spot'' temperature of the windings.

- Heater coil is fed with a current proportional to the windings current through a current transformer mounted on the winding under measurement. Heater coil is either placed on the heater bulb enveloping the sensing element of the winding temperature indicator immersed in oil or in the instrument.
- The value of the current fed to the heater is such that it raises the temperature by an amount equal to the hot spot gradient of the winding, as described above. Thus temperature of winding is simulated on the dial of the instrument. Pointer is connected thought a mechanism to indicate the hot spot temperature on dial. WTI is provided with a temperature recording dial main pointer. Maximum pointer and re setting device and two sets of contacts for alarm and trip.

(4) Oil Temperature Indicator

- Oil temperature indicator provides local temperature of top oil. Instruments are provided with temperature sensing bulb, temperature recording dial with the pointer and maximum reading pointer and resetting device.
- Electrical contacts are provided to give alarm or trip at a required setting (on capillary tube type thermometer).

(5) Conservator Tank:

- It is an Expansion Vessel
- It maintains oil in the Transformer above a Minimum Level
- It has a Magnetic Oil Level Gage.
- It can give an alarm if the oil level falls below the limit
- A portion of the Tank is separated for use with OLTC.
- This usually has oil level indicators
- Main Conservator Tank can have a Bellow
- It has an oil filling provision
- It has an oil drain valve
- Provision is there for connecting a Breather

(6) Silica Gel Breather:

- Prevents Moisture Ingress.
- Connected to Conservator Tank
- Silica Gel is Blue when Dry; Pink when moist
- Oil Seal provides a Trap for Moisture before passing thro Silica Gel

(7) Cooling:

- ONAN. Oil Natural Air Natural
- ONAF. Oil Natural Air Forced
- OFWF. Oil Forced Water Forced
- ODWF. Oil directed Water Forced.
- By Forced Cooling, the Transformer capacity can be increased by more than 50%

(8) Bushing:

- **Manufacturing:**
- Insulators and Bushings are built with the best quality Porcelain shells manufactured by wet process.
- For manufacture of electro porcelain, high quality indigenous raw materials viz, China Clay, Ball Clay, Quartz and Feldspar is used Quartz and feldspar are ground to required finesses and then intimately mixed with ball and china clay in high speed blungers.
- They are then passed through electromagnetic separators, which remove iron and other magnetic impurities. The slip produced is passed to a filter press where extra water is removed under pressure and the resulting clay cakes are aged over a period. The aged cakes are extruded to required form viz, cylinders, on high vacuum de-airing pug mill. The extruded blanks or cylinders are given shapes of Insulators / Bushings which are conditioned and are shaped on copying lathes as the case may be.
- **Testing, Assembly & packing:**
- All insulators & bushings undergo routine electrical and mechanical tests. The tests before and after assembly are carried out according to IS Specifications, to ensure their suitability for actual conditions of use. Porosity tests are also carried out regularly on samples from every batch, to ensure that the insulators are completely vitrified.

- These insulators are then visually checked and sorted, before they are packed in sea worthy packing, to withstand transit conditions.
- **Types of Insulators & Bushings:**
- Bushing Insulators: Hollow Porcelain Bushings up to 33 KV
- Application: Transformers, Capacitors, Circuit Breakers
- Pin Insulators: Up to 33 KV
- Post type Insulators: Post type insulators, complete with metal fittings, generally IS Specifications and other International Standards up to 33 KV
- **Solid Core Insulators:**
- Line Post ,Long Rod , Support ,
- **Special Type Insulators**
- C.T. up to 66 KV , P.T. up to 33 KV , Weather Casing
- **L.T. Insulators**
- Shackel Type ,Spool Type , Pin Type , Guy strain
- **H.V. Bushings (IS:3347)**

12 to17.5 KV / 250 amps	24 KV / 1000 amps
12 to 17.5 KV / 630 amps	24 KV / 2000 to 3150 amps
12 to 17.5 KV / 1000 amps	36 KV / 250 amps
12 to 17.5 KV / 2000 to 3150 amps	36 KV / 630 amps
24 KV / 250 amps	36 KV / 1000 amps
24 KV / 630 amps	36 KV / 2000 to 3150 amps

- **L.V. Bushings (IS:3347)**

11 KV / 250 amps	1 KV / 2000 amps
1 KV / 630 amps	1 KV / 3150 amps
1 KV / 1000 amps	

- **H.V. Bushings (IS:8603)**

12KV / 250 amps	36 KV / 250 amps
12/ 630 amps	36 KV / 630 amps
12KV / 1000 amps	6 KV / 1000 amps
12KV / 2000 to 3150 amps	36 KV 3150 amps

- **C.T. Bushings (IS:5612)**

11 KV	1 KV / 2000 amps
1 KV / 630 amps	1 KV / 3150 amps
1 KV / 1000 amps	

- **Epoxy Bushing:**
- All Epoxy Resin Cast Components are made from hot setting reins cured with anhydrides; hence these provide class-F Insulation to the system. In an oxidizing atmosphere, certain amine cured Epoxy Resins can start to degrade at 150ºC whereas the anhydride cured systems are stable at 200ºC therefore our epoxy components are cured with anhydrides which gives them a longer life.

(9) Buchholz Relay:

- The purpose of such devices is to disconnect faulty apparatus before large scale damage caused by a fault to the apparatus or to other connected apparatus. Such devices generally respond to a change in the current or pressure arising from the faults and are used for either signaling or tripping the circuits.
- Considering liquid immersed transformer, a near ideal protective device is available in the form of gas and oil operated relay described here. The relay operates on the well known fact that almost every type of electric fault in a liquid immersed transformer gives rise to a gas. This gas is collected in the body of the relay and is used in some way or the other to cause the alarm or the tripping circuit to operate.
- In the event of fault in an oil filled transformer gas is generated, due to which buchholz relay gives warning of developing fault. Buchholz relay is provided with two elements one for minor faults (gives alarm) and other for major faults (tripping). The alarm elements operate after a specific volume gets accumulated in the relay. Examples of incipient faults which will generate gas in oil are:- Buchholz Relay
- i) Failure of core bolt insulation.
- ii) Shorting of lamination and core clamp.

- iii) Bad Electrical contact or connections.
- iv) Excessive hot spots in winding.
- The alarm element will also operated in the event of oil leakage. The trip element operates due to sudden oil surge in the event of more serious fault such as: -
- i) Earth fault due to insulation failure from winding to earth.
- ii) Winding short circuit inter turn, interlayer, inter coil etc.
- iii) Short circuit between phases.
- iv) Puncture of bushing.
- The trip element will also operate if rapid loss of oil occurs. During the operation of transformer, if there is an alarm transformer should be isolated from lines and possible reasons, listed above for the operation of relay should be checked starting with simple reason such as loss of oil due to leaks, air accumulation in relay chamber which may be the absorbed air released by oil due to change in temperature etc. Rating of contacts: - 0.5 Amps. At 230 Volts AC or 220 Volts. DC.

Pre commissioning Inspection of Transformer:

- Sample of oil taken from the transformer to electric test (break down value) of 50KV (RMS) as per IS: 335.
- Release trapped air through air release plugs and valve fitted for the purpose on various fittings like radiators, bushing caps, tank cover, Bushing turrets etc.
- The float lever of the magnetic oil level indicator (if provided) should be moved up and down between the end positions to check that the mechanism does not stick at any point. If the indicator has signaling contact they should be checked at the same time for correct operation.
- Check whether gas operated rely (if provided) is mounted at angle by placing a spirit level on the top of the relay. See that the conservator is filled up to the filling oil level marked on plain oil gauge side and corresponding to the pointer reading in MOG side. Check the operation of the alarm and trip contacts of the relay independently by injecting air through the top cocks using a dry air bottle. The air should be released after the tests. Make sure that transformer oil runs through pert cock of Buchholz relay.
- Check alarm and trip contacts of WTIs, Dial type thermometer, magnetic oil gauge etc. (if provided).
- Ensure that off circuit switch handle is locked at the desired tap position with padlock.
- Make sure that all valves except drain, filter and sampling valves are opened (such as radiator valves, valves on the buchholz relay pipe line if Provided).
- Check the condition of silica gel in the breather to ensure that silica gel in the breather is active and colour is blue. Also check that the transformer oil is filled in the silica gel breather up to the level indicated.
- Check tightness of external electrical connections to bushings.
- Give a physical check on all bushing for any crack or any breakage of porcelain. Bushing with cracks or any other defects should be immediately replaced.
- Check the neutral earthing if specified.
- Make sure that neutrals of HV / LV are effectively earthed.
- Tank should be effectively earthed at two points.
- Check that the thermometer pockets on tank cover are filled with oil.
- If the oil temperature indicator is not working satisfactorily, loosen and remove the thermometer bulb from the pocket on the cover and place it with a standard thermometer in a suitable vessel filled with transformer oil. Warm the oil slowly while string it and take reading of the thermometers if an adjustment of the transformer thermometer is necessary the same many be done. Also check signaling contacts and set for the desired temperature.
- CT secondary terminals must be shorted and earthed if not in use.
- Check relief vent diaphragm for breakage. See that the Bakelite diaphragm at bottom and glass diaphragm at top are not ruptured.
- Check all the gasket joints to ensure that there is no leakage of transformer oil at any point.
- Clear off extraneous material like tools earthling rods, pieces of clothes, waste etc.
- Lock the rollers for accidental movement on rails.
- Touching of paint may be done after erection.

Parts of Transformer:

(1) Transformer Oil

- Oil is used as coolant and dielectric in the transformer and keeping it in good condition will assist in preventing deterioration of the insulation, which is immersed in oil. Transformer oil is always exposed to the air to some extent therefore in the course of time it may oxidize and form sludge if the breather is defective, oil may also absorb moisture from air thus reducing dielectric strength.

(2) Transformer Winding:

- The primary and secondary windings in a core type transformer are of the concentric type only, while in case of shell type transformer these could be of sand-witched type as well. The concentric windings are normally constructed in any of the following types depending on the size and application of the transformer.
- (1)Cross over Type.
- (2) Helical Type.
- (3) Continuous Disc Type.
- Distributed.
- Spiral.
- Interleaved Disc.
- Shielded Layer

(a) Distributed Winding:

- Used for HV windings of small Distribution Transformers where the current does not exceed 20 amps using circular cross section conductor .

(b) Spiral:

- Used up to 33 KV for low currents using strip conductor. Wound closely on Bakelite or press board cylinders generally without cooling ducts. However, multi layer windings are provided with cooling ducts between layers. No Transposition is necessary.

(c) Interleaved Disc:

- Used for voltages above 145 KV. Interleaving enables the winding withstand higher impulse voltages.

(d) Shielded Layer :

- Used up to 132 KV in star connected windings with graded insulation. Comprises of a number of concentric spiral coils arranged in layers grading the layers.
- The longest at the Neutral and the shortest at the Line Terminal. The layers are separated by cooling ducts. This type of construction ensures uniform distributed voltages.

(e) Cross-over type winding:

- It is normally employed where rated currents are up-to about 20 Amperes or so.
- In this type of winding, each coil consists of number of layers having number of turns per layer. The conductor being a round wire or strip insulated with a paper covering.
- It is normal practice to provide one or two extra lavers of paper insulation between lavers. Further, the insulation between lavers is wrapped round the end turns of the lavers there by assisting to keep the whole coil compact.
- The inside end of a coil is connected to the outside end of adjacent coil. Insulation blocks are provided between adjacent coils to ensure free circulation of oil.

(f) Helical winding:

- Used for Low Voltage and high currents .The turns comprising of a number of conductors are wound axially. Could be single, double or multi layer winding. Since each conductor is not of the same length, does not embrace the same flux and of different impedances, and hence circulating currents, the winding is transposed.
- The coil consists of a number of rectangular strips wound in parallel racially such that each separate turn occupies the total radial depth of the winding.
- Each turn is wound on a number of key spacers which form the vertical oil duct and each turn or group of turns is spaced by radial keys sectors.
- This ensures free circulation of oil in horizontal and vertical direction.
- This type of coil construction is normally adopted for low voltage windings where the magnitude of current is comparatively large.
- **Helical Disc winding:**
- This type of winding is also termed "interleaved disk winding."

- Since conductors 1 – 4 and conductors 9 – 12 assume a shape similar to a wound capacitor, it is known that these conductors have very large capacitance. This capacitance acts as series capacitance of the winding to highly improve the voltage distribution for surge.
- Unlike cylindrical windings, Helical disk winding requires no shield on the winding outermost side, resulting in smaller coil outside diameter and thus reducing Transformer dimension. Comparatively small in winding width and large in space between windings, the construction of this type of winding is appropriate for the winding, which faces to an inner winding of relatively high voltage.
- Thus, general EHV or UHV substation Transformers employ Helical disk winding to utilize its features mentioned above.

(g) Continuous disc type of windings:

- Used for 33kv and 132 KV for medium currents. The coil comprises of a number of sections axially. Cooling ducts are provided between each section.
- IT is consists of number of Discs wound from a single wire or number of strips in parallel. Each disc consists of number of turns, wound radically, over one another.
- The conductor passing uninterruptedly from one disc to another. With multiple-strip conductor.Transpositions are made at regular intervals to ensure uniform resistance and length of conductor. The discs are wound on an insulating cylinder spaced from it by strips running the whole length of the cylinder and separated from one another by hard pressboard sectors keyed to the vertical strips.
- This ensures free circulation of oil in horizontal and vertical direction and provides efficient heat dissipation from windings to the oil.
- The whole coil structure is mechanically sound and capable of resisting the most enormous short circuit forces.This is the most general type applicable to windings of a wide range of voltage and current
- Rectangular wire is used where current is relatively small, while transposed cable is applied to large current. When voltage is relatively low, a Transformer of 100MVA or more capacity handles a large current exceeding 1000A. In this case, the advantage of transposed cable may be fully utilized
- Since the number of turns is reduced, even conventional continuous disk construction is satisfactory in voltage distribution, thereby ensuring adequate dielectric characteristics. Also, whenever necessary, potential distribution is improved by inserting a shield between turns.
- **Arrangement of layers**
- According to the number of layers used the paper is applied as follows.
- Two layers: =Where there are two layers both of them are wound in opposite directions.
- More than two layers: =Where there are more than two layers all the layers are applied in the same direction, all, except the outermost layer is butt wound, and the outermost layer is overlap wound. Within each group of papers the position of the butt joints of any layer relative to the layer below is progressively displaced by approximately 30 percent of the paper width.
- Note: Overlapping can also be done as per customer requirements.
- **Grade of paper**
- The paper, before application, is ensured to be free from metallic and other injurious inclusions and have no deleterious effect on insulating oil.
- The thickness of paper used is between 0.025 mm to 0.075 mm.
- **Enamelled Conductor**
- Apart from paper covered conductors, we have all the facilities of producing enameled conductors as per customer specified requirements.
- Copper: Usually in 8 to16mm rods is drawn to the required sizes and then insulated with paper etc..
- Annealing is done for softening and stress relieving in electrically heated annealing plant under vacuum upto 400-500ºC. After 48hrs when the temperature reaches ambient, the vacuum is slowly released and the material is transferred to Insulation section.
- Conductors are one of the principal materials used in manufacturing of transformers. Best quality of copper rods are procured from indigenous as well as foreign sources. Normally 8 mm & 11 mm rods are procured. For each supply of input, test certificate from suppliers is obtained and at times.
- After the wires & strips are drawn as per clients requirements they are moved on to paper covering process.
- To prevent the inclusion of copper dust or other extraneous matter under paper covering the conductor is fully cleaned by felt pads or other suitable means before entering the paper covering machine. As per the

customers' requirements DPC, TPC & MPC conductors are produced. It is ensured that each layer of paper is continuous, firmly applied and substantially free from creases.

- No bonding or adhesive material is used except to anchor the ends of paper. Any such bonding materials used to anchor the ends do not have deleterious effect on transformer oil, insulating paper or the electric strength of the covering. It is ensured that the overlapping percentage is not less than 25% of the paper width.
- The rectangular paper-covered copper conductor is the most commonly used conductor for the windings of medium and large power transformers.
- These conductors can be individual strip conductors, bunched conductors or continuously transposed cable (CTC) conductors. In low voltage side of a distribution transformer, where much fewer turns are involved, the use of copper or aluminum foils may find preference.
- To enhance the short circuit withstand capability, the work hardened copper is commonly used instead of soft annealed copper, particularly for higher rating transformers
- In the case of a generator transformer having high current rating, the CTC conductor is mostly used which gives better space factor and reduced eddy losses in windings. When the CTC conductor is used in transformers, it is usually of epoxy bonded type to enhance its short circuit strength.

(3) Transformer Core:

- **Purpose of the core:**
- To reduce the magnetizing current. (For topologies such as Forward, Bridge etc we need the magnetizing current to be as small as possible. For fly-back topology, though the magnetizing current is used to transfer energy, the size of the transformer will be very large to get the required inductance if a core is not used.)
- To improve the linkage of the flux within windings if the windings are separated spatially.
- To contain the magnetic flux within a given volume
- In magnetic amplifier applications a saturable core is used as a switch.
- **Core Material:**
- Different types of material used for cores
- Iron-Silicon Steel- Nickel-Iron-Iron-Cobalt-Ferrite-Molybdenum-Met-glass
- **Salient characteristics of a core material:**
- Permeability, Saturation flux density, Coercive force, Remnant flux, Losses due to Hysteresis& Eddy Current.
- The power loss is a function of frequency and the ac flux swing and is given by the equation P = K1 * (frequency)K2 * (Flux Density)K3
- Every transformer has a core, which is surrounded by windings. The core is made out of special cold rolled grain oriented silicon sheet steel laminations. The special silicon steel ensures low hysteresis's losses. The silicon steel laminations also ensure high resistively of core material which result in low eddy currents. In order to reduce eddy current losses, the laminations are kept as thin as possible. The thickness of the laminations is usually around 0.27 to 0.35 mm.
- Transformer cores construction is of two types, viz, core type and shell type. In core type transformers, the windings are wound around the core, while in shell type transformers, the core is constructed around the windings. The shell type transformers provide a low reactance path for the magnetic flux, while the core type transformer has a high leakage flux and hence higher reactance.
- The limb laminations in small transformers are held together by stout webbing tape or by suitably spaced glass fiber bends. The use of insulated bolts passing through the limb laminations has been discontinued due to number of instances of core bolt failures. The top and bottom mitered yokes are interleaved with the limbs and are clamped by steel sections held together by insulated yoke bolts. The steel frames clamping the top and bottom yokes are held together by vertical tie bolts.
- Grain Oriented steel sheets namely ORIENTCORE, ORIENTCORE H1-B & ORIENTCORE HI-B.LS are some of the finest quality of core.
- ORENTCORE.HI-B is a breakthrough in that it offers higher magnetic flux density, lower core loss and lower magnetostriction than any conventional grain-oriented electrical steel sheet.
- ORIENT.HI-B.LS is a novel type with marked lower core losses, produced by laser irradiation of the surface of ORIENTCORE.HI-B sheets.
- **Annealing of stacked electrical sheets**
- Annealing is to be done at 760 to 845ºC to

- Reduce mechanical stress
- Prevent contamination
- Enhance insulation of lamination coating
- Though ORIENTCORE and ORIENTCORE.HI-B are grain orient steel sheets with excellent magnetic properties, mechanical stress during such operations as cutting, punching and bending affect their magnetic properties adversely. When these stress are excessive, stress relief annealing is necessary.
- Following method is observed for stress relief annealing

1. Stacked electrical steel sheets are heated thoroughly in the edge-to-edge direction rather than in the face-to-face direction, because heat transfer is far faster in side heating.
2. A cover is put over sheets stacked on a flat plate. Because ORIENTCORE and ORIENTCORE.HI-B have extremely low carbon content and very easily decarburized at annealing temperatures, the base, cover and other accessories used are of very low carbon content .
3. To prevent oxidation so as to protect the coating on the sheets, a no oxidizing atmosphere free from carbon sources is used having less than 2%hydrogen or high-purity nitrogen gas. Due point of the atmosphere is maintained at 0ºC or less.
4. Care is taken to the flatness of annealing base, because an uneven base distorts cores, leading to possible distortion during assembly.
5. Annealing temperature ranging from 780ºC to 820ºC is maintained for more than 2 hours or more. Cooling is done up to 350ºC in about 15 hours or more.

- **Available Grades:**
- ORIENTCORE:M1, M2, M3, M4, M5 & M6
- ORIENTCORE.HI-B:23ZH90, 23ZH95, 27ZH95, 27ZH100, 30ZH100,M-0H, M-1H, M-2H, M-3H
- ORIENTCORE.HI-B.LS: 23ZDKH90, 27ZDKH95
- Non-oriented silicon steel, hot rolled grain oriented silicon steel,cold rolled grain oriented (CRGO) silicon steel, Hi-B, laser scribed and mechanically scribed. The last three materials are improved versions of CRGO.
- Saturation flux density has remained more or less constant around 2.0 Tesla for CRGO; but there is a continuous improvement in watts/kg and volt-amperes/kg characteristics in the rolling direction.
- The core building technology has improved from the non-mitred to mitred and then to the step-lap construction
- The better grades of core steel not only reduce the core loss but they also help in reducing the noise level by few decibels
- Use of amorphous steel for transformer cores results in substantial core loss reduction (loss is about one-third that of CRGO silicon steel). Since the manufacturing technology of handling this brittle material is difficult, its use in transformers is not widespread
- In the early days of transformer manufacturing, inferior grades of laminated steel (as per today's standards) were used with inherent high losses and magnetizing volt-amperes. Later on it was found that the addition of silicon content of about 4 to 5% improves the performance characteristics significantly, due to a marked reduction in eddy losses (on account of the increase in material resistivity) and increase in permeability. Hysteresis loss is also lower due to a narrower hysteresis loop. The addition of silicon also helps to reduce the aging effects.
- Although silicon makes the material brittle, it is well within limits and does not pose problems during the process of core building.
- The cold rolled manufacturing technology in which the grains are oriented in the direc tion of rolling gave a new direction to material development for many decades, and even today newer materials are centered around the basic grain orientation process.
- Important stages of core material development are: non-oriented, hot rolled grain oriented (HRGO), cold rolled grain oriented (CRGO), high permeability cold rolled grain oriented (Hi-B), laser scribed and mechanically scribed.
- Laminations with lower thickness are manufactured and used to take advantage of lower eddy losses. Currently the lowest thickness available is 0.23 mm, and the popular thickness range is 0.23 mm to 0.35 mm for power transformers.
- Maximum thickness of lamination used in small transformers can be as high as 0.50 mm.
- Inorganic coating (generally glass film and phosphate layer) having thickness of 0.002 to 0.003 mm is provided on both the surfaces of laminations, which is sufficient to withstand eddy voltages (of the order of a few volts).

- Since the core is in the vicinity of high voltage windings, it is grounded to drain out the statically induced voltages.While designing the grounding system, due care must be taken to avoid multiple grounding, which otherwise results into circulating currents and subsequent failure of transformers.

(4) Transformer Core:

(a) Core Type Construction: (Mostly Used):

- Generally, in India, Core type of construction with Two/Three/Five limbed cores is used. Generally five limbed cores are used where the dimensions of the Transformer is to be limited due to Transportation difficulties. In three limbed core the cross section of the Limb and the Yoke are the same where as in five Limbed core, the cross section of the Yoke and the Flux return path Limbs are ver y less (58% and 45% of the principal Limb).
- **Limb:** which is surrounded by windings, is called a limb or leg?
- **York:** Remaining part of the core, which is not surrounded by windings, but is essential for completing the path of flux, is called as yoke.
- **Advantage:**
- Construction is simpler, cooling is better and repair is easy.
- The yoke and end limb area should be only 50% of the main limb area for the same operating flux density.
- Zero-sequence impedance is equal to positive-sequence impedance for this construction (in a bank of single-phase transformers).
- Sometimes in a single-phase transformer windings are split into two parts and placed around two limbs as shown in figure (b). This construction is sometimes adopted for very large ratings. Magnitude of short-circuit forces are lower because of the fact that ampere-turns/height are reduced. The area of limbs and yokes is the same. Similar to the single-phase three-limb transformer.
- The most commonly used construction, for small and medium rating transformers, is three-phase three-limb construction as shown in figure (d).For each phase, the limb flux returns through yokes and other two limbs (the same amount of peak flux flows in limbs and yokes).
- Limbs and yokes usually have the same area. Sometimes the yokes are provided with a 5% additional area as compared to the limbs for reducing no-load losses.
- It is to be noted that the increase in yoke area of 5% reduces flux density in the yoke by 5%, reduces watts/kg by more than 5% (due to non-linear characteristics) but the yoke weight increases by 5%. Also, there may be additional loss due to cross-fluxing since there may not be perfect matching between lamination steps of limb and yoke at the joint. Hence, the reduction in losses may not be very significant.
- In large power transformers, in order to reduce the height for transportability, three-phase five-limb construction depicted in figure (e) is used. The magnetic length represented by the end yoke and end limb has a higher reluctance as compared to that represented by the main yoke. Hence, as the flux starts rising, it first takes the path of low reluctance of the main yoke. Since the main yoke is not large enough to carry all the flux from the limb, it saturates and forces the remaining flux into the end limb. Since the spilling over of flux to the end limb occurs near the flux peak and also due to the fact that the ratio of reluctances of these two paths varies due to non-linear properties of the core.
- Fluxes in both main yoke and end yoke/end limb paths are non-sinusoidal even though the main limb flux is varying sinusoidal [2, 4]. Extra losses occur in the yokes and end limbs due to the flux harmonics. In order to compensate these extra losses, it is a normal practice to keep the main yoke area 60% and end yoke/end limb area 50% of the main limb area.
- The zero-sequence impedance is much higher for the three-phase five-limb core than the three-limb core due to low reluctance path (of yokes and end limbs) available to the in-phase zero-sequence fluxes, and its value is close to but less than the positive-sequence impedance value.

(b) Shell-type construction:

- Cross section of windings in the plane of core is surrounded by limbs and yokes, is also used.
- Shell type of construction of the core is widely used in USA.
- **Advantage:**
- One can use sandwich construction of LV and HV windings to get very low impedance, if desired, which is not easily possible in the core-type construction.
- **Analysis of overlapping joints and building factor:**
- While building a core, the laminations are placed in such a way that the gaps between the laminations at the joint of Limb and yoke are overlapped by the laminations in the next layer.

- This is done so that there is no continuous gap at the joint when the laminations are stacked one above the other (figure). The overlap distance is kept around 15 to 20 mm.
- There are two types of joints most widely used in transformers: non-mitred and mitred joints.
- **Non-mitered joints**:
- In which the overlap angle is 90°, are quite simple from the manufacturing point of view, but the loss in the corner joints is more since the flux in the joint region is not along the direction of grain orientation. Hence, the on-mitred joints are used for smaller rating transformers. These joints were commonly adopted in earlier days when non-oriented material was used
- **Mitered joints**:
- The joint where these laminations meet could be Butt or Mitred. In CRGO, the Mitred Joint is preferred as it reduces the Reluctance of the Flux path and reduces the No Load Losses and the No Load current (by about 12% & 25% respectively).
- The Limb and the Yoke are made of a number of Laminations in Steps. Each step comprises of some number of laminations of equal width. The width of the central strip is Maximum and that at the circumference is Minimum. The cross section of the Yoke and the Limb are nearly Circular. Mitred joint could be at 35/45/55 degrees but the 45 one reduces wastage.
- The angle of overlap (a) is of the order of 30° to 60°, the most commonly used angle is 45°. The flux crosses from limb to yoke along the grain orientation in mitred joints minimizing losses in them. For airgaps of equal length, the excitation requirement of cores with mitred joints is sin a times that with non-mitred joints.
- **Building Factor:**
- Better grades of core material (Hi-B, scribed, etc.) having specific loss (watts/kg) 15 to 20% lower than conventional CRGO material (termed hereafter as CGO grade, e.g., M4) are regularly used. However, it has been observed that the use of these better materials may not give the expected loss reduction if a proper value of building factor is not used in loss calculations
- The building factor generally increases as grade of the material improves from CGO to Hi-B to scribed (domain refined). This is a logical fact because at the corner joints the flux is not along the grain orientation, and the increase in watts/kg due to deviation from direction of grain orientation is higher for a better grade material.
- The factor is also a function of operating flux density; it deteriorates more for better grade materials with the increase in operating flux density. Hence, cores built with better grade material may not give the expected benefit in line with Epstein measurements done on individual lamination. Therefore, appropriate building factors should be taken for better grade materials using experimental/test data.
- Also the loss contribution due to the corner weight is higher in case of 90° joints as compared to 45° joints since there is over-crowding of flux at the inner edge and flux is not along the grain orientation while passing from limb to yoke in the former case. Smaller the overlapping length better is the core performance; but the improvement may not be noticeable.
- The gap at the core joint has significant impact on the no-load loss and current. As compared to 0 mm gap, the increase in loss is 1 to 2% for 1.5 mm gap, 3 to 4% for 2.0 mm gap and 8 to 12% for 3 mm gap. These figures highlight the need for maintaining minimum gap at the core joints.
- Lesser the laminations per lay, lower is the core loss. The experience shows that from 4 laminations per lay to 2 laminations per lay, there is an advantage in loss of about 3 to 4%. There is further advantage of 2 to 3% in 1 lamination per lay. As the number of laminations per lay reduces, the manufacturing time for core building increases and hence most of the manufacturers have standardized the core building with 2 laminations per lay.
- Joints of limbs and yokes contribute significantly to the core loss due to cross-fluxing and crowding of flux lines in them. Hence, the higher the corner area and weight, the higher is the core loss.
- The corner area in single-phase three-limb cores, single-phase four-limb cores and three-phase five-limb cores is less due to smaller core diameter at the corners, reducing the loss contribution due to the corners. However, this reduction is more than compensated by increase in loss because of higher overall weight (due to additional end limbs and yokes).
- Building factor is usually in the range of 1.1 to 1.25 for three-phase three-limb cores with mitred joints. Higher the ratio of window height to window width, lower is the contribution of corners to the loss and hence the building factor is lower.
- **Step-lap joint** :
- It is used by many manufacturers due to its excellent performance figures. It consists of a group of laminations (commonly 5 to 7) stacked with a staggered joint as shown in figure.

- Its superior performance as compared to the conventional mitred construction.
- It is shown that, for a operating flux density of 1.7 T, the flux density in the mitred joint in the core sheet area shunting the air gap rises to 2.7 T (heavy saturation), while in the gap the flux density is about 0.7 T. Contrary to this, in the step-lap joint of 6 steps, the flux totally avoids the gap with flux density of just 0.04 T, and gets redistributed almost equally in laminations of other five steps with a flux density close to 2.0 T. This explains why the no-load performance figures (current, loss and noise) show a marked improvement for the step-lap joints.
- **Yoke Studs:**
- The assembled core has to be clamped tightly not only to provide a rigid mechanical structure but also required magnetic characteristic. Top and Bottom Yokes are clamped by steel sections using Yoke Studs. These studs do not pass through the core but held between steel sections. Of late Fiber Glass Band tapes are wound round the Limbs tightly upto the desired tension and heat treated. These laminations , due to elongation and contraction lead to magnetostriction, generally called Humming which can be reduced by using higher silicon content in steel but this makes the laminations become very brittle.
- **Over Excited:**
- The choice of operating flux density of a core has a very significant impact on the overall size, material cost and performance of a transformer.
- For the currently available various grades of CRGO material, although losses and magnetizing volt-amperes are lower for better grades, viz. Hi-B material (M0H, M1H, M2H), laser scribed, mechanical scribed, etc., as compared to CGO material (M2, M3, M4,M5, M6, etc.), the saturation flux density has remained same (about 2.0 T).The peak operating flux density (Bmp) gets limited by the over-excitation conditions specified by users.
- The slope of B-H curve of CRGO material significantly worsens after about 1.9 T (for a small increase in flux density, relatively much higher magnetizing current is drawn). Hence, the point corresponding to 1.9 T can be termed as knee-point of the B-H curve.
- It has been seen in example 1.1 that the simultaneous over-voltage and under-frequency conditions increase the flux density in the core. Hence, for an over-excitation condition (over-voltage and under-frequency).
- When a transformer is subjected to an over-excitation, core contains an amount of flux sufficient to saturate it. The remaining flux spills out of the core. The over-excitation must be extreme and of a long duration to produce damaging effect in the core laminations
- The laminations can easily withstand temperatures in the region of 800°C (they are annealed at this temperature during their manufacture), but insulation in the vicinity of core laminations, viz. press-board insulation (class A: 105°C) and core bolt insulation (class B: 130°C) may get damaged. Since the flux flows in air (outside core) only during the part of a cycle when core gets saturated, the air flux and exciting current are in the form of pulses having high harmonic content which increases the eddy losses and temperature rise in windings and structural parts.

Winding Insulation in Transformer:

- In Transformers, the insulating oil provides an insulation medium as well as a heat transferring medium that carries away heat produced in the windings and iron core. Since the electric strength and the life of a Transformer depend chiefly upon the quality of the insulating oil.

Requirement of Insulating Oil	
400KVA to 1600KVA	1.0 Litter / KVA
1600KVA to 8000KVA	0.6 Litter / KVA
Above 80000KVA	0.5 Litter / KVA

- It is very important to use a high quality insulating oil to provide a high electric strength and Permit good transfer of heat.
- **Transformer have low specific gravity**: In oil of low specific gravity particles which have become suspended in the oil will settle down on the bottom of the tank more readily and at a faster rate, a property aiding the oil in retaining its homogeneity.
- **Transformers have a low viscosity:**Oil with low viscosity, i.e., having greater fluidity, will cool Transformers at a much better rate.
- **Transformers havelow pour point:** Oil with low pour point will cease to flow only at low temperatures.

- **Transformers havehigh flash point:** The flash point characterizes its tendency to evaporate. The lower the flash point the greater the oil will tend to vaporize When oil vaporizes, it loses in volume, its viscosity rises, and an explosive mixture may be formed with the air above the oil

The Core Insulation Material:

- SRBP- Synthetic Resin Bonded Paper
- OIP – Oil Impregnated Paper
- RIP – Resin Impregnated Paper
- Resin Coated Paper/ Kraft Paper/ Crepe Kraft Paper is used for making core for the above It is Hermetically Sealed.
- Pre-compressed pressboard is used in windings as opposed to the softer materials used in earlier days. The major insulation (between windings, between winding and yoke, etc.)
- Mineral oil has traditionally been the most commonly used electrical insulating medium and coolant in transformers. Studies have proved that oil-barrier insulation system can be used at the rated voltages greater than 1000 KV.A high dielectric strength of oil-impregnated paper and pressboard is the main reason for using oil as the most important constituent of the transformer insulation system.
- Manufacturers have used silicon-based liquid for insulation and cooling. Due to non-toxic dielectric and self-extinguishing properties. High cost of silicon is an inhibiting factor for its widespread use.
- Super-biodegradable vegetable seed based oils are also available for use in environmentally sensitive locations.
- SF6 gas has excellent dielectric strength and is non-flammable. Hence, SF6 transformers find their application in the areas where fire-hazard prevention is of paramount importance.
- Due to lower specific gravity of SF6 gas, the gas insulated transformer is usually lighter than the oil insulated transformer. The dielectric strength of SF6 gas is a function of the operating pressure; the higher the pressure, the higher the dielectric strength.
- However, the heat capacity and thermal time constant of SF6 gas are smaller than that of oil, resulting in reduced overload capacity of SF6 transformers as compared to oil-immersed transformers. Environmental concerns, sealing problems, lower cooling capability and present high cost of manufacture are the challenges.
- Dry-type resin cast and resin impregnated transformers use class F or C insulation. High cost of resins and lower heat dissipation capability limit the use of these transformers to small ratings.
- The dry-type transformers are primarily used for the indoor application in order to minimize fire hazards. Nomex paper insulation, which has temperature withstand capacity of 220°C, is widely used for dry-type transformers. The initial cost of a dry-type transformer may be 60 to 70% higher than that of an oil-cooled transformer at current prices, but its overall cost at the present level of energy rate can be very much comparable to that of the oil-cooled transformer.

Transformer Noise:

- Core, windings and cooling equipment are the three main sources of noise. The core is the most important and significant source of the transformer noise.
- The core vibrates due to magnetic and magnetostrictive forces. Magnetic forces appear due to non-magnetic gaps at the corner joints of limbs and yokes. These magnetic forces depend upon the kind of interlacing between the limb and yoke; these are highest when there is no overlapping (continuous air gap).
- The magnetic forces are smaller for 90° overlapping, which further reduce for 45°overlapping. These are the least for the step-lap joint due to reduction in the value of flux density in the overlapping region at the joint.
- The forces produced by the magnetostriction phenomenon are much higher than the magnetic forces in transformers.Magnetostriction is a change in configuration of magnetisable material in a magnetic field, which leads to periodic changes in the length of material. An alternating field sets the core in vibration.
- This vibration is transmitted, after some attenuation, through the oil and tank structure to the surrounding air. This finally results in a characteristic hum.
- The magnetostriction force varies with time and contains even harmonics of the power frequency (120, 240, 360, Hz for 60 Hz power frequency). Therefore, the noise also contains all harmonics of 120 Hz.
- The amplitude of core vibration and noise increase manifold if the fundamental mechanical natural frequency of the core is close to 120 Hz.
- The value of the magnetostriction can be positive or negative, depending on the type of the magnetic material, and the mechanical and thermal treatments.

- Magnetostriction is generally positive (increase in length by a few microns with increase in flux density) for CRGO material at annealing temperatures below 800°C, and as the annealing temperature is increased (=800°C), it can be displaced to negative values. The mechanical stressing may change it to positive values
- Magnetostriction is minimum along the rolling direction and maximum along the 90° direction.
- Most of the noise transmitted from a core comes principally from the yoke region because the noise from the limb is effectively damped by windings (copper and insulation material) around the limb.
- The quality of yoke clamping has a significant influence on the noise level.
- Apart from the yoke flux density, other factors which decide the noise level are: limb flux density, type of core material, leg center (distance between the centers of two adjacent phases), core weight, frequency,.
- The higher the flux density, leg centers, core weight and frequency of operation, the higher is the noise level.
- The noise level is closely related to the operating peak flux density and core weight.
- If core weight is assumed to change with flux density approximately in inverse proportion, for a flux density change from 1.6 T to 1.7 T, the increase in noise level is 1.7 dB
- Hence, one of the ways of reducing noise is by designing transformer at lower operating flux density. For a flux density reduction of 0.1 T, the noise level reduction of about 2 dB is obtained. This method results into an increase of material content, and it may be justified economically if the user has specified a lower no-load loss, in which case the natural choice is to use a lower flux density.
- Use of step-lap joint gives much better noise reduction (4 to 5 dB).
- Some manufacturers also use yoke reinforcement (leading to reduction in yoke flux density), the method has the advantage that copper content does not go up since the winding mean diameters do not increase. Bonding of laminations by adhesives and placing of anti-vibration/damping elements between the core and tank can give further reduction in the noise level.The use of Hi-B/scribed material can also give a reduction of 2 to 3 dB. When a noise level reduction of the order of 15 to 20 dB is required, some of these methods are necessary but not sufficient.
- Transformers located near a residential area should have sound level as low as possible. Levels specified are 10 to 15 dB lower than the prevailing levels mentioned in the international standards.

Transformer Protection:

Internal Protection:

(a) Bucholtz Relay:

- This Gas operated relay is a protection for minor and major faults that may develop inside a Transformer.
- This relay is located in between the conservator tank and the Main Transformer tank in the Pipe line which is mounted at an inclination of 3 to 7 degrees.
- A shut off valve is located in between the Bucholtz relay and the Conservator.
- The relay comprises of a cast housing which contains two pivoted Buckets counter balanced weights.
- The relay also contains two mercury y switches which will send alarm or trip signal to the breakers controlling the Transformer. In healthy condition, this relay will be full of oil and the buckets will also be full of oil and is counter balanced by the weights.
- In the event of a fault inside the transformer, the gases flow up to the conservator via the relay and push the oil in the relay down. Once the oil level falls below the bottom level of the buckets, the bucket due to the weight of oil inside tilts and closes the mercury switch and causes the Alarm or trip to be actuated and isolate the transformer from the system.

(b) Oil Surge / Bucholtz Relay for OLTC:

- This relay operating on gas produced slowly or in a surge due to faults inside the Diverter Switch of OLTC protects the Transformer and isolates it from the system.

(c) Pressure Relief Valve for Large Transformers:

- In case of a serious fault inside the Transformer, Gas is rapidly produced.
- This gaseous pressure must be relieved immediately otherwise it will damage the Tank and cause damage to neighboring equipment.
- This relay is mounted on the top cover or on the side walls of the Transformer. The valve has a corresponding port which will be sealed by a stain less steel diaphragm .
- The diaphragm rests on an O ring and is kept pressed by two heavy springs. If a high pressure is developed inside, this diaphragm lifts up and releases the excessive gas.

- The movement of the diaphragm lifts the spring and causes a micro switch to close its contacts to give a trip signal to the HV and LV circuit breakers and isolate the transformer.
- A visual indication can also be seen on the top of the relay. For smaller capacity transformer, an Explosion vent is used to relieve the excess pressure but it cannot isolate the Transformer.

(d) Explosion Vent Low & Medium Transformers:

- For smaller capacity Transformers, the excessive pressures inside a Transformer due to major faults inside the transformer can be relieved by Explosion vents. But this cannot isolate the Transformer.

(e) Winding /Oil Temperature Protection :

- These precision instruments operate on the principle of liquid expansion.
- These in conjunction with mercury switches provide signals for excessive temperature alarm annunciation and also isolate the Transformer for very excessive temperatures. These also switch on the cooler fans and cooler pumps if the temperature exceeds the set values. Normally two separate instruments are used for oil and winding temperatures. In some cases additional instruments are provided separately for HV, LV and Tertiary winding temperatures.
- The indicator is provided with a sensing bulb placed in an oil pocket located on the top cover of the Transformer tank. The Bulb is connected to the instrument housing by means of flexible connecting tubes consisting of two capillary tubes.
- One capillary tube is connected to an operating Bellow in the instrument. The other is connected to a compensating Bellow .
- The tube follows the same path as the one with the Bulb but the other end, it does not end in a Bulb and left sealed. This compensates for variations in Ambient Temperatures.
- As the temperature varies, the volume of the liquid in the operating system also varies and operates the operating Bellows transmitting its movements to the pointer and also the switching disc. This disc is mounted with mercury float switches which when made provides signals to alarm/trip/cooler controls.
- Oil and winding temperature indicators work on the same principles except that the WTI is provided with an additional bellows heating element. This heating element is fed by a current transformer with a current proportional to the load in the winding whose temperature is to be measured/monitored. The tem premature increase of the heating element is proportional to the temperature rise of winding over top oil temperature.
- The operating bellow gets an additional movement simulating the increase of winding temperature over top oil temperature and represents the Winding Hot Spot. This is called Thermal Imaging process.

(f) Conservator Magnetic Oil Level Protection :

- Inside the conservator tank, a float is used to sense the levels of oil and move. This is transmitted to a switch mechanism by means of magnetic coupling. The Float and the Magnetic mechanism are totally sealed. The pointer connected to the magnetic mechanism moves indicating the correct oil level and also provision is made for Low oil level alarm by switch.

(g) Silica gel Breather:

- This is a means to preserve the dielectric strength of insulating oil and prevent absorption of moisture, dust etc. The breather is connected to the Main conservator tank. It is provided with an Oil seal. The breathed in air is passed through the oil seal to retain moisture before the air passes through the silica gel cr ystals which absorbs moisture before breathing into the conservator tank. In latest large transformers, Rubber Diaphragm or Air cells are used to reduce contamination of oil.

(h) Transformer Earthing :

- For Distribution Transformers, normally Dy11 vector Group, the LT Neutral is Earthed by a separate Conductor section of at least half the section of the conductor used for phase wire and connected to a Separate Earth whose Earth Resistance must be less than 1 ohm.
- The Body of the Tank has two different earth connections, which should be connected to two distinct earth electrodes by GI flat of suitable section.
- For Large Power Transformers, Neutral and Body Connections are made separately but all the Earth Pits are connected in parallel so that the combined Earth Resistance is always maintained below 0.1 ohm.
- The individual and combined earth resistance is measured periodically and the Earth Pits maintained regularly and electrodes replaced if required.

External Protection:

1. Lightning Arrestors on HV & LV for Surge Protection
2. HV / LV Over Current Protection(Instantaneous /IDMT- Back up)
3. Earth Fault Protection (Y connected side)
4. REF (HV & LV) (For internal fault protection)
5. Differential Protection (for internal fault protection)
6. Over Fluxing Protection (against system Kv & HZ variations)
7. HG Fuse Protection for Small Capacity Transformers.
8. Normally Each Power Transformers will have a LV Circuit Breaker. For a Group of Transformers up to 5 MVA in a substation, a Group control Circuit Breaker is provided. Each Transformer of 8 MVA and above will have a Circuit Breaker on the HV side.

Transformer Cooling:

- The Heat in a transformer is produced due to I2R in the windings and in the core due to Eddy Current and Hysteresis Loss.
- In Dry type Transformer the Heat is directly dissipated into the atmosphere but in Oil filled Transformer, the Heat is dissipated by Thermosyphon and transmitted to the top and dissipated into the atmosphere through Radiators naturally or by forced cooling fans or by Oil pumps or through Water Coolers.
- The following Standard symbols are adopted to denote the Type of Cooling:

Code	Description
A	Air Cooling
N	Natural Cooling by Convection
B	Cooling by Air Blast Fans
O	Oil (mineral) immersed cooling
W	Water Cooled
F	Forced Oil Circulation by Oil Pumps
S	Synthetic Liquid used instead of Oil
G	Gas Cooled (SF6 or N2)
D	Forced (Oil directed)
ONAF	Oil immersed Transformer with natural oil circulation and forced air external cooling is designated
ONAN	Oil Immersed Natural cooled
ONAF	Oil Immersed Air Blast
ONWN	Oil Immersed Water Cooled
OFAF	Forced Oil Air Blast Cooled
OFAN	Forced Oil Natural Air Cooled
OFWF	Forced Oil Water Cooled
ODAF	Forced Directed Oil and Forced Air Cooling

Chapter: 10 Basic of Current Transformer

Principle operationof CT

- A current transformer is defined as "as an instrument transformer in which the secondary current is substantially proportional to the primary current (under normal conditions of operation) and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections."
- Current transformers are usually either "measuring" or "protective" types.

Some Definitions used for CT:

(1) Rated primary current:

- The value of primary current which appears in the designation of the transformer and on which the performance of the current transformer is based.

(2) Rated secondary current:

- The value of secondary current which appears in the designation of the transformer and on which the performance of the current transformer is based.
- Typical values of secondary current are 1 A or 5 A. In the case of transformer differential protection, secondary currents of 1/ root 3 A and 5/ root 3 A are also specified.

(3) Rated burden:

- The apparent power of the secondary circuit in Volt-amperes expressed at the rated secondary current and at a specific power factor (0.8 for almost all standards)

(4) Rated output:

- The value of the apparent power (in volt-amperes at a specified power (factor) which the current transformer is intended to supply to the secondary circuit at the rated secondary current and with rated burden connected to it.

(5) Accuracy class:

- In the case of metering CT s, accuracy class is typically, **0.2, 0.5, 1 or 3.**
- This means that the errors have to be within the limits specified in the standards for that particular accuracy class.
- The metering CT has to be accurate from 5% to 120% of the rated primary current, at 25% and 100% of the rated burden at the specified power factor.
- In the case of protection CT s, the CT s should pass both the ratio and phase errors at the specified accuracy class, usually **5P or 10P**, as well as composite error at the accuracy limit factor of the CT.

(6) Current Ratio Error:

- The error with a transformer introduces into the measurement of a current and which arises from the fact that actual transformation ratio is not equal to the rated transformer ratio. The current error expressed in percentage is given by the formula:
- **Current error in % = (Ka(Is-Ip)) x 100 / Ip**
- Where Ka= rated transformation ratio ,Ip= actual primary current, Is= actual secondary current when Ip is flowing under the conditions of measurement

(7) Accuracy limit factor:

- The value of primary current up to which the CT complies with composite error requirements. This is typically **5, 10 or 15**, which means that the composite error of the CT has to be within specified limits at 5, 10 or 15 times the rated primary current.

(8) Short time rating:

- The value of primary current (in kA) that the CT should be able to withstand both thermally and dynamically without damage to the windings, with the secondary circuit being short-circuited. The time specified is usually 1 or 3 seconds.

(9) Instrument security factor (factor of security):

- This typically takes a value of less than 5 or less than 10 though it could be much higher if the ratio is very low. If the factor of security of the CT is 5, it means that the composite error of the metering CT at 5 times the rated primary current is equal to or greater than 10%. This means that heavy currents on the primary are not passed on to the secondary circuit and instruments are therefore protected. In the case of double ratio CT's, FS is applicable for the lowest ratio only.

(10) Class PS X CT:

- In balance systems of protection, CT s with a high degree of similarity in their characteristics is required. These requirements are met by Class PS (X) CT s. Their performance is defined in terms of a knee-point voltage (KPV), the magnetizing current (Imag) at the knee point voltage or 1/2 or 1/4 the knee-point voltage, and the resistance of the CT secondary winding corrected to 75C. Accuracy is defined in terms of the turn's ratio.

(11) Knee point voltage:

- That point on the magnetizing curve where an increase of 10% in the flux density (voltage) causes an increase of 50% in the magnetizing force (current).
- The 'Knee Point Voltage' (Vkp) is defined as the secondary voltage at which an increase of 10% produces an increase in magnetizing current of 50%. It is the secondary voltage above which the CT is near magnetic saturation.

(12) Core balance CT (CBCT):

- The CBCT, also known as a zero sequence CT, is used for earth leakage and earth fault protection. The concept is similar to the RVT. In the CBCT, the three core cable or three single cores of a three phase system pass through the inner diameter of the CT. When the system is fault free, no current flows in the secondary of the CBCT. When there is an earth fault, the residual current (zero phase sequence current) of the system flows through the secondary of the CBCT and this operates the relay. In order to design the CBCT, the inner diameter of the CT, the relay type, the relay setting and the primary operating current need to be furnished.

(13) Phase displacement:

- The difference in phase between the primary and secondary current vectors, the direction of the vectors being so chosen that the angle is zero for the perfect transformer. The phase displacement is said to be positive when the secondary current vector leads the primary current vector. It is usually express in minutes

(14) Highest system voltage:

- The highest rms line to line voltage which can be sustained under normal operating conditions at any time and at any point on the system. It excludes temporary voltage variations due to fault condition and the sudden disconnection of large loads.

(15) Rated insulation level:

- That combination of voltage values (power frequency and lightning impulse, or where applicable, lightning and switching impulse) which characterizes the insulation of a transformer with regard to its capability to withstand by dielectric stresses. For low voltage transformer the test voltage 4kV, at power-frequency, applied during 1 minute.

(16) Rated short-time thermal current (Ith):

- The rms value of the primary current which the current transformer will withstand for a rated time, with their secondary winding short circuited without suffering harmful effects.

(17) Rated dynamic current (Idyn):

- The peak value of the primary current which a current transformer will withstand, without being damaged electrically for mechanically by the resulting electromagnetic forces, the secondary winding being short-circuited.

(18) Rated continuous thermal current (Un)

- The value of current which can be permitted to flow continuously in the primary winding, the secondary windings being connected to the rated burdens, without the temperature rise exceeding the specified values.

(19) Instrument security factor (ISF or Fs):

- The ratio of rated instrument limits primary current to the rated primary current. The times that the primary current must be higher than the rated value, for the composite error of a measuring current transformer to be equal to or greater than 10%, the secondary burden being equal to the rated burden. The lower this number is, the more protected the connected instrument are against.

(20) Sensitivity

- Sensitivity is defined as the lowest value of primary fault current, within the protected zone, which will cause the relay to operate. To provide fast operation on an in zone fault, the current transformer should have a 'Knee Point Voltage' at least twice the setting voltage of the relay.

(21) Field Adjustment of Current Transformer Ratio:

- The ratio of current transformers can be field adjusted to fulfil the needs of the application. Passing more secondary turns or more primary turns through the window will increase or decrease the turns ratio.

- **Actual Turns Ratio = (Name Plate Ration- Secondary Turns Added) / Primary Turns.**

Types of Current transformers (CT's)

According to Construction of CT:

(1) Bar Type:

- Bar types are available with higher insulation levels and are usually bolted to the current caring device.

- Bar type current transformers are insulated for the operating voltage of the system.
- Bar-type CTs operate on the same principle of window CTs but have a permanent bar installed as a primary conductor

(2) WoundCT's:

- Capacity: There are designed to measure currents from 1 amp to 100 amps.
- the most common one is the wound type current transformer. The wound type provides excellent performance under a wide operating range. Typically, the wound type is insulated to only 600 volts.

- Since the load current passes through primary windings in the CT, screw terminals are provided for the load and secondary conductors. Wound primary CT's are available in ratios from 2.5:5 to 100:5.
- Wound CTs have a primary and secondary winding like a normal transformer. These CTs are rare and are usually used at very low ratios and currents, typically in CT secondary circuits to compensate for low currents, to match different CT ratios in summing applications, or to isolate different CT circuits. Wound CTs have very high burdens, and special attention to the source CT burden should be applied when wound CTs are used.

(3) Window:

- Window CTs are the most common. They are constructed with no primary winding and are installed around the primary conductor. The electric field created by current flowing through the conductor interacts with the CT core to transform the current to the appropriate secondary output. Window CTs can be of solid or split core construction. The primary conductor must be disconnected when installing solid window CTs. However, split core CTs can be installed around the primary conductor without disconnecting the primary conductor

- **Ring Core CT's :**
- Capacity: Thereare available for measuring currents from 50 to 5000 amps

- Size: with windows (power conductor opening size) from 1" to 8" diameter.
- **Split Core CT's:**
- Capacity: Thereare available for measuring currents from 100 to 5000 amps.
- Size: with windows in varying sizes from 1" by 2" to 13" by 30".
- Split core CT's have one end removable so that the load conductor or bus bar does not have to be disconnected to install the CT.

(4) Bushing

- Bushing CTs are window CTs specially constructed to fit around a bushing. Usually they cannot be accessed, and their nameplates are found on the transformer or circuit-breaker control cabinets.
- The bushing type is typically used around the bushing on circuit breakers and transformers and may not have a hard protective outside cover.
- Donut type current transformers are typically insulated for 600 volts. To ensure accuracy, the conductor should be positioned in the center of the current transformer opening.

According to Application of CT:

(1) Measuring CT:

- The principal requirements of a measuring CT are that, for primary currents up to 120% or 125% of the rated current, its secondary current is proportional to its primary current to a degree of accuracy as defined by its "Class" and, in the case of the more accurate types, that a specified maximum phase angle displacement is not exceeded.
- A desirable characteristic of a measuring CT is that it should "saturate" when the primary current exceeds the percentage of rated current specified as the upper limit to which the accuracy provisions apply. This means that at these higher levels of primary current the secondary current is less than proportionate. The effect of this is to reduce the extent to which any measuring device connected to the CT secondary is subjected to current Overload.

(2) Protective CT:

- On the other hand, the reverse is required of the protective type CT, the principal purpose of which is to provide a secondary current proportional to the primary current when it is several, or many, times the rated primary current. The measure of this characteristic is known as the **"Accuracy Limit Factor"** (A.L.F.).
- A protection type CT with an A.L.F. of 10 will produce a proportional current in the secondary winding (subject to the allowable current error) with primary currents up to a maximum of 10 times the rated current.
- It should be remembered when using a CT that where there are two or more devices to be operated by the secondary winding, they must be connected in series across the winding. This is exactly the opposite of the method used to connect two or more loads to be supplied by a voltage or power transformer where the devices are paralleled across the secondary winding.
- With a CT, an increase in the burden will result in an increase in the CT secondary output voltage. This is automatic and necessary to maintain the current to the correct magnitude. Conversely, a reduction in the burden will result in a reduction in the CT secondary output voltage.
- This rise in secondary voltage output with an increase in burden means that, theoretically, with infinite burden as is the case with the secondary load open circuit, an infinitely high voltage appears across the secondary terminals. For practical reasons this voltage is not infinitely high, but can be high enough to cause a breakdown in the insulation between primary and secondary windings or between either or both windings and the core. For this reason, primary current should never be allowed to flow with no load or with a high resistance load connected across the secondary winding.
- When considering the application of a CT it should be remembered that the total burden imposed on the secondary winding is not only the sum of the burden(s) of the individual device(s) connected to the winding but that it also includes the burden imposed by the connecting cable and the resistance of the connections.
- If, for example, the resistance of the connecting cable and the connections is 0.1 ohm and the secondary rating of the CT is 5A, the burden of the cable and connections (RI2) is 0.1 x 5 x 5 = 2.5VA. This must be added to the burden(s) of the connected device(s) when determining whether the CT has an adequately large burden rating to supply the required device(s) and the burden imposed by the connections.
- Should the burden imposed on the CT secondary winding by the connected device(s) and the connections exceed the rated burden of the CT the CT may partly or fully saturate and therefore not have a secondary current adequately linear with the primary current.
- The burden imposed by a given resistance in ohms [such as the resistance of a connecting cable] is proportional to the square of the rated secondary current. Therefore, where long runs of cable between CT and the connected device(s) are involved, the use of a 1A secondary CT and a 1A device rather than 5A will result in a 25-fold reduction in the burden of the connecting cables and connections. All burden ratings and calculations are at rated secondary current.
- Because of the foregoing, when a relatively long [more than a very few meters] cable run is required to connect a CT to its burden [such as a remote ammeter] a calculation should be made to determine the cable burden. This is proportional to the "round trip" resistance, i.e. twice the resistance of the length of twin cable used. Cable tables provide information on the resistance values of different sizes of conductors at 20o C per unit length.

The calculated resistance is then multiplied by the square of the CT secondary current rating [25 for 5A, 1 for 1A]. If the VA burden as calculated by this method and added to the rated burden(s) of the device(s) to be driven by the CT exceeds the CT burden rating, the cable size must be increased [to reduce the resistance and thus the burden] or a CT with a higher VA burden rating must be used, or a lower CT secondary current rating [with matching change in the current rating of the device(s) to be driven] should be substituted

Nomenclature of CT:

1. **Ratio:** input / output current ratio
2. **Burden (VA):** total burden including pilot wires. (2.5, 5, 10, 15 and 30VA.)
3. **Class:** Accuracy required for operation (Metering: 0.2, 0.5, 1 or 3, Protection: 5, 10, 15, 20, 30).
4. **Accuracy Limit Factor:**
5. **Dimensions:** maximum & minimum limits
6. Nomenclature of CT: Ratio, VA Burden, Accuracy Class, Accuracy Limit Factor.
7. **Example:1600/5, 15VA 5P10** (Ratio: 1600/5, Burden: 15VA, Accuracy Class: 5P, ALF: 10)
8. **As per IEEE Metering CT:** 0.3B0.1 rated Metering CT is accurate to 0.3 percent if the connected secondary burden if impedance does not exceed 0.1 ohms.
9. **As per IEEE Relaying (Protection) CT:** 2.5C100 Relaying CT is accurate within 2.5 percent if the secondary burden is less than 1.0 ohm (100 volts/100A).

(1) Current Ratio of CT:

- The primary and secondary currents are expressed as a ratio such as 100/5. With a 100/5 ratio CT, 100A flowing in the primary winding will result in 5A flowing in the secondary winding, provided the correct rated burden is connected to the secondary winding. Similarly, for lesser primary currents, the secondary currents are proportionately lower.
- It should be noted that a 100/5 CT would not fulfil the function of a 20/1 or a 10/0.5 CT as the ratio expresses the current rating of the CT, not merely the ratio of the primary to the secondary currents.
- The rated secondary current is commonly 5A or 1A, though lower currents such as 0.5A are not uncommon. It flows in the rated secondary load, usually called the burden, when the rated primary current flows in the primary winding.
- **Increasing or Decreasing Turns Ratio of CT:**
- **Increasing Number of Turn:** Increasing the number of primary turns can only decrease the turn's ratio. A current transformer with a 50 to 5 turn's ratio can be changed to a 25 to 5 turn's ratio by passing the primary twice through the window.
- **Increasing or Decreasing Turns Ratio:**
- The turn's ratio can be either increased or decreased by wrapping wire from the secondary through the window of the current transformer.
- Increasing the turn's ratio with the secondary wire, turns on the secondary are essentially increased. A 50 to 5 current transformer will have a 55 to 5 ratio when adding a single secondary turn.
- Decreasing the turn's ratio with the secondary wire, turns on the secondary are essentially decreased. A 50 to 5 current transformer will have a 45 to 5 ratio when adding a single secondary turn.
- Decreasing the turn's ratio with the primary, accuracy and VA burden ratings are the same as the original configuration.
- Increasing the turn's ratio with the secondary will improve the accuracy and burden rating.
- Decreasing the turn's ratio with the secondary will worsen the accuracy and burden rating.
- When using the secondary of a current transformer to change the turn's ratio, the right hand rule of magnetic fields comes into play. Wrapping the white lead or the X1 lead from the H1 side of the transformer through the window to the H2 side will decrease the turn's ratio. Wrapping this wire from the H2 side to the H1 side will increase the turn's ratio.
- Using the black or X2 lead as the adjustment method will do the opposite of the X1(white) lead. Wrapping from the H1 to the H2 side will increase the turns ratio, and wrapping from the H2 to the H1 side will decrease the turns ratio.

(2) Burden of CT:

- **Common burden ratings of CT:** 2.5, 5, 10, 15 and 30VA.
- The external load applied to the secondary of a current transformer is called the "burden".
- The burden of CT is the maximum load (in VA) that can be applied to the CT secondary.

- The burden can be expressed in two ways.
- The burden can be expressed as the total impedance in ohms of the circuit or the total volt-amperes (VA) and power factor at a specified value of current or voltage and frequency.
- Formerly, the practice was to express the burden in terms of volt-amperes (VA) and power factor, the volt-amperes being what would be consumed in the burden impedance at rated secondary current (in other words, rated secondary current squared times the burden impedance). Thus, a burden of 0.5Ωimpedance may be expressed also as "12.5 VA at 5 amperes," if we assume the usual 5-ampere secondary rating. The VA terminology is no longer standard, but it needs defining because it will be found in the literature and in old data.
- ## Burden for Measuring CT:
- **Total burden of Measuring CT = Sum of Meters Burden in VA (Ammeter, Wattmeter, Transducer etc.) connected in series to the CT secondary circuit + Connecting Secondary Circuit Cable Burden in VA.**
- Cable burden = I2 x R x2 L, where I = CT secondary current, R = cable resistance per length, 2L is the tro &fro distance of cable length L from CT to metering circuits. If the proper size and short length of wire is used, cable burden can be ignored.
- The CT secondary circuit load shall not be more than the CT VA rating. If the load is less than the CT burden, all meters connected to the measuring CT should provide correct reading.
- In the case of Measuring Current transformer, the burden depends on the connected meters and quantity of meters on the secondary i.e. no of Ammeters, KWh meters, Kvar meters, Kwh meters, transducers and also the connection cable burden (I2 x R x2 L) to metering shall be taken into account.
- Note Meters burden can be obtained from manufacturer catalogue.
- Selected CT burden shall be more than the calculated burden.
- ## Burden for Protecting CT:
- In the case of Protection CTs the burden is calculated in the same way as above except the burden of individual protective relays burden shall be considered instead of meters. The connecting cable burden is calculated in the same way as metering CT
- **Total burden of Protection CT=Connecting cable Burden in VA + sum of Protective relays Burden in VA.**
- All manufacturers can supply the burden of their individual devices. Although not used very often these days, induction disk over-current devices always gave the burden for the minimum tap setting. To determine the impedance of the actual tap setting being used, First Square the ratio of minimum divide by the actual tap setting used and second multiply this value by the minimum impedance.
- Suppose an impedance of 1.47 + 5.34j at the 1A tap. To apply the relay at the 4A tap the engineer would multiply the impedance at the 1A taps setting by (1/4)2. The impedance at the 4A tap would be 0.0919 + 0.3338j or 0.3462 Z at 96.4 power factor.
- The CT burden impedance decreases as the secondary current increases, because of saturation in the magnetic circuits of relays and other devices. Hence, a given burden may apply only for a particular value of secondary current. The old terminology of volt-amperes at 5 amperes is most confusing in this respect since it is not necessarily the actual volt amperes with 5 amperes flowing, but is what the volt-amperes would be at 5 amperes
- If there were no saturation. Manufacturer's publications give impedance data for several values of over current for some relays for which such data are sometimes required. Otherwise, data are provided only for one value of CT secondary current.
- If a publication does not clearly state for what value of current the burden applies, this information should be requested. Lacking such saturation data, one can obtain it easily by test. At high saturation, the impedance approaches the DC resistance. Neglecting the reduction in impedance with saturation makes it appear that a CT will have more inaccuracy than it actually will have. Of course, if such apparently greater inaccuracy can be tolerated, further refinements in calculation are unnecessary. However, in some applications neglecting the effect of saturation will provide overly optimistic results; consequently, it is safer always to take this effect into account.
- It is usually sufficiently accurate to add series burden impedances arithmetically. The results will be slightly pessimistic, indicating slightly greater than actual CT ratio inaccuracy. But, if a given application is so borderline that vector addition of impedances is necessary to prove that the CTÕs will be suitable, such an application should be avoided.
- If the impedance at pickup of a tapped over current-relay coil is known for a given pickup tap, it can be estimated for pickup current for any other tap. The reactance of a tapped coil varies as the square of the coil turns, and the resistance varies approximately as the turns. At pickup, there is negligible saturation, and the resistance is small

compared with the reactance. Therefore, it is usually sufficiently accurate to assume that the impedance varies as the square of the turns. The number of coil turns is inversely proportional to the pickup current, and therefore the impedance varies inversely approximately as the square of the pickup current.

- Whether CT is connected in wye or in delta, the burden impedances are always connected in wye. With wye-connected CT the neutrals of the CT and of the burdens are connected together, either directly or through a relay coil, except when a so-called zero phase-sequence-current shunt is used.
- It is seldom correct simply to add the impedances of series burdens to get the total, whenever two or more CT are connected in such a way that their currents may add or subtract in some common portion of the secondary circuit. Instead, one must calculate the sum of the voltage drops and rises in the external circuit from one CT secondary terminal to the other for assumed values of secondary currents flowing in the various branches of the external circuit. The effective CT burden impedance for each combination of assumed currents is the calculated CT terminal voltage divided by the assumed CT secondary current. This effective impedance is the one to use, and it may be larger or smaller than the actual impedance which would apply if no other CTÕs were supplying current to the circuit.
- If the primary of an auxiliary CT is to be connected into the secondary of a CT whose accuracy is being studied, one must know the impedance of the auxiliary CT viewed from its primary with its secondary short-circuited. To this value of impedance must be added the impedance of the auxiliary CT burden as viewed from the primary side of the auxiliary CT; to obtain this impedance, multiply the actual burden impedance by the square of the ratio of primary to secondary turns of the auxiliary CT. It will become evident that, with an auxiliary CT that steps up the magnitude of its current from primary to secondary, very high burden impedances, when viewed from the primary, may result.
- Burden is depending on pilot lead length
- For Metering Class CTs burden is expressed as ohms impedance. For Protection-class CTs burden is express as volt-amperes (VA).

VA	Applications
1 To 2 VA	Moving iron ammeter
1 To 2.5VA	Moving coil rectifier ammeter
2.5 To 5VA	Electrodynamics instrument
3 To 5VA	Maximum demand ammeter
1 To 2.5VA	Recording ammeter or transducer

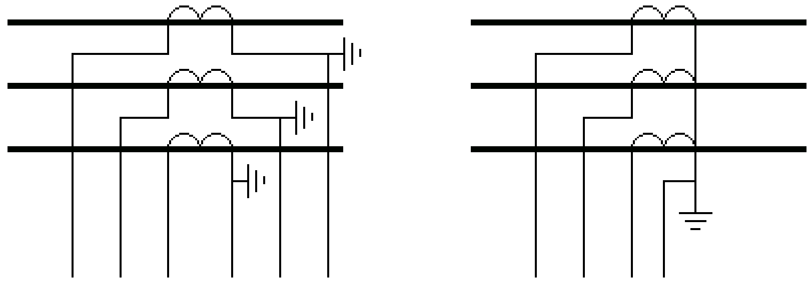
- **Burden (VA) of copper wires between instrument & current transformer for 1A and 5A secondary's**

Cross Section (mm2)	CT 1 Amp Secondary Burden in VA (Twin Wire)					
	Distance					
	10 meter	20 meter	40 meter	60 meter	80 meter	100 meter
1.0	0.35	0.71	1.43	2.14	2.85	3.57
1.5	0.23	0.46	0.92	1.39	1.85	2.31
2.5	0.14	0.29	0.57	0.86	1.14	1.43
4.0	0.09	0.18	0.36	0.54	0.71	0.89
6.0	0.06	0.12	0.24	0.36	0.48	0.6

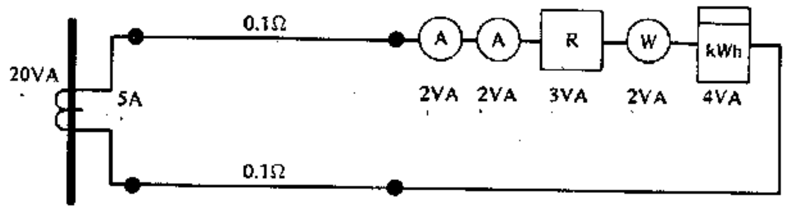
Cross Section (mm2)	CT 5 Amp Secondary Burden in VA (Twin Wire)					
	Distance					
	1 meter	2 meter	4 meter	6 meter	8 meter	10 meter
1.5	0.58	1.15	2.31	3.46	4.62	5.77
2.5	0.36	0.71	1.43	2.14	2.86	3.57
4.0	0.22	0.45	0.89	1.34	1.79	2.24
6.0	0.15	0.30	0.60	0.89	1.19	1.49
10.0	0.09	0.18	0.36	0.54	0.71	0.89

- ## CT Burden Calculation:
- The Actual burden is formed by the resistance of the pilot conductors and the protection relay(s). The resistance of a conductor (with a constant cross-sectional area) can be calculated from the equation:
- **R =pxL / A**

- where p = resistivity of the conductor material (given typically at +20°C) ,L= length of the conductor , A = cross sectional area
- If the resistivity is given in μΩm, the length in meters and the area in mm2, the equation 1 will give the resistance directly in ohms.
- Resistivity: Copper **0.0178 μΩm** at 20 °C and **0.0216μΩm** at 75 °C
- ## Burden of CT for 4 or 6 wire connection:
- If 6-wire connection is used, the total length of the wire, naturally, will be two times the distance between the CT and the relay. However, in many cases a common return conductor is used as shown in figure then, instead of multiplying the distance by two, a factor of 1.2 is typically used. This rule only applies to the 3-phase connection only. The factor 1.2 allows for a situation, where up to 20% of the electrical conductor length, including terminal resistances, uses 6-wire connection and at least 80% 4-wire connection.



- Example: the distance between the CT and the relay is 5 meters the total length is 2 x 5 m = 10 meter for 6-wire connection, but only 1.2 x 5 m = 6.0 meter when 4-wire connection is used.
- ## Burden of the relay:
- **Example:** The Distance between the CTs and the protection relay is 15 meters, 4 mm2 Cu conductors in 4-wire connection are used. The burden of the relay input is less than 20 mΩ (5 A inputs). Calculate the actual burden of the CT at 75°C , the input impedance is less than 0.020 Ω for a 5 A input (i.e. burden less than 0.5 VA) and less than 0.100 Ω for a 1 A input (i.e. less than 0.1 VA):
- **Solution:**
- p = 0.0216 μΩm (75°C) for copper conductor.
- R =pxL / A,R = 0.0216 μΩm x (1.2 x 15 m) / 4 mm2 = 0.097 Ω
- Burden of CT = 0.097 Ω + 0.020 Ω = 0.117 Ω.
- Using CTs of burden values higher than required, is unscientific since it leads to inaccurate reading (meter) or inaccurate sensing of fault / reporting conditions.
- Basically, such high value of design burden extends saturation characteristics of CT core leading to likely damage to the meter connected across it under overload condition. e.g.When we expect security factor (ISF) to be 5, the secondary current should be restricted toless than 5 times in case primary current shoots to more than 5 times its rated value.
- In such an overload condition, the core of CT is desired to go into saturation, restricting the secondary current thus the meter is not damaged. However, when we ask for higher VA, core doesn't go into saturation due to less load (ISF is much higher than desired) which may damage the meter.
- To understand the effect on Accuracy aspect, let's take an example of a CT with specified burden of 15 VA, and the actual burden is 2.5 VA:15 VA CT with less than 5 ISF will have saturation voltage of 15 Volts (15/5x5), and actual burden of 2.5 VA the saturation voltage required shall be (2.5/5 x 5) 2.5 Volts against 15 Volts resulting ISF = 30 against required of 5.
- **Example:** Decide Whether5A,20VA CT is sufficient for following circuit



- Total instrument burden = 2 + 2 + 3 + 2 + 4 = 13V A.
- Total pilot load resistance = 2 x 0.1 = 0.2 ohm.

- With 5A secondary current, volt-drop in leads is 5 x 0.2 = 1 V.
- Burden imposed by both leads = 5A x 1 V = 5V A.
- Total burden on CT = 13 + 5 = 18V A.
- As the CT is rated 20V A, it has sufficient margin.

(3) Accuracy Class of CT:

- The CT accuracy is determined by its certified accuracy class which is stamped on nameplate. For example, CT accuracy class of 0.3 means that the CT is certified by the manufacturer to be accurate to within 0.3 percent of its rated ratio value for a primary current of 100 percent of rated ratio.
- CT with a rated ratio of 200/ 5 with accuracy class of 0.3 would operate within 0.45 percent of its rated ratio value for a primary current of 100 amps. To be more explicit, for a primary current of 100A it is certified to produce a secondary current between 2.489 amps and 2.511 amps.
- Accuracy is specified as a percentage of the range, and is given for the maximum burden as expressed in VA. The total burden includes the input resistance of the meter and the loop resistance of the wire and connections between the current transformer and meter.
- Example: Burden = 2.0 VA. Maximum Voltage drop = 2.0 VA / 5 Amps = 0.400 Volts.
- Maximum Resistance = Voltage / Current = 04.00 Volts / 5 Amps =0.080 Ohms.
- If the input resistance of the meter is 0.010Ω, then 0.070Ω is allowed for loop resistance of the wire, and connections between the current transformer and the meter. The length and gauge of the wire must be considered in order to avoid exceeding the maximum burden.
- If resistance in the 5 amp loop causes the burden to be exceeded, the current will drop. This will result in the meter reading low at higher current levels.
- As in all transformers, errors arise due to a proportion of the primary input current being used to magnetize the core and not transferred to the secondary winding. The proportion of the primary current used for this purpose determines the amount of error.
- The essence of good design of measuring current transformers is to ensure that the magnetizing current is low enough to ensure that the error specified for the accuracy class is not exceeded.
- This is achieved by selecting suitable core materials and the appropriate cross-sectional area of core. Frequently in measuring currents of 50A and upwards, it is convenient and technically sound for the primary winding of a CT to have one turn only.
- In these most common cases the CT is supplied with a secondary winding only, the primary being the cable or bus bar of the main conductor which is passed through the CT aperture in the case of ring CTs (i .e. single primary turn) it should be noted that the lower the rated primary current the more difficult it is (and the more expensive it is) to achieve a given accuracy.
- Considering a core of certain fixed dimensions and magnetic materials with a secondary winding of say 200 turns (current ratio 200/1 turns ratio 1/200) and say it takes 2 amperes of the 200A primary current to magnetize the core, the error is therefore only 1% approximately. However considering a 50/1 CT with 50 secondary turns on the same core it still takes 2 amperes to magnetize to core. The error is then 4% approximately. To obtain a 1% accuracy on the 50/1 ring CT a much larger core and/or expensive core material is required
- **Accuracy Class of Metering CT:**

Metering Class CT	
Class	**Applications**
0.1 To 0.2	Precision measurements
0.5	High grade kilowatt hour meters for commercial grade kilowatt hour meters
3	General industrial measurements
3 OR 5	Approximate measurements

Protective System	**CT Secondary**	**VA**	**Class**
Per current for phase & earth fault	1A	2.5	10P20 Or 5P20
	5A	7.5	10P20 Or 5P20
Unrestricted earth fault	1A	2.5	10P20 Or 5P20
	5A	7.5	10P20 Or 5P20
Sensitive earth fault	1A or 5A		Class PX use relay manufacturers formula
Distance protection	1A or 5A		Class PX use relay manufacturers formula
Differential protection	1A or 5A		Class PX use relay manufacturers formula

High impedance differential impedance	1A or 5A		Class PX use relay manufacturers formula
High speed feeder protection	1A or 5A		Class PX use relay manufacturers formula
Motor protection	1A or 5A	5	5P10

- **Accuracy Class of Letter of CT:**

Metering Class CT	
Accuracy Class	**Applications**
B	Metering Purpose
Protection Class CT	
C	CT has low leakage flux.
T	CT can have significant leakage flux.
H	CT accuracy is applicable within the entire range of secondary currents from 5 to 20 times the nominal CT rating. (Typically wound CTs.)
L	CT accuracy applies at the maximum rated secondary burden at 20 time rated only. The ratio accuracy can be up to four times greater than the listed value, depending on connected burden and fault current. (Typically window, busing, or bar-type CTs.)

- **Accuracy Class of Protection CT:**

Class	Applications
10P5	Instantaneous over current relays & trip coils: 2.5VA
10P10	Thermal inverse time relays: 7.5VA
10P10	Low consumption Relay: 2.5VA
10P10/5	Inverse definite min. time relays (IDMT) over current
10P10	IDMT Earth fault relays with approximate time grading:15VA
5P10	IDMT Earth fault relays with phase fault stability or accurate time grading: 15VA

- **Accuracy Class: Metering Accuracy as per IEEE C37.20.2b-1994**

Ratio	B0.1	B0.2	B0.5	B0.9	B1.8	Relaying Accuracy
50:5	1.2	2.4	-	-	-	C or T10
75:5	1.2	2.4	-	-	-	C or T10
100:5	1.2	2.4	-	-	-	C or T10
150:5	0.6	1.2	2.4	-	-	C or T20
200:5	0.6	1.2	2.4	-	-	C or T20
300:5	0.6	1.2	2.4	2.4	-	C or T20
400:5	0.3	0.6	1.2	1.2	2.4	C or T50
600:5	0.3	0.3	0.3	1.2	2.4	C or T50
800:5	0.3	0.3	0.3	0.3	1.2	C or T50
1200:5	0.3	0.3	0.3	0.3	0.3	C100
1500:5	0.3	0.3	0.3	0.3	0.3	C100
2000:5	0.3	0.3	0.3	0.3	0.3	C100
3000:5	0.3	0.3	0.3	0.3	0.3	C100
4000:5	0.3	0.3	0.3	0.3	0.3	C100

- **Important of accuracy & phase angle**
- Current error is an error that arises when the current value of the actual transformation ratio is not equal to rated transformation ratio.
- **Current error (%) = {(Kn x Is – Ip) x 100}/Ip**
  Kn = rated transformation ratio, Ip = actual primary current, Is = actual secondary current
- Example: In case of a 2000/5A class 1 5VA current transformer
  Kn = 2000/5 = 400 turn, Ip = 2000A, Is = 4.9A
  Current error = ((400 x 4.9 – 2000) x100)/2000 = -2%
- For protection class current transformer, the accuracy class is designed by the highest permissible percentage composite error at the accuracy limit primary current prescribed for the accuracy class concerned.
- Accuracy class includes: 5P, 10P

- ## By phase angle
- Phase error is the difference in phase between primary & secondary current vectors, the direction of the vectorsto be zero for a perfect transformer.
- You will experience a positive phase displacement when secondary current vector lead primary current vector.
- Unit of scale expressed in minutes / cent radians.
- Circular measure = (unit in radian) is the ratio of the distance measured along the arc to the radius.
- Angular measure = (unit in degree) is obtained by dividing the angle subtended at the center of a circle into 360 deg equal division known as "degrees".
- Limits of current error and phase displacement for measuring current transformer (Classes 0.1 To 1)

Accuracy Class	+/- Percentage Current (Ratio) Error at % Rated Current				+/- Phase Displacement at % Rated Current							
					Minutes				Centi radians			
	5	20	100	120	5	20	100	120	5	20	100	120
0.1	0.4	0.2	0.1	0.1	15	8	5	5	0.45	0.24	0.15	0.15
0.2	0.75	0.35	0.2	0.2	30	15	10	10	0.9	0.45	0.3	0.3
0.5	1.5	0.75	0.5	0.5	90	45	30	30	2.7	1.35	0.9	0.9
1.0	3	1.5	1	1	180	90	60	60	5.4	2.7	1.8	1.8

- limits of current error and phase displacement for measuring current transformer For special application

Accuracy Class	+/- Percentage Current (Ratio) Error at % Rated Current					+/- Phase Displacement at % Rated Current									
						Minutes					Centi radians				
	1	5	20	100	120	1	5	20	100	120	1	5	20	100	120
0.2S	0.75	0.35	0.2	0.2	0.2	30	15	10	10	10	0.9	0.4	0.3	0.3	0.3
0.5S	1.50	0.75	0.5	0.5	0.5	90	45	30	30	30	2.7	1.3	0.9	0.9	0.9

- limits of current error for measuring current transformers (classes 3 and 5)

Accuracy Class	+/- Percentage Current (Ratio) Error at % Rated Current	
	50	120
3	3	3
5	5	5

- ## Class X Current Transformer:
- Class X current transformer is use in conjunction with high impedance circulating current differential protection relay, eg restricted earth fault relay. As illustrated in IEC60044-1, the class X current transformer is needed.
- The following illustrates the method to size a class X current transformer.
- Step 1: calculating knee point voltage Vkp

  Vkp = {2 x Ift (Rct+Rw)}/ k

  Vkp = required CT knee point voltage, Ift = max transformer through fault in ampere

  Rct = CT secondary winding resistance in ohms, Rw = loop impedance of pilot wire between CT and the

  K = CT transformation ratio
- Step 2: calculate Transformer through fault Ift

  Ift = (KVA x 1000)/ (1.732 x V x Impedance)

  KVA = transformer rating in kVA ,V = transformer secondary voltage, Impedance = transformer impedance
- Step 3: How to obtain Rct .
- To measure when CT is produce
- Step 4: How to obtain Rw
- This is the resistance of the pilot wire used to connect the 5th class X CT at the transformer star point to the relay
- In the LV switchboard. Please obtain this data from the Electrical contractor or consultant. We provide a table to
- Serve as a general guide on cable resistance.
- Example:
- Transformer Capacity: 2500kVA
- Transformer impedance: 6%
- Voltage system : 22kV / 415V 3phase 4 wire
- Current transformer ratio: 4000/5A

- Current transformer type: Class X PR10
- Current transformer Vkp : 185V
- Current transformer Rct : 1.02½ (measured)
- Pilot wire resistance Rw : 25 meters using 6.0mm sq cable
- = 2 x 25 x 0.0032 = 0.16½
- Ift = (kVA x 1000) / (1.732 x V x impedance) = (2500 x 1000) / (1.732 x 415 x 0.06)= 57,968 (Say 58,000A)
- Vkp = {2 x Ift (Rct+Rw)} / k= {2 x 58000 (1.02+0.16)} / 800= 171.1½.

(4) Accuracy Limit Factor:

- Standard Accuracy Limit Factors: 5, 10, 15, 20 and 30.
- Accuracy of a CT is another parameter which is also specified with CT class. For example, if a measuring CT class is 0.5M (or 0.5B10), the accuracy is 99.5% for the CT, and the maximum permissible CT error is only 0.5%.
- Accuracy limit Factor is defined as the multiple of rated primary current up to which the transformer will comply with the requirements of 'Composite Error'. Composite Error is the deviation from an ideal CT (as in Current Error), but takes account of harmonics in the secondary current caused by non-linear magnetic conditions through the cycle at higher flux densities.
- The electrical requirements of a protection current transformer can therefore be defined as :
- **Selection of Accuracy Class & Limit Factor.**
- Class 5P and 10P protective current transformers are generally used in over current and unrestricted earth leakage protection. With the exception of simple trip relays, the protective device usually has an intentional time delay, thereby ensuring that the severe effect of transients has passed before the relay is called to operate. Protection Current Transformers used for such applications are normally working under steady state conditions Three examples of such protection is shown. In some systems, it may be sufficient to simply detect a fault and isolate that circuit. However, in more discriminating schemes, it is necessary to ensure that a phase to phase fault does not operate the earth fault relay.
- **Calculation of the Accuracy limit factor**
- **Fa=Fn X ((Sin+Sn) / (Sin+Sa))**
- Fn = Rated Accuracy Limit Factor, Sin = Internal Burden of CT secondary Coil
- Sn= Rated Burden of CT (in VA), Sa= Actual Burden of CT (in VA)
- **Example:** The internal secondary coil resistance of the CT(5P20) is 0.07 Ω, the secondary burden (including wires and relay) is 0.117 Ω and the CT is rated 300/5, 5P20, 10 VA. Calculate the actual accuracy limit factor.
- Fn = 20 (CT data 5P20), Sin = (5A)2 × 0.07 Ω =1.75 VA,Sn = 10 VA (from CT data),
- Sa = (5A)2 × 0.117 Ω = 2.925 VA
- Accuracy limit factor ALF (Fa) = 20 X ((1.75+10) / (1.75+2.925)) =50.3

Selection of CT:

(1) Indoors or Outdoor:

- Determine where CT needs to be used. Indoor transformers are usually less costly than outdoor transformers. Obviously, if the current transformer is going to be enclosed in an outdoor enclosure, it need not be rated for outdoor use. This is a common costly error in judgment when selecting current transformers.

(2) What do we need:

The first thing we need to know that what degree of accuracy is required. Example, if you simply want to know if a motor is lightly or overloaded, a panel meter with 2 to 3% accuracy will likely suit for needs. In that case the current transformer needs to be only 0.6 to 1.2% accurate. On the other hand, if we are going to drive a switchboard type instrument with 1% accuracy, we will want a current transformer with 0.3 to 0.6 accuracy. We must keep in mind that the accuracy ratings are based on rated primary current flowing and per ANSI standards may be doubled (0.3 becomes 0.6%) when 10% primary current flows. As mentioned earlier, the rated accuracies are at stated burdens. We must take into consideration not only the burden of the load (instrument) but you must consider the total burden. The total burden includes the burden of the current transformers secondary winding, the burden of the leads connecting the secondary to the load, and the burden of the load itself. The current transformer must be able to support the total burden and to provide the accuracy required at that burden. If we are going to drive a relay you must know what relay accuracy the relay will require.

(3) Voltage Class:

- You must know what the voltage is in the circuit to be monitored. This will determine what the voltage class of the current transformer must be as explained earlier.

(4) Primary Conductor:

- If you have selected a current transformer with a window you must know the number, type and size of the primary conductor(s) in order to select a window size which will accommodate the primary conductors.

(5) Application:

- The variety of applications of current transformers seems to be limited only by ones imagination. As new electronic equipment evolves and plays a greater role in the generation, control and application of electrical energy, new demands will be placed upon current transformer manufacturers and designers to provide new products to meet these needs

(6) Safety:

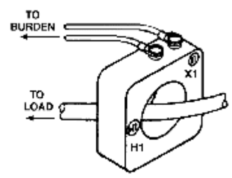
- For personnel and equipment safety and measurement accuracy, current measurements on conductors at high voltage should be made only with a conducting shield cylinder placed inside the CT aperture. There should be a low electrical impedance connection from one end only to a reliable local ground. An inner insulating cylinder of adequate voltage isolation should be between the shield cylinder and the conductor at high voltage. Any leakage, induced or breakdown current between the high voltage conductor and the ground shield will substantially pass to local ground rather than through the signal cable to signal ground. Do not create a "current loop" by connecting the shield cylinder to ground from both ends. Current flowing in this loop will also be measured by the CT.

(7) CT output signal termination:

- The CT output coaxial cable should preferably be terminated in 50 ohms. CT characteristics are guaranteed only when CT is terminated in 50 ohms. The termination should present sufficient power dissipation capability. When CT output is terminated in 50 ohms, its sensitivity is half that when terminated in a high-impedance load.

Installing of CT:

- Measurements must have the same polarity to keep the power factor and direction of power flow measurements accurate and consistent.
- Most CTs are labelled that shows which side of the CT should face either the source orthe load.



- **Primary Side:**
- The Primary of CT is marked with H1 and H2 (or only marking dot on one side)
- The label “H1” or dot defines the direction as flowing current into the CT (H1 or the dot should face the Power sourceside). H2 side to load facing direction
- **Secondary Side:**
- The Secondary (The output wires) of CT is marked with X1 and X2.
- X1 corresponds to H1, or the input side.The X1 secondary terminal is the polarity terminal. The polarity marks of a current transformer indicate that when a primary current enters at the polarity mark (H1) of the primary, a current in phase with the primary current and proportional to it in magnitude will leave the polarity terminal of the secondary (X1).
- Normally **CT's** should not be installed on live services. The power should be disconnected when the **CT's** are installed. Many times this is not possible because of critical loads such as computers, laboratories, etc. that cannot be shut down. Split core **CT's** should not be installed on liveun insulated bus bars under any conditions.

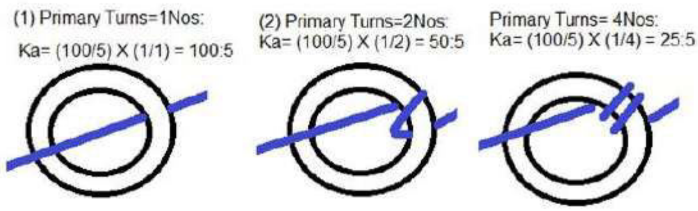
Modification of Primary & Secondary Turns Ratio:

- The nameplate current ratio of the current transformer is based on the condition that the primary conductor will be passed once through the transformer opening. If necessary, this rating can be reduced in even multiples by looping this conductor two or more times through the opening.
- A transformer having a rating of 300 amperes will be changed to 75 amperes if four loops or turns are made with the primary cable.

- The ratio of the current transformer can be also modified by altering the number of secondary turns by forward or backwinding the secondary lead through the window of the current transformer.
- By adding secondary turns, the same primary amperage will result in a decrease in secondary output.
- By subtracting secondary turns, the same primary amperage will result in greater secondary output. Again using the 300:5 example, adding two secondary turns will require 310 amps on the primary to maintain the 5 amp secondary output or 62/1p = 310p/5s.
- Subtracting two secondary turns will only require 290 amps on the primary to maintain the 5 amp secondary output or 58s/5p = 290p/5s. The ratio modifications are achieved in the following manner:
- To add secondary turns, the white lead should be wound through the CT from the side opposite the polarity mark.
- To subtract turns, the white lead should be wound through the CT from the same side as the polarity mark.

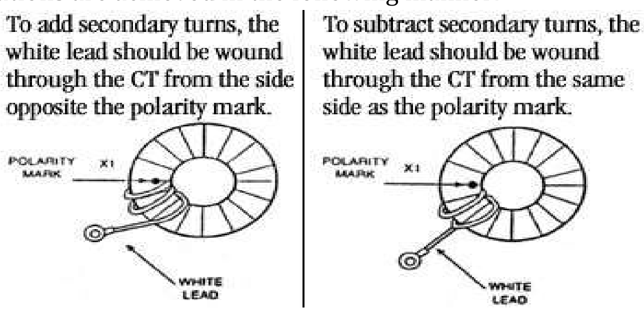
(1) Modifications in Primary Turns Ratio of CT:

- The ratio of the current transformer can be modified by adding more primary turns to the transformer. By adding primary turns, the current required to maintain five amps on the secondary is reduced.
- **Ka = Kn X (Nn/Na)**
- Ka= Actual Turns Ration.
- Kn=Name Plate T/C Ratio.
- Nn=Name Plate Number of Primary Turns.
- Na=Actual Number of Primary Turns.
- Example: 100:5 Current Transformers.



(2) Modifications in Secondary Turns Ratio of CT:

- **Formula: Ip/Is = Ns/Np**
- Ip = Primary Current, Is = Secondary Current , Np = No of Primary Turns, Ns = No of Secondary Turns
- Example: A 300:5 Current Transformer.
- The ratio of the current transformer can be modified by altering the number of secondary turns by forward or back winding the secondary lead through the window of the current transformer.
- By adding secondary turns, the same primary current will result in a decrease in secondary output. By subtracting secondary turns, the same primary current will result in greater secondary output.
- Again using the 300:5 example adding five secondary turns will require 325 amps on the primary to maintain the 5 amp secondary output or: 325 p / 5s = 65s / 1p
- Deducting 5 secondary turns will only require 275 amps on the primary to maintain the 5 amp secondary output or: 275p / 5s = 55s / 1p
- The above ratio modifications are achieved in the following manner:



- **Current Transformer Ratio Modification:**

CT Ratio	Number of Primary Turns	Modified Ratio
100:5A	2	50:5A
200:5A	2	100:5A
300:5A	2	150:5A
100:5A	3	33.3:5A
200:5A	3	66.6:5A

300:5A	3	100:5A
100:5A	4	25:5A
200:5A	4	50:5A
300:5A	4	75:5A

- A primary turn is the number of times the primary conductor passes through the CT's window. The main advantage of this ratio modification is you maintain the accuracy and burden capabilities of the higher ratio. The higher the primary rating the better the accuracy and burden rating.
- You can make smaller ratio modification adjustments by using additive or subtractive secondary turns.
- For example, if you have a CT with a ratio of 100:5A. By adding one additive secondary turn the ratio modification is 105:5A, by adding on subtractive secondary turn the ratio modification is 95:5A.
- Subtractive secondary turns are achieved by placing the "X1" lead through the window from the H1 side and out the H2 side. Additive secondary turns are achieved by placing the "X1" lead through the window from the H2 and out the H1 side.
- So, when there is only one primary turn each secondary turn modifies the primary rating by 5 amperes. If there is more than one primary turn each secondary turn value is changed (i.e. 5A divided by 2 primary turns = 2.5A).
- The following table illustrates the effects of different combinations of primary and secondary turns:

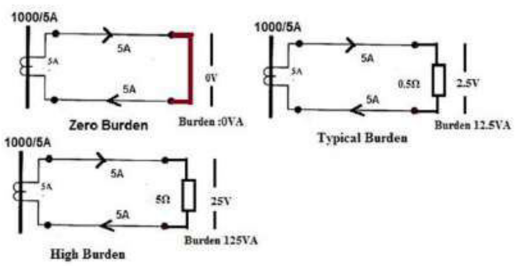
CT RATIO 100:5A		
PRIMARY TURNS	**SECONDARY TURNS**	**RATIO ADJUSTMENT**
1	-0-	100:5A
1	1+	105:5A
1	1-	95:5A
2	-0-	50:5A
2	1+	52.5:5A
2	2-	45.0:5A
3	-0-	33.3:5A
3	1+	34.97:5A
3	1-	31.63:5A

Advantages of using a CT having 1A Secondary:

- The standard CT secondary current ratings are 1A & 5A,The selection is based on the lead burden used for connecting the CT to meters/Relays.5A CT can be used where Current Transformer & protective's device are located within same Switchgear Panel.
- 1A CT is preferred if CT leads goes out of the Switchgear.
- For Example if CT is located in Switch Yard & CT leads have to be taken to relay panels located in control room which can be away.1A CT is preferred to reduce the load burden. For CT with very High lead length, CT with Secondary current rating of 0.5 Amp can be used.
- In large Generator Circuits, where primary rated current is of the order of few kilo-amperes only,5A CTs are used, 1A CTs are not preferred since the turns rations becomes very high & CT becomes unwieldy.

Danger with Current Transformer:

- When a CT secondary circuit is closed, current flows through it, which is an exact proportion of the primary current, regardless of the resistance of the burden. In the CT have a ratio of 1000/5A and to have 1000A flowing in the primary is carrying exactly 5A.



- If the secondary terminals S1 and S2 are short- circuited, there is no voltage between them.

- If now the short-circuit be replaced by a resistance of, say, 0.5 ohm the same 5A will flow through, causing a volt-drop of 2.5V and a burden of 5 x 2.5 = 12.5V A. If the resistance were increased to 5 ohms the terminal voltage with 5A flowing would rise to 25V and the burden to 125V A.
- The greater the resistance, the greater would be the voltage and burden until, as it approached infinity (the open-circuit condition), so also in theory would the voltage (and burden) become infinite. This cannot of course happen in practice because the CT would saturate or the terminals flash over due to the very high secondary voltage between them. But it does show the danger of open-circuiting the secondary of running CT. lethal voltages can be produced at the point of opening. This is why CT secondaries are never fused.
- The danger from an open-circuited CT is twofold. It can produce lethal voltages and so is a very real danger to personnel. The high voltage across the secondary winding could also cause insulation failure in that winding, leading at best to inaccuracy and at worst to burn- out or fire.
- Before ever an instrument or relay is removed from the secondary loop of a running CT (if such a thing had to be done), the wires feeding that instrument must first be securely short- circuited at a suitable terminal box or, better, at the CT itself. Similarly, if a running CT is ever to be taken out of circuit, it must first be firmly shorted. CTs with 1 A secondary's are more dangerous than those with 5A, as the induced voltages are higher.
- Ammeter resistance is very low ,the current transformer normally works short circuited.
- If for any reason the ammeter is taken out of secondary winding then the secondary winding must be short circuited with the help of short circuit switch .
- If this is not done, then due to high m.m.f. will set up high flux in the core and it will produces excessive core loss which produce heat and high voltage across the secondary terminals
- Hence the secondary of current transformer is never left open

Sizing of CT for Building:

- **New construction**:
- size the CT to handle about 80% of the circuit breaker capacity. If the building is served by a 2000 amp breaker, use 1600 amp (2000 x 0.8) CT's.
- **Older buildings:**
- The peak demand can generally be determined from the power company or from past billings. In this case add 20 to 30% to the peak demand and size the CT's for this load. If the peak demand was 500 kW, the peak current on a 480/3/60 system would be **500,000 / (480 x 1.73 x 0.9 pf) = 669 amps.** This assumes a 0.9 power factor. (Peak current would be higher with a lower power
  Factor.) Use CT's about 20% larger. 800:5 CT's would be a good selection.
- For older buildings with no demand history, size the **CT's** the same as for new construction. Where possible, use multi-tap **CT's** so that the ratio can be reduced if the maximum load is much less than 80% of the breaker size.
- CT's that are used to monitor motor loads can be sized from the nameplate full load motor amps.

Chapter: 11 Selection of Street Light Luminar

Terminology for Road Light Illumination:

(1) Luminance (E):

- Luminance is the amount of light falling on a surface.
- The luminance refers to the incidence of the light flux on a surface, per unit of surface.
- **E = Phi / A (lx)**
- The luminance is expressed in lux (lx).
- Full moon has 0.1 Lux ,Emergency lighting has 1 Lux ,Street lighting has 10 Lux ,Winter day has 10 000 Lux , Summer day has 100 000 Lux

(2) Lumen (lm):

- Lumen is a unit of measure of the quantity of light.
- One lumen is the amount of light which falls on an area of one square foot every point of which is one foot from the source of one candela.
- A light source of one candela emits a total of 12.57 lumens.

(3) Lux:

- **Lux** is a metric measurement of light on a surface.
- The illumination of light flux is expressed in Lux hence unit of luminance is Lux.
- The luminous flux per unit area of 1 square meter on a sphere of radius 1 meter is called 1 Lux.
- 1 Lux= 1 Lumen per square Meter.
- **Lux = Lumens / Area (sq meter).**
- 1 Lux equals 0.0929 foot candle
- **Difference between Lumens and Lux**
- One Lux is defined as being equivalent to one lumen spread over an area of one square meter.
- Measurement of lux (light intensity) tells us how many lumens (total light output) we need in the given area of illumination.
- Lighting a larger area to the same measurement of lux requires a larger number of lumens which is usually achieved by increasing the number of light fixtures.

(4) Foot candle (fc):

- It is the English unit of Illuminance.
- It is the amount of light flux density. It is the unit of measure used when describing the amount of light in a room and expressed in lumens per square foot.
- It is the amount of light that falls on the area we want to illuminate. We also want to know the lumens per square foot or square meter in a space.
- This quantity called Light Flux Density is the common term Foot-candle (fc).
- Foot candle = Lumens / Area
- Example: A 40-watt fluorescent lamp 120 centimeters long produces 3,200 lumens of light in a room having a general dimensions of 10 x 20 ft. Find the illumination on the floor.
- Foot candle (fc) = Lumens / Area
- Foot candle (fc) = 3,200 lm / 10x20 ft = 16 foot candle
- The foot candle is an important unit of measure in calculating the desired illumination and layout of fixtures.

(5) Foot candle (fc):

- The unit of luminance = the luminous fl ux per square foot on a sphere of radius 1 foot.
- One foot-candle is approximately 10 lux.

(6) Luminance:

- Luminance indicates the degree of brightness with which the human eye perceives a light source or an illuminated surface.
- **L = E/A (cd/m2)**
- The luminance is expressed in candela per square meter (cd/m2).

- The amount of light reflected from a surface. It is sort of the "brightness" we see, i.e. the visual effect of the luminance.
- It depends on the amount of luminance and on the reflective properties of the surface as well as on the projected area on the plane perpendicular to the direction of view.
- The unit is candela per square meter (cd/m2), or candela per square foot

(7) Lamp Circuit Efficacy:

- Amount of light (lumens) emitted by a lamp for each watt of power consumed by the lamp circuit, i.e. including control gear losses. This is a more meaningful measure for those lamps that require control gear. It's Unit is lumens per circuit watt (lm/W)

(8) Uniformity ratio:

- G = Emin/Egem (%) The uniformity ratio is the ratio between the minimum luminance and the average luminance on a surface. This figure indicates the degree of "evenness". E = 1 indicates complete uniformity.

(9) Utilization Factor (UF):

- UF (%) The utilization factor indicates how well a lighting installation uses the luminous flux of the lamps. This is indicated as the ratio between the luminous flux that reaches the working plane and the light source of the „bare" lamps, expressed as a percentage.
- The utilization factor of lamps is the ratio of luminous flux which is arrived to the road from the full luminous flux of lamp. It is calculated by using the curse sign of utilization factor which is different from each lamp.

(10) Coefficient of Utilization (CU):

- A design factor that represents the percentage of bare lamp lumens that are utilized to light the pavement surface. This factor is based on the luminaries position relative to the lighted area.

Coefficient of Utilization	
Fixture Description	**cu**
Efficient fixture, large unit colored room	0.45
Average fixture, medium size room	0.35
Inefficient fixture, small or dark room	0.25

(11) Lamp Lumen Depreciation Factor (LLD):

- As the lamp service life increase, the lumen output of the lamp decreases. This is an inherent characteristic of all lamps.
- The initial lamp lumen value is adjusted by a lumen depreciation factor to compensate for the anticipated lumen reduction. This assures that a minimum level of illumination will be available at the end of the assumed lamp life, even though lamp lumen depreciation has occurred. This information is usually provided by the manufacturer.
- Mostly used LLD=0.80

(12) Luminaries Dirt Depreciation Factor (LDD):

- Dirt on the exterior and interior of the luminaire, and to some extent on the lamp itself, reduces the amount of light reaching the pavement.
- Various degrees of dirt accumulation may occur depending upon the area in which the luminaire is located. Industrial areas, automobile exhaust, diesel trucks, dust and other environs all affect the dirt accumulation on the luminaire.
- Higher mounting heights, however, tend to reduce the vehicle-related dirt accumulation.
- Mostly LDD=0.9

(13) Maintenance Factor (MF):

- The maintenance factor is the combination of light loss factors used to denote the reduction of the illumination for a given area after a period of time compared to the initial illumination on the same area. It is the product of the lamp lumen depreciation factor and the luminaire dirt depreciation factor (i.e., MF = LLD x LDD).
- Consult the manufacturer's data and the Electrical and Mechanical Unit for the appropriate factors to use.

Maintenance Factor	
Enclosed fixture, clean room	0.8
Average conditions	0.7
Open Fixture or dirty room	0.6

(14) Color Rendering Index (CRI):

- It is ability of a light source to render colors and make them appear "normal."

- The index scale runs from 0-100. A CRI of 100 means colors look "normal", a low CRI means colors look distorted.
- CRI of 60 means the source renders 60% of the colors well and 40% poorly.
- Halogen and Incandescent lamps generally have a CRI of 100.

Illumination Unit Comparisons		
Term	**English**	**Metric (SI)**
Length	Feet	Meter
Area	Square foot	Square meter
Luminance Flux	Lumens	Lumens
Illumination Flux Density	Foot candles	Lux
Luminance	Foot lamberts	Lambert or Milli-Lamberts

Recommended Lux Level:

Illumination Level	
Area	**Lux Level**
Very Bright Summer Day (Max)	Up to 100000 Lux
Very Bright Summer Day (Min)	20000 Lux
Nighttime Car Park	1 Lux
Nighttime Urban Street	10 Lux
Night Light on a Building	60 Lux
Machine shop	400 Lux
Offices	500 Lux
Kitchens (food preparation area)	400 Lux
Counters	240 Lux
Machine shop	700 Lux
Canteens	300 Lux
Waiting Rooms	80 Lux
Foyers	200 Lux
Entrance halls	160 Lux
Stairs	40 Lux
Warehouses	80 Lux
Passageways	80 Lux
Corridors	40 Lux

Illuminance for Various Roadway Types (ANSI/IES RP-8)	
Road Type	**Illuminace Lux**
Urban Freeway	10
Freeway Interchange	14
Commercial Arterial	20
Residential Collector	8
Local	6

Light levels as per IS 1944				
Classification of road	**Type of road**	**Average level of illumination (lux)**	**Min:Avg**	**Min:Max (%)**
Group A1	Important traffic routes carrying fast traffic	30	0.4	33
Group A2	Other main roads carrying mixed traffic, like main city streets, arterial roads, throughways etc	15	0.4	33
Group B1	Secondary roads with considerable traffic like principal local traffic routes, shopping streets etc	8	0.3	20
Group B2	Secondary roads with light traffic. important traffic routes carrying	4	0.3	20

	fast traffic			

Minimum Level of illumination in Lux			
Road	**Residential**	**Industrial**	**Commercial**
Arterial Roads	10.0	13.0	17
Collector Road	6.0	10.0	13.0
Local Roads	4.0	7.0	9.0
Walkways & Pathways	4.0		
Lanes	4.0	2.0	2.0

Recommended Levels of Illumination (BIS, 1981)Table 6			
Road Characteristics	**Avg Illumination (Lux)**	**Min / Avg Illumination (Lux)**	**Type of Luminaries Preferred**
Important traffic routes carrying fast traffic	30	0.4	Cutoff
Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	15	0.4	Cutoff
Secondary roads with considerable traffic like local traffic routes, shopping streets	8	0.3	Cutoff or semi-cutoff
Secondary roads with light traffic	4	0.3	Cutoff or semi-cutoff

Recommended Average Horizontal Illumination level in Lux				
Pedestrian Traffic	**Vehicular traffic Classification**			
	Very light	**Light**	**Medium**	**Heavy to Heaviest**
Heavy	9.68	12.91	16.14	12.52
Medium	6.46	8.61	10.26	12.91
Light	2.15	4.30	6.46	9.68

Classification of Street:

Classification Roadway Traffic		
Classification Number	**Number of Vehicles per Hour**	
	Maximum Night Hour	**Both Direction**
Very light traffic	Under	150
Light traffic	150	500
Medium traffic	500	1200
Heavy traffic	1200	2400
Very heavy traffic	2400	4000
Heavy traffic	Over	4000

Classification of Pedestrian Traffic	
Light or No Traffic	Residential, warehouse areas on express / elevated depressed roadways
Medium Traffic	Secondary business streets and some industrial roads
Heavy Traffic	Business streets.

Mounting Height of Street Light Laminar:

- The distance the lamp is mounted above the roadway will affect the illumination intensity, uniformity of brightness, area covered, and relative glare of the unit.
- Higher mounted units will provide greater coverage, more uniformity, and reduction of glare, but a lower illumination level.
- It is necessary to weigh the effects of larger lamps against a greater number of smaller units at lower mounting heights with maximum glare potential.

- The height of luminaries above the roadway surface varies from **5 Meter to more than 20 Meter.**
- Conventional roadway lighting utilized mounting height of **8 to 20 Meter**. The lower mounting heights require the use of cutoff or semi-cutoff luminary's distribution to minimize glare.

Height of Pole	Application
6 Meter	For streets ,alleys, public gardens and parking lots
8 Meter	Urban traffic route, multiplicity of road junctions,
	Narrow roads such as local access roads in residential areas in which a mounting height between 10 M or 12 M and 5 M or 6 M is required.
10 Meter	Urban traffic route, For wide heavily used routes where a large number of intersection, bends can lead to a short spacing making the use of 12 M mounting height uneconomical.
12 Meter	Wide or heavily used routes where advantage can be taken of a longer spacing of luminaries.
18 Meter and above	High mast lighting poles shall be installed at large-scale area such as airports, dockyards, large industrial areas, sports areas and road intersections

Road and Type of Luminar				
Type of Road	**Pole**	**Pole Height**	**Laminar Watt**	**Type of Laminar**
Rural	Aluminum or Steel Pole	10 to 16 Meter	250W to 400W	HPS
Urban	Aluminum	10 to 13 Meter	250W to 400W	HPS (Cut off or Semi Cut off)

High Mast Lighting Systems:

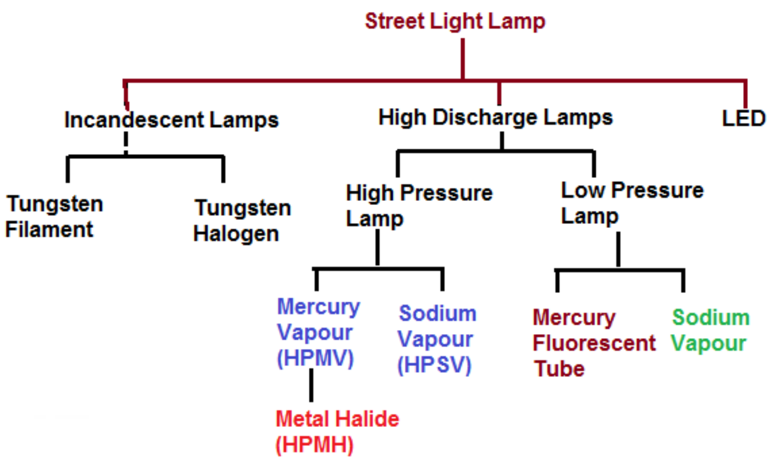
- High mast lighting has 3 or 4 no's of 1000 watt HPS luminaries mounted on poles /towers, at mounting heights (30 Meter). It develops a highly uniform light distribution.
- **Advantage:**
- Excellent uniformity of illumination, reduce glare with a substantially smaller number of pole locations.
- **Application:**
- Where continuous lighting is desirable such as lighting of toll plazas, rest areas, parking areas, general area lighting, highways, traffic lanes.
- High mast lighting is also desirable where there is minimal residential area.
- High Mast used at remote location to eliminates the need for maintenance, vehicles obstructing traffic on the roadway.
- High Mast having symmetric or asymmetric distribution
- The design and installation of high mast lighting equipment is more complex than conventional lighting.

Lamp Comparison Chart (Bureau of Energy Efficiency, Delhi)					
Lamp Type	**Lamp (Watts)**	**Efficacy (Lumens /Watt)**	**Color Render**	**Lamp Life (Hr)**	**Remarks**
Incandescent (GLF) Lamps:					
(Incandescent bulbs)	15,25,40,60,75,100,150,200, 300,500 (no ballast)	8 to 17	100	1000	
Tungsten Halogen	75,100,150,500,1000 ,2000 (no ballast)	13 to 25	100	2000	
Fluorescent Tube lights (Argon filled)	20,40,65, (32,51,79)	31 to 58	67 to 77	5000	
Fluorescent Tubular Lamp (T5)	18,20,36,40,58 ,65	100 to 120	Very Good	15,000 to 20,000	Energy-efficient, long lamp life, only available in low wattages
Compact	5,7,9,11,18,24,36	26 to 64	85	8000	

Fluorescent Lamps (CFLs)					
HID Lamps:					
High Pressure Mercury Vapor (HPMV)	80,125,250,400,1000 ,2000	25 to 60	45 (Fair)	16,000 to 24,000	High energy use, Poor lamp life
High Pressure Metal Halide Lamps (HPMH)	70,150,250, 400,1000,2000	62 to 72	70 (Excellent)	8000 to 12000	High luminous efficacy, Poor lamp life
High Pressure Sodium Vapor Lamps (HPSV)	70,150,250,400,1000	69 to 108	25 to 60 (Fair)	15000 to 24000	Energy-efficient, poor color rendering
Low Pressure Sodium Vapor Lamps (LPSV)	35,55,135	90 to 133	Very Poor	18000 to 24000	Energy-efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamps (T8 & T12)	35,55,135	30 to 90	Good	5000 to 10000	Poor lamp life, medium energy use, only available in low wattages
LED Lamps					
Light Emitting Diode (LED)		70 to 160	Good	40,000 to 90,000	High energy savings, low maintenance, long life, no mercury. High investment cost, nascent technology

Type of Street Light Lamp:

- Street lighting Lamps normally used three types High intensity discharge (HID) lamps, High pressure sodium vapor (HPSV), Metal halide (MH), or Mercury vapor (MV).
- However Mainly Lamps for Street lighting can be divided into three main categories
- **(1) Incandescent lamps and**
- **(2) luminescent gaseous discharge lamps.**
- **(3) LED**
- The lamps used in street lighting today are mostly High Intensity Discharge (HID) lamps that include high pressure sodium, low pressure sodium, high pressure mercury and metal halide lamps.
- In order to reduce the emission of greenhouse gases, the use of energy efficient lamps such as Light Emitting Diodes (LED) for Street lighting has increased.

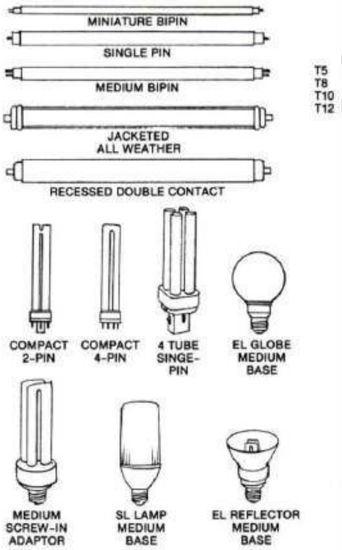


(1) Incandescent (INC):

- The incandescent or filament lamp was for many years the most commonly used. However, its low efficacy and short rated life have made it undesirable for new installations.
- **Advantage:**
- Inexpensive
- Available in Different Configurations & Colors
- No warm up is required
- Easily controlled
- **Dis Advantage:**
- Inefficient (10-25 lumens/watt)
- Short lamp life
- Vibration sensitive
- Over-voltage sensitive

(a) Fluorescent (FL):

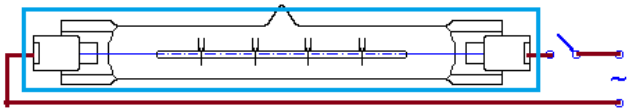
- At many places tube lights are used for Street Light lighting.
- Tube lights in general are available in lower wattages and they cannot produce the same kind of brightness as a Halogen or Sodium Vapour lamp. **So they should not be used to replace Halogen lamps, as they cannot produce the same amount of brightness**
- Lamps are available in the following configurations: T5,T8,T10,T12,T17



- **Standard Fluorescent Lamps T8 Lamps:** 32W and 55W
- Typically used with electronic ballast
- **Standard Fluorescent Lamps T5 Lamps:** 14W, 21W, 24W, and 35W
- Typically is used with electronic ballast
- **Standard Fluorescent Lamps T12 Lamps:** Standard lamp wattages
- **Advantages**
- Efficient (75+ lumens/watt)
- Available in many configurations
- Desirable colors available (2,700K to 4,100K)
- Long life (6,000 –20,000 hours)
- **Disadvantages**
- Require a ballast
- Temperature sensitive
- May require special controls

(b) Tungsten-Halogen Lamps:

- Halogen lamp is incandescent Type lamp. It has a tungsten filament filled with halogen gas.



- **Advantages**
- More compact
- Longer life
- More light
- Whiter light (higher color temp.)
- **Disadvantages**
- More Cost
- Increased IR
- Increased UV
- **Light Color:** Whit Yellow, light Blue Color
- **Efficiency:** Poor Efficiency (10 to 18 lumen/Watt)
- **Lamp Life:** Long Life (2400 Hours)
- **Initial Cost:** High initial Cost
- **Warm up Time:** Instant
- **Application:**
- For outdoor areas/ parking lot lighting

(2) High Intensity Discharge (HID) Lamps:

- HID lamps in general require an external ballast to operate. HID lamps usually take between 1 and 5 minutes to reach full brightness, and if there is a dip in electricity, these lamps will shut off.
- HID lamps must cool sufficiently to re strike, which usually takes from 1 minute to 10 minutes.
- There are Mainly Two type of High discharge lamp
- **(I) High Pressure Lamp (HP)**
- (a) Mercury Vapor Lamp(MV)
- (b) Metal Halide Lamp
- (c) Sodium Lamp
- **(II) Low Pressure Lamp (LP)**
- (a) Mercury Fluorescent Tube
- (b) Sodium Lamp
- Ballasts, which are required by both fluorescent and HID lamps, provide the necessary circuit conditions (voltage, current, and wave form) to start and operate the lamps.

(I) High Pressure Lamp (HP):

- **HID Lamps Characteristics**
- All HID lamps utilize an internal arc tube and outer envelope construction
- All HID lamps require ballast for operation.
- All HID lamps require warm up period
- All HID lamps require cool-down period before they can re-strike

(a) High Pressure Mercury Vapor Lamps (HPMV):

- It is oldest Type of Lamp in HID Type.
- Prior to the introduction of HPS lamps, MV was the most commonly used light source in highway applications. The MV lamp produces a bluish white light and is not as efficient as the HPS lamp.
- **Lamp sizes:** 50,70,100,150,175,200,250,350, 400, and 450W
- **Advantage:**
- Mercury vapor lamps can provide certain low cost options for replacing less efficient lamps such as incandescent lamps without changing the fixtures.
- Pulse start MH lamps utilize an improved ballast design to improve operation
- Higher efficacy
- Faster warm-up and re-strike longer life

- Better color uniformity
- Energy & maintenance savings (15%)
- **Disadvantages:**
- Due to their lower efficacy and poor color rendition they are seldom used in new construction. Color shift toward the end of lamp life
- Some lamps are designed for enclosed fixtures only
- Orientation sensitive (horizontal vs. vertical)
- **Light Color:** Bluish white ,Pale Blue-Green Color
- **Efficiency:** Lowest Efficiency in HID Type (30 to 65 lumen/Watt)
- **Lamp Life:** Long Life (2400 Hours)
- **Initial Cost:** Low initial Cost
- **Warm up Time:** Faster warm-up and re-strike longer life
- **Application:**
- For outdoor areas/ parking lot lighting ,farm light, fish pond

(b) High Pressure Metal Halide lamps (MPMH):

- MH lamps produce better color at higher efficiency than MV lamps. However, life expectancy for MH lamps is shorter than for HPS or MV lamps.
- They also are more sensitive to lamp orientation than other light sources.
- Metal Halide bulbs are as energy efficient as Sodium Vapour lamps.
- Metal halide lamps are similar in construction to MV lamps. Some MH lamps can be operated off MercuryVapor ballasts.
- MH lamps offer a number of advantages over MV lamps.

- **Light Color:** A crisp clear white lights
- Efficiency: Quite Efficient (80 lumen/Watt)
- **Lamp Life:** Less (6000-20000 hrs)
- **Warm up Time:** 2-3 minutes, hot re-strike 10-20 minutes.
- **Application:**
- It is used where color rendering is critical, such as car lots, service stations, athletic fields, industrial manufacturing.

(c)High Pressure Sodium Vapor Lamp (HPSV):

- High pressure sodium lamps are used for both interior and exterior applications and mainly used for street lighting.
- HPS is higher efficient and better choice than metal halide for street light applications.
- HPS is the energy efficient options for halogen lamps as they provide double the amount of brightness for the same amount of wattage.
- HPS lamps differ from mercury and metal-halide lamps because HPS do not contain starting electrodes, the ballast circuit includes a high-voltage electronic starter.
- The arc tube is made of a ceramic material

- **Advantages:**
- If a Halogen is replaced with Sodium Vapour lamp, 20-25% savings can be achieved.
- **Disadvantages:**
- Their brightness is highest in the canter (just below the pole) and is lesser on the outside

- **Light Color:** golden-yellowish-White, Orange color light.
- Advances in electronics now make it possible to dim HPS fixtures in a cost effective manor such as production areas and warehouses.
- **Efficiency:** Quit Efficient (80 to 100lumen/Watt)
- **Lamp Life:** Long Life (2400 Hours)
- **Warm up Time:** 10 minutes, hot re-strike within 60 seconds
- Operating sodium at higher pressures and temperatures makes it highly reactive
- **Application:**
- Mostly use on Street lighting.
- plant growing in green houses

(II) Low Pressure Sodium Lamp (LPS):

- Low Pressure Sodium (LPS) lamp is by far the most efficient light source used in street lighting.
- LOW Pressure Sodium is not an HID source.
- IT is a gaseous discharge type lamp, similar in operations to fluorescent lamps.
- While very efficient (160 lumens/watt), LPS lamps are monochromatic light source.
- They produce only one light color, a dirty yellow color. That is CRI for LPS is negative.
- When this type of lamp is first switched on, a small current passes through the gas giving off a faint red discharge. After several minutes the sodium inside evaporates.
- This makes colour perception very difficult which means that it is almost solely used for street lighting.
- **Light Color**:Bright yellow color light
- **Advantage:**
- The Low Pressure Sodium lamp has the highest lamp efficacy of all sources
- **Disadvantages:**
- Lamps require special ballasts and increase material size as the wattage increases.
- Large size makes it difficult to obtain good light control in a reasonably sized fixture.
- For a long time the poor color rendition, when the lamp is on, everything around it looks either orange-yellow, black or shades in between them so LPS lamp made it unpopular for use in other than industrial or security applications.
- The wattage (energy used) increases as time passes(Age of Lamp increased).
- **Application:**
- Outdoor lighting i.e. street lighting, security lighting, Parking Light

(3) LED:

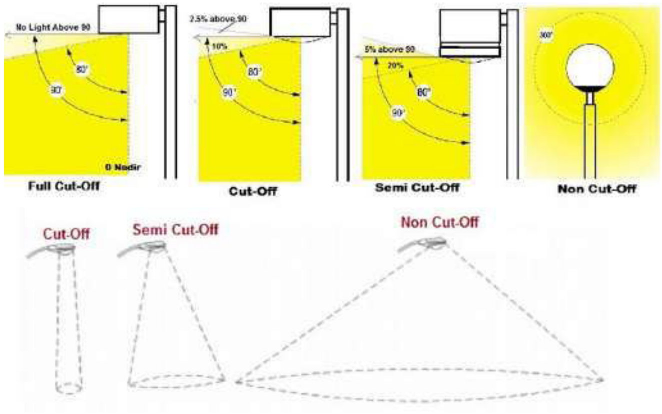
- These are the latest and most energy efficient options for street lighting.
- Their brightness is much more uniform and can give up to 50% savings over Sodium Vapour lamps.
- **Advantages:**
- Produce less glare and can reduce visual fatigue for drivers and pedestrians.
- Long and predictable lifetime
- Reduced maintenance costs
- Increased road safety
- Low power consumption
- Dimming can be possible. adjusting to specific light levels
- Reducing energy consumption and light pollution
- Flexible, flat and compact lamp design
- High color rendering (CRI)
- LED lights are better at focusing light in the downward direction so less light is lost in the air and surrounding environment
- **Disadvantages:**
- Very expensive to buy with longer paybacks.
- They also LEDs offer the following advantages when used as light sources in street lighting applications.
- Adequate heatsinking is required to ensure • long life with high-powered LED.
- **Light Color:** LED Produce more natural white / yellow light.
- **Warm up Time:** Quick turn on / off. No problem with hot ignition. Turn on / off without time delay

Lamp	Power (watt)	Efficiency (lm/w)	Life (Hr)	CRI	CRI Status
Inductance	100 to 150	100	100000	60 to 70	Good
HPSV	50 to 400	39 to 140	24000	20 to 30	Poor
HPMH	35 to 400	70 to 90	60000	60 to 70	Good
HPMV	50 to 400	35 to 90	100000	40 to 60	O.K
LPSV	18 to 180	100 to 160	200000	Less than 20	Very Poor
Florescent	18 to 57	50 to 80	90000	40 to 90	Good
LED	112	55	500000	20 to 95	Good

Advantage & Disadvantage of Luminar		
Type of Lamp	**Advantage**	**Disadvantage**
High Pressure Sodium Vapor Lamp (HPSV)	Long lamp life, Highestlamp output.	High initial cost. Poorcolor rendering, cycles on and off at end of life, not dimmable, cannot use electronic ballast
High Pressure Metal Halide Lamp (HPMH)	Moderately long lamp life. High light output. Makes colors look close to natural.	High initial cost.
High Pressure Mercury Vapor Lamp (HPMV)	Long lamp life, High light output.	High initial cost.
Low Pressure Sodium Vapor Lamp (LPSV)		Completely monochromatic, lends no color perception, shorter life than HPS, optical control difficult
Florescent	Long lamp life, High light output. Low brightness.	High initial cost. Frequent switching cuts life, needs ballast, Runs poorly in cold temperatures
LED	Long life, very efficient, can be dimmable, can offer excellent color quality (w/ less efficiency)	Very high initial cost, very sensitive to overheating, requires large heat sinks, variable color and quality

Controlling of Street Light Glare /Shielding of Light:

- As the vertical light angle increases than disability and discomfort glare also increase. To distinguish the glare effects on the driver created by the light source, IES has defined the vertical control of light distribution as follows:
- The amount of light emitted upward or lower side of laminar and at high or low angle is called shielding of Lights ("Cut off"). It is classified on how much of light is dispersed above the horizontal line of luminaries.
- The Cutoff means amounts of light above 90 degrees, but it is generally agreed that the light should be no more than the value at 90 degrees, and should be decreasing as the angle increases. In fact, there could be some measurable light emitted at 180 degrees (Zenith)
- There are Four Type of arrangement of Luminaries
- (1) Non cutoff,
- (2) Semi cutoff,
- (3) Cutoff
- (4) Full cutoff.



(a) Non-cutoff:

- **Fixture Arrangement:**
- The non-cutoff fixtures usually include the globe-shaped lamps that are mounted on top of lampposts.
- These lamps distribute their light in all directions.
- **Disadvantages:**
- A major problem is created by the light pollution and glare, as they shoot their light upwards into trees and towards the sky rather than down towards the ground.
- Non-cutoff fixtures are rarely found on roadways because they tend to blind the driver.

(b) Semi cutoff:

- **Fixture Arrangement:**
- Most of the light can be emitted below 90 degrees but 5% of the light can emitted above 90 degrees of Fixtures and 20 % or less emitted at the 80-degree angle of nadir.
- **Advantage:**
- These fixtures do a very good job of spreading the light towards the ground but some up light is possible, though not as serious as non-cutoff fixtures.
- Semi cutoff fixtures are often mounted on tall poles.
- This is the most popular street lighting, lighting distribution arrangement. The semi cutoff fixtures usually refer to the cobra heads, but they can also apply to some lamppost-mounted fixtures that do not emit their light upwards.
- **Disadvantages:**
- Little control of light at property line. Potential for increased glare when using high wattage luminaries.
- Typically directs more light into the sky than cut-off.

(c) Cutoff:

- **Fixture Arrangement:**
- Less than 2.5% of the light can leave the fixture above 90 degrees and 10 % or less emitted at the 80 degree angle of nadir
- **Advantage:**
- This type of light gives more light control than semi cutoffs.
- The cutoff lights have a wider spread of light than full-cut offs, and they generate less glare than semi cutoffs. The cutoff lenses consist of a shallow curved glass (also called a sag lens) that is visible just below the lighting area on the fixture
- Cutoff fixtures have gained popularity in recent years.
- Small increase in high angle light allows increased pole spacing.
- **Disadvantages:**
- Allows some up light from luminaries. Small overall impact on sky glow.

(d) Full cutoff:

- **Fixture Arrangement:**
- These lights do not allow any of the light to escape the fixture above 90 degrees (90 degrees above nadir).
- Zero light emitted above a horizontal plane drawn through the lowest part of the luminaries, no more than 10% of light emitted at the 80-degree angle above nadir. Also known as “fully shielded.”

- **Advantage:**
- Full-cut offs distribute light in a defined pattern, potentially providing more light on the ground at lower power consumption.
- Full cutoff luminaries are totally environmentally friendly (causing no light pollution).
- Limits spill light onto adjacent property, reduces glare.
- **Disadvantages:**
- May reduce pole spacing to maintain uniformity and increase pole and luminaries quantities

Type of Ballasts:

- Discharge lamps (fluorescent, HID) and solid-state lamps cannot be connected directly to the mains for its functioning. It required control gear for starting the Lamp.
- This gear has mainly two functions ignition of the lamp and control of the functioning by supplying the right lamp voltage and limiting the electric current.
- Control gear conventionally consists of three parts (1) Ballast (coil), (2) Capacitor and (3) Igniter.
- Commonly the control gear is called ballast.
- Ballast is classified under the following categories. (1) Electromagnetic and (2) electronic.
- **Electronics Ballast:** Electromagnetic ballast has electromagnetic ballast, an igniter (not for HPM-lamps) and a capacitor.
- The ballast lifetime depends on service hours. Normally, magnetic ballasts last as long as the luminaries if they are placed inside the luminaries (and thus are protected against rain).
- The lifetime of igniters associated with magnetic ballasts does not depend on hours in service but on the number of times that the lamps are switched on.
- **Electronics Ballast**: An electronic ballast is mostly one unit that provides both ignition and good functioning (by supplying the right lamp voltage and limiting the electric current) of the lamp.
- For electronic ballasts, lifetimes of 40.000 to 60.000 hours (10 to 15 years) are considered.
- The lifetime of electronic ballasts decreases strongly if the working temperature in reality exceeds the indicated working temperature.
- Electronic ballast includes an ignition device and does not have a separate igniter.

Power Consumption in Ballasts:

- **Electronics Ballast:** Normally the Fluorescent lights are using electronic ballast (called solid state ballast) which consume above 12 watts power.
- **Magnetic Ballast:** the stating modes are available in Programmed stat, instant stat, and rapid start Lamp flicker index is 0.04 to 0.07, Dimming is not available for this ballast.
- **Hybrid Ballast:** the stating mode is rapid stat, Lamp flicker index is 0.04-0.07. Dimming is not available for this ballast.
- **Instant start Ballast:** supply a high initial voltage (over 400V) to start the lamp. High voltage is required to initiate the Discharge between unheated electrodes.
- **Rapid Start Ballast:** supply 200-300V to start the lamp, which can heating the electrodes to approximately 1470˚F(800˚C).
- It starts the lamp with brief delay but without flashing. And for the Fluorescent lamp, warm up time is also minimum 5 minutes.

Replacement of Laminar:

- HSPV produce a yellowish light, have a long life, are very energy-efficient, and have good lumen maintenance (maintain light output for a long period of time), but have poor color rendering properties.
- MH lamps are the most frequently used alternative to HSPV in new installations. They are also quite efficient and provide much better color rendering. However, these lamps tend to have a shorter lamp life (< 10000 hours) and poor lumen maintenance over the life of the lamp.
- **Mercury lamp replaced to incandescent lamp:**
- This is popular conversion of laminar. The initial cost of MV Lamp is high and it requires ballast, but MV Lamp have high efficacy and long life make it considerably more attractive than the incandescent lamp.
- The blue-white color of the clear lamp is generally acceptable, and the arc tube size provides a light source that is small enough to permit good light control.

- A phosphor-coated outer bulb, featuring both higher output and more pleasing color rendition, is also available. However, the light source is the size of the outer bulb, presenting a problem in light control.
- The metal halide lamp is a type of mercury lamp in which the arc tube contains, in addition to mercury, certain metal halides which improve both the efficacy and the color rendition without the use of a phosphor-coated bulb. The light source size is that of the arc tube, permitting good light control in the same fixture used for clear mercury lamps.
- MV lamps are the least efficient of the HID types and have poor lumen maintenance
- **High pressure sodium (HPS) lamp replaced tomercury :**
- The high pressure sodium (HPS) lamp is presently replacing the mercury lamp. It has golden-white color light output.
- HPS lamps are normally operated with special ballasts that provide the necessary high voltage to start the lamp. However, lamps are available that can be operated from certain types of mercury lamp ballasts, but with poorer lumen maintenance and shorter life. There are also HPS lamps available that provide improved color rendition or almost instant restart after a power interruption; either feature results in a reduction in rated life.
- **LED replaced toHigh pressure sodium (HPS) lamp :**
- LED lights use approximately 60% less electricity than HPS lights

Savings by Use of More Efficient Lamps (Bureau of Energy Efficiency)		
Existing Lamp	**Replace by**	**Energy Savings**
GLS (Incandescent)	Compact Fluorescent Lamp (CFL)	35 to 60 %
	High Pressure Mercury Vapor (HPMV)	40 to 50 %
	Metal Halide	65 %
	High Pressure Sodium Vapor (HPSV)	65 to 75%
Tungsten Halogen	High Pressure Mercury Vapor (HPMV)	50 to 60 %
	Metal Halide	40 to 70 %
	High Pressure Sodium Vapor (HPSV)	40 to 80 %
High Pressure Mercury Vapor (HPMV)	Metal Halide	35 %
	High Pressure Sodium Vapor (HPSV)	35 to 60 %
	Low Pressure Sodium Vapor (HPSV)	60 %
Metal Halide	High Pressure Sodium Vapor (HPSV)	30 %
	Low Pressure Sodium Vapor (HPSV)	40 %
High Pressure Sodium Vapor (HPSV)	Low Pressure Sodium Vapor (HPSV)	40 %

Variation in Light Output and Power Consumption (BEE, India)				
Type of Lamp	**10% lower voltage**		**10% Higher voltage**	
	Light Out Put	**Power Out Put**	**Light Out Put**	**Power Out Put**
Fluorescent lamps	Decreased 9%	Decreased 15%	Increased 9%	Increased 15%
HPMV lamps	Decreased 20%	Decreased 16%	Increased 20%	Increased 17%
Mercury Blended lamps	Decreased 24%	Decreased 20%	Increased 30%	Increased 20%
Metal Halide lamps	Decreased 30%	Decreased 20%	Increased 30%	Increased 20%
HPSV lamps	Decreased 28%	Decreased 20%	Increased 30%	Increased 26%
LPSV lamps	Decreased 4%	Decreased 8%	Increased 2%	Increased 3%

References:

- Indian Renewable Energy Development Agency
- URBAN DESIGN STANDARDS MANUAL
- USAID-India.
- HIGHWAY LIGHTING-Illinois

Chapter: 12 Different Type of Lamp & Control Gear

Introduction:

- Artificial luminous radiation can be produced from electrical energy according to two principles:
- **Incandescence:** Itis the production of light via temperature elevation. The most common example is a filament heated to white state by the circulation of an electrical current. The energy supplied is transformed into heat by the Joule effect and into luminous flux.
- **Luminescence:** It is the phenomenon of emission by a material of visible or almost visible luminous radiation. A gas (or vapors) subjected to an electrical discharge emits luminous radiation (Electroluminescence of gases).Since this gas does not conduct at normal temperature and pressure, the discharge is produced by generating charged particles which permit ionization of the gas.
- The nature, pressure and temperature of the gas determine the light spectrum. Photoluminescence is the luminescence of a material exposed to visible or almost visible radiation (ultraviolet, infrared).When the substance absorbs ultraviolet radiation and emits visible radiation which stops a short time after energization, this is fluorescence.

Incandescent lamps:

- Incandescent lamps are historically the oldest and the most often found in common use. They are based on the principle of a filament rendered incandescent in a vacuum or neutral atmosphere which prevents combustion. A distinction is made between:
- **Standard Incandescent bulbs**
- These contain a tungsten filament and are filled with an inert gas (nitrogen and argon or krypton).
- **Halogen Incandescent bulbs**
- These also contain a tungsten filament, but are filled with a halogen compound and an inert gas (krypton or xenon). This halogen compound is responsible for the phenomenon of filament regeneration, which increases the service life of the lamps and avoids them blackening. It also enables a higher filament temperature and therefore greater luminosity in smaller-size bulbs.
- The main disadvantage of incandescent lamps is their significant heat dissipation, resulting in poor luminous efficiency.

Fluorescent lamps

- This family covers fluorescent tubes and compact fluorescent lamps. Their technology is usually known as "low-pressure mercury".
- In fluorescent tubes, an electrical discharge causes electrons to collide with ions of mercury vapor, resulting in ultraviolet radiation due to energization of the mercury atoms.
- The fluorescent material, which covers the inside of the tubes, then transforms this radiation into visible light. Fluorescent tubes dissipate less heat and have a longer service life than incandescent lamps, but they do need an ignition device called a "starter" and a device to limit the current in the arc after ignition. This device called "ballast" is usually a choke placed in series with the arc.
- Compact fluorescent lamps are based on the same principle as a fluorescent tube. The starter and ballast functions are provided by an electronic circuit (integrated in the lamp) which enables the use of smaller tubes folded back on themselves.

1. Fluorescent tube
2. HP mercury vapour
3. High-pressure sodium
4. Low-pressure sodium
5. Metal halide
6. LED

Applications of Bulbs:

Type	Application	Advantage	Disadvantage
Standard Incandescent	(1) Domestic use (2) Localized	(1) Direct connection without intermediate	(1) Low luminous efficiency and high electricity consumption

bulbs	decorative lighting	switchgear (2) Reasonable purchase price (3) Compact size (4) Instantaneous lighting (5) Good colour rendering	(2) Significant heat dissipation (3) Short service life
Halogen Incandescent bulbs	(1) Spot lighting (2) Intense lighting	(1) Direct connection (2) Instantaneous efficiency (3) Excellent colour rendering	(1) Average luminous efficiency
Fluorescent tube	(1) Shops, offices, workshops (2) Outdoors	(1) High luminous efficiency (2) Average colour rendering	(1) Low light intensity of single unit (2) Sensitive to extreme temperatures
HP mercury vapour	(1) Workshops, halls, (2) hangars. (3) Factory floors	(1) Good luminous efficiency (2) Acceptable colour rendering (3) Compact size (4) Long service life	(1) Lighting and relighting time of a few minutes
High-pressure sodium	(1) Outdoors (2) Large halls	(1) Very good luminous efficiency	(1) Lighting and relighting timeof a few minutes
Low-pressure sodium	(1) Outdoors (2) Emergency lighting	- Good visibility in foggy weather - Economical to use	(1) Long lighting time (5 min.) (2) Mediocre colour rendering
Metal halide	(1) Large areas (2) Halls with high ceilings	- Good luminous efficiency - Good color rendering - Long service life	(1) Lighting and relighting timeof a few minutes
LED	(1) Signalling (3-color traffic lights, “exit” signs and emergency lighting)	(1) Insensitive to the number of switching operations (2) Low energy consumption (3) Low temperature	(1) Limited number of colours (2) Low brightness of single unit

Type of HID (High Intensity Discharge) Lamp:

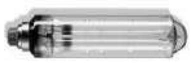
- The term High Intensity Discharge or HID describes lighting systems that produce light through an electrical discharge which typically occurs inside a pressurized arc tube between two electrodes. In general, these systems feature long life, high light output for the size of the lamp and increased efficiency compared to fluorescent and incandescent technologies. HID lamps are named by the type of gas and metal contained within the arc tube. There are five different families of HID: Mercury Vapor, High Pressure Sodium, Quartz Metal Halide, Pulse Start Quartz Metal Halide, and Ceramic Metal Halide.
- HID lamps require a ballast to operate. Typically, the HID ballast (sometimes with the addition of a capacitor and igniters) serves to start and operate the lamp in a controlled manner.
- HID lamps take several minutes to warm-up. Full light output is reached after the arc tube temperature rises and the metal vapours reach final operating pressure. A power interruption or voltage drop will cause the lamp to extinguish. Before the lamp will re-light, it must cool to the point where the lamp's arc will re strike.
- There are four basic types of lamps considered as HID light sources:
  1. Mercury vapour,
  2. Low pressure sodium,
  3. High pressure sodium and
  4. Metal halide.
- All are arc discharge lamps. Light is produced by an arc discharge between two electrodes at opposite ends of the arc tube within the lamp.

- Each HID lamp type has its own characteristics that must be individually considered for any lighting application.

(a) High Pressure Sodium

- **Efficacy:**80 to 140 lumens per watt.
- **Life:** A long lamp life of 20,000 to 24,000 hours, and the best lumen maintenance of all HID sources.
- **Wattages:** 35W to 1000W and the warm-up time is from 2 to 4 minutes.
- **Re-strike time:** Approximately 1 minute.
- **Applications:** Roadway lighting
- High pressure sodium and metal halide lamps comprise the majority of HID lighting applications.
- The biggest drawback of high pressure sodium is the yellowish colour light output, but it is acceptable for use in many industrial and outdoor applications (e.g. Roadway lighting).

(b) Low Pressure Sodium



- Low pressure sodium (LPS) lamps are grouped with HID lamps, but in fact do not have a compact, high intensity arc. They are more like a fluorescent lamp with a long stretched-out arc.
- **Colour:** LPS lamps have no colour rendering index as the colour output is monochromatic yellow.
- **Efficacy:**100 to 185 lumens per watt
- **Wattages:**18W to 180W
- **Life:** Average 14,000 to 18,000 hour lifetimes.
- **Re-strike time:** shortest re-strike time among HID sourcesonly 3 to 12 seconds.
- **Applications:** LPS has few viable applications beyond street, parking lot and tunnel lighting.
- They have excellent lumen maintenance but the longest warm up times, from 7 to 15 minutes.

(c)Metal Halide

- **Efficiency:** Efficacy of 60 to 110 lumens per watt
- **Warm-up Time:** 2 to 5 minutes.
- **Re-strike time:** 10 to 20 Minutes.
- **Wattages:** 20W to1000W
- **Life:** 6,000 to 20,000 hours.
- **Applications:** This technology is ideal for Lamp applications requiring truer colour as in fruit, vegetable, Clothing and other accent lighting in retail displays.
- Wattages from 1500W to 2000W are specialty lamps used for sports lighting and have lamplife ratings of only 3000 to 5000 hours.
- **Advantages:** The advantage of metal halide lighting is its bright crisp, white light output suitable for commercial, retail, and industrial installations where light quality is important. However, lumen maintenance over the life of the lamps is less than optimal relative to other HID sources.
- The arc tube material for metal halide lamps was quartz until 1995 when ceramic arc tube technology was developed.

- Ceramic arc tubes are now predominantly used in low wattage (20W to 150W) lamps, though new designs up to 400W have emerged in recent years.
- Ceramic arc tubes provide improved Colon consistency over lamp life.

General Descriptions of Ballast:

- HID lamps provide light from an electric discharge or arc and have a negative resistance characteristic that would cause them to draw excessive current leading to instant lamp destruction if operated directly from line voltage.
- The ballast is a power supply for arc discharge lamps. Its purpose in HID lighting is to provide the proper starting voltage to initiate and maintain the lamp arc and to sustain and control lamp current once the arc is established.
- Ballasts and lamps are designed to meet standards for interchange ability between lamps and ballasts of the same type and wattage. A lamp must be operated by the ballast designed for that lamp, as improper matching of lamp and ballast may cause damage to the lamp or ballast or both.
- For many years all HID ballasts were magnetic ballasts operating at the power line frequency of 50 or 60 Hertz to provide proper lamp operation.
- In the past few years electronic ballasts have been developed, primarily for metal halide lamps, using integrated circuits that monitor and control lamp operation. Electronic ballast circuits sense lamp operation characteristics and regulate lamp current to operate the lamp at constant wattage, thus providing a more uniform light output and color rendition throughout lamp life.
- They also sense lamp end of life and other circuit conditions and shut down the ballast when the lamp operating characteristics fail to meet operating specifications.

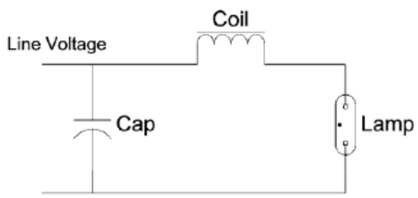
Type of HID (High Intensity Discharge) Ballast:

- HID lamps, like fluorescent lamps require a ballast to provide the proper starting voltage for the lamp and limit the operating current once the lamp is ignited. HID lamps have negative impedance, which means that the lamp draws more current than is required for it to operate. Without ballast, running in this negative impedance condition, the lamp would self-destruct in a very short period of time.
- HID ballasts are classified by the type of circuit they use
- **Electromagnetic Ballast (EM):**
  1. Reactor (R).
  2. High Reactance Autotransformer (HX).
  3. Constant wattage Autotransformer (CWA)
  4. Magnetic Regulator.
- **Electronic Ballast.**
- Further HID ballasts are classified by the type of Power Factor
  1. High Power Factor (HPF)
  2. Normal Power Factor (NPF).

(1) Electromagnetic Ballasts (EM)

- Electromagnetic Ballasts use magnetic components to start and regulate the operation of a lamp. Inductors are used as the current limiting component in EM ballasts. Although the inductor is very good at regulating current, it causes a phase shift input of the current waveform creating a non-ideal power factor. Often times a Capacitor is used in Electromagnetic Ballasts to correct

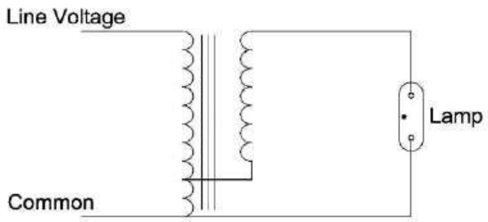
(a) Reactor (R):



- Single coil ballast can be used when the input voltage to a fixture meets the starting and operating voltage requirements of an HID lamp. In this situation, the reactor ballast performs only the current-limiting function since the voltage necessary to initiate the ignitor pulses, and start and sustain the lamp comes directly from the input voltage to the fixture.

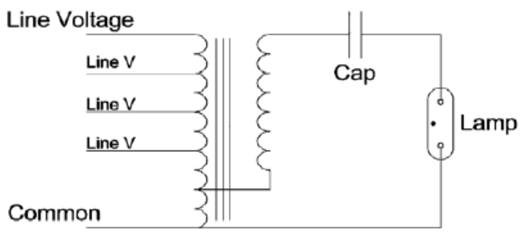
- The reactor ballast is electrically in series with the lamp.
- There is no capacitor involved with the operation of the lamp. Because of that, the lamp current crest factor is desirably low, in the 1.4 to 1.5 range.
- Without a capacitor, the reactor ballasts are inherently normal power factor devices (50%). When desired to reduce the ballast input current required during lamp operation, a capacitor may be utilized across the input line to provide high power factor (90%) operation, but the addition of the capacitor will not affect how the ballast operates the lamp.

(b) High Reactance Autotransformer (HX):



- When the input voltage does not meet the starting and operating voltage requirements of the HID lamp, a high reactance autotransformer ballast can be used. In addition to limiting the current to the lamp, an HX ballast transforms the input voltage to the lamp's required level.
- Two coils, called the primary and secondary, are employed within the ballast. The operating characteristics, such as lamp wattage regulation are similar to the reactor.
- The high reactance autotransformer ballast is also inherently a normal power factor (50%) ballast but can be corrected to a high power factor (90%) with the addition of a capacitor across the primary coil. As with the reactor ballast, the addition of this capacitor does not affect the lamp's operation.
- Both reactor and high reactance ballasts provide the same degree of lamp wattage regulation. For example, a simple 5% change in line voltage results in a 10-12% change in lamp operating wattage. However, this fair degree of lamp regulation is acceptable for many applications.
- **Advantages:**
- Slightly higher in cost than reactors, but
- less than regulated type ballasts
- Lower ballast losses than regulator types
- Provides good wattage regulation when line voltage is controlled within ± 5%
- Can be used with 120V, 208V, 240V, 277V, and 480V supply.
- **Disadvantages:**
- High operating current
- Higher starting current
- Poor regulation

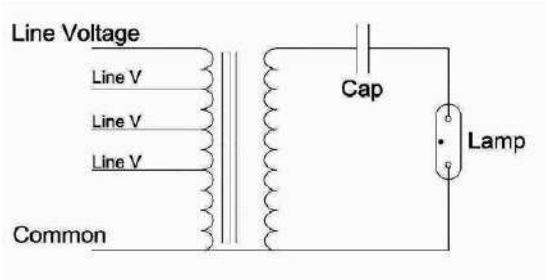
(c) Constant Wattage Autotransformer (CWA), "Peak Lead Autotransformer":



- To correct the higher input current associated with reactor and high reactance ballasts, and to provide a greater level of lamp wattage regulation, the 2-coil CWA ballast was developed.
- It is the most commonly used ballast circuit for medium and high wattage (175W – 2000W) applications and typically represents the best compromise between cost and performance.
- The CWA is a high-power factor ballast utilizing a capacitor in series with the lamp rather than across the input. The capacitor works with the core-and-coil to set and regulate the lamp current to the prescribed level.
- The CWA ballast provides greatly improved lamp wattage regulation over reactor and high reactance circuits. A ± 10%-line voltage variation will result in a ± 10% change in lamp wattage for metal halide.

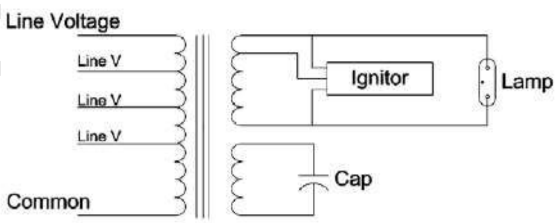
- The metal halide and high-pressure sodium ballasts also incorporate wave shaping of the open circuit voltage to provide a higher peak voltage than a normal sine wave.
- This peak voltage (along with a high voltage ignition pulse when an ignitor is used) starts the lamp and contributes to the lamp current crest factor (typically 1.60 -1.65).
- With the CWA ballast, input current during lamp starting or open circuit conditions does not exceed the input current when the lamp is normally operating. CWA ballasts are engineered to tolerate 25-30% drops in line voltage before the lamp extinguishes (lamp dropout), thus reducing accidental lamp outages.

(d) Constant Wattage Isolated (CWI):



- The CWI ballast is a two-coil ballast similar to the CWA ballast except that its secondary coil is electrically isolated from the primary coil.
- This isolated design permits the socket screw shell to be grounded for phase-to-phase input voltage applications such as 208-, 240- and 480-volt inputs.
- **Advantages:**
- High power factor (over 90%) and low operating current
- Good regulation–permits and responds favourably to line voltage
- Slightly larger in size and weight than variations of up to +5% or –10% Reactor Ballast
- Starting current is even lower than operating current
- Costs less than magnetic regulator
- Provides good regulation of lamp wattage, especially in nominal and below normal systems
- Ballast losses are less than for magnetic regulator.
- **Disadvantages:**
- More expensive than Reactor type ballast
- Available for all standard voltages

(e) Magnetic Regulator



- Magnetically Regulated (Mag Reg) and Regulated Lag (Reg Lag) are another type of EM ballasts. They utilize a magnetic with three separate coils. One coil connects to a capacitor for increased Power Factor and to regulate current into the lamp coil. The lamp coil is isolated from the power supply. This circuit provides very good control over light output. In some ballast designs, large changes in voltage cause very small changes in lamp wattage
- **Advantages:**
- High power factor (over 90%)
- Excellent line voltage regulation, it is responsive to systems that operate
- normally in extremely high or extremely low line voltage situations–in the "near to ± 10%" range
- Low operating current and lower starting current
- Isolated secondary reduces danger of electrical shock
- At nominal voltage, its volts/watts trace is quite like the performance of a Reactor Ballast
- Provides better lamp regulation.
- **Disadvantages:**

- Most expensive of all types of ballasts
- Heavier and larger than other ballasts

(2) Electronic HID (e HID) Ballasts:

- There are two basic designs for electronic HID ballasts:
- Low frequency square wave (typically used for low-wattage lamps or with ceramic arc tube lamps in the 250W-400W range) and
- High frequency (for medium wattage lamps in the 250W to 400W range).
- Both make use of integrated circuit technology to provide closer regulation and control of lamp operation over a variety of input voltage and lamp aging conditions.
- The integrated circuits in both types of ballasts continuously monitor input line voltage and lamp conditions and regulate lamp power to the rated wattage. If any power line or lamp circuit condition exists that will cause the lamp or ballast to operate beyond their specified limits the ballast shuts down (removes power from the lamp) to prevent improper operation.
- Electronic HID ballasts improve lamp life, lamp lumen maintenance, and system efficiency.
- Integrated circuit control allows most electronic ballasts to operate at multiple input line voltages and, in some cases, operate more than one lamp wattage. The lamps are operated with constant lamp power that provides better light output regulation and more consistent light color over the life of the lamp.
- Some electronic HID ballasts also offer a continuous dimming function that will dim the lamp to 50% (minimum) lamp power using 0-10V (DC) dimming control voltage.
- All functions required to correct power factor, line current harmonics, and to start and control lamp operation are inherent in the ballast.
- The lamp socket must be pulse rated (dependant on lamp type) because there is an ignition pulse supplied to start the lamp.

Starting of HID Lamp:

- In cold state mercury vapour and halides are in non-ionized state. Impedance between two electrodes is very high. To overcome this impedance we need to ionize the mercury vapor. A high amplitude pulse in the order of 3.5 KV or more with sufficient energy that can create an initial arc. Minimum limit for amplitude has been specified in IEC60926/927 specification.
- Igniters pulses continue to support ionization till current through the lamp becomes 90 percent of the rated value or voltage across the lamp 110 percent of rated value. Declared life of lamp is based on one switching per 24 hours.
- In many parts of Asia frequent power supply interruption is very common. For example in eastern India average 5 to 6 power supply interruption observed per 12 hours burning of the lamp per day. So the lamps are also switched on/off 5 to 6 times during their 12 hours burning (Average) per day.
- This causes repeated dissolution /erosion of thorium coated tungsten electrode. This phenomenon is also observed in indoor sports stadium where lamps are repeatedly switched on/off according to sports fixture. To save energy. So we find there are two parameters, which determine the life of Metal Halide and other HID lamp

  (i) Ageing- No of burning hours.

  (ii) Switching- No of switching on/off cycle.
- Till date, data supplied by lamp manufacturer for successful ignition is

  (a)Minimum amplitude of ignitior pulses

  (b) Pulse duration.
- Maximum energy content of ignitor pulse is unrestricted; it has been also not specified in IEC60926/927 specification. Field report from luminaries manufacturers say

  (a) Lamp failures in 18 meter tower(lighting Mast) are less than 6 meter tower ,where as components such as pulse ignitor (internationally certified) ,ballast and lamps and luminaries are same(control gear for the luminaries are at the bottom of the tower)

  (b) 30 percent of Metal Halide Lamps in street light fails in 6 months or early when pulse ignitors used compare to superimposed ignitor (ignitor which can ignite lamp at short distance).
- Metal Halide lamp with long distance ignitor used inbuilt into the luminaries has more failure than ignitor which can ignite lamp at short distance.

What is Dragon Kink?

- Maximum energy which lamp can be successfully subjected is termed as **critical energy (Le)** Typically 0.75 mJ (may vary depending on discharge tube parameter).
- High amplitude high energy ignition pulses greater than critical energy(Le) causes dissolution / erosion of electrode of Metal Halide(M.H) and Sodium vapor (SON) lamp, this results in increase in minimum ignition energy required to ignite a Metal Halide(M.H) /Sodium vapor (SON) lamp with increase in number of switching ON/OFF operation .
- Higher the energy content of high amplitude pulses of ignitor, rapid is the increase in minimum ignition energy at which HID lamp ignites for subsequent switching on.
- This phenomena of increase in minimum ignition energy required to start Metal Halide (M.H) and Sodium vapor (SON) lamp with increase in no of switching on/off due to impact of high energy pulses of Ignitor is named as **"Dragon Kink" effect. This phenomena is more prominent in Metal Halide lamp**.
- This phenomenon of increase of ignition energy with no of switching on/off determines switching life of the lamp. However this increase of ignition energy which can start a lamp with increase in no of switching on/off cycles could be almost arrested if lamps are ignited with ignitor pulses reaching lamp has energy content less than critical energy (Le).
- In the summary we can say that we need to develop an ignitor system that takes care of 'Dragon Kink 'effect
  (I) Energy content of igniter pulses across the lamp are adequate for stating but below critical limit (Le) as need to be declared by lamp manufacturer/IEC specification for ensuring availability of total useful life by preventing early switching life failure.
  (II) Useful minimum and maximum distance marked on the ignitor to take into account of Dragon Kink effect so that full switching life of Metal Halide Lamp/other HID lamp is available

Component of HID (High Intensity Discharge):

(1) Ballast:

- All HID lamps are negative resistance light sources (this means that once the arc is initiated, the lamp's resistance continually decreases as current increases; for all practical purposes, the lamp becomes a short circuit). They require a support device (ballast), that limits the lamp and line current when voltage is applied, to prevent the lamp from being destroyed.
- In addition, the ballast provides the lamp with proper voltage to reliably start and operate the lamp throughout its rated service life. If a transformer is integral to the ballast circuit, it modifies the available supply voltage to provide the voltage required for the lamp.
- A distinction must be made between lag circuit and lead circuit ballasts. The lamp current control element of a lag circuit ballast consists of an inductive reactance in series with the lamp. The current control element in lead circuit ballasts consists of both inductive and capacitive reactance in series with the lamp; however, the net reactance of such a circuit is capacitive in mercury and metal halide ballasts, and inductive in high pressure sodium ballasts.
- High pressure sodium (HPS) lamps are greatly different than the mercury or metal halide lamps. Mercury and metal halide lamps maintain a relatively stable voltage drop across the arc tube throughout its life (wattage is also essentially constant) with aging being reflected only in lamp lumen depreciation, decreasing light output.
- The HPS lamp is a dynamic device with performance changing as the lamp ages. The arc tube voltage rises with usage; therefore, the wattage and lumen output change with age.

(2) Capacitors

- All high power factor (HPF) Reactor (R) and High Reactance (HX) ballasts, as well as all Constant Wattage Autotransformer (CWA), Constant Wattage Isolated (CWI) and Regulated Lag ballasts require a capacitor.
- With core and coil and encapsulated core-and-coil units the capacitor is a separate component and must be properly connected electrically.
- The capacitor for outdoor weatherproof, indoor enclosed-can and postline types is already properly connected within the assembly.
- **Two types of capacitors are currently in use:**
- (A) Dry metalized film and
- (B) Oil-filled.
- Present capacitor technology has allowed all but a few capacitor applications to be dry film. Oil-filled capacitors are used only when dry film technology cannot satisfy capacitor voltage requirements.
- **Dry Metalized Film Capacitors:**

- Available to fill almost all needs for HID ballast applications.
- Advance dry film capacitors typically require only half the space used by oil filled capacitor and do not require additional spacing for safety.

- The compact, light weight, cylindrical non-conductive case and two insulated wires or terminals reduce the required mounting space as compared with oil-filled capacitors.
- The discharge resistors (when required) are installed within the capacitor case. Dry film capacitors are UL Recognized and contain no PCB material.
- The maximum allowed dry film capacitor case temperature is 105°C.
- ### Oil-Filled capacitors:
- Contain non-PCB oil and are a UL-Recognized component. Oil-filled capacitors are only supplied with ballasts where the capacitor operating voltage cannot be satisfied by dry film capacitors.

- When required, the capacitor discharge resistor is connected across the capacitor terminals.
- Additional precautions must be taken when an oil filled capacitor is installed.
- Underwriters Laboratories, Inc. (UL) requires clearance of at least 3/8 inch above the terminals to allow for expansion of the capacitor in the event of failure.
- The maximum case temperature for oil-filled capacitors is 90°C.

(3) Igniters (Starters):

- An ignitor is an electronic component that must be included in the circuitry of all high pressure sodium, low wattage metal halide (35W to 150W) and pulse start metal halide (175W to 1000W) lighting systems. The ignitor provides a pulse of at least 2500 volts peak to initiate the lamp arc.
- When the lighting system is energized, the ignitor provides the required high voltage pulse until the lamp arc is established and automatically stops pulsing once the lamp has started.
- It also furnishes the pulse continuously when the lamp has failed or the socket is empty.

- Ballasts that include an ignitor to start the HID lamp are limited in the distance they may be mounted remotely from the lamp because the ignitor pulse attenuates as the wire length between the ballast and lamp increases.
- For most of these ballast/ignitor combinations, the typical maximum ballast- to-lamp distance is listed in the Atlas as 2 feet. When this distance is exceeded the lamp may not start reliably and a long range ignitor is required.
- Some lighting applications require instant restarting of lamps after a momentary loss of power to the fixtures. When an HID lamp is hot after operation and power is removed and reapplied, it will not restart with a standard ignitor until the lamp sufficiently cools.
- When instant re strike of a hot lamp is required, a special ignitor is necessary that will provide a pulse with much greater peak voltage.
- Some ballast designs require ignitors to start the lamp. Ignitors create a glow discharge in the lamp by providing a voltage high enough to ionize the gas. This glow discharge is created by a 2500 volt pulse. Once the lamp is started, the ignitor stops pulsating automatically.
- Ignitors are designed to last thousands of hours. However, if the lamp has failed, or if the socket is empty, the ignitor will continue pulsing. In these situations, it is important to replace the lamp or turn off the HID fixture to preserve the ignitor's life.
- **Standard Ignitors** are supplied with all High Pressure Sodium, Pulse Arc, and Metal Halide ballast requiring ignitors. These ballasts are supplied with the appropriate external ignitor and are to be wired within two feet of the lamp. Sometimes the ignitors can be permanently attached to or built into the ballast.

- **Long range Ignitors** are used in situations where an ignitor must be mounted further from the lamp than is recommended for a standard ignitor. The maximum lamp to ignitor distance for these ignitors is 50 feet, which may vary depending on the type of lamp, ballast, fixture, and wiring.
- **Instant Restrike Ignitors** generate multiple pulses to restrike lamp arc without a cool down time, after a brief power interruption has extinguished it. This requires a special lamp and is still subject to warm-up time.
- **Automatic Shutoff Ignitors** will apply pulses for 10 to 12 minutes and then deactivate if a lamp arc cannot be initiated. This saves the on ignitor life because a standard ignitor will continue to pulse. Resetting the Automatic Shutoff ignitor is accomplished by momentarily interrupting the power to the ballast. They should not be used on unswitched circuits that cannot be reset.
- **It is important to note that igniters are specifically designed to operate properly with specific ballasts and cannot be interchanged with other igniters or different brands of igniters and ballasts.**
- **The ignitor should always be mounted near the ballast but not on the ballast.**

Installation & Testing of HID (High Intensity Discharge):

- Only the input to HID lighting systems is a sine wave. Once the voltage and current is processed through the ballast and lamp, it is changed and is no longer a perfect sine wave. As a result of this transformation, **only TRUE RMS volt and amp meters will give proper readings.**
- TRUE RMS clamp-on current meters are also available and are most convenient when reading lamp current.
- There are many brands of test meters available. Some indicate RMS and some indicate TRUE RMS on the meter. They are not the same. Only those that have TRUE RMS will read non-sinusoidal waveforms accurately. The RMS meters will give readings 10 to 20% low depending on the shape of the voltage or current waveform.

Normal End of Lamp Life

- Most fixtures fail to light properly due to lamps that have reached end of life. Normal end of life indications are low light output, failure to start or lamps cycling off and on these problems can be eliminated by replacing the lamp.

Supply Input Measurement:

- Measure the line voltage at input to the fixture to determine if the power supply conforms to the requirements of the lighting system. For constant wattage ballasts (CWA, CWI), the measured line voltage should be within ±10 % of the nameplate rating. For reactor (R) or high reactance (HX) ballasts, the line voltage should be within ±5 % of the nameplate rating.
- Check breakers, fixture fuses, photocells and switches when no voltage reading can be measured. High, low or variable voltage readings may be due to load fluctuations.
- **The supply voltage should be measured with the defective fixture connected to the line and power applied to help determine possible voltage supply problems.**

Open Circuit & Short Circuit Voltage:

- If the proper input voltage is measured, most HID fixture problems can be determined by measuring open circuit voltage and short circuit current.

Measuring Open Circuit Voltage

- To determine if the ballast is supplying proper starting voltage to the lamp, an open circuit voltage test is required. The proper test procedure is:
- (1) Measure input voltage (V1) to verify rated input voltage is being applied to the ballast.
- (2) If the ballast has an ignitor [HPS, low wattage MH (35W to 150W) or pulse start MH], the ignitor must be disconnected or disabled with a capacitor (1000 pF or larger) across the voltmeter input to protect the meter from the high voltage ignitor pulse.
- **Some ballasts have an integral or built in ignitor. If you are not sure if an ignitor is used put a capacitor across the meter for all open circuit voltage measurements.**
- (3) With the lamp out of the socket and the voltage applied to the ballast or the proper tap of the ballast with multiple voltage inputs, read the voltage (V2) between the lamp socket center pin and shell. Some lamp socket shells are split. Make sure connection is being made to the active part. Open circuit voltage must be measured with a TRUE RMS voltmeter to provide an accurate reading.
- (4) Constant wattage (CWA, CWI) ballasts have a capacitor in series with the lamp. If the capacitor is open there will be no open circuit voltage. Measure the voltage on both sides of the capacitor. If the voltage exists on the ballast side but not on the lamp side,

- **Change the capacitor and re-measure the open circuit voltage at the lamp socket. If there is still no voltage disconnect the lamp socket from the ballast and measure open circuit voltage again. Once a voltage is measured test the lamp socket for shorts with an Ohm-meter or replace the lamp socket. An ohm-meter test is not conclusive as the test is at low voltage and the failure may be due to the open-circuit voltage.**
- **Short Circuit Lamp Current Test**
- **Do not be concerned about momentarily shorting a magnetic HID ballast output. They will not instantly burn up. An HID ballast is designed to limit current at the specified value range.**
- To assure that the ballast is delivering the proper current under lamp starting conditions, a measurement may be taken by connecting an ammeter between the lamp socket center pin and the socket shell with rated voltage applied to the ballast. If available, a lamp socket adapter may be used as described in the open circuit voltage test.
- (1) Energize ballast with proper rated input voltage.
- (2) Measure current with ammeter at A1 and A2 as shown in the diagram shown below.
- (3) Readings must be within test limits. A clamp-on TRUE RMS ammeter may also be used to perform this test by placing an 18-gauge wire between the lamp and common leads of the ballast. When using a clamp-on ammeter for this measurement, be certain the meter is not near the ballast magnetic field or any steel object that may affect the reading.
- The short circuit current test will also determine a defective capacitor in constant wattage circuits. A shorted capacitor will result in high short circuit current, while an open capacitor or low value capacitor will result in no or low short circuit current.
- **Capacitor Testing and Ballast Performance**
- Disconnect the capacitor from the circuit and discharge it by shorting the terminals or wires together.
- Check the capacitor with an ohmmeter set to the highest resistance scale
- If the meter indicates a very low resistance, then gradually increases, the capacitor does not require replacement.
- If the meter indicates a very high initial resistance that does not change, it is open and should be replaced
- If the meter indicates a very low resistance that does not increase, the capacitor is **shorted** and should be replaced.
- The ohmmeter method of testing capacitors will only determine open or shorted capacitors. The capacitance value can be tested by many available portable TRUE RMS meters having that capability, though a test using a dedicated capacitance meter is more conclusive.
- The capacitance value will affect lamp performance of Constant Wattage ballasts in ways that cannot be determined by the ohmmeter method.
- **A capacitor may look good visually, but should be tested for capacitance value or replaced.**
- The capacitor in a reactor or high reactance ballast circuits will only affect the ballast power factor and not ballast operation.
- Capacitor failure in these circuits will cause line supply current changes possibly causing circuit breakers to activate or fixture fuse failures.
- **Ballast Continuity Checks**
- **Continuity of Primary Coil**
- Disconnect the ballast from power source and discharge the capacitor by shorting its terminals or wires together.
- Check for continuity of ballast primary coil between the voltage input leads.
- **Continuity of Secondary Coil**
- Disconnect the ballast from power source and discharge the capacitor by shorting its terminals or wires together.
- Check for continuity of ballast secondary coil between lamp and common leads
- **Ignitor Testing**
- Ignitors are used as a lamp starting aid with all high-pressure sodium; low wattage metal halide and pulse start lamps.
- Measurement of the starting pulse characteristics of an ignitor is beyond the capability of instruments available in the field. In laboratory tests, an oscilloscope equipped with a high voltage probe is used to measure pulse height and width. In the field, some simple tests may be performed to determine if the ignitor is operable.
- **It is first assumed that the lamp has already been replaced with a known operable lamp.**
- Replace the ignitor with a known operable ignitor. If the lamp starts, the previous ignitor was either mis-wired orInoperative.

- If the lamp does not light check the open circuit voltage and short circuit secondary current
- **Further Magnetic Ballast Checks**

(a) Probable Causes of Inoperable Ballasts

- Normal ballast end-of-life failure
- Operating incorrect lamps. Use of higher or lower wattage lamps than rated for the ballast may cause premature ballast end-of-life.
- Overheating due to heat from the fixture or high ambient temperatures causing the ballast temperature to exceed the
- Specified temperature.
- Voltage surge from lightening or power source malfunction.
- Mis-wired, pinched or shorted wires.
- Shorted or open capacitor.
- Incorrect capacitor for the ballast.
- Capacitor not connected to the ballast correctly.

(b) Probable Causes of Shorted or Open Capacitors

- Normal capacitor end-of-life failure.
- Overheated due to heat in the fixture or ambient temperature.
- Capacitor mounted too close to ballast.
- Incorrect voltage or capacitor value for ballast.
- Mechanical damage such as over-tightened capacitor clamp.

(c) Electronic HID Ballasts

- Electronic HID ballasts present special troubleshooting challenges. The previously discussed procedures cannot be used to test electronic HID circuits. Electronic integrated circuit control limits reliable testing that can be performed in the field.
- An energized electronic HID ballast will attempt lamp ignition by producing high voltage pulses for a specified time period, usually between 10 and 30 minutes. Consult the ballast label for specific times.
- **Unlike magnetic HID ballasts, momentary shorting either output lead of an electronic HID ballastto ground or each other.**

Fluorescent Ballast / Lamp Troubleshooting:

Problem	Action
Lamps will not operate.	Check if there is power to the fixture.
	Be sure lamp is properly seated in socket.
	Replace lamp.
	Reseat or change starter (preheat only)
	Check wiring connections.
Slow or erratic Starting	Check ground (fixture must be grounded for reliable starting)
	Check ballast label for correct lamp.
	Check wiring connections.
	Check for low supply voltage.
	Be sure lamp is properly seated in socket.
	Test ballast
Excessive Noise	Tighten loose components.
	Install ballasts of the proper sound rating.
	Replace faulty ballast(s). Normal operation should resume.
	Note: All fluorescent ballasts emit some noise
Lamp flickering and or swirling	New lamps with less than 100 hours of service can exhibit this
	Defective starters
	Lamp to cold
	Defective lamp
	Improper voltage
	Defective ballast
Stroking /Blinking	Improper fixture design or ballast application

	High circuit voltage
	Improper wiring or installation
	Defective ballast
	Poor lamp maintenance
	Incorrect type of lamps
	Incorrect number of lamps
	High ambient temperature

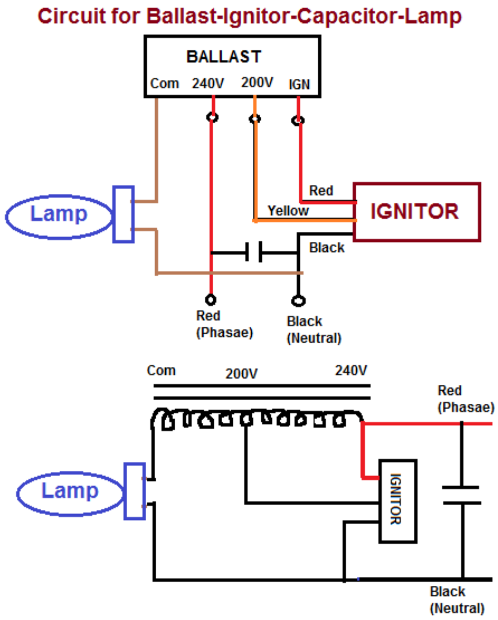
HID Ballast / Lamp Troubleshooting

- **Normal End of Lamp Life**
- Normal end of life is important to understand for troubleshooting. It occurs when the lamp has aged to the point that the arc can no longer be sustained. End of life can be induced prematurely when lamps are operated at improper voltages, temperatures and positions.
- Mercury and metal halide lamps tend to emit low light output at end of life and starting will become intermittent. There will also be significant blackening on the arc tube located at thecenter of the lamp. High pressure sodium lamps retain their light output at the end of life, however, starting becomes intermittent at first and then impossible.
- There will be some blackening on the end of the arc tube located in the center of the lamp.
- Verify average rated lamp life as published by the lamp manufacturer and compare it to the actual life of the lamps in the system. Remember that the average rated life is not the same as the minimum life expectancy. The average rated life means that for a population of lamps, the average lamp lasted this long. When a system of lamps installed at the same time reaches the average rated life, we can expect half of the population of lamps to have failed. It is always important to be aware of the operation of the system when evaluating lamp life. For example, is the system operated round the clock either intentionally or as the result of faulty controls?
- **Lamps Will Not Start**
- Check to see if lamp is loose in the socket. Check for arcing (blackening) at the center contact button and retighten lamp until it isproperly seated. Tightening too much may cause lamp breakage.
- Check to see if lamp has failed or is damaged. Visually inspect for loose, broken internal parts or broken bulb wall.
- Visually inspect for separation of the lamp base. Check for looseness or for significant discoloration of the bulb wall near the base.
- Test the lamp in an adjacent fixture that is operating properly.
- Check to assure that the voltage at the fixture is not too low.
- Check the nameplate rating for the ballast. The voltage should be within 5% for reactor and high reactance ballasts, and within 10% for all others
- **Lamp Cycling (starting and shutting off repeatedly)**
- Lamp cycling is a common end of life failure mode for high pressure sodium lamps.
- **Check the capacitor:** Verify the capacitor has the correct microfarad (uF) value as specified on the ballast. Inspect the capacitor for a swollen or ruptured case. Disconnect the capacitor and discharge it by shorting across its terminals with a piece of insulated wire. Use an If the resistance starts low and gradually increases, the capacitor is good. Any other reading indicates either an open or short circuit condition and the capacitor is bad.
- **Check the ballast**:If it is an older system, it could be simply the normal end of ballast life. Replace the ballast, capacitor (if present) and ignitor (if present). If the ballast is located in an extremely high ambient temperature, it can overheat the ballast or other parts. Check for discoloration of the ballast or other parts. Also check for failed capacitor (see above).Check the ballast open circuit voltage.
- **Short Lamp Life**
- Verify the correct ballast type and wattage, and correct capacitor value.
- Check the input voltage and verify that it does not exceed 10% ballast input voltage shown on the label.
- Inspect the capacitor for a swollen or ruptured case.
- Check the lamp specification for "base up" or "base down" position specifics. Usethe specified lamp only in the current orientation.
- Replace with a known good lamp.
- **Fuses Blow or Circuit Breakers or Circuit Breakers Open On Lamp Start Up**

- Overloaded Circuit - Rewire to accommodate starting current of lamp/ballast combination.
- High Momentary Transient Current - Can be caused by reactor or autotransformer ballasts which draw high initial currents. Use current protective devices incorporating time delay elements. If these fail, change ballast as its characteristics will affect lamp life.

Step Guide to Fault Finding in Reactor Type Circuits:

1. If metal halide, disconnect neutral wire from ignitor.
2. Check all electrical connections.
3. Remove lamp.
1. Check voltage at choke output is equal to mains.
2. If no voltage, check the continuity of choke by measuring resistance against a known good choke. Depending upon wattage, this reading should be from 2-50Ω.
3. If reading is infinity, choke is faulty. Replace.
4. Check voltage at lamp holder. Must equal mains voltage.
5. If OK, replace neutral wire in ignitor and replace lamp. If lamp does not fire – faulty ignitor. Replace.



Chapter:13 What should you know before buying LED Bulbs

Introduction:

- The market of LED Lights is blooming very fast. Many companies serve LED Bulb to their customer and it is not easy for customer to choose best LED Bulb among them.
- The customer does not aware the technical parameter of LED, so It becomes more difficult to find out the best quality of LED Bulbs.
- With traditional incandescent light bulbs it was simple to get the right light bulb. If a 60 watt bulb is the broke or fused you have just get another 60 watt. When it comes to LED lighting, it's very different. Since LED light bulbs doesn't use the same amount of power that incandescent bulbs use.
- LED is described in terms of incandescent equivalence so we may see an LED bulb described as a 60 watt equivalent when in reality it only uses about 9.5 watts. This is because LEDs are measured by lumens (the total amount of visible light put out by a light bulb). There is not a direct mathematical comparison between the lumen ratings used in LEDs and the wattage consumed by an incandescent.
- To choose best LED Bulbs we should consider following technical Parameters.

Parameters for Choosing LED Bulbs

- There are different factors to consider when choosing a suitable LED replacement bulb

A. Basic Technical Parameter:

- Lumen (Lighting Intensity)
- Watt (Power Consumption)
- Correlated Color Temperature (Light color)
- Color Rendering Index (CRI)
- Beam angle (Spread of light)
- Efficiency (Lumen / Watt)
- Power Factor

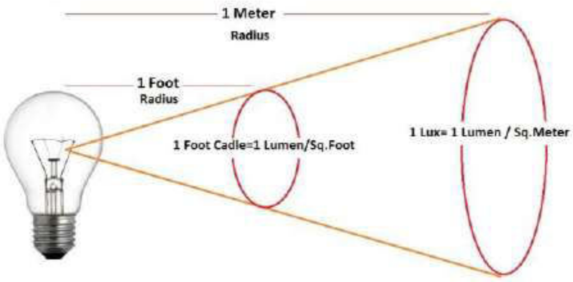
B. Other Technical Parameter:

- Instant Light
- Dimming capacity
- LED Driver
- LED Chip
- Weight
- Heating

Basic Technical Parameter:

(1) Lumen (Brightness):

- When we deal with brightness of LED bulb, we must to know Lumens not Watts.
- The amount of light emitted from a light bulb is measured in Lumens.
- When we replace an incandescent or CFL bulb with an LED bulb we should confirm that LED bulb produces the same number of lumens that the old bulb did.
- As a general benchmark, a standard 60-watt incandescent bulb, for example, produces about 800 lumens of light. By comparison, a CFL bulb produces that same 800 lumens using less than 15 watts
- **Do not use watts as a measure of brightness.**
- Lumens represent the amount of light emitted by a light source, and are a more accurate measure of the brightness of a bulb.
- More lumens mean brighter light, fewer lumens mean dimmer light
- **1 Foot Cadle:** 1 foot candle of light is the amount of light (Lumen) that generates one foot radius away from Lighting source so 1 Foot Candle= 1 Lumen / Sq.Foot
- **1 Lux:** 1 Lux of light is the amount of light (Lumen) that generates one Metert radius away from Lighting source so 1 Lux= 1 Lumen / Sq.Meter



- It is meaningless if we compare lumens between an LED bulb and a CFL to an incandescent bulb. While we are measuring lumens, we also have to consider useful lumens.
- LED gives directional light unlike incandescent, halogen or compact fluorescent bulbs that give out omni-directional light (or light all around the bulb). If a light bulb emits light in every direction similarly over and beneath, then light that going up can get trapped in the light fitting and totally wasted.
- 50% of light emitted from a CFL or incandescent bulb is trapped inside the fitting and never makes it out and reached to objects. This trapped light is just gets absorbed and wasted as heat.
- The amount of lumens that actually reached at the objects of Room that bulb produces are called as the useful lumens.

Lumen Chart for Incandescent, CFL,LED		
Wattage	**Lumens**	**Useful Lumens**
LED 9W	800 lm	800lm
CFL 20W	1000lm	500lm
Incandescent 60W	1000lm	500lm

- There is no rule for how many Lumen is required.It will depend on room size and shape, height of ceilings, colour scheme, type of lamps & fitting.

Area	**Lumens/Sq Meter**
Kitchen	300 to 400
Kitchen (Task)	700 to 800
Living Room	400 to 500
Hallway	300
Bedroom	300 to 400
Bedroom (Task)	700 to 800
Bathroom	500 to 600
Bathroom (Task)	700 to 800
Reading Area	400

(2) Watt (Power Consumption):

- The amount of energy a light bulb consumed is indicated by Watt.
- The watts refer to **how much energy a bulb will use**.
- The lower the watts, the lower the electric bill. CFLs and LEDs have a lower wattage than incandescent bulbs, but emit the same light output
- Watts measure power consumption, whereas lumens measure light actual brightness..
- **Wattage is no longer a reliable way to gauge a light bulb's brightness.**
- In old days, when there was only one basic type of incandescent light bulb was available.consumers could buy the incandescent bulb on the term "watts".
- Incandescent lamps use the filament material heated to the same temperature, the only way to increase their light output is to increase the wattage. We actually feel difference in brightnes between 60 Watt, 100Watt or 150 Watt light bulbs incandescent bulb.
- When new technology introduce the energy-saving CFL bulbs of 15 Watt CFL bulb produced the same light of a 60 Watt incandescent. A 25 Watt CFL was comparable to a 100 Watt incandescent in light output.
- Generally LEDs produce the same amount of light as an incandescent bulb that has five to six times the wattage.
- LED sources are much more efficient at converting watts to lumens. Different materials can be used within the LED sources with different light extraction efficacy so **two different LED sources can consume the same number of watts but having different lumen output.**

Watt	Approximate Lumens
25 Watt	230 to 270
35 Watt	250 to 410
40 Watt	440 to 460
50 Watt	330 to 450
60 Watt	800 to 850
75 Watt	1000 to 1100
100 Watt	1500 to 1600

Incandescent Watts	CFL Watts	LED Watts	Lumens (Brightness)
40	8 - 12	4 - 5	450
60	13 - 18	6 - 8	750 - 900
75 - 100	18 - 22	9 - 13	1100 - 1300
100	23 - 30	16 - 20	1600 - 1800
150	30 - 55	25 - 28	2600 - 2800

(3) Correlated Color temperature (CCT):

- Color temperature refers to the light's color characteristics.
- Color Temperature is measured in Kelvin.
- It refers to the **warmness or coolness of the light that bulb produces.**
- The color temperature of a light source is a numerical measurement of its color appearance.
- This temperature is based on the principle that any object will emit light if it is heated to a high enough temperature and that the color of that light will shift in a predictable manner as the temperature is increased.
- Color temperature is a description of the warmth or coolness of a light source. When a piece of metal is heated (temperature increases) the color of light it emits will change. This color begins as red in appearance and graduates to orange, yellow, white, and then blue-white to deeper colors of blue.
- Color Temperature is not an indicator of lamp heat.
- The sun, for example, rises in morning at approximately 1800 Kelvin and changes from red to orange to yellow and to white as it rises to over 5000 Kelvin at high noon. It then goes back down the scale as it sets in evening.
- The warm white ranges from about 2700k to 3800k, natural white ranges from 3800k to 4800k, pure white or daylight from about 4800k to 6000k. Cool white starts from around 6000k upwards.
- Colors and light sources from the red/orange/yellow side of the spectrum are described as warm (incandescent) and those toward the blue end are referred to as cool (natural daylight).
- In Color Temperature Value higher Kelvin temperatures (3600–5500 K) are consider cool and lower color temperatures (2700–3000 K) are considered warm.
- When choosing a color, the two considerations are important one is color rendering (How well the light shows the true color of objects) and temperature.

(a) Soft White / Warm White (2700K- 3000K):

- Warm light is preferred for living spaces because it is more flattering to skin tones and clothing.
- Recommended for indoor general and task lighting applications.
- Living Rooms
- Bedrooms
- Rooms decorated in earthy tones (reds, oranges, and yellows)
- It gives effect like incident or halogen Light.

(b) Natural / Cool White (3500K- 4500K):

- Cool light is preferred for visual tasks because it produces higher contrast than warm light.
- Recommended for use in Domestic Applications.
- Warmer Whites are preferable in living and dining areas as well as reception areas to create a more relaxed environment.
- Natural Whites are preferable for kitchens and bathrooms where tasks are performed.
- Suitable for work areas where contrast is important.
- Kitchens

- Bathrooms
- Rooms decorated in airy, fresh hues (blues, greens, whites)
- It gives effect like Fluorescent Light.

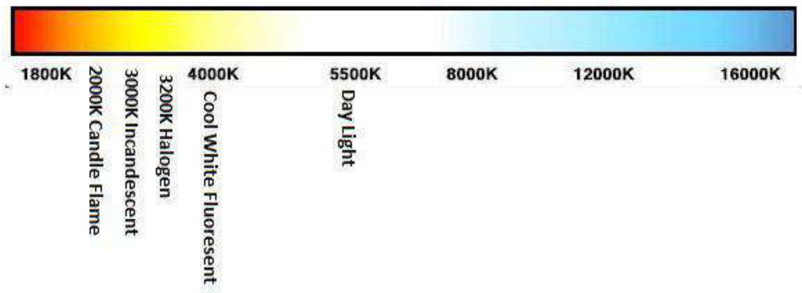
(c) Bright White (4500-5000K):

- Recommended for use in: Office

(d) Daylight / Full Spectrum (5000K- 6500K):

- Recommended for use in:
- Garages
- Offices
- Industrial and hospital areas.

Correlated Color temperature (CCT):

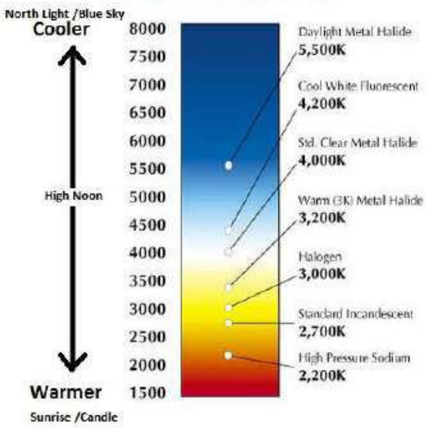


Lighting Source CCT	
Source	**Color temperature in Kelvin**
Skylight (blue sky)	12,000 - 20,000
Average summer shade	8000
Light summer shade	7100
Typical summer light (sun + sky)	6500
Daylight fluorescent	6300
Xenon short arc	6400
Overcast sky	6000
Clear mercury lamp	5900
Sunlight (noon, summer, mid-latitudes)	5400
Design white fluorescent	5200
Special fluorescents used for color evaluation	5000
Daylight photoflood	4800 - 5000
Sunlight (early morning and late afternoon)	4300
Brite White Deluxe Mercury lamp	4000
Sunlight (1 hour after dawn)	3500
Cool white fluorescent	3400
Photoflood	3400
Professional tungsten photographic lights	3200
100-watt tungsten halogen	3000
Deluxe Warm White fluorescent	2950
100-watt incandescent	2870
40-watt incandescent	2500
High-pressure sodium light	2100
Sunlight (sunrise or sunset)	2000
Candle flame	1850 – 1900
Match flame	1700
Skylight (blue sky)	12,000 - 20,000
Average summer shade	8000
Light summer shade	7100
Typical summer light (sun + sky)	6500
Daylight fluorescent	6300

Xenon short arc	6400
Overcast sky	6000
Clear mercury lamp	5900
Sunlight (noon, summer, mid-latitudes)	5400
Design white fluorescent	5200
Special fluorescents used for color evaluation	5000
Daylight photoflood	4800 - 5000
Sunlight (early morning and late afternoon)	4300
Bright White Deluxe Mercury lamp	4000
Sunlight (1 hour after dawn)	3500
Cool white fluorescent	3400
Photoflood	3400
Professional tungsten photographic lights	3200
100-watt tungsten halogen	3000
Deluxe Warm White fluorescent	2950
100-watt incandescent	2870
40-watt incandescent	2500
High-pressure sodium light	2100
Sunlight (sunrise or sunset)	2000
Candle flame	1850 – 1900
Match flame	1700

CCT – Correlated Color Temperature			
Kelvin	**Associated Effects**	**Type of Bulbs**	**Appropriate Applications**
2700°	Warm White, Very Warm White	incandescent bulbs	Homes, Libraries, Restaurants
3000°	Warm White	most halogen lamps, lightly 'whiter' than ordinary incandescent lamps	Homes, Hotel rooms and Lobbies, Restaurants, retail Stores
3500°	White	Fluorescent or CFL	Executive offices, public reception areas, supermarkets
4100°	Cool White		Office, classrooms, mass merchandisers, showrooms
5000°	Daylight	Fluorescent or CFL	Graphic industry, hospitals
6500°	Cool Daylight	Extremely 'white'	Jewelry stores, beauty salons, galleries, museums, printing

Correlated Color temperature



(4) Color Rendering Index (CRI):

- There are two standard measurements for the color characteristics of light: "color rendering index" (CRI) and "color temperature", which expresses the color appearance of the light itself.
- Color rendering index measures the ability of a light bulb to reproduce colors.

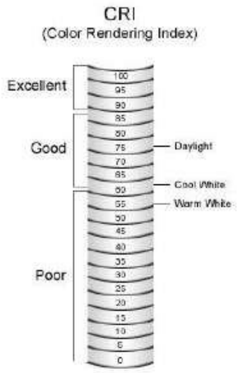
- CRI is described How artificial light source is able to render the true color of objects as seen by natural outdoor sunlight which has a CRI of 100
- The higher the CRI rating is, the better its color rendering ability.
- Color Rendering Index (CRI) is a scale from 0 to 100.Incandescent bulbs are rated at 100 and most LED bulbs are usually rated somewhere between 80 and 85
- **CRI scoring of 100 is best and a CRI of zero being the worst.**
- **CRI of 0:** For a source like a low-pressure sodium vapor lamp, which is monochromatic compare to a source like an incandescent light bulb which has CRI of 100?
- **CRI of 62:** A standard "cool white" fluorescent lamp will have a CRI near 62.
- **CRI of 70:** Lamps with CRIs above 70 are typically used in office and living environments.
- **CRI of 82 to 86:** Compact fluorescent lamps are graded at 82-86 CRI, which is considered high quality color rendering. CRI is a more important consideration for retail lighting design than it is for office lighting.
- **CRI of 80 and above:** It is considered high and indicates that the source has good color properties.
- Incandescent lamps and daylight have a CRI of 100, the highest possible CRI.
- The higher the CRI of the light source, the "true" it renders color.
- The CRI can only be used to compare two light sources that have the same color temperature. A 5000 K, 80 CRI light source is not necessarily superior to a 4000 K, 70 CRI light source.

Color Rendering Index	
Light source	**CRI**
clear mercury	17
white deluxe mercury	45
warm white fluorescent tube	55
cool white fluorescent tube	65
deluxe warm white fluorescent	73
daylight fluorescent	79
metal halide 4200K	85
deluxe cool white fluorescent	86
metal halide 5400K	93
low pressure sodium	0-18
high pressure sodium	25
100-watt incandescent	100

Color Temperature & CRI		
Lighting source	**Color Temperature**	**Color Rendering Index**
High Pressure Sodium Lamp	2100K	25
Incandescent Lamp	2700K	100
Tungsten Halogen Lamp	3200K	95
Tungsten Halogen Lamp	3200K	62
Clear Metal Halide Lamp	5500K	60
Natural Sun Light	5000K to 6000K	100
Day Light Bulb	6400K	80

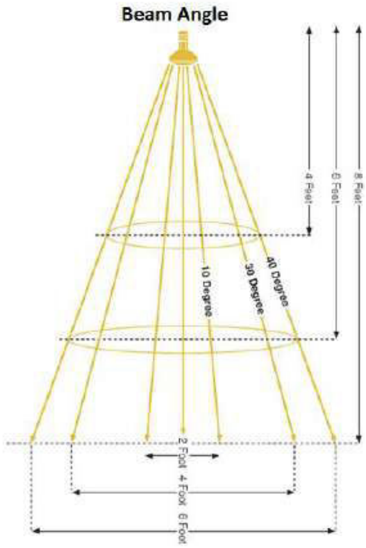
Color Temperature & CRI			
Kelvin	Light Effect	CCT	CRI
Below 3600K	Incandescent Fluorescent (IF)	2750	89
Below 3600K	Deluxe warm white (WWX)	2900	82
Below 3600K	Warm white (WW)	3000	52
3200K to 4000K	White (W)	3450	57
3200K to 4000K	Natural white (N)	3600	86
Above 4000 K	Light white (LW)	4150	48
Above 4000 K	Cool white (CW)	4200	62
Above 4000 K	Daylight (D)	6300	76
Above 4000 K	Deluxe Daylight (DX)	6500	88

Above 4000 K	Sky white	8000	88



(5) Beam angle:

- How the light spreads out from the bulb (Beam Angle) is very important.
- The beam angle determines how light is spread from the bulb into a given space.
- The beam angle is the degree of width that light emanates from a light source. Specifically: The angle between those points on opposite sides of the beam axis where the intensity drops to 50% of maximum.
- Typically a narrow beam angle is a 'spot' of light and called “Spot Light”. While a broader beam angle 'floods' with light, called a flood light. There are a number of much more specific designations of beam angle.
- Beam angles of LEDs vary greatly and depend on their application. The shape of an LED bulb determines the direction light is emitted.
- Narrow Spot Beam Angle: 05-15 degrees
- Spot Beam Angle: 16-22 degrees
- Narrow flood Beam Angle: 23-32 degrees
- Flood Beam Angle: 33-45 degrees
- Wide flood Beam Angle: 45+ degrees
- Narrow angle bulbs less than 30 degrees are usually used when placing multiple down lights close to each other, such as in a hallway or when lighting cabinetry.
- Larger beam angles are used with high-power LEDs for floodlighting. If you’re replacing incandescent or halogen lamps with LEDs, make sure the beam angle is similar to the old bulb.
- Very large beam angles are sometimes found in pantries or walk-in wardrobes. As beam angle increases, we require more lumens (light output) to maintain the light’s intensity.



(6) Efficacy (Lumen / Watt):

- It is another important parameter to decide the performance of the LED bulb in terms of lumens.
- It indicates effectiveness of the light bulb by converting electrical energy into visible light energy on watts used by Lighting Bulb; hence efficacy is total lumens per watt.
- Example: 9W light bulb comes with lumens of 800 has an efficacy of 90 Lumens per Watt.

- Incandescent bulbs give us light by passing electricity through a filament which heats up and emits light. In fact, 95% of the energy in these bulbs is lost to heat and only 5% is what produces light Hence, incandescent bulbs produce only 16 lumens / watt.
- CFLs in the way they are built are more efficient and can give us between 50 to 70 lumens / watt (at least 3 times more than incandescent bulbs)
- LED bulbs on the other hand, can output up to 100 lumens / watt – which make them one of the most efficient sources of lighting.

Parameter of LED Bulbs			
Parameter	**Average**	**Good**	**Best**
Lumens/Watt	75	90	100
Power Factor	0.7	0.8	0.9
CRI	60	70	80
LED Life in Hours	15000	25000	50000

Other Technical Parameter:

(I) Instant Light:

- LED Bulbs must be instant start and gives full Lumens from Starting.
- When turning on CFLs and Fluorescent light bulbs, there is a slight hesitation before brightness is achieved, and some bulbs may flicker during warm up or even during operation.
- Unlike fluorescents, LED bulbs, like incandescent bulbs, reach full illumination as soon as they are turned on.
- LED lights produce a steady light which does not flicker.

(II) Dimming Capability:

- Earlier versions of LED bulbs had the disadvantage of not being dimmable. Today, many LED bulbs are designed to work in dimmable switches which are provided in many lamps and home lighting fixtures.
- Dimmable LEDs cost about 40% more than non-dimmable LEDs of similar wattage

(III) LED Driver:

- The main cause of LED bulb failure is the driver. The driver is a small transformer that steps down the voltage from 230V AC to a much lower DC voltage for the LED.
- It's usually located inside the back of the bulb. A poor quality driver could result in bulb failure within months. The LED chip itself rarely fails until driver fails.

LED Chip:

- LED chips are manufactured by various big and small enterprises in the world. Some Good Suppliers make LED Chip of highest quality for longer life and more reliability.
- Larger chips provide more lights, good stability against current variations, but it costs more.
- Cheap and small led chips provide less light and stability. Ceramic COB lights are totally different in terms of size; they use multiple small chips to provide more lights and stability.

(IV) Weight

- LED lights need good heat dispassion, this can be achieved by good amount of aluminum. Aluminum is generally used to provide better heat sink and extends the life of LED chip.
- A thin heat sink can provide more area with less weight but transfer enough heat for the removal.
- Some lower quality products provide 12 to 20W lights in very low weight in plastic body. These products would not perform well even in small span of time.

(V) Heating:

- Although LEDs don't produce much heat they can overheat in operation if they're not cooled correctly. Cheap LED's are less efficient, produce more heat and are more heat sensitive. Operating above 60°C can damage cheaper LED's shortening their life, reducing light output and efficiency. Generally, the higher the wattage/power of a GU10 LED bulb, the more heat it produces requiring a more thermally efficient bulb body to keep the LEDs cool. Therefore, beware of cheap higher wattage bulbs that don't have a metallic or ceramic finned body. Another issue is that higher wattage thermally efficient LED bulbs may be so large that they are no longer a suitable size.

Chapter:14 Type of Light Bulb Base & Socket

Introduction:

- A lamp holder is the device which holds a light bulb or lamp. It's important that the lamp holder is compatible with the type of bulb we want to use, with the wrong base selection will not fit in the lamp or fixture.
- Light bulb sockets are normally defined by a letter-number-letter (Third Letter is optional).
- The first letter indicates the shape of the base.
- The Second numbers indicates either the width of the base or the distance between the pins.
- The Third Letter indicates the number of pins or contacts on the lamp. The numbers are normally in millimeters.

Type of Sockets:

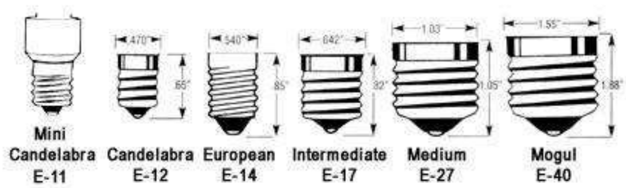
- There are different types of Socket available in market
  1. Bayonet Cap Base (B)
  2. Edison Screw Cap Base (E)
  3. Single Pin Type Base (F)
  4. Bi Pin or Multi Pin Type (G)
  5. Cable Connections (K)
  6. Pre-focused Light Base (P)
  7. Recessed Contact Base (R)
  8. Flange Base Light Bulb Base (F)
  9. Slide Base (S)
  10. Wedge Base (W)
  11. Special Type Light bulb Base (X)

(1) Bayonet Cap Base (B)

- **Type of Connection:** "push and twist" action
- **Pin Configuration:** Bxx or BCxx:
- The First letter indicates the shape or Style of the base.
- The Second number indicates the width of the base (normally in millimeters).
- **Example:** B22.
- The "B" refers to the style of Base which is a Bayonet, and the 22 means it has a 22 mm base width.
- **Application:** All Regular type of Blubs including specialist low voltage halogen lamps

(2) Edison Screw Cap (E / ES):

- Named as inventor Thomas Edison, the Edison Screw or "ES" lamp fitting is used in a vast range of applications.



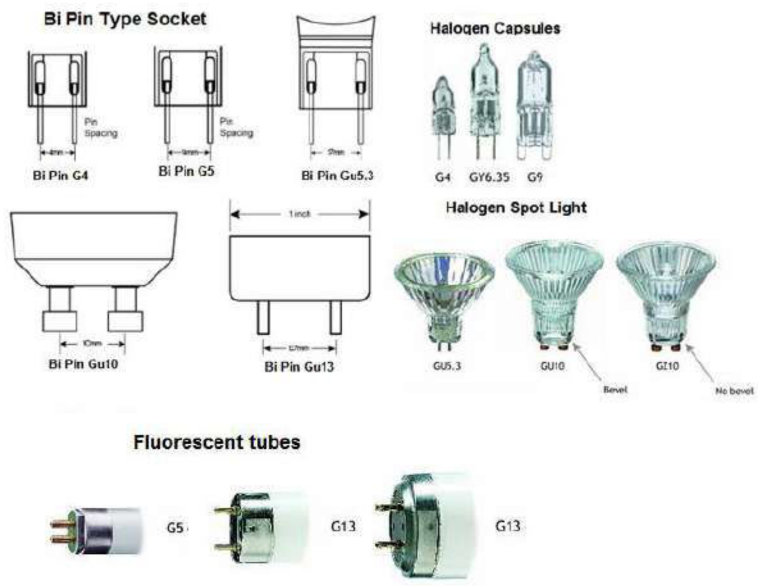
- **Type of Connection**: "Screw" Action
- **Pin Configuration: Exx or ESxx**
- The First letter indicates the shape or Style of the base.
- The Second number indicates the width of the base (normally in millimeters).
- **Example:** E26 base.
- The "E" refers to the style which is an Edison screw-in, and the 26 means it has a 26 mm base width.

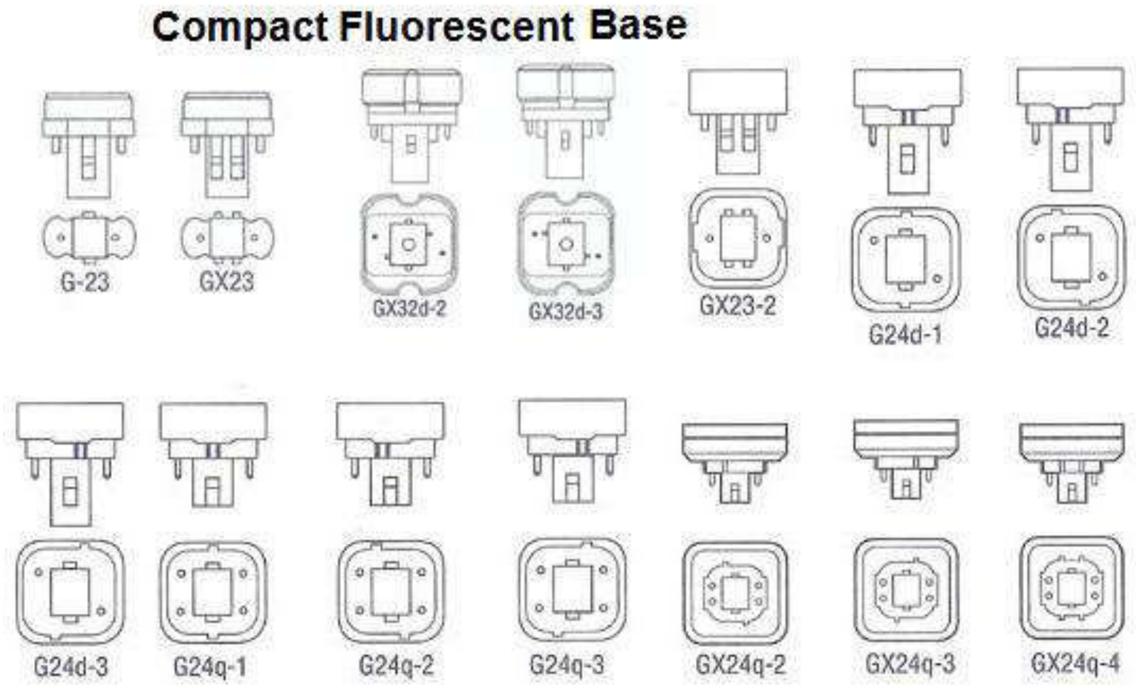
- **Application:** Large chandeliers Some Decorative Lamps.
- The most commonly used screw fittings are shown in the table below. Other, less frequently used, sizes include E11, E17 and E26.

Designation	Diameter	Name	Abbreviation
E5	5mm	Lilliput Edison Screw	LES
E10	10mm	Miniature Edison Screw	MES
E12	12mm	Candelabra Edison Screw	CES
E14	14mm	Small Edison Screw	SES
E17	17mm	Intermediate Edison Screw Base	IES
E27	27mm	Medium Edison Screw	ES
E39	39mm	Mogul or Giant Edison Screw Base	GES
E40	40mm	Giant Edison Screw	GES

(3) Bi Pin or Multiple Pin Type Base (G):

- The "G" type of lamp base is used to as a "pinned" base. This may be several Numbers of different Types of pins.
- **Type of Connection:** “Pin” Type
- **Pin Configuration:** (G(U,X,Y,Z) -xx-x-x)
- It is indicated by Letter (or Letters)-Numbers-Optional letter- Letter:
- The first letters include "G" which is followed by a Second (optional Letter) Letter U, X, Y or Z.
- The second letter (U, X, Y,Z) represents the configuration of the base, which determines the diameter and shape of the pins.
- For example, pins may be rounded, square, grooved, fat or slender.
- Without any Optional Letter = Base length is 8.25mm and Pin Diameter is 0.7mm
- For Y=Base length is >6mm and Pin Diameter is 0.7mm
- For X= Base length is <7.5mm and Pin Diameter is 1mm
- For U= Base length is >6mm and Pin Diameter is 1mm With One or Two Grip channel.
- For Z=P Base length is >6mm and Pin Diameter is 1mm without Grip Channel.
- The Third number indicates the Distance in millimeters between the centers of each pin.
- The Forth (optional Letter) Letter indicate the number of pins, no letter means 2 pins. d for double Pin ,s for Single pin, t for Triple pin or 3 pins and q for Quadruple pin or 4 pins.
- The Fifth Letter indicates position of Dowel (Slot) in Socket
- **Examples:** GU10 base type, GU24q 2Pin base type, G13d 3pin.
- For GU24q 2 Socket, U=Pin length is>6mm with diameter 1mm with Grip channel, No of Pin is 4 no’s and Dowel is on Left Side

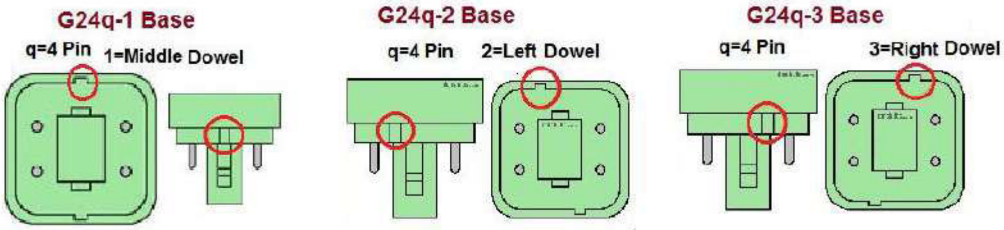




- Application: Halogen, Compact Fluorescent ,LED Types Bulbs

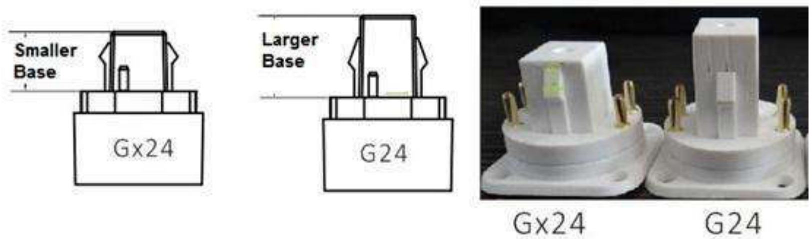
Difference between G24q-1, G24q-2, G24q-3 Type Socket

- Here G=Type/ Shape of Socket
- 24=Distance between each Pin
- q= Quadruple (Four) Pin.
- 1=Indicate Dowel (Slot) Position ,1=Middle, 2=Left, 3=Right Position



Difference between Gx24, G24 Type Socket

- In Gx24 The Base is smaller while in G24 Base is larger.



Type	Pin to pin distance	Pin Diameter	Typical Bulbs that use this base
G4	4mm	0.65-0.75mm	MR11 and other small halogens of 5/10/20 watt and 6/12 volt
GU4	4mm	0.95-1.05mm	
GY4	4mm	0.65-0.75mm	
GZ4	4mm	0.95-1.05mm	
G5	5mm		T4 and T5 fluorescent tubes

G5.3 GU5.3 GX5.3 GY5.3	5.33 mm	1.47-1.65mm	MR16 and other small bulbs typically using 12/24 volts
G6.35 GX6.35 GY6.35	6.35 mm	0.95-1.3mm	
G8	8mm		
G9	9mm		
GU10	10mm		bulbs using twist-lock bi-pin base
G13	12.7mm		T8,T10 & T12 fluorescent tubes
G23	23mm	2mm	
GU24	24mm		2 and 4 pin bases with center key
GX53	53mm		used with puck shaped lamps typically twist-lock

(4) Single Pin Type Base (F):

- The "F" type of lamp base is used to as a "pinned" base.
- This Type of socket have Single Pin.
- **Type of Connection:** "Pin" Type
- **Pin Configuration: Fx**

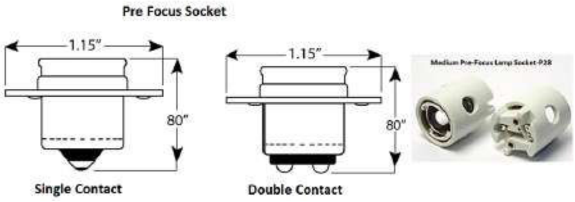
(5) Cable connected Socket (K):

- **Action:** "Cable" Type
- **Pin Configuration:** K
- K indicates that a cable is the power connection for a lamp.
- The product is a wired connection to power.

- **Example:** K4 , K6
- **Application:**
- with standardized connecting cable for electrically operated valves, mechanical position switches and valves with central connection

(6) Pre-focused Sockets (P):

- **Action:** "Push" Type
- **Pin Configuration:** P
- **Types:**
- LED light bulb pre-focus base types: S.C. Prefocus and D.C. Prefocus
- **Application:** Automobile

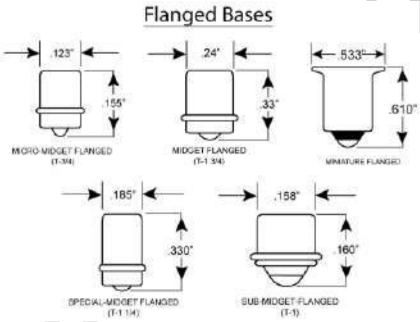


(7) Recessed Contact Base (R)

- **Action:** "Spring Loaded"
- **Pin Configuration: Rx**
- Here "R" indicate recessed Type Socket.
- Recessed Double Contact Base used for Fluorescent type lighting bulbs having high output.
- **Applications**
- For Fluorescent type lighting bulbs

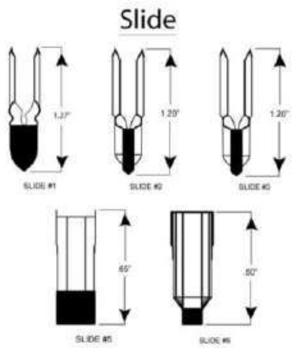
(8) Flange base Sockets (F or T):

- **Action:** "Push" Type
- **Pin Configuration:** F or T



- **Type of Flange Base Socket**: Micro-midget flanged base, Midget flanged, Miniature midget flanged, Sub-midget flanged, and Special-midget flanged base types.
- **Application:** LED light bulb, Electrical Panel, Indication Lamp, Automotive, Electronic device lighting applications.

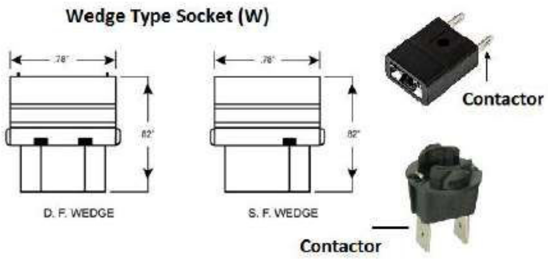
(9) Slide base Sockets (S):



- **Action:** "Push" Type
- **Pin Configuration:** S
- **Type:**
- There are various types like Slide1 ,Slide2
- Slide base LED replacement bulb is perfect for industrial indicator lights.
- It is also used as an LED pilot light bulb.

- **Applications**
- Indicator LED replacements
- LED Pilot light bulb

(10) Wedge base Sockets (W):



- **Action:** “Push” Type
- **Type:** Double Side (D.F) Contactor and Single Side (SF) Contactor
- **Pin Configuration: WX2.5x16q**
- **W** =Wedge Type, Second Letter indicate the width in millimeters and third lowercase **d** to indicate a double-contact (single-filament) bulb or **q** for a quad-contact (dual-filament) one.
- A wedge base is a type of connector used as a fitting for small light bulbs in Automobile. It is same as bi-pin connector, except that the two "pins" are the same wires that extend into the bulb (rather than being rigid), and the wires are bent up onto the sides of the base, where they make contact with the socket.
- The wires are usually inserted into a plastic base that the bulb is mounted in, and which is often narrower at the tip than at the bulb, giving it a wedge shape and usually ensuring a tight connection.
- The bulb is inserted and removed with straight in or out force, without turning as with a bayonet mount or Edison screw. compression is the force that holds the bulb in
- **Application:** In Automobile and in low-voltage lighting used in landscape lighting.

Chapter:15 Lighting Bulbs Shapes and Sizes

Introduction:

- There are various Shapes of bulbs available in market. Some lamp shape is widely used on other hand some lamp shape is used in special requirements.
- If we properly understand bulb codes, it's easy to select appropriate bulb for a light fixture.
- Bulbs shapes are mostly classified according to direction of lights, lighting glare and Bulb size.
- Every light bulb has identifying characteristics that are represented by a letter or series of letters and a number, these are known as light bulb codes.

Types of Lamps in a Lighting system

- There are following types of lamps which are available in different shapes.

1) Incandescent lamps
2) Fluorescent tube
3) Compact fluorescent lamps (CFL)
4) Halogen lamps
5) Light Emitting Diode (LED)
6) Neon lamps
7) High intensity discharge lamps

a. Metal Halide.
b. High-Pressure Sodium
c. Low-Pressure Sodium
d. Mercury Vapor

Nomenclature of Bulb:

- The Bulb Code is indicating as a **Letter-Number-Letter** format, the last letter is optional.
- The First Letter in a bulb code indicates either shape or special features such as reflector type.
- The Second Letter (Number) in a bulb code indicates size of Bulb in millimeters or eighths of an inch .It will tell us whether the bulb will fit in fixture or not.
- The Third Letter is optional which indicate Bulb length.
- Example: **BR30S**
- First Letter: BR=" Bulged Reflector"
- Second Letter = diameter of Light Bulb =30/8 inches, or 3 and 3/4 inches.
- We can say that PAR30, R30 and BR30 all have same size bulb.
- Knowing the diameter and sizes of these light bulbs is important because in some unique cases the R and PAR are interchangeable as LED bulb replacements.
- If in Code there is "**S**" or an **"L"** indication in last, that stands for either short neck or long neck.

Shapes of Lighting Bulbs:

- There are following Shapes of Lamps, Some are very common in everyday uses while some are use in special requirements.
- **According to Shape:**
  1) A (Arbitrary) Type Bulb (Code: A)
  2) B (Blunt Tip) Type Bulb (Code : C)
  3) C (Candle / Flame Tip) Type Bulb (Code : C , CA)
  4) F (Flame Tip) Type Bulb (Code : F)
  5) G (Globe) Type Bulb (Code: G)
  6) S (Straight Side) Type Bulb (Code: S)
  7) T (Tubes) Type Bulb: (Code : T,T3)
  8) Double Ended Type Bulb (Code:T3)
  9) Pear Shape Type Bulb (Code: PS)
  10) Sign Type Bulb (Code : S)
  11) H (Chimney) Type Bulb (Code: H)
- **According to Reflector:**

1) R (Reflector) Type Bulb (Code : R)
2) BR (Bulged Reflector) Type Bulb (Code : BR)
3) MR (Mirror Reflector) Type Bulb (Code : MR)
4) PAR (Parabolic Aluminized Reflector) Type Bulb (Code : PAR)

- **According to HID:**

1) E (Elliptical) Type Bulb (Code : E)
2) ED (Elliptical Dimple) Type Bulb (Code : ED)
3) ER (Elliptical Reflector) Type Bulb (Code : ER)
4) BT (Blown or Bulbous Tube) Type Bulb (Code : ET)

- **According to Application:**

1) Flood Light (Code: E)
2) Panel Light (Code: Panel Light)
3) Strip Light
4) Down Light (Code: GU)
5) Recess Down Light (Code: Down light)
6) Spot Light
7) Corn Type Bulb
8) Flat Tube
9) High Bay
10) RGB Light
11) Street Light

Lighting Bulb according to Shape:

(i) A (Arbitrary) Type Bulb (Code: A):

- A Means **"Arbitrary".** It shape looks like ordinary Light Bulb.
- It is also known as **"Classic Globe Type"** or **"Standard shape Type" Bulb.**
- This lamp is the most commonly used as household lamp.
- It is normally used in fixtures where the bulb is visible.
- It is not known that why it known as A Type. It doesn't look like an A Shape until we turn it down.
- We can assume that this is the first type of light bulb introduce in market hence it called "A" Type.
- **Nomenclature:** A35, A20.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- A15 bulb: 15/8 = 1-7/8″ diameter
- **Lighting direction:** Omni direction.
- **Bulb Technology:** incandescent, LED, CFL.

- **Application:**
- Standard / arbitrary (A) bulbs are normally widely used in Household lighting.
- These bulbs work well for a variety of applications, such as ceiling lights, lamps, vanity lights, kitchen lights, closet lights, porch light fixtures, Room lighting, Reading lamps, Ceiling Light, Wall Light and Hallways Light. It also used in some chandeliers.

(ii) B (Blunt Tip) Type Bulb (Code: B):

- "B" means Blunt-tip.
- This is a slimmer version of the Type A Bulb.
- The bulb is generally in narrow and bullet shape.

- B bulbs are very similar to C-type bulbs but they have a bulged base that tapers to a pointed tip hence look like a torpedo or bullet shape.
- It is available in **Clear or Frosted** (opal)
- **Nomenclature:** B10.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- B10 bulb: 10/8 = 1-1/4″ diameter
- **Lighting direction:** Omni direction.
- **Bulb Technology:** incandescent, LED, Tungsten-halogen, CFL.

- **Application:**
- This is most often used for decorative purposes and chandeliers, wall sconces, pendant lights.
- It is also used in low wattage applications as a home lighting applications and night lights.

(iii) C (Candle / Flame Tip) Type Bulb (Code: C, CA):

- "C" means **Conical** or **Candle** and "CA" means **Conical Angular**.
- CA bulbs are shaped like a cone but have a bent tip.
- The shape of this Bulb is look like as a candle flame and referred to as candle bulbs.
- Candelabra Light Bulbs are similar as B Shaped bulbs but bulb's tip is bent giving the slight look of a flicking flame.
- It is available in **Clear or Frosted** (opal)
- **Nomenclature:** C7.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- C7 bulb: 7/8 = 7/8″ diameter
- **Lighting direction:** Omni direction.
- **Bulb Technology:** incandescent , LED, Tungsten-halogen , CFL

- **Application:**
- These bulbs are common in chandeliers and decorative light strands, holiday light strands, pendant lights, and night lights.
- We choose a blunt shape in more contemporary chandeliers if the bulb were seen.
- It also use in low voltage application and as s night lights.

(iv) F (Flame Tip) Type Bulb (Code: F):

- "F" means **"Flame"** .
- F light bulbs are similar in size and shape to C Type light bulbs.
- However the glass of the bulb is blown or etched in such a way that causes the light to look as though it is flickering like a flame.
- This bulb comes with a white finish, but to achieve candle-like appearance, a clear finish is preferred.
- If the bulb is colored, a transparent color allows the filament to be visible.
- It is available in **clear or frosted** (opal)
- **Nomenclature:** F10.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.

- F10 bulb: 10/8 = 1-1/4″ diameter.
- **Lighting direction:** Omni direction.
- **Bulb Technology:** incandescent , LED, Tungsten-halogen , CFL

- **Application:**
- F light bulbs are used in decorative applications such as chandeliers, bathrooms, and restaurants and commercial applications.

(v) G (Globe) Type Bulb (Code: G)

- G means **"Globe".**
- Globe (G) bulbs have a full, round shape and are available in various sizes
- It is available in candelabra or medium base.

- **Nomenclature:** G15, G20.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- G15 bulb: 15/8 = 1-7/8″ diameter.
- **Lighting direction:** Omni direction.
- **Bulb Technology:** incandescent , LED, tungsten-halogen
- **Application:**
- Globe light bulbs are used in decorative applications in theatres, restaurants, and hotels
- Globe light bulbs are used in a variety of applications where a decorative ball shaped light source is required such as ceiling fans, accent fixtures, kitchen lights, bathroom and makeup vanities, chandeliers, ornamental fixtures and table lamp, wall and floor lamps.

(vi) S (Straight Side) Type Bulb (Code: S)

- "S" means **Straight Side**.
- **Nomenclature:** S20.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- S20 bulb: 20/8 = 2-1/2″ diameter
- **Lighting direction:** Uni direction.
- **Bulb Technology:** incandescent, LED, tungsten-halogen, CFL

- **Application:**
- S type miniature light bulbs are found in many applications including: indicator, auto stop and turn signal lights, scientific and medical instruments, microscopes and aircraft.

(vii) T (Tubular) Type Bulb (Code: T)

- T means **"Tubular".**
- It is known as "T" type because it has a shape of cylindrical Tube.
- (T)Tubular type light bulb is available in wide bulb technology like Incandescent, Linear fluorescent, HID and LED.
- T light bulbs have very different applications according to its shape.
- Incandescent T6 light bulbs are used in exit and stairway signs and picture lights.
- Linear fluorescent T12, T10, T8, and T5 light bulbs come in a variety of lengths, ranging from 2 to 8 feet. These light bulbs are used for general lighting in offices, retail outlets, hospitals, and parking garages.
- High intensity discharge light bulbs also come in T shapes, including T9 and T15. These light bulbs are used in sports arenas, billboard signage, and industrial applications.
- Tube Type bulbs are available in different shape like
- **Linear Tube Light Shape:**
- T12, T8 and T5 are naming convention for tube lights where "12" is the thickest and "5" is the slimmest tube light.
- **U-Bend :**
- U-Bend Tube light bulbs T8 is created by bending a 4-foot length T light bulb into a U shape in order to reduce the maximum overall length of the light bulb. This is desirable in some locations that have limited space. By bending a 4-foot light bulb into a U configuration that is comparable to a 2 foot light bulb in length, the end user will receive double the light output in the smaller space. This light bulb is used in offices, hospitals, and retail applications.
- **Spiral Shape:**
- The spiral light bulb is the shape of a compact fluorescent light bulb. A smaller diameter fluorescent T light bulb, such as T4, T3, T2, or T1, is twisted into a spiral or coil configuration in order to provide the most amount of light output in the least amount of space.
- Spiral light bulbs are typically used to replace incandescent light bulbs and can be used virtually anywhere, including residential, commercial, retail, hospitality, and restaurant applications.
- **Nomenclature:** T4, T8.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- T8 bulb: 8/8 = 1″ diameter
- **Lighting direction:** illuminates its light in Omni direction.
- **Bulb Technology:** Incandescent, CFL, High Intension Discharge Lamps, Metal Halide Lamp, Sodium Discharge, Mercury Vapor Lamp and LED.

- **Applications:**
- Depending on their size, these bulbs can be used in applications ranging from chandeliers, wall sconces, and pendant lights to basement and garage light fixtures.
- Exhibition hall, showing and advertising board
- Industry plant, workshop, warehouse
- Sports lighting, stadium, gymnasium and car parking area
- Flood lighting for tunnel, port, viaduct, Public Square and construction site etc.

(viii) Double Ended Type Bulb (Code: T3)

- It is "T" Type cylindrical Tube Blub having a both end connection.
- Double ended Bulb (T3) is installed in horizontal position.
- These light bulbs are a cost-effective alternative to standard light bulbs and a completely dimmable in multiple lighting applications
- **Nomenclature:** T3.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.

- T3 bulb: 3/8 = 0.3″ diameter
- **Lighting direction:** illuminates in Omni direction.
- **Bulb Technology:** Incandescent, Metal Halide, halogen, LED.

- **Application:**
- Mostly used in commercial lighting, ambient lighting and flood lighting.
- It can be horizontally installed. With a compact size it provides a uniform lighting for a large area.

(ix) PS (Pear shape) Type Bulbs (Code: PS)

- PS means **“Pear shape”.**
- Pear shape light bulbs are similar to A Type light bulbs, except they have a larger diameter, which causes the bulb to look like a pear.
- **Nomenclature:** PS30,PS40.
- Numbers in each code refer to the bulb’s diameter in one-eighths of an inch.
- PS15 bulb: 15/8 = 1-7/8″ diameter
- **Lighting direction:** illuminates its light in Omni direction.
- **Bulb Technology:** incandescent, LED, CFL.

- **Application:**
- Office buildings and retail stores, Radio towers, cellular towers, bridge power lines, and high tension wires.

(x) S (Sign) Type Bulbs (Code: S)

- S means **“Sign light”.**
- Sign light bulbs also known as the “original light bulb” of the incandescent.
- Sign Bulbs also used in low-wattage lights.
- Sign Bulbs come in clear, frosted and colored options.
- Sign Bulbs available in transparent amber, blue, green, pink, red and yellow.
- **Nomenclature:** S30, S40.
- Numbers in each code refer to the bulb’s diameter in one-eighths of an inch.
- S15 bulb: 15/8 = 1-7/8″ diameter
- **Lighting direction:** illuminates its light in Omni direction.
- **Bulb Technology:** incandescent, LED, CFL.

- **Application:**

- Ideal for multiple residential and commercial uses with incandescent lamps features excellent light output and good optic control along with dimming capabilities.
- Sign light bulbs are found in outdoor signs used by casinos, hotels, restaurants, and theatres.
- Sign lamps can be as simple as a way to promote your business by eye-catching company Signage installations.

Lighting Bulbs According to Reflector:

a) R (Reflector) Type Bulb (Code: R)

- "R" stands for **Reflector**.
- This light bulb contains a mirrored coating on the back of the light bulb that maximizes the direction of the light which emitted by Bulb.
- Traditionally, inside of R type Bulb was covered with a reflector material coating that used to gather light and cast it away from the bulb. Nowadays, R type bulbs have an evenly frosted coating that works to diffuse light and prevents glare.
- Unlike the PAR bulb, the entire envelope of R type bulb, excluding the base is constructed by using blown glass and the exterior part of the bulb is very smooth. The few components of this bulb which includes a brass base, a thin glass and filament make it lightweight.
- Reflective Coating of Bulb In Reflector (R) or Bulged Reflector (BR) bulbs directs light forward side , while Flood types (FL) bulb spread light and Spot types (SP) concentrate the light.
- Reflector (R) bulbs put approximately double the amount of light (Lumen) on the front central area as General Standard "A" Shape Bulb for same wattage
- **Nomenclature:** R20.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- R20 bulb: 20/8 = 2-1/2″ diameter
- **Lighting direction:** one direction.
- **Bulb Technology:** incandescent, LED, tungsten-halogen, CFL

- **Application:**
- The R type bulb is usually not waterproof but can be used in a fixture protected from the weather as long as it is not sealed.
- Reflector light bulbs are used mainly in recessed Lights for hotels, restaurants, retail and residential lighting.
- R bulbs are ideal for display lights as well as for providing soft ambient and directional light. The right place to use R bulbs is in hallways, in a kitchen, living room, media rooms or pool area.
- R Type floods provide a wider beam angle with a soft edge and are perfect for recessed down lights, track lighting, display lighting and various outdoor fixtures.

b) BR (Bulged Reflector) Type Bulb (Code: BR)

- BR stands for **"Bulged Reflector"**.
- The 'bulge' allows the light to be distributed in a manner which is very pleasing to our eye.
- R shapes have largely been replaced by the more efficient "bulged reflector" BR shape.
- BR lamps are a new and improved version of the R Type reflector lamp. The primary difference is the "bulge" in the shape of lamp. This shape focuses more light into the beam of light to direct it out of the recessed fixture.
- In traditional, the inside surface of BR bulb is covered in reflector material that is used to gather and cast a wide beam of light away from the bulb.
- It is considered a wide-angle floodlight often exceeding 100-degree beam angles.
- However, in LED BR bulbs do not require the reflector material coating.
- These bulbs can have a frosted, clear, or patterned dome-shaped lens that diffuses light and provides a gradual fade into no illuminated areas.

- **BR bulbs also produce less shadow compared to PAR bulbs.** They have a bit longer than PAR bulbs and tend to protrude from light housings but are used in similar applications, such as track lights, recessed lights, display lights, or can lights.
- As per the comparison to the R20 and BR20, the glass part of BR20 is more curved.
- One disadvantage of the BR lamp is that it's a little longer than the PAR and MR, which means it tends to sit lower in the recessed fixture and perhaps, protrude from the bottom of the recessed light fixture.
- The light transmission pattern can be clear, frosted, or even patterned.
- **Nomenclature:** BR20, BR40.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- BR20 bulb: 20/8 = 2-1/2″ diameter
- **Lighting direction:** one direction.
- **Bulb Technology:** incandescent , LED, tungsten-halogen, CFL

- **Application:**
- The BR bulbs kind of balloon out of Light fixtures. Often they are bulging down just below the ceiling from recessed fixtures.

c) MR (Mirror / Multi Reflector) Type Bulb (Code: MR)

- MR stands for **"Multi-faceted Reflector".**
- MR Bulb use mirror as a technique for reflecting the maximum light out in the front of a lamp, It help gather light from the filament to create a very concentrated light beam (narrower light beam).
- It is normally used for small lamps. It is the narrowest of the bulb types (2 inches in diameter or less) mostly used as a spotlight.
- MR Lamps provide various beam spread (narrow flood, flood and spotlight).
- LED MR doesn't require tiny mirrored squares to put the light where we want it to be.

- **Nomenclature:** MR11, MR16.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- MR11 bulb: 11/8 = 1-3/8″ diameter
- **Lighting direction:** one direction.
- **Bulb Technology:** incandescent , LED
- **Applications:**
- It is used for accent and spot lighting in various retail, residential, commercial applications, track lighting and all kinds of display case lighting.
- These bulbs are available in a variety of colors and can be used for many applications, including track lighting, recessed lighting, desk lights, and display case lighting.
- Many MR bulbs operate on low-voltage wiring systems, which makes them great for outdoor and landscape applications such as driveway lights, path lights, gazebo lights, paver lights that have weatherproof housings.
- A light bulb, often a halogen style, that plugs into the socket with two prongs, it's often used in kitchen settings.

d) PAR (Parabolic Aluminized Reflector) Type Bulb (Code: PAR)

- PAR means **"Parabolic Aluminized Reflector".**

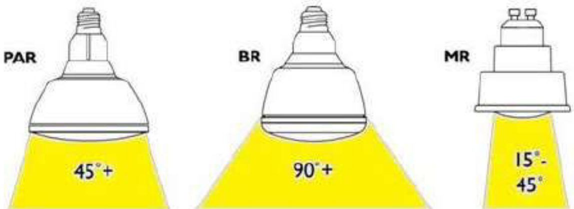
- PAR Bulb uses an aluminized reflector in a parabola shape for directing the light.
- Bulb is covered with a hard glass lens to control the light beam, which is available in a variety of beam spreads from narrow spot to wide flood. This hard glass covering also helps to withstand harsh environmental conditions.
- Parabola shape Reflector (U-shaped) collect and reflect the light out the front of the bulb, produces a tighter and more controlled beam of light than standard reflector bulbs.
- PAR bulbs are commonly used in stage and theatrical lighting, as well as in the home for accent and art lighting. Many halogen spot and flood lights use a parabolic (however this technique is generally not required in LED lamps).
- It is best used for a focused, narrow beam of light.
- Most PARs do not exceed a beam angle of 45 degrees in most cases.
- If brightness is priority in a recessed light, than we need to select a PAR lamp in the appropriate size.
- These bulbs have a shorter body than BR bulbs and usually install flush with ceilings or fixtures, which reduces glare.
- PAR's look a more modern, and often have a clear lens
- Unlike R Type bulbs, PAR bulbs feature an aluminum reflector with a special pattern of impressions that amplifies and concentrates light in a single area.
- The bulb envelope is made of two pieces, the glass face and the shiny aluminum wall of the envelope. The texture of the bulb will be either rough or textured and the bulb will be heavier than an R Type bulb due to thicker glass construction.
- Both LED PAR bulbs and CFL PAR bulbs are easy to find, though they are not always weatherproof like traditional halogen so be sure to check their IP listing before installing them outdoors.
- This PAR shape is very similar to the R shape and in some cases the PAR and R is interchangeable as per shapes but PAR LED bulbs have a shorter body than R type bulbs.
- **Nomenclature:** PAR36, PAR20.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- PAR20 bulb: 20/8 = 2-1/2″ diameter
- PAR30 bulb: 30/8 = 3-3/4″ diameter
- **Lighting direction:** PAR illuminates its light in one direction having various Beam Angles.
- 12° to 20° = Spot
- 25° to 30° = Narrow Flood
- 35° to 40° = Flood
- >45° = Wide Flood
- **Bulb Technology:** incandescent, tungsten-halogen, metal halide and LED.

- **Applications:**
- PAR Type floods provide a tighter beam angle with a hard edge and act more like a spot light and used both indoor and outdoor applications.
- PAR LEDs are perfect for track lighting, recessed lighting and Down Lighting and flood lights.
- Unlike R or BR bulbs that offer general area lighting, PAR shaped bulbs have more sharply focused light to help highlight specific areas or objects like in indoors to emphasize one area of a room over the rest of the room, or to highlight a piece of art, furniture or retail items in commercial .
- These bulbs come in a variety of "beam angles" or "beam spreads" to meet these highlighting needs; the smaller the beam angle, the smaller an area the light will cover.
- Ceiling Light Fixtures, Flood Light, soffit light fixtures, garage security light, kitchen can light.
- These bulbs run on low-voltage and suitable for outdoor fixtures as either spotlights (narrower beam angle) or floodlights (wider beam angle) and other outdoor applications like landscape lighting applications such as architectural lights, driveway lights, path lights, gazebo lights, and paver lights, clothing store, museum and gallery applications..

- They're commonly found in outdoor emergency light, spot light, or floodlight fixtures but can also be used indoors for track lights, recessed lights, display lights, or can lights.

What is difference between R,BR,MR and PAR bulbs

- ### Difference between an R and BR Bulb
- There is confusion between selecting R and BR type of Bulbs.
- There is minor difference between R and BR type Bulb.
- Both types of Bulbs have a reflector flood, and that is what the R stands for in the code.
- The R is an old design for reflectors that are not as energy efficient as a BR reflector.
- The BR was designed to replace the older R.
- For same Light output and size in length and width, BR Bulb use less watts (due to the reflector in a BR is more directed) hence BR Bulb produce less heat and more efficient.
- Both of these lamp types are interchangeable.
- BR is an upgraded version of R
- ### Difference between PAR and BR / MR Bulb:
- The main difference between PAR and MR is according to its Size, variety, and heat transformation.
- The primary difference between these bulbs is according to Beam Angle, internal construction and as per Reflector.
- **Different Type of Beam Angles.**
- BR (for bulged reflector) bulbs are lamps with "wide flood" beam angles, which means that they provide more than a 45 degree angle when lighting an area.
- PAR (Parabolic Aluminized Reflector) bulbs are available in these angles:
- Narrow spot (5 to 15 degrees)
- Spot, (16 to 22 degrees)
- Narrow flood,(23 to 32 degrees)
- Flood, (33 to 45 degrees(
- Wide flood beam, over 45 degrees.



- **Different Type of Reflector and Application of Bulb.**
- The BR bulbs have a frosted/patterned coating of reflector (for broad beam angle) allows to less concentrated light and provides better coverage thus eliminating shadows in the intended area hence **BR Bulb produces less shadow than PAR bulbs.**
- BR Bulbs are commonly used indoors in household ceilings like in kitchens, family rooms, and stair lighting with high ceilings with recessed type.
- The reflective surface of PAR does not allow light to spread much further than the angle of the beam spread hence PAR lamps deliver strong, narrow to wide, directional light , which is little harsher where the light starts and where it ends.
- A PAR bulb is used in indoor/outdoor security lighting, theatre, performance sets, and spot-lighting signs and restaurant lighting applications as well.
- **Different Type of Construction and Heat dissipation.**
- BR bulbs are a common reflector lamp with a bulged reflector. They are incandescent, LED bulbs. The sides of the outer part of the blown glass bulb are coated with a reflecting material that directs light. The light transmission pattern can be clear, frosted, or even patterned.

- PAR bulbs are incandescent, tungsten-halogen, metal halide, LED Bulbs. They have a hard glass cover which is hermetically (airtight) sealed to the reflecting surface. Inside there is a lenses that controls beam spread and cannot be altered in position in relation to the filament. There are flood bulbs and spot bulbs. Flood bulbs diffuse or scatter light, while spots focus all light in one direction.
- **MR type bulbs have dichotic glass reflectors while PAR bulbs have aluminized glass reflectors** which direct the heat generated by the bulb to the front of the bulb. Due of this, PAR bulbs are not suitable for ceiling installations of 8 feet or lower.
- PAR bulbs also produce more directional yet duller lighting and have a standard, medium screw-in type of base and work in medium sized E26 sockets.
- MR on the other hand, generates heat to the rear of the bulb and produces a lot more light for the wattage because of the multi-faceted reflector (MR).

Lighting Bulb according to HID Technology:

(1) E (Elliptical) Type HID Bulbs (Code: E)

- E means HID Type light bulb that has a shape of **"Elliptical".**
- E Type Halogen light bulbs can be used to replace incandescent light bulbs. High intensity discharge light bulbs.
- **Nomenclature:** E28.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- E20 bulb: 20/8 = 2-1/2″ diameter
- **Lighting direction:** illuminates its light in one direction.
- **Bulb Technology:** incandescent, CFL, High Intension Discharge Lamps, Metal Halide Lamp, Sodium Discharge, Mercury Vapor Lamp and LED.

(2) ED (Elliptical Dimple) Type HID Bulbs (Code: ED)

- ED means **"Elliptical Dimple".**
- ED light bulbs have an elliptical shape to house the arc tube of a high intensity discharge light bulb.
- They are not as efficient as their alternatives, but their use may be dictated by color rendering requirements. The lamps require only ballast for additional control.
- Inside surfaces coated with europium-activated phosphor which converts the UV elements in 'warm' light to produce a cool white light. They are an acceptable alternative to fluorescent lighting
- **Nomenclature:** ED17.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- EDR20 bulb: 20/8 = 2-1/2″ diameter
- **Lighting direction:** illuminates its light in one direction.
- **Bulb Technology:** High Intension Discharge Lamps, Metal Halide Lamp, Sodium Discharge, Mercury Vapor Lamp and LED.

- **Applications:**
- ED light bulbs are used in sports arenas, high bay industrial lighting, parking lots and garages and car dealerships.
- These lamps are used in some industrial, warehousing applications as a floodlight and other suitable light fittings with appropriate ballast gear.
- **FEATURES & BENEFITS**

- Metal Halide HID light bulb produces high light output
- Ideal for various commercial and industrial applications where color rendering is important
- **RECOMMENDED USES**
- Retail areas
- Area lighting
- Accent lighting
- Sports lighting
- Security lighting
- Parking garages

(3) ER (Elliptical Reflector) Type HID Bulbs (Code: ER)

- ER means **"Elliptical Reflector".**
- In ER bulb, the elliptical reflector increases the overall lumen output by redirecting side light of Bulb (Which is normally lost) to the redirect it to the forward Side of Bulb.
- Elliptical (ellipsoidal) reflector light bulbs are uniquely designed to project light further than other reflector bulbs. They are a great option for use in deep recessed can lights as they lose less light in baffles than standard BR or R type bulbs.
- ER halogen light bulbs can be used to replace incandescent light bulbs. High intensity discharge light bulbs.
- An incandescent lamp with a built-in elliptically-shaped reflecting surface. This shape produces a focal point directly in front of the lamp which reduces the light absorption in some types of luminaires. It is particularly effective at increasing the efficacy of baffled down lights.
- **Nomenclature:** ER28, ER37.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- ER20 bulb: 20/8 = 2-1/2″ diameter
- ER30 bulb: 30/8 = 3-3/4″ diameter
- ER36 bulb: 36/8 = 4-1/2″ diameter
- **Lighting direction:** illuminates its light in one direction.
- **Bulb Technology:** incandescent, CFL, High Intension Discharge Lamps, Metal Halide Lamp, Sodium Discharge, Mercury Vapor Lamp and LED.

- **Applications:**
- The most common size is ER30. These light bulbs are used for down lighting in recessed cans for residential, hotel, and office applications.

(4) BT (Blown or Bulbous Tube) Type HID Bulbs (Code: ET)

- BT means **"Blown or Bulbous Tube".**
- (BT)The blown tube light bulb is a HID Tube Type (T) light bulb that has had the glass blown in the middle so that it appears to have a bubble in the middle of the tube.
- BT halogen light bulbs can be used to replace incandescent light bulbs.
- **Nomenclature:** BT28, BT37.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- BTR20 bulb: 20/8 = 2-1/2″ diameter
- **Lighting direction:** illuminates its light in one direction.
- **Bulb Technology:** High Intension Discharge Lamps, Metal Halide Lamp, Sodium Discharge, Mercury Vapor Lamp and LED.

- **Applications:**
- These are used in sports arenas, car dealerships, canopy lighting, and industrial applications.

Lighting Bulb according to Applications:

a) Flood Light (Code: F)

- A flood light is a large, powerful fixture which has a wide beam spread.
- It is a high-intensity to illuminate a large area. Most often used outside.
- Floodlights are mostly used to illuminate outdoor playing fields and sports events. It can also be used indoors for lighting stages to create an artificial daytime setting.
- When choosing a floodlight, some points to be considering like Fixture types, Bulb Type, Type of mounting wall-mounted, ground-mounted and post top.
- **Nomenclature:** F40, F20.
- Numbers in each code refer to the bulb's diameter in one-eighths of an inch.
- **Bulb Technology:** Fluorescent , Metal halide lamps, LED, Halogen

- **Application:**
- Advertisement board and Subway
- Airport and Architecture lighting
- Football and tennis field
- Tunnels and parks
- Clubs, Bars, Hotels and Art galleries
- Villa and parking lot

b) Panel Lighting:

- LED panel lights are very thin either surface or recessed mounted ceiling light.
- Panel lights are square, Round or rectangular.
- LED panel lights are high-grade indoor lighting lamps.
- They are made of aluminum alloy by anodic oxidation.
- It has simple design and appearance with adorable illumination effects.
- It comes with different powers like 12W, 18W, 21W, 36W, 48W, 72W, and 85W.
- It used for home application and easy to install by recessed application with clamping springs.
- Recess mounted Slim Circular type LED color changing panel light in white finish with anti-glare diffuser and separate energy efficient electronic driver.

Panel Light Surface Panel Light Panel Light

- **Nomenclature:** Panel
- **Lighting direction:** illuminates its light in one direction.

- **Bulb Technology:** LED, CFL.
- **Applications:**
- Low-profile 6" Round LED Panel Light for kitchen lighting, living room lighting, office lighting, basement lighting, museum lighting, hospital lighting.

c) Down Light

- Downlights in help to create a feeling of more space, clean lines, and a clutter-free environment.
- A downlight is mostly hidden in or above the ceiling. The only visible part of the light fitting is the decorative rim, and the light bulb in the middle. Everything else is held in place in the ceiling by spring clips that stop the whole thing giving in to gravity and falling out.

- **Nomenclature:** Down Light.
- **Lighting direction:** illuminates its light in one direction.
- **Bulb Technology:** LED, CFL.
- **Applications:**
- Downlight especially in kitchens and bathrooms have become very popular, as they provide a modern appearance to the room. More recently the trend has spread to every other room. Lounges, bedrooms and hallways all look great when fitted with recessed downlight.

Difference Between Panel Light and Down Light.

- There is confusion between Panel light and Down Lights. Both Lights are either Round or Square shaped, so we cannot easily difference between them.
- There are some differences between LED panel light and downlight in following points.
- **Structure:**
- Both have a diffuser to spread out light. The panel light has a light guide plate (LGP) which guides light across the panel so that it is evenly spread. There is a reflector plate right at the back of the LED guide plate (LGP) which reflect lighting source.
- The downlight does not have this type of arrangement.
- **Lighting:**
- Inside LED panel light, the LED is fitted around (In a circular frame). The LGP and the diffuser gather the light and spread it creating an evenly soft lighting.
- The downlight lighting on the other hand have a LED in the middle. Consequently, the light produced is brighter than in the round panel light.
- **Size of Heat Sink:**
- Typically, the downlight has a thicker heat sink than the panel light.
- **Fixture Thickness:**
- LED panel light is super thin, looks simple but stylish.
- **Fixture Size Vs Lumen:**
- To spread light uniformly all Panel light are made with high dimension fixture. As you increase output watt you will have to choose bigger and bigger.
- **Power Saving:**
- Panel lights are less power saver compared to Down Light.
- Panel lights have efficiency of only 60-80 Lm/watt compared to down light which has efficiency of 100-120 Lm/watt.
- **Applications:**
- If you are looking for bright LED lighting, your best choice will be the downlight. However, if you are angling for a softer and relatively polished feel to the room, then go for the round panel.

d) Strip Light

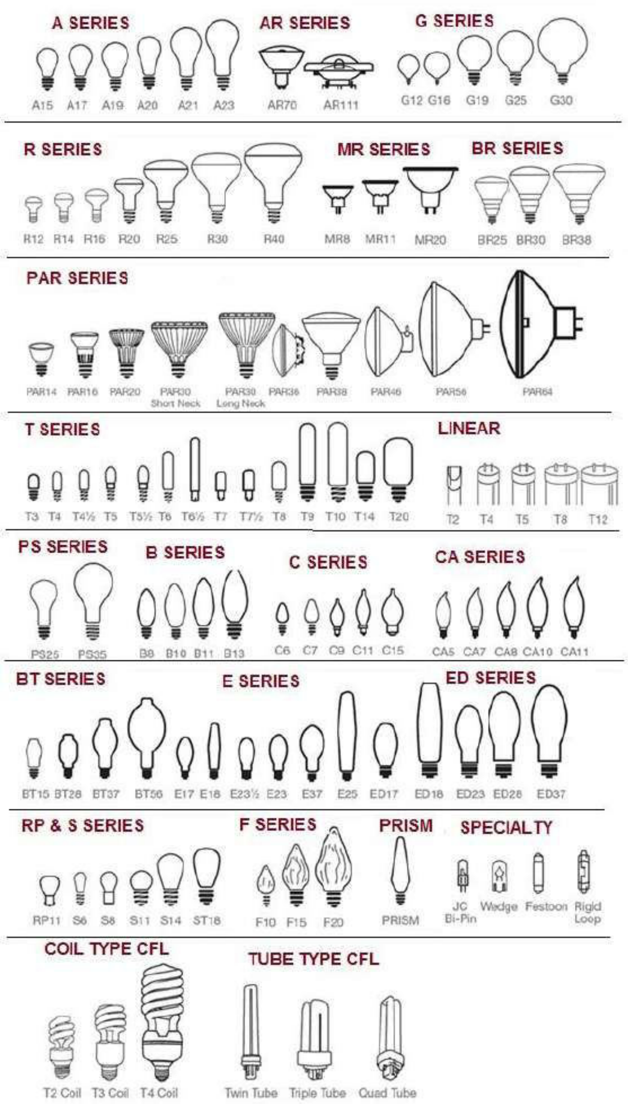
- Strip lights are available in both tape and rope configurations.

- **Nomenclature:** Strip
- **Lighting direction:** illuminates its light in one direction.
- **Bulb Technology:** LED
- **Applications:**
- Under-counter Lights, cove Lights, Display lighting and Exterior Lighting

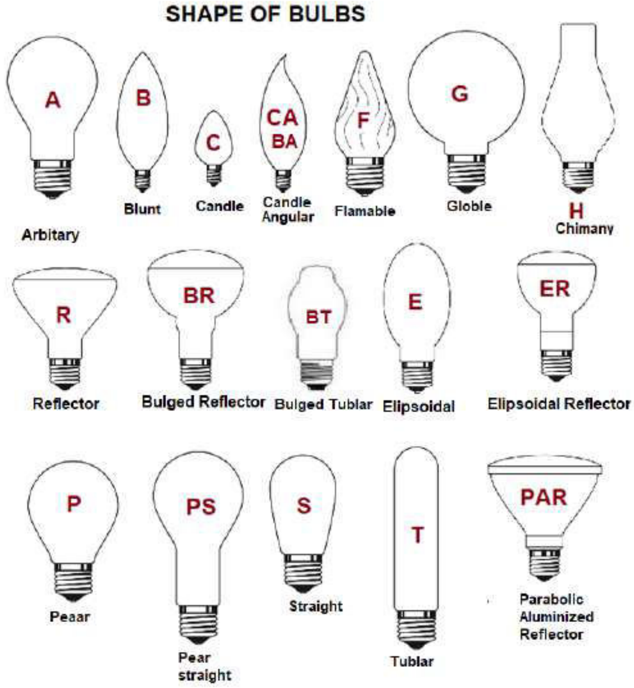
Bulb Shapes and Applications			
Code	**Bulb Shape Designations**	**Type of Bulbs**	**Applications**
A	Arbitrary	Incandescent ,CFL ,LED, Metal Halide, High Pressure Sodium ,Mercury vapor,	In household light. Table lamps. Wall Light, Ceiling lights.
AR	Arbitrary with Reflector	Incandescent ,CFL ,LED, Metal Halide, High Pressure Sodium ,Mercury vapor,	In household light. Table lamps. Wall Light, Ceiling lights.
B	Bulged	Incandescent ,CFL ,HID,LED	In various light fixtures, Decorative Lights.
BT	Blown Tubular	Incandescent ,CFL ,HID,LED	Less in general used, In various light fixtures. Table Lamp.
BR	Bulged Reflector	Incandescent ,CFL ,HID,LED	In Track lighting (spot lights) In recessed lighting.
MR	Mirror Reflector	LED	In Track lighting
C	Candle	Incandescent ,CFL ,HID,LED	Widely used in ceiling and table chandeliers and decorative light fixtures. In small appliances and indicator lamps They have a smaller base.
CA	Candle Angular	Incandescent ,CFL ,HID,LED	Like Candle bulbs, used in chandeliers and similar light fixtures. They also often have a smaller base.
CW	Candle Twisted	Incandescent ,CFL ,HID,LED	These are used in chandeliers and have smaller bases.
CP	Crystalline Pear	Incandescent ,CFL ,HID,LED	Used in various decorative light fixtures in wall lights, ceiling lights and table lamps. To create interesting reflective effects.
E	Ellipsoidal	Incandescent ,CFL ,HID,LED	Widely used in various light fixtures.
ER	Extended Reflector	Incandescent ,CFL ,HID,LED	in track lighting and other fixtures for spot lights.
F	Flambeau	Incandescent ,CFL ,HID,LED	in chandeliers and similar decorative interior lighting fixtures.
G	Globe	Incandescent ,CFL ,HID,LED	Widely used in ceiling and table lamps. in Bathrooms. In ornamental lighting and some

			floodlights
GA	Decorator	Incandescent ,CFL ,LED	Used in ceiling lamps, table lamps and other decorative fixtures.
HX	Hexagonal Candle	Incandescent ,CFL ,LED	Used in chandeliers and other decorative light fixtures to create beautiful reflective light effects.
P	Pear	Incandescent ,CFL ,LED	Used in various light fixtures. In standard for streetcar and locomotive headlights
PAR	Parabolic Aluminum Reflector	Incandescent, CFL ,LED	Widely used in track lighting and spot light fixtures. used in floodlights
PC	Ogive	Incandescent, CFL ,LED	Used in decorative light fixtures.
PS	Pear Straight	Incandescent, CFL ,LED	Used in various light fixtures.
R	Reflector	Incandescent, CFL ,LED	Widely used in Recessed cans and track lighting ,spot light fixtures.
S	Straight Sided	Incandescent ,CFL ,LED	Used in various light fixtures. lower wattage lamp as sign and decorative
ST	Straight Tubular	Incandescent ,CFL ,LED	Used in various light fixtures.
T	Tubular	Incandescent ,CFL ,LED	Used in various light fixtures according to functional rather than decorative purposes. Showcase and appliance lighting =In closets/garages.
TA	Tubular Angular	Incandescent, CFL ,LED	Used in various light fixtures, often for decorative effect.

TYPES OF BULBS



SHAPE OF BULBS



Incandescent Bulb Shapes

Compact Fluorescent Bulb Shapes

Halogen Bulb Shapes

HID Bulb Shpes

LED Bulb Shapes

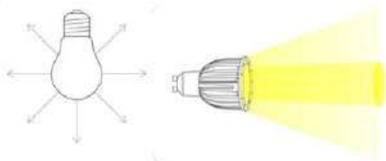
Chapter:16 What is Fixture's Beam Angle & Beam Diameter

Introduction:

- Lamps are available with multiple beam angle options hence Beam angle is an important factor in lighting design.
- The beam angle is the width of light that is emanated from the bulb and it is measured in degrees and can vary according to the different styles of bulbs.
- The beam angle of the Light is mainly depend ceiling height or distance of an object from the light source, and the lux level (brightness) which is required for a particular object or floor area.

Light Terminology

- **Lumens:** Lumen is the total amount of light emitted by that lamp in all directions.
- The luminous flux (Lumen) is provided by lamp manufacturers and common lumen values are included on the lamp.



- **Lux:** It is amount of illumination intensity in specified direction of specified area.
- Lumen is related to lux. one lux is one lumen per square meter.
- **1 lux = 1 lumen/m²**
- Lux is simply the amount of lumens in a specified area.
- Lux is measured on a distance of 1 or 10 meters.

Difference between Lumen and Lux:

- The difference between the lumen and lux is that the lux takes into account the area over which the luminous flux (Lumen) is spread.
- A flux of 1000 lumens, concentrated into an area of 1 square meter lights with a luminance of 1000 lux.
- The same 1000 lumens, spread out over 10 square meters, produces a dimmer illuminance of only 100 lux.
- Mathematically, **1 lux = 1 lm/m².**
- Lumens are measured in all directions from the light source. This is not the best measurement to describe how bright a light is going to be on a specific area.
- To perfect describe How much lights going to on Specified area, luminance lux or foot-candle are used.
- Lux changes according to beam angle and height

Difference between Beam Angle, Field Angle and Cut off Angle:

Beam Angle:

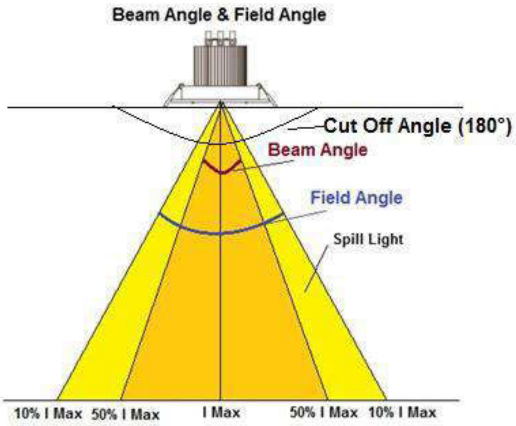
- The beam angle is the **degree of width** that light **emits from a light source**.
- Beam Angle is the angle of the light between two points of 50% of Maximum intensity.
- It helpful in knowing how much "usable" light the fixture puts out in a fairly even field.

Field angle:

- It is the angle between the two directions opposed to each other over the beam axis for which the luminous intensity is 10% that of the maximum luminous intensity.
- In certain fields of applications the field angle was formerly called beam angle.
- This angle tells you how far the light reaches until it (basically) fades into the darkness.

Cut off Angle:

- This the angle which encompasses all forward light emitted by the directional lamp



Relation between Beam Angle and Filed Angle:

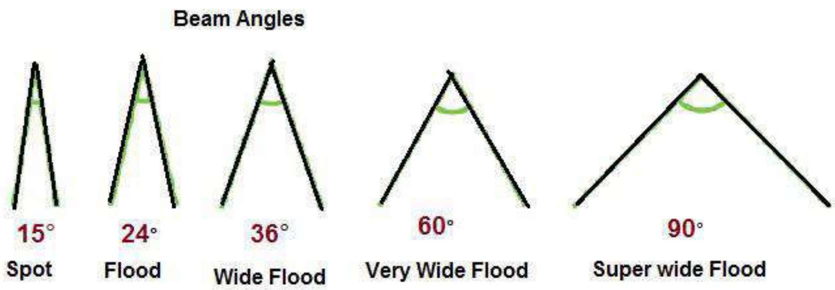
- The Beam and Field Angles determine how a spot light lights the surrounding area.
- Normally, the field angle should be **180 degrees**, because that creates a softer transition at the edge of the beam angle.
- If we change the default field angle to 180 to 75 this should give better results and it tighter angle, then over rider it.

Changing Field Angle with Same Beam Angle

Beam Angle=60 & Field Angle=180 (Default) Beam Angle=60 & Field Angle=75

Selecting Beam Angle for various Applications:

- Beam angle is an important factor in lighting design and Lamps are often available with multiple beam angle options.
- The beam angle of the Light we choose is determined initially by the ceiling height or distance of an object from the light source, and the lux level (brightness) that is required for a particular object or floor area.



- **Smaller beam angles (25° to 45° degrees):**
- It will produce a more focused beam of higher intensity and are more suited to spot lighting in commercial or artistic applications.
- Buildings with very high ceilings of 3m or greater may also benefit from more focused beam angles.
- **Medium beam angle (40 degrees):**
- This is a medium spread beam that offers a good combination of intensity and coverage.
- **Wider beam angles (60 degrees):**
- Very popular for Down lights. A 60 degree beam can be used more effectively in larger rooms. Although the wider beam spread doesn't provide more light, it does spread the light out further. If we need higher brightness, higher lumen output down lights will be required as a down lights for a good level of uniformity.
- **Larger beam angles (60° to 135° degrees):**

- It will produce a broader beam suited for most residential applications or ambient lighting in commercial applications.
- They are also useful in lower ceiling applications (< 3m). Whereas a 45° beam spread may be more useful in higher ceiling applications or for corridor lighting.
- A bulb with a wide beam angle ensures to get a really clear, even light.
- The spread of light makes no dark areas in the room; and can allow you to use fewer bulbs.
- **Very Larger beam angles (120° degrees):**
- LED light bulbs of 120° or greater are used in high light dispersion applications in place of traditional incandescent or CFL light bulbs or T5, T8 and T12 fluorescent tubes. While 60° to 90° LED light bulbs are more common halogen down light replacements.

Various Beam Angle as per Applications			
(MR Type) Flood Light	**(PAR Type) Spot Light**	**Descriptions**	**Applications**
<7°	<15°	Very Narrow Spot	Highlight a small statue or figure on display in a museum or in a jewelry store to make diamonds "pop."
5° to 15°	15° to 30°	Narrow spot	Special or sale item or in landscape bullets illuminating a sign or garden feature.
16° to 22°	30° to 60°	spot	Used in stores to highlight a special or sale area or outdoors to illuminate an architectural feature.
23° to 32°	60° to 90°	Narrow flood	highlight a display table, while homes might use this bulb in recessed eyeball lights to illuminate a painting
32° to 45°	90° to 120°	flood	Pendant lights in coffee shops to recessed lights in living rooms.
45° to 60°	120° to 160°	Wide flood	Common in many general illumination applications from motion-sensing lights above garage doors to recessed cans in auditoriums and movie theaters.
>60°	>160°	Very wide flood	used to illuminate without highlighting any particular object or area. They're good options for outdoor flood lighting and low-ceiling recessed lights.

Ceiling Height and Beam angle	
Ceiling Height	**Beam Angle**
2.5 to 3.5 meters	60° beam angle
3.5 to 4.5 meters	38° or 40° beam angle
5 meters	24° to 30° beam angle

How to Measure Beam Spread Diameter at Floor:

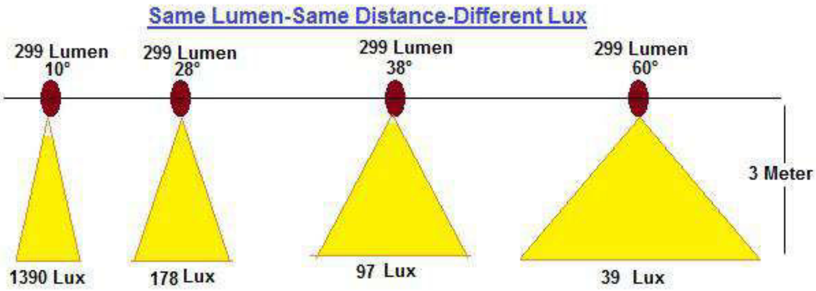
- If we install lights at a certain height then how much light will be on the surface will be calculated by following equation.
- **Diameter of light Speared on Floor = 0.018 × Beam angle × The distance**
- For example if we need to calculate the diameter of light for a spotlight of 14° at 3 meter distance.
- Diameter of Light Spread on Floor=0.018×14×3=0.756

- As light moves away from a light source, it spreads out and becomes less intense.
- The beam spread chart below gives a quick reference for common light angles and distances.

Beam Spread at various Beam angle and distance				
Beam Angle	**At 5 Feet**	**At 10 Feet**	**At 15 Feet**	**At 20 Feet**
10°	0.9 feet	1.8 feet	2.7 feet	3.6 feet
15°	1.35 feet	2.7 feet	4.05 feet	5.4 feet
20°	1.8 feet	3.6 feet	5.4 feet	7.2 feet
25°	2.25 feet	4.5 feet	6.75 feet	9 feet
40°	3.6 feet	7.2 feet	10.8 feet	14.4 feet
60°	5.4 feet	10.8 feet	16.2 feet	21.6 feet
90°	8.1 feet	16.2 feet	24.3 feet	32.4 feet
120°	10.8 feet	21.6 feet	32.4 feet	43.2 feet

Lamp has Same Lumen but Different Lux due to change in Beam Angle:

- Amount of Lux at Floor is depending upon Distance between lamp and working floor and Beam Angle of Lamp.



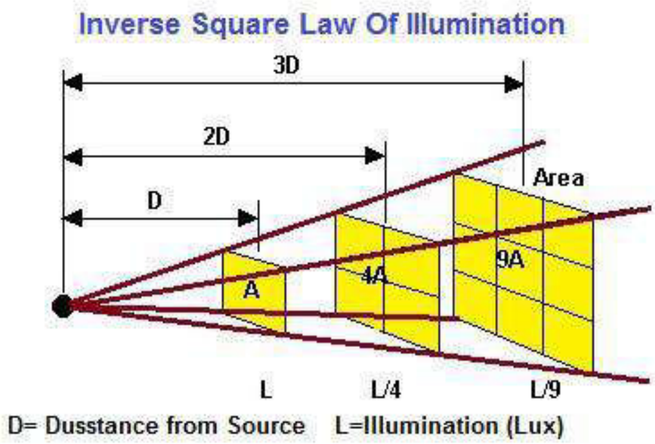
- If the Lumens and distance between working plan and lamp is the same for all the four lights having beam angle of 10°,28°,38° and 60°.
- The amount of Lux at working plan is different. At narrow beam angle 10° it is more Lux at the center of Light (1390 Lux) and it will be reduce as we move from the center. While for wide angle 60° it is less Lux at the Center (39 Lux).

Narrow Beam Angle have Good Light (Lux) at Central

- A LED light bulb with a narrower beam angle may also seem brighter but the overall total luminous flux (Lumen) will be the same as the same LED light bulb with a lens which produces a wider beam angle. The brighter light is created by focusing the light within a more localized area, much like a magnifying glass can be used to focus the light of the sun. This is sometimes referred to the angular intensity of the light.
- If we use a narrower beam angle, we will increase light intensity but reduce the size of the area being illuminated for the same height.
- The 10 degree beam will be brightest in the center; however, the lux drops very fast away from the center. Thus, it totally is wrong to conclude that 10 degree beam is brighter than the 60 degree beam and hence10 degree beam is a better light.
- The 60 degree beam has low center lux because it has more light spread over a larger area. The 10 degree beam is good to provide spot lighting. The 60 degree beam may be good for different lighting ambiance.

Illumination as per Distance (Inverse Square Law of Illumination):

- Only natural light provides even illumination on earth even though it pass from clouds, environment and shadows.
- But all artificial light are affected from various factor and when the distance increases from the light source then the illuminance reduces according to distance.
- This is phenomena is called the inverse square law of illumination where the illuminance falls to a quarter of its value if the distance is doubled.



- As the luminous flux (Lumen) travels away from the light source the area over which it spreads increases, therefore the illuminance (lux) must decrease. The relationship is called as the inverse square law.
- **Illumination (E) = Lighting Intensity (Lumen) / (Distance)2**
- The inverse square law describes how the intensity of a light is inversely proportional to the square of the distance from the light source (the illuminator).
- As light travels away from the point source it spreads both horizontally and vertically and therefore intensity decreases. In practice this means that if an object is moved from a given point, to a point double the distance from the light source it will receive only a ¼ of the light (2 times the distance squared = 4).
- Taking this theory further, if an object at 10m from a light source receives 100 LUX, moving the object to 40m, it will receive only 1/16th of the light (4 times the distance, squared = 16) resulting in the object receiving only 6.25 LUX.

Chapter:17 Difference between High Bay-Low Bay and Flood Light

Introduction:

- In the lighting industry, the term "bay" means to illuminate any large area.
- High Bay fixtures and Low Bay fixtures are used to for illumination in Buildings with higher ceilings like warehouse lighting, industrial lighting, Commercial lighting, retail lighting, and gym lighting.
- High Bay Lighting and Low Bay Lighting are mounted at high level via a pendant, chain, or directly to a ceiling or ceiling girder.

Type of Lighting Fixture for Larger Area Illumination:

- There are three type of lighting fixture to illuminate large open Area
  1) Low Bay Lighting Fixtures
  2) High Bay Lighting Fixtures
  3) Flood Lights

(1) Low Bay Light Fixture.

- As the name says, these bay lights are often used with lower ceilings in open areas.
- Low bay lights are designed to illuminate open areas with ceilings Between **12 foot to 20 foot.**
- Anything use over this height treat as high bays, and anything lower is very uncommon in large open area facilities, and would require a different type of light fixture.
- The reflectors or lens for low bays also spread the light far out to maintain a desired lighting level.

Applications:

- Ware House.
- Petrol Station.
- Garage.
- Retail Store.

(2) High Bay Light Fixture.

- As their name implies, high-bay lights are used to illuminate spaces with high ceilings. That usually means ceilings ranging from **20 feet to 45 feet.**
- These light is effective at high Ceiling Level to provide well distributed and uniform light for open areas.
- They need specifically reflectors (for HPS / MH bulbs) or lens angles to ensure light reaches the floor evenly and reduces wasted light. Different kinds of reflectors can accomplish different kinds of illumination tasks for high-bay lights. Aluminum reflectors make light from the fixtures flow directly downward to the floor, while prismatic reflectors create a more diffused lighting useful for illuminating shelves and other elevated objects in a space.
- High-ceiling location has more space to fill, hence a high-bay by definition is a powerful light source that can brighten up a large area.
- High-bay lighting is provides clear, uniform lighting of what's below it with little glare.
- Numerous types of fixtures can be used as a high-bay lights like LED lights, induction lights, metal halide lights, and fluorescent lights.
- For instance, LED lights offer extremely long life and energy efficiency but require a bigger initial investment, while traditional incandescent lights are less expensive to purchase initially but don't last as long and use more energy.
- There are several types of fixtures available for high-bay lights. Round high-bay lights, linear high-bays, architectural high-bays and grid-mount high-bays.

Applications:

- Whenever a large indoor space needs to be illuminated, high bay lighting is usually appropriate. These area is typically vast and cover a lot of vertical as well as horizontal space. This need powerful lighting to provide the appropriate Lux levels to adequately illuminate.
- High bay lighting fixtures typically hang from the ceiling via hooks, chains or pendants, or they may be fixed to the ceiling directly (similar to troffer lights).
- Various industries and facilities require high bay lighting. Some of the most common are
- Warehouses.
- Industrial facilities.
- Manufacturing facilities.
- School and university gymnasiums.
- Municipal facilities like community centers or recreation centers.
- Commercial applications like department stores.
- Airport hangar or any large open area industrial and commercial space with relatively high ceilings

Choosing the Correct High Bay & Low Bay Fixture

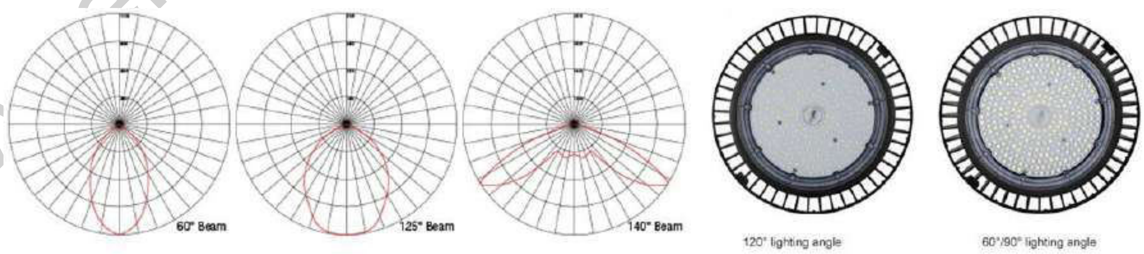
- Choosing the right High Bay fixture can make the difference between a successful lighting project or failure.
- A light designed for a warehouse is a totally different than a light designed for a gymnasium or a factory floor. In gymnasium or a factory floor, a light can distribute in the area evenly while in a warehouse, a light can light up the face of the shelves and on the path way between two shelves.

(A) Lumen Output of Lamps:

- We cannot be assumed that 100% of the lamp output will be emitted from the fitting or that the light output will be constant over its operational lifetime.
- The actual total illumination levels that can be provided by an installed commercial light fitting will depend on the Light Output Ratio:
- As an example, an industrial or warehouse high bay light fitting with a LOR of 70%, this indicates that 30% of the lamp's light output is lost due to the design of the fitting.
- The light output ratio is need to be consider in commercial lighting installation because when a lamp is positioned in a light fitting (such as an industrial 400W metal halide high bay) losses of light occur within the fitting itself.

(B) Beam Angle:

- For maximum light coverage, we need to select a beam configuration that matches the height of the high bay LED light.



- The common beam angles used for high-bay lighting are 60°, 90° and 120°.
- The narrow beam angle creates a more focused beam enabling a high lux level on the floor or the platform.
- The wider beam angle ensures large open areas with lower roof heights receive an excellent spread of light.

Beam Angle	
Beam Angle	**Ceiling Height**
140°	Up to 4 meter

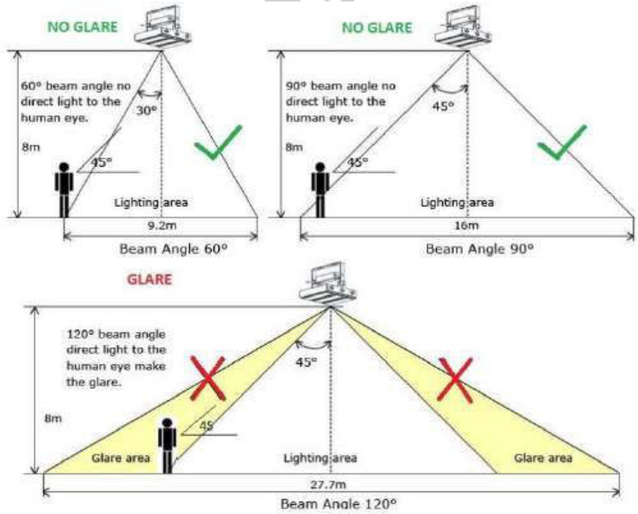
120°	4 to 6 meter
90°	6 to 8 meter
60°	8 to12 meter

Beam Angle & Applications	
Beam Angle	**Applications**
10°	Spot Lights Stadium Lights
25°	Spot Lights Stadium Lights
40°	Residential and Architectural Lighting
60°	Commercial and Industrial Lighting
90°	Commercial and Industrial Lighting
120°	Low Ceiling Gas Stations and Public Spaces
150°	Industrial Lighting Parking Garages

Beam Angle & Fitting Type	
Beam Angle	**Type of Fitting**
4° To 9°	Spot Light
20° To 35°	Flood Light
36° To 49°	Wide Flood Light
More than 60°	Very Wide Flood Light

(C) Glare:

- When there is an excessive contrast between the dark areas and bright areas in the direction of viewing, then glare can occur. When there is too much light, it will cause glare.
- Glare can happen during daytime and nighttime. Examples of where glare can occur includes moving from a shaded location into bright sunlight, and the reflection of light from a surface which is shiny.



(D) Fixtures Shape

- Circular fixtures creates circular beams; rectangular fixtures creates rectangular beams.
- Round LED high bays certainly have their universal application, but if we are going to illuminate a long workbenches or a production line, we may get more efficient results from a rectangular linear high bay

(3) Flood Light Fixture.

- A floodlight is called Flood Light because it illuminate evenly a large area with high intensity of Light.
- Flood lights are a general method for illuminating areas where a conventional mounting arrangement of Fixtures may or may not be an available and we can also change direction Light or tilt Angle.

Flood Light Fixtures

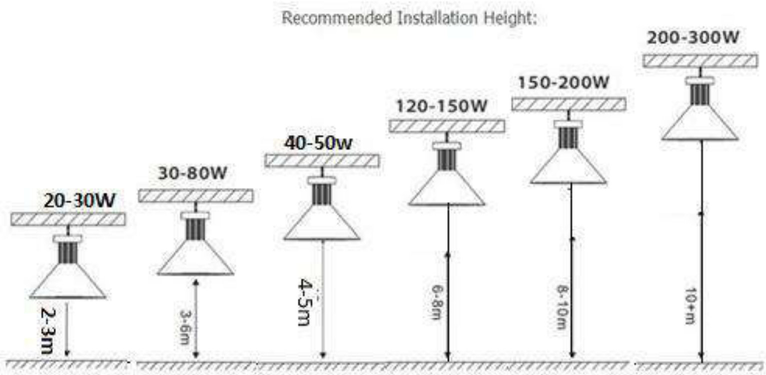
- The flood light have an asymmetric throw of light which can be angled into the space to be illuminate.
- LED flood light illuminate uniformly in all directions and its exposure range can be adjusted.
- Flood Lights utilizing light bulbs of high power to illuminate a big outdoor location.
- LED flood light is able to equably shine in all directions. Besides, the shine angels could change freely and is able to generate shadow. It is most widely used to illuminate the whole area.
- When we install floodlights, we should need to care about glare because the brightness of the fitting is high and it angled close to horizontal.
- LED Flood Light is different from spot light. Its light beam is highly diffuse without direction. Therefore, its shadow is gentle and transparency.

Applications:

- Floodlights are broad beamed, high intensity lights often used to illuminate outdoor playing fields while an outdoor sports event.
- Flood light is a good choice for lighting and decoration of construction sites, squares, parks, arts venues.
- Flood light also use as a object Lighting.
- Factory buildings, stadiums, golf courses, shops, hotels, subway stations, gas stations, buildings.
- Sculptures and other indoor and outdoor applications.

Difference between High Bay and Low Bay Lighting.

- Normally, there is a confusion between LED high bay light and LED low bay light because both looks like same and having same applications except installation height and intensity of illumination and lumen output.
- High bay and low bay fixtures both are typically suspension mounted using chains or hooks, but they may also have the option of being surface mounted depending on the fixture.
- Actually both are not same lights. There are some differences between them.
- **The wattage**
- The wattage or applications of both are different. The wattage and application determines whether to call them high bay or low bay.
- If the wattage used is above 100 Watts then it is called LED high bay. Those using below 100 Watts are called LED low bay fixtures.
- **The Mounting Height**
- LED low bay light fixtures are used in areas where the bottom of the fixture is up to 20 feet or less above the floor.
- They are usually spread the light evenly. They also contain optical refractors which cover the lamp thereby reducing glare. Their widespread distribution improves the vertical illumination and also permits spacing as much as 2 or more times the mounting height.
- LED High bay lighting fixtures, they are mostly used in areas where the bottom of the fixture is 20 feet or more above the floor.
- They allowing for a more concentrated beam spreading with a prominent downward component. High wattage is needed so as to illuminate the space properly.



Spacing between lights	
Height	**Spacing**
15 feet	12 feet to 15 feet
20 feet	15 feet to 18 feet

30 feet	20 feet to 25 feet

Height and lumens	
Height	**Spacing**
10 to 15 feet	10,000 to 15,000 lumens
15 to 20 feet	16,000 to 20,000 lumens
25 to 30 feet	33,000 lumens

Low Bay / High Bay Lighting Fixtures		
Watt	**Installation height**	**Distance Fixture To Fixture**
50 Watt	3 Meter	3 To 6 Meter
90 Watt	4 Meter	6 Meter
120 To 150 Watt	5 Meter	6 To 8 Meter
200 Watt	7 Meter	9 To 10 Meter
300 Watt	8 Meter	More than 10 Meter

Difference between Spot Light and Flood Light.

- A spotlight casts a narrow beam of light, usually no wider than 45°. This beam is more concentrated and easier to point and control.
- A floodlight can have a beam spread of up to 120°. It can illuminate a larger amount of space with the same wattage and lumen output as a spotlight.
- Flood Lights is generally utilized for highlighting the architectural appearance of an outstanding or historically Building.
- By utilizing flood lights, we can boost the in-depth framework of a building.

Determining Beam Width:

- The width of a light's beam in degrees is not always helpful. It should be much easier to know the beam width in feet, from a given distance away.
- There is a simple formula to know Beam width
- **Beam Width =Angle of Beam x 0.018 x Distance from Light Bulb**
- If we have an 80 degree floodlight, and we want to know how wide the beam will be from 10 feet away.
- Beam Width = 80 degrees x 0.018 x 10 feet = 14.4 feet wide

LED Vs Metal Halide	
LED Watt	**Metal Halide Watt**
20W to 50W	75W
30W to 75W	100W
40W to 125W	150W
50W to 175W	225W
60W to 225W	250W
80W to 250W	300W
100W to 350W	350W
120W to 400W	400W
150W to 500W	500W

Chapter:18 Various Factors for Illumination Calculations

Introduction:

- Interior and exterior lighting design requires a reasonable uniform illuminance in all working areas.
- There are two important factors in the planning or designing of lighting Scheme.
- (1) Maintenance factors (MF)
- (2) Utilization factor (UF)
- The illuminance and luminance levels in a lighting installation do not remain constant over its period of operation. Over time, they decrease due to degradation and failure of light sources, soiling of lamps and luminaires due to the reduced reflectance values of the room surfaces. At g planning stage these factors need to be consider in the head of maintenance factor.
- The right selection of maintenance factor for each lighting calculation at planning stage is depend upon some details like Type of Lighting Fixtures and Lamp, the environmental information , the cleaning intervals, Total Working Hours.
- **The Lighting Scheme may be satisfactory, economical, safe, colorful, effective and comfortable and energy efficient by choosing proper maintenance factor and utilization factor.**

Importance of Maintenance Factor and Utilization Factor:

(A) By choosing Constant M.F & U.F for any Project (Cost of Project)

- We normally choose 0.8 as a Maintenance factor as a useful rule of thumb.
- There is no reason why we choose M.F as 0.8 on every lighting installation project. Every project is different so the maintenance factor should be derive according to the circumstances and the lighting technology being used.

(B) The Location and environment Condition (Cost and Life of Luminar):

- The location where the luminaires is very important and which have an effect on light levels.
- For close area like in industrial warehouse and in office we may select open type and without waterproof Lighting Fixtures.
- For open Area, we should select close and waterproof fixtures.
- Environment condition (Pollution, Clean) should effect on light levels hence directly effect on number of luminaire and space of luminar which effect Cost of Luminar.
- For very long service life this criteria is impact on the overall maintenance factor.

(C) Service life (Energy use and Cost)

- It is very important to decide the service life of Luminar in calculations because it will lead to decisions on the initial light level and the number of installed luminaires.
- This will mainly affect the amount of lighting required and therefore have an impact on both capital and operational costs.

(D) More Lights and Over Spacing (More Energy Bills)

- The MF has a great impact on energy efficiency. If we select too much lighting in designing lighting project due to inaccurate maintenance factors, then the we will pay more electricity bills for that.

(E) The products availability and Operating Time (Project Cost)

- The correct maintenance factor for a lighting project has other benefits in terms of planning.
- If we plan a 50,000-hour life in their lighting system (for 10Years of operation), But we use Luminars only a 7 years due to lease for an office space.
- By changing this value, the LLMF will be changed and the amount of light and number of luminaires could be greatly reduced. This will save the money in the short and long-term.

Numbers of Factors for Illumination Calculation:

- There are mainly below two Factors which are important while we design Illumination.

(1) Utilization Factor (UF)
(2) Maintenance Factor (MF)

- **Equation for Required Illumination is**
- **$E = N (n \times \varphi) \times MF \times UF / A$**
- **$N = (E \times A) / MF \times UF \times (\varphi \times n)$**
- Where:
- N = Number of luminaires required

- E = Maintained Illuminance (lux)
- φ = Initial lamp output (lumens)
- n = Number of lamps in luminaire
- MF = Maintenance factor (sometimes also called light loss factor LLF)
- UF = Utilization factor
- A = Area of room (m2)

(A) UTILISATION FACTOR (UF):

- The light flux reaching at the working plane is always less than the lumen output of the lamp due to some of the light is absorbed by the various surface textures.
- Utilization Factor is Proportion of light reaching working plane to the light output of lamps.
- **UF = Lumens received on Working Plan / Lumens output of luminaires**
- The lighting manufacturers' catalogues give Utilization Factors for standard conditions.
- **The UF is expressed as a number which is always <1.**
- A typical value might be 0.9 for a modern office building.
- The Utilization Factor takes the account of Room Reflectance, Room shape, Polar distribution and Light output ratio of the fitting
- Brighter colors with high reflectance result in a higher UF.
- A high UF means Less Nos of lamps are required resulting in a more energy efficient light design.
- Utilization Factor mainly depends on
- (1) Type of light, light fitting.
- (2) Color surface of walls and ceiling.
- (3) Mounting height of lamps.
- (4) Area to be illuminated.
- (5) Room Index (Area and Mounting Height)

Room Surface Reflectance:

- To determine the UF from the luminaire data sheet it is necessary to know the average room surface reflectance.
- The ceiling is normally considered to be light in color and an average value of **70%** (or 0.7) is normally used.
- The Floor is usually considered to be dark and an average value of **20%** (or 0.2) is normally used.
- The walls, however, can vary from light to dark depending on the wall surface colors. Luminaire manufacturers usually provide UFs for three average wall reflectance of **50%, 30% and 10%.** A value of 50% applies to walls of light decor, 30% moderate decor and 10% dark decor.

Table 1.7 Typical Reflectance Factors

Color	Refelextion (%)
White	80% To 85%
Light gray	**45% To 70%**
Dark gray	**20% To 25%**
Ivory white	**70% To 85%**
Ivory	60% To 70%
Pearl gray	70% To 75%
Buff	40% To 70%
Tan	30% To 50%
Brown	20% To 40%
Green	25% To 50%
Olive	20% To 30%
Azure blue	35% To 40%
Sky blue	35% To 40%
Pink	50% To 70%
Cardinal red	20% To 25%
Red	20% To 40%

Space Height Ratio (SHR):

- The ratio of Distance between two luminaire centers, in a regular square array of luminaires, divided by their height above the working plane.

SPACING AND MOUNTING HEIGHT RATIO	
Direct Concentrating	0.40
Direct Spreading	1.20
Direct Indirect Diffusing	1.30
Semi-direct-Indirect	1.50

Room Index (RI):

- This takes account of room proportions and height of the luminaire above the working plane.
- It is used to determine the Utilization factor.
- **R.I. = L x W / (L + W) Hm**
- where
- L = Length
- W = Width
- Hm = Height of luminaire above working plane.

Utilization factor											
Room Reflectance			Room Index								
Ceiling	**Wall**	**Floor**	**0.75**	**1**	**1.25**	**1.5**	**2**	**2.5**	**3**	**4**	**5**
0.7	0.5	0.2	0.43	0.49	0.55	0.6	**0.66**	0.71	0.75	0.8	0.83
0.7	0.3	0.2	0.35	0.41	0.47	0.52	0.59	0.65	0.69	0.75	0.78
0.7	0.1	0.2	0.29	0.35	0.41	0.46	0.53	0.59	0.63	0.7	0.74
0.5	0.5	0.2	0.38	0.44	0.49	0.53	0.59	0.63	0.66	0.7	0.73
0.5	0.3	0.2	0.31	0.37	0.42	0.46	0.53	0.58	0.61	0.66	0.7
0.5	0.1	0.2	0.27	0.32	0.37	0.41	0.48	0.53	0.57	0.62	0.66
0.3	0.5	0.2	0.3	0.37	0.41	0.45	0.52	0.57	0.6	0.65	0.69
0.3	0.3	0.2	0.28	0.33	0.38	0.41	0.47	0.51	0.54	0.59	0.62
0.3	0.1	0.2	0.24	0.29	0.34	0.37	0.43	0.48	0.51	0.56	0.59
0	0	0	0.19	0.23	0.27	0.3	0.35	0.39	0.42	0.46	0.48

(B) Maintenance factor (MF) / (Light Loss factor LLF):

- The Light Loss Factor has been replaced by maintenance factor in the 1994 CIBSE Guide.
- Previously LLF and MF are differently mentioned but there is no account of the lamp lumen maintenance factor (LLMF).
- In the 1994 Guide, maintenance factor (MF), LLMF and LSF are mention.
- **MF = RSMF x LMF x LLMF x LSF**
- Lamp Lumen Maintenance Factor (LLMF) decrease in luminous flux as per aging of the light source.
- Lamp Survival Factor (LSF) takes into account the lamp's service life without immediate replacement.
- Luminaire Maintenance Factor (LMF) decrease in the output of the luminaires due to pollution.
- Room Surface Maintenance Factor (RSMF) soiling or dusting in the Room space.

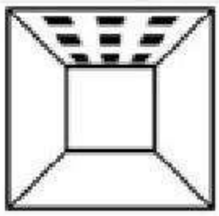
Quick Consideration of Maintenance factor			
Room Classification	**Lamp Maintenance Factor**	**Maintenance Factor for dirty lamp**	**Total Maintenance Factor**
Very clean	0.09	0.85	0.9
Clean	0.9	0.9	0.8
Average	0.9	0.8	0.7
Dirty	0.9	0.7	0.6

Environment Activity or Task Area	
Very Clean	Clean rooms, semiconductor plants, hospital clinical areas, computer centers
Clean	Offices, schools, hospital wards
Normal dirty Dirty	Shops, laboratories, restaurants, warehouses, assembly areas, workshops

	Steelworks, chemical works, foundries, welding, polishing, woodwork

Quick Consideration of Maintenance Factor	
Enclosed fixture, clean room	0.80
Average conditions	0.70
Open fixture or dirty room	0.60

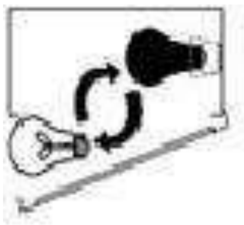
Room Surface Maintenance Factor (RSMF): (dirt on the surfaces of the room)



- It takes account of the effect of dirt and dust accumulation and other degradation of the reflectivity of the room surfaces.
- The room surface maintenance factor is the ratio of the room surfaces reflectance before and after cleaning.
- It depends highly on the conditions in a room like very clean, clean, dirty or very dirty.
- The more dirty the room, the lower the maintenance factor.
- RSMF is depending upon Room Surface Cleaning.
- RSMF does not depend on LMF and LLMF.

Room Surface Maintenance Factor (Annual Clean) – RSMF				
Type of Room	1 Year Room Clean		3 Year Room Clean	
	Direct Luminaires	Direct /Indirect Luminaires	Direct Luminaires	Direct /Indirect Luminaires
Very Clean	0.97	0.96	0.97	0.95
Clean	**0.95**	0.91	0.94	0.91
Normal	0.91	0.84	0.9	0.83
Dirty	0.86	0.75	0.86	0.75

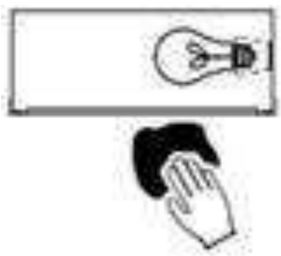
Lamp Lumen Maintenance Factor (LLMF): (Lamp Aging)



- The lamp lumen maintenance factor is the ratio of light output of a lamp, after a specified number of hour's operation, to the initial light output of the lamp.
- It is describing the ageing of the lamp or the reduction of light intensity over time. Manufacturers offer comprehensive tables about their lamps luminous flux behavior.
- **Lamp Lumen Maintenance Factor takes accounts the effect of the decrease in Lumen of the light sources during its Life time Operation.**
- The LLMF expresses the usual reduction of the luminosity over the lifetime, e.g. by a factor of 0.92 after 2000 hours. After 2,000 hours the illuminant still emits 92% of the luminosity when new.
- The lamp lumen maintenance factor considers the average decrease in luminous flux of the light source

Lamp Lumen Maintenance Factors (LLMF)					
Lamp Type	**Operating Hours**				
	4000 Hr.	**6000 Hr.**	**8000 Hr.**	**10000 Hr.**	**12000 Hr.**
High Pressure Sodium	0.98	0.97	0.94	0.91	0.9
Metal Halide	0.82	0.78	0.76	0.74	0.73
High Pressure Mercury	0.87	0.83	0.8	0.78	0.76
Low Pressure Sodium	0.98	0.96	0.93	0.9	0.87
Tubular Fluorescent	0.95	0.94	0.93	0.92	0.91
Compact Fluorescent	**0.91**	0.88	0.86	0.85	0.84

Luminaire Maintenance Factors (LMF): (Dirt on lamp)



- The luminaire maintenance factor is the ratio of the luminaires luminous flux before and after cleaning.
- It depends on the luminaire construction and design (open housing or closed one) as well as on environmental conditions (dirty or clean).
- The higher the luminaires protection degree from dust, and the cleaner the room, the higher the maintenance factor.
- LMF is depending upon Type of Laminar, Location and Frequency of cleaning.
- LMF Luminaire Maintenance Factor takes account of the effect of dust and dirt accumulation on the luminaire.
- Luminaires are classified according to their degree of sealing and their distribution, obviously dust accumulation on an open up light is far more onerous than on a sealed downlight.
- Dust and dirt build up on the rear Heatsink Increases LED temperature, lowers output and effects life

Luminar Maintenance Factor (LMF)						
IP Category	**Environment Condition**	**Expose Time**				
		1 Year	**1.5 Year**	**2 Year**	**2.5 Year**	**3 Year**
IP2X	Dirty	0.53	0.48	0.45	0.43	0.42
	Normal	0.62	0.58	0.56	0.54	0.53
	Clean	0.82	0.8	0.79	0.78	0.78
IP5X	Dirty	0.89	0.87	0.84	0.8	0.76
	Normal	0.9	0.88	0.86	0.84	0.82
	Clean	0.92	0.91	0.9	0.89	0.88
IP6X	Dirty	0.91	0.9	0.88	0.85	0.83
	Normal	0.92	0.91	0.89	0.88	0.87
	Clean	0.93	0.92	0.91	0.9	0.9

Luminar Maintenance Factor (LMF)							
Type of Distribution	**Environment Condition**	**Expose Time**					
		1 Year	**2 Year**	**3 Year**	**4 Year**	**5 Year**	**6 Year**
Open Distribution	**Very Clean**	0.96	0.94	0.92	0.9	0.88	0.87
	Clean	0.93	0.89	0.85	0.82	0.79	0.77
	Normal	0.89	0.84	0.79	0.75	0.7	0.67
	Dirty	0.83	0.78	0.73	0.69	0.65	0.62
Direct Distribution	**Very Clean**	0.95	0.92	0.89	0.86	0.84	0.82
	Clean	**0.9**	0.84	0.79	0.74	0.7	0.67

	Normal	0.86	0.8	0.74	0.69	0.64	0.6
	Dirty	0.83	0.75	0.68	0.62	0.57	0.53
Closed Distribution	**Very Clean**	0.94	0.91	0.89	0.87	0.86	0.85
	Clean	0.88	0.83	0.79	0.75	0.72	0.7
	Normal	0.82	0.77	0.73	0.69	0.65	0.62
	Dirty	0.77	0.71	0.66	0.61	0.57	0.53
Indirect-Distribution	**Very Clean**	0.93	0.88	0.85	0.82	0.79	0.77
	Clean	0.86	0.77	0.7	0.64	0.59	0.55
	Normal	0.81	0.66	0.55	0.48	0.43	0.4
	Dirty	0.74	0.57	0.45	0.38	0.33	0.3

- Dirt on acclimation on Lamp Surface can be minimized by proper sealing of lamp compartment against entry of moisture and dust. This can be achieved by selecting proper IP rating of fixture.

Lamp Survival Factor (LSF): (Lamp Failure Rate)

- The % of lamps still operating in an installation after a specified number of hour's operation.
- LSF Lamp Survival Factor takes account of the effect of the failure of light sources during the maintenance period. (reduced light output due to lamps failing)
- It is determined by the failure rate at the end of the estimated period of use of light sources.
- The lamp survival factor depends on the service lifetime of a lamp.
- Some lamp lifetimes are reduced by frequent switching.
- The lamp manufacturers provide tables indicating the lamp survival factor.
- If a lamp is not working any more, the decision for immediate replacement or group replacement needs to be taken.
- If the lamp is replaced immediately (mostly in areas where the luminaire is easily reachable) the LSF can be 1.
- **LSF 1 is saying that there will be no loss of light because of lamp failure.**
- On the other hand, the decision could be to replace lamps in special terms or GroupWise. This could be the case in huge halls, where machines need to be stopped to reach the luminaires. The stopping of the machines is connected to less production rates of the factory, so they won't change each single lamp.

Lamp Survival Factors (LSF)					
Lamp Type	**Operating Hours**				
	4000 Hr	**6000 Hr**	**8000 Hr**	**10000 Hr**	**12000 Hr**
High Pressure Sodium	0.98	0.96	0.94	0.92	0.89
Metal Halide	0.98	0.97	0.94	0.92	0.88
High Pressure Mercury	0.93	0.91	0.87	0.82	0.76
Low Pressure Sodium	0.92	0.86	0.8	0.74	0.62
Tubular Fluorescent	0.99	0.99	0.99	0.98	0.96
Compact Fluorescent	**0.98**	0.94	0.9	0.78	0.5

Example:

- Calculate Utilization Factor and Maintenance Factor for Office having following Details.
- Length of Room is 10meter and width of Room is 20Meter.
- Lighting Fixture mounting Height is 3 Meter.
- Room Wall color is ivory White. Ceiling Color is ivory White and Flooring Color is Dark Gray
- Office Working hours: 5 days a week, 16h each day, 50 working weeks a year (4000h/a)
- Type of Lamp : Compact Fluorescent
- Type of Fixtures : Direct Luminaires
- Room Surface: Cleaned
- Room Cleaning Frequency: 1 time in Annum.
- Total Lamp Working Hour : 16Hour/Day , 5Day/Week, 50Week/Year (4000H/Annum)

Calculations:

I. Utilization Factor

- Room Refection from above Table are
- Wall=0.5. Ceiling=0.7and Flooring=0.2
- Fixture Mounting Height is 3 Meter.
- Room Index = L x W / ((L + W)x Hm)
- Room Index=(10x20) / ((10x20)x3) =2
- **From Above Table Utilization Factor is 0.6**

II. Maintenance Factor

- **Room Surface Maintenance Factor (RSMF):**
- Room is Clean and Frequency of Room Cleaning is 1time/Annum.
- From Above Table RSMF if 0.95
- **Lamp Luminaire Maintenance Factor (LLMF):**
- Type of Lamp is Compact Fluorescent and Lamp Working hour is 4000Hr/Annum.
- From Above Table LLMF if 0.91
- **Luminaire Maintenance Factors (LMF):**
- Lamp distribution is direct and Frequency of Room Cleaning is 1time/Annum..
- From Above Table LMF if 0.9
- **Lamp Survival Factor (LSF):**
- Type of Lamp is Compact Fluorescent and Lamp Working hour is 4000Hr/Annum.
- From Above Table LSF if 0.98.
- **Maintenance Factor = RSMF x LMF x LLMF x LSF**
- Maintenance Factor = 0.95x0.9x0.91x0.98
- **Maintenance Factor =0.76**

Chapter:19 How to Design Efficient Street Lighting

Introduction:

- The basic idea of roadway and Highway lighting is to provide uniform level of illumination on road at horizontal and vertical level and provide a safe and comfortable environment for the night time driver.
- Lighting design is basic idea of the selection and the location of lighting equipment to provide improved visibility and increased safety.
- Street lighting systems should be designed in a way to avoid significant differences in luminance levels at the light source and on road areas. Furthermore, continuous variation of lighting levels can cause eye strain and should be avoided, in particular on long roads.
- Road lighting provides visual conditions for safe, quick and comfortable movement of Road users.

Designing Factor for Street Light:

- The factors that are playing a vital role in the Road Lighting are following.

A. Type of Road
1) Road Classification

B. Street Light Pole
1) Street Light Pole Arrangements
2) Placement of Pole

C. Lighting Fixture
1) Lighting Fixture Mounting Height
2) Lighting Fixture Classification
3) Lighting Fixture Distributor

D. Lighting Factors
1) Maintenance Factor
2) Coefficient of Utilization

E. Lighting Uniformity
1) Lighting Uniformity
2) Surrounding Ratio

F. Lighting Pollution
1) Glare
2) Sky Glow
3) Trespass

G. Selection of Luminas
1) Type of Light
2) Watt
3) Lumen
4) CRI
5) Efficiency

(A)Classification As per Road:

Table 4 : Road Classes as per SP 72 (Part 8), IS 1944 (Part 1) and IS 1970	
Class A1	Important routes with rapid and dense traffic where safety, traffic speed, and driving comfort are the main considerations
Class A2	Main Roads with considerable volume of mixed traffic, such as main city streets, arterial roads and thoroughfares.
Class B1	Secondary roads with considerable traffic such as main local traffic routes, shopping streets
Class B2	Secondary roads, with light traffic
Class C	Lighting for residential and unclassified roads not included in previous groups
Class D	Lighting for bridges and flyovers

Class E	Lighting for town and city centers
Class F	Lighting for roads with special requirement such as roads near air fields, railways and docks

TYPE OF ROAD			
TYPE OF ROAD	**DENSITY OF TRAFFIC**	**TYPE**	**EXAMPLE**
A	Heavy and high speed motorized traffic	Road with fixed separators, No crossings for very long distance	National highways or state highways or called interstate highways, express ways or motor ways
B	Slightly lower density and lower speed traffic termed	Road which is made for vehicular traffic with adjoining streets for slow traffic and pedestrians as we find in metros	Trunk road or major road in a city
C	Heavy and moderate speed traffic	Important urban roads or rural roads. they do not interfere with the local traffic within the town	Ring roads
D	Slow traffic, pedestrians	Linking to shopping areas and invariably the pedestrians, approach road	Shopping street, trunk road
E	Limited speed. Slow or mixed traffic predominantly pedestrians,		Local streets, collectors road

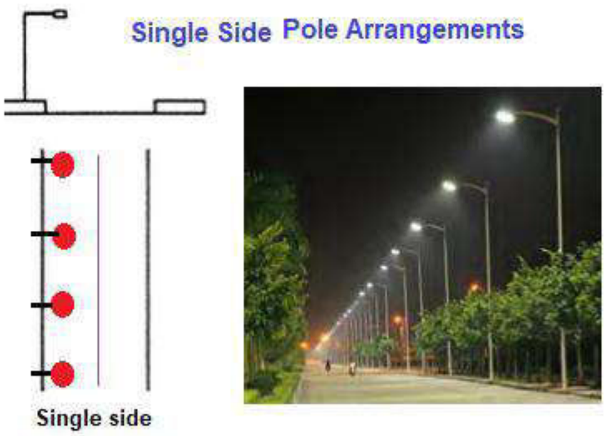
(B)Street Light Pole:

(1) Street Light Arrangement:

- There are four basic types of street lighting layout arrangements used for streets or highways illumination.

a) One Side Pole Layout:

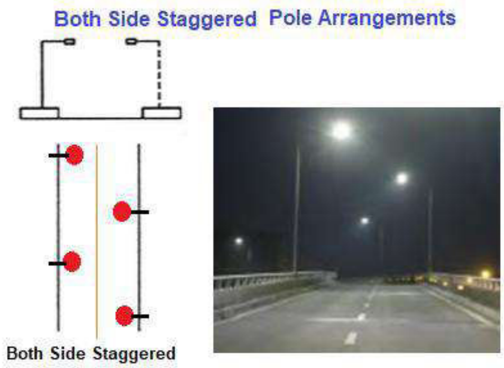
- **Arrangement:** In One Side Pole Layout, all luminaries are located on one side of the road.
- **Road Width:** For narrower roads.
- **Pole Height:** The installation height of the lamp be equal to or less than the effective width of the road surface.



- **Advantage:** There are good indelibility and low manufacturing cost.
  Disadvantage: The brightness (illuminance) of the road on the side where the lamp is not placed is lower than the on which side the light pole is placed.

b) Both Side Staggered Pole Layout:

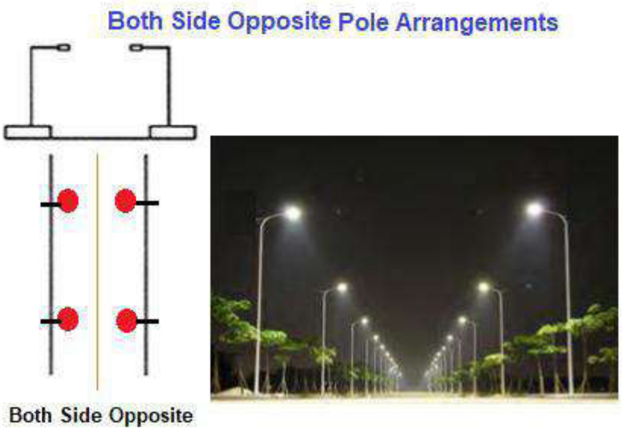
- **Arrangement:** In the staggered arrangement, the luminaires are placed alternately on each side of the road in a "zig-zag" or staggered fashion.
- **Road Width:** For Medium Size roads.
- **Pole Height:** The installation height of the lamp is equal or 1.5 time the effective width of the road.



- **Advantage:** This type of arrangement is better than single side arrangement.
- **Disadvantage:** Their longitudinal luminance uniformity is generally low and creates an alternating pattern of bright and dark patches. However, during wet weather they cover the whole road better than single-side arrangements.

c) Both Side opposite Pole Layout:

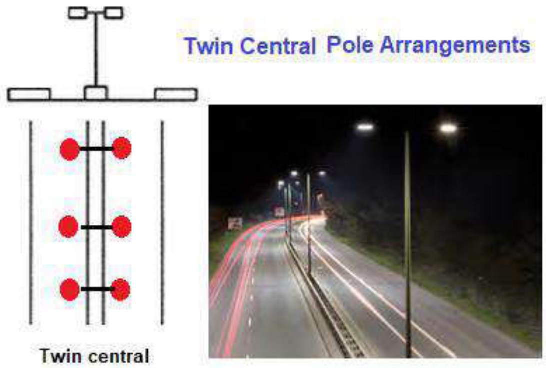
- **Arrangement:**
- In Both Side Opposite Pole Layout, the luminaries located on both sides of the road opposite to one another.
- **Road Width:** For Medium Size roads.
- **Pole Height:** The installation height of the lamp will be 2 to 2.5 time the effective width of the road.



- **Advantage:** opposite arrangements may provide slightly better lighting under wet conditions.
- **Disadvantage:**
- If the arrangement is used for a dual carriageway with a central reserve of at least one-third the carriageway with, or if the central reserve includes other significant visual obstructions (such as trees or screens), it effectively becomes two single-sided arrangements and must be treated as such.

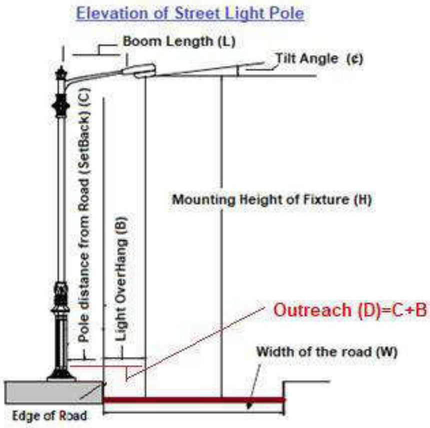
d) Twin-central Pole Layout:

- **Arrangement:** In Twin central arrangement, the luminaries are mounted on a T-shaped in the middle of the center island of the road. The central reserve is not too wide, both luminaires can contribute to the luminance of the road surface on either lane.
- **Road Width:** For Large Size roads.
- **Pole Height:** The installation height of the lamp be equal to the effective width of the road.



- **Advantage:** This arrangement generally more efficient than opposite arrangements. However, opposite arrangements may provide slightly better lighting under wet conditions.

(2) Proper Placement of Pole:



e) Setback

- Set back is the horizontal distance between the face of a light pole and the edge of traveled way.
- Placing luminaries too close to a vertical surface results in hotspots at its base.
- A setback of 3 foot to 4 foot works well for many applications.
- Light from luminaires at extremely short setbacks grazes the surface and enhances its texture.
- Light from luminaries at Long setbacks (Luminaries too far from a vertical surface) cause shadows at low levels.
- Longer setbacks may be required for taller surfaces.
- Scallops between fixtures become more noticeable as setback increases.
- As setback (or spacing) distance increases, Light levels and uniformity decrease.

Set Back (BS 5489)	
Design Speed	**Pole Set Back**
50 Km/Hr	0.8 Meter
80 Km/Hr	1 Meter
100 Km/Hr	1.5 Meter
120 Km/Hr	1.5 Meter

f) Overhang

- Overhang is the horizontal distance between the center of a luminaries mounted on a bracket (Nadir) and the adjacent edge of a carriage way or traveled way.
- In general, overhang should not exceed one fourth of the mounting height to avoid reduced visibility of curbs, obstacles, and footpaths.

(a) Outreach

- Outreach is the horizontal distance between the center of the column and the center of the luminaries and is usually determined for architectural aesthetic considerations.

(b) Pole Boom(Arm) Length:

- The use of an arm places the light source closer to the traveled way while allowing the pole to be located further from the edge of the traveled way.

- Depending on the application, Pole arms may be single and/or double mast arms or davit arms at the top of the pole.
- There are several different arm lengths and styles of arms that are used.
- **Arm Type:**
- Type A bracket an arm has a single member arm. It is used when the Arm length is less than 3.5 Meter.
- Type B bracket arm has a two member truss arm design. Type B arms are used when the Arm length is more than 3.5 Meter.
- **Arm Lengths:**
- The length of the bracket arm is dependent upon a street width, pole location in relation to the curb and the presence of a median.
- Type A (Single member bracket) arms are available in 2 Meter and 2.5 Meter lengths.
- Type B (Twin member bracket) arms are available in 3.5 Meter, 4 Meter and 5 Meter Lengths.
- **Pole Height is 10 Meter:** On typical streets that are 12 Meter' wide from curb to curb, either a 2 Meter or 2.5 Meter arm is used. Depending on whether the pole is located behind the sidewalk or in the grass parkway between the sidewalk and the curb, the arm length may need to be increased to 4 Meter.
- **Pole Height is 13 Meter:** On an undivided street, generally Meter, 2.5 Meter or 4 Meter arms are used.
- **Pole Height is 13 Meter:** divided Street, typically have a 8 Meter wide center median to divide opposing lanes of traffic. On streets where the light poles are installed in a raised median, two 4 Meter arms oriented 180° apart are used.

(c) Boom Tilt Angle (Boom Angle)

- When the angle of tilt is larger, a uniformity ratio is increasing. Otherwise discomfort glare is increasing because strong light comes into driver's eyes. So the angle of tilt shall be kept from 15° to 30°.

Tilt Angle		
Pole Height	**Arm Length**	**Arm Tile Angle**
6 Meter	0.5 Meter	5°,10°,15°
8 Meter	1 Meter	5°,10°,15°
10 Meter	1.5 Meter	5°,10°,15°
>=12 Meter	2 Meter	5°,10°,15°

(d) Pole Height:

- Light poles for conventional highway lighting applications support luminaire mounting heights ranging from approximately 30 ft to 50 ft (9.1 m to 15.2 m).
- Light towers for high-mast lighting applications generally range from 80 ft to 160 ft (24.4 m to 48.8 m) and are designed in multiple sections.
- Weathering steel is a common material choice for light towers.
- Ornamental light Poles used for local streets generally range in height for 8 ft to 15 ft (2.4 m to 4.5 m).

Pole Height	Application
< 6 Meter	Majority of side streets or alleys, Public gardens and parking Area to make people feel safe
8 Meter	Urban traffic route , the multiplicity of road junctions
10 Meter	Urban traffic routes
12 Meter	Heavily used routes
18 Meter	High mast lighting poles shall be installed at large-scale area such as airports, dockyards, large industrial areas, sports areas and road Intersections.

(e) Poles distance from Curb (Offset):

- The lighting poles should not be installed very close to the pavement edge, because the capacity of the roadway is decreased and the free movement of traffic is obstructed.
- For roads with raised curbs (as in urban roads) =Min. 0.3 meter and desirable 0.6 meter from the edge of raised curb.
- For roads without raised curbs (as in rural roads)=Min. 1.5 meter from the edge of the carriageway, subject to min. 5.0 meter from the center line of the carriageway.
- Height and overhang of mounting
- The glare on eyes from the mounted lights decreases with increases in the height of mounting. Usually, mounting height range from 6 to 10m.

- Overhangs on the lighting poles would keep the poles away from the pavement edges, but still allow the lamp to be held above the curb or towards the pavements.

(f) Pole to Pole Spacing

- Spacing is the distance, measured along the center line of the road, between successive luminaries in an installation.
- To preserve longitudinal uniformity, the space height ratio should generally be greater than 3.
- Placing luminaries too far apart creates scallops at the base of the surface.
- Spacing distances that are equal to 3 to 4 times the setback work well for many applications.
- Placing luminaries closer together eliminates scallops.
- Uniformity and light levels increase as spacing (or setback) distances decrease.
- Spacing of luminaires normally does not exceed five to six mounting heights.
- The span must not be more than 45 meters and for an average of 20-30 meters.

Lighting Pole details as per Road

Road	Road Width (Meter)	Pole Arrangement	Lamp (Watts)	Pole to Pole Spacing (Meters)	Mounting Height, (Meters)	Arm Length, (Meters)
Expressway	10	Twin Central	250	25 To 35	12	1.5
	15		250	20 To 35	12	3.0
	20	Opposite	250	20 To 45	12	1.5
	25		250	20 To 40	12	1.5
	30		250	20 To 30	12	1.5
	36		250	20 To 25	12	1.5
	40		250	20 To 22	12	1.5
Major	10	One-side	250	10 To 40	10	1.5
	15		250	10 To 45	12	3.0
	10	Twin Central	150	20 To 37	10	1.5
	15		250	20 To 43	12	3.0
	20	Opposite	150	20 To 40	10	3.0
	25		250	20 To 45	10	1.5
	30		250	20 To 45	10	1.5
	36		250	20 To 45	12	3.0
	40		250	20 To 45	2	3.0
Collector	10	One-side	150	10 To 40	10	1.5
	15		250	10 To 50	12	3.0
	10	Twin Central	150	20 To 40	10	1.5
	15		150	20 To 37	12	3.0
	20	Opposite	150	20 To 47	10	1.5
	25		250	20 To 48	10	1.5
Rural Highway	8	One-side	150	10 To 38	8	1.5
	10		150	10 To 37	8	3.0
	15		150	15 To 38	10	3.0
	10	Twin Central	150	20 To 45	10	3.0
	15		150	20 To 39	12	3.0
	20					1.5
Minor	4	One-side	70	10 To 40	8	1.5
	6		70	10 To 40	8	1.5
	8		70	10 To 40	8	1.5
	10		70	10 To 39	8	1.5
	10	Twin Central	70	20 To 35	8	1.5
	15	Staggered	70	10 To 20	8	1.5
	15	Opposite	70	20 To 40	8	1.5

Illumination Level		
Classification	**Average Illumination (lux)**	**Ratio Minimum to average illumination**
Class A1	30	0.4
Class A2	15	0.4
Class B1	8	0.3
Class B2	4	0.3

Relationship between Mounting Height and Spacing of Fixtures				
Pole Arrangement	**Cut-off type**		**Semi cutoff type**	
	Height	**Spacing**	**Height**	**Spacing**
Single side	>=0.7 X Width of Road	<=3 X Fixture Mounting Height	>=0.8 X Width of Road	<=3.5 X Fixture Mounting Height
Both Side Staggered	>=1.5 X Width of Road	<=3.5 X Fixture Mounting Height	>=1.7 X Width of Road	<=4 X Fixture Mounting Height
Both Side Opposite	>=0.5 X Width of Road	<=3 X Fixture Mounting Height	>=0.6 X Width of Road	<=3.5 X Fixture Mounting Height
Twin central	>=0.7 X Width of Road	<=3.5 X Fixture Mounting Height	>=0.8 X Width of Road	<=4 X Fixture Mounting Height

Pole to Pole Distance vs Lux Level				
Pole Height	**Lamp**	**Pole to Pole Distance**	**Max. Illumination (Lux)**	**Average (Lux)**
4 Meter	15 watt	12 to 18 Meter	25	18
5 Meter	18 watt	14 to 20 Meter	30	18
6 Meter	30 watt	18 to 24 Meter	32	20
7 Meter	50 watt	21 to 28 Meter	32	20
8 Meter	100 watt	24 to 32 Meter	40	22
9 Meter	110 watt	27 to 35 Meter	34	20
10 Meter	140 watt	30 to 40 Meter	35	22
12 Meter	180 watt	30 to 40 Meter	33	23
14 Meter	200 watt	30 to 40 Meter	30	21

Lux Vs Mounting Height	
Fixtures (Lux)	**Mounting Height**
3000 to 10000 Lux	6 to 7 Meter
10000 to 20000 Lux	7 to 9 Meter
More than 20000 Lux	More than 9 Meter

Road – Pole Detials											
Road	**Road Type**	**Type of Pole positions**	**Individual Carriageway Width (Meter)**	**Central Verge (Meter)**	**Pole Height above Ground (Meter)**	**Maximum Pole to Pole Spacing (Meter)**	**Clearance from Road Edge (Meter)**	**Bracket Length (Meter)**	**Tilt Angle**	**Lighting Specifications**	**Lamp (Watt)**
A1	Dual Carriage	Central Verge	10	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W

A1	Dual Carriage	Central Verge	11	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
A1	Dual Carriage	Central Verge	12	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
A1	Dual Carriage	Central Verge	14	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
A1	Dual Carriage	Central Verge	16	1.2	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
A1	Single Carriage	Opposite	12	0	12	35	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 250 W
A1	Single Carriage	Opposite	14.5	0	12	35	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 250 W
A1	Single Carriage	Opposite	16	0	12	40	0.6	Around one meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
A1	Single Carriage	Opposite	18	0	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
A1	Single Carriage	Opposite	21	0	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
	Single Carriage	Opposite	25	0	12	40	0.6	1 meter	10°	35 lux /0.4/ 0.33	HP SV 400 W
A1	Single Carriage	Opposite	31	0	12	40	0.6	1 meter	10°	35 lux/ 0.4/ 0.33	HP SV 400 W
A2	Single Carriage	Single Sided	10		11	30	0.6	< 1.0 meter	10°	25 lux /0.4/ 0.33	HP SV 250 W
A2	Single Carriage	Single Sided	9		11	30	0.6	< 0.5 meter	10°	25 lux /0.4/ 0.33	HP SV 250 W
A2	Single Carriage	Single Sided	7		11	30	0.6	< 0.5 meter	10°	25 lux /0.4/ 0.33	HP SV 250

											W
A2	Single Carriage	Single Sided	7		11	30	0.6	< 0.5 meter	10°	25lux /0.4/ 0.33	HP SV 250 W
A3	Single Carriage	Single Sided	7		8	20	0.6	< 0.5 meter	10°	20lux /0.4	HP SV 150 W
Pede strian Path way	Single Carriage	Single Sided	3m-6m		7.5	20-25	0.6	<0.5 meter	10°	20 lux /0.4	HP SV 150 W

Pole Data						
Poles (Meter)	**Top Dia (mm)**	**Bottom Dia (mm)**	**Thickness (mm)**	**Base plate (mm)**	**Single Arm Bracket (mm)**	**Double Arm Bracket (mm)**
3	70	130	3	200x200x12	1000	NA
3	70	130	3	200x200x12	NA	1000
4	70	130	3	200x200x12	1000	NA
4	70	130	3	200x200x12	NA	1000
4	70	130	3	200x200x12	1000	NA
5	70	130	3	200x200x12	NA	1000
5	70	130	3	200x200x12	1000	NA
6	70	130	3	200x200x12	NA	1000
6	70	130	3	200x200x12	1000	NA
7	70	135	3	225x225x16	1000	NA
7	70	135	3	225x225x16	NA	1000
8	70	135	3	225x225x16	1000	NA
8	70	135	3	225x225x16	NA	1000
9	70	155	3	260x260x16	1000	NA
9	70	155	3	260x260x16	NA	1000
9	70	175	3	275x275x16	1000	NA
9	70	175	3	275x275x16	NA	1000
10	70	175	3	275x275x16	1000	NA
10	70	175	3	275x275x16	NA	1000
10	70	200	3	290x290x16	1000	NA
10	70	200	3	290x290x16	NA	1000
11	70	210	3	320x320x20	1000	NA
11	70	210	3	320x320x20	NA	1000
12	70	230	3	325x325x20	1000	NA
12	70	230	3	325x325x20	NA	1000

Recommended Levels of Illumination (BIS 1981) (IS 1944)							
Type of Road	**Road Characteristics**	**Road Width (Meter)**	**Average Level of Illumination on Road Surface in Lux**	**Ratio of Minimum/Average Illumination**	**Ratio of Minimum/Max Illumination**	**Type of Luminaire Preferred**	**Luminas Mounting Height**
A-1	Important traffic routes carrying	>10.5,12,14,16,18,20,	30	0.4	33	Cutoff	9 To 10 Meter

	fast traffic	30					
A-2	Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	> 7 m up to 10 m	15	0.4	33	Cutoff	9 To 10 Meter
B-1	Secondary roads with considerable traffic like local traffic routes, shopping streets	< 7m Colony Roads	8	0.3	20	Cutoff or semi-cutoff	7.5 To 9 Meter
B-2	Secondary roads with light traffic	4m,5m, 6m	4	0.3	20	Cutoff or semi-cutoff	7.5 To 9 Meter

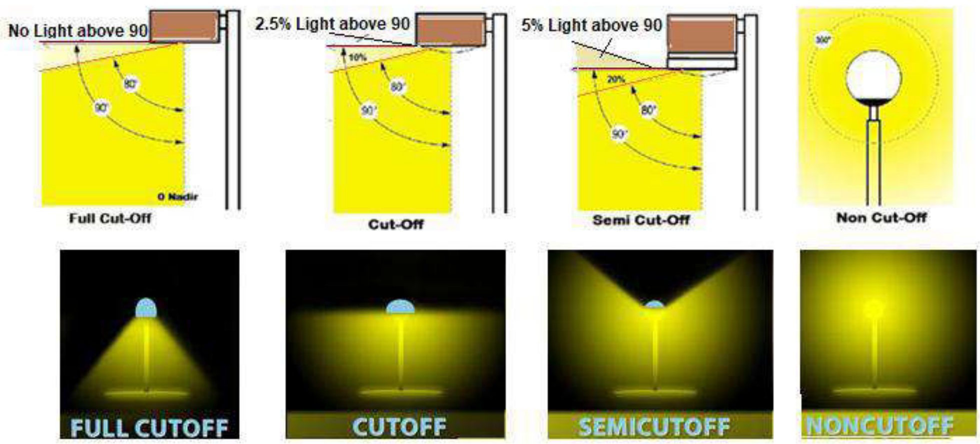
(C) Lighting Fixture:

(I) Fixture's Mounting Height:

- Higher mounting heights used in conjunction with higher wattage luminaries enhances lighting uniformity and typically reduces the number of light poles needed to produce the same illumination level.
- In general, higher mounting heights tend to produce a more cost-effective design. For practical and aesthetic reasons, the mounting height should remain constant throughout the system.
- The manufacturer's photometric data is required to determine an appropriate mounting height.
- Typical mounting heights for highway lighting purposes range from 30 ft to 55 ft (9.1 meter to 16.8 meter).
- Mounting heights for light towers or High mast is typically 80 ft (24 m) or greater.
- The installation height is too low, the glare of the lamp increases.
- As the installation high increase, glare decreases, but the lighting utilization rate decreases.

(II) Fixtures Classification:

- The Illuminating Engineering Society of North America (IESNA, IES or BIS1981) provides classifications for luminaires according to their glare control and high-angle brightness.



a) Full Cutoff (F):

- A luminaire light distribution is designated as full cutoff (F) when Zero intensity at or above horizontal (90° above nadir) and Less than 10% of lamp lumens at or above 80°.
- Full-cutoff fixtures reduce glare dramatically and eliminate direct up light by sending all their light toward the ground .This efficiency should translate into lower bulb wattages if the existing poles are used. However, some lighting engineers believe that to achieve the same illumination uniformity as their semi-cutoff counterparts, full-cutoff fixtures need to be mounted either on taller poles or closer together

- **Benefits:**
- Limits spill light on to adjacent property, reduces glare. No light is emitted directly from the luminaries into the sky.
- Reduce Lighting Pollution.
- **Limitations:**
- May reduce pole spacing to maintain uniformity and increase pole and luminaire quantities.
- **Application:**
- Use for roadway, parking, and other vehicular lighting applications. Minimizes glare and light pollution and light trespass.

b) Cutoff (C):

- A luminaries light distribution is designated as cutoff (C) when Less than 2.5% Intensity at or above horizontal (90° above nadir) and Less than 10% of lamp lumens at or above 80°.
- The direction of maximum intensity may vary but should be below 65º.
- **Benefits:**
- Small increase in high-angle light allows increased pole spacing.
- Cutoff system is the reduction of glare.
- **Limitations:**
- May allow some up light (Sky Light) from luminaries. Typically a small overall impact on sky glow.
- **Application:**
- Interchange lighting and rural intersections due to the ability to reduce glare.
- Use in applications where pedestrians are present. Provides more vertical illuminance than Full Cutoff luminaires.
- Lamp rating should be less than 3200 lumens.
- The cutoff design is where the luminaire light distribution is less than 25,000 lm at an angle of 90° above nadir (vertical axis) and 100,000 lm at a vertical angle of 80° above nadir.

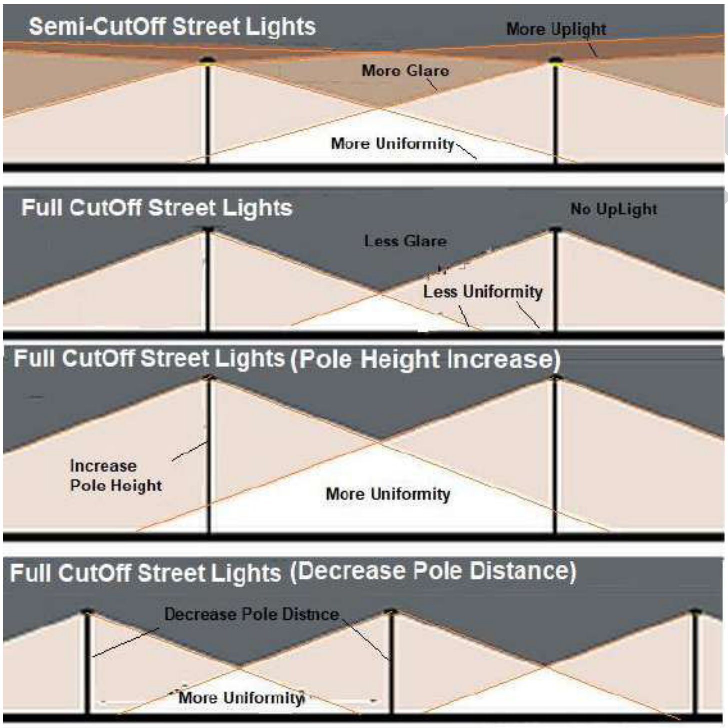
c) Semi Cutoff (S) (Medium Beam Angle):

- A luminaire light distribution is designated as Semi cutoff (S) when Less than 5% Intensity at or above horizontal (90° above nadir) and Less than 20% of lamp lumens at or above 80°.
- The direction of maximum intensity may vary but should be below 75º.
- **Benefits:**
- High-angle light accents taller vertical surfaces such as buildings. Most light is still directed downward.
- **Limitations:**
- Little control of light at property line.
- Potential for increased glare when using high wattage luminaries. Typically directs more light into the sky than cutoff.
- **Application:**
- Used for standard road lighting. Adequate glare control is obtained with reasonable spacing.
- The principal advantage of the semi-cutoff system is a greater flexibility in sitting.
- Use in pedestrian areas. If using in residential areas, provide with house side shields to minimize light trespass. Lamp rating should be less than 3200 lumens.
- For the semi-cutoff design, the luminous flux numbers become 50,000 lm for 90° above nadir and 200,000 lm at a vertical angle of 80° above nadir.
- Semi-cutoff fixtures create broad cones of light that permit wide spacing between poles. But such fixtures create harsh glare and send some light directly into the sky.

d) Non Cutoff (N) (Higher Beam Angle):

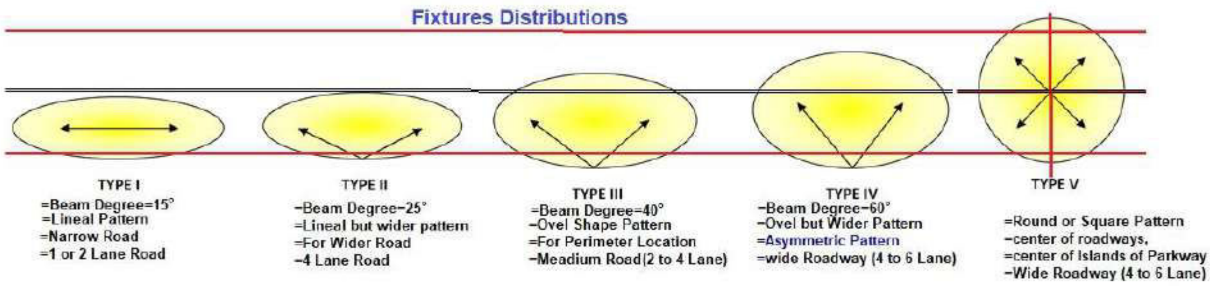
- A luminaries light distribution is designated as Non Cutoff (N) when Emit light into all directions.
- No limitations on light distribution at any angle.
- There is considerable output near the horizontal plane.
- **Benefits:**

- Uniform luminous surfaces such as internally illuminated signs or globes. Wattage should be limited. Suitable for sports lighting, facade, landscape or other applications where luminaires are tilted due to limitations in pole or fixture locations
- **Limitations:**
- Location and aiming are critical. Most likely of all categories to produce offensive brightness and sky glow.
- **Application:**
- Used in areas with a lot of background light. Non-cutoff luminaries shall not be used at lower mounting heights because of glare.
- Use for decorative applications only. Lamp rating should be less than 3200 lumens.
- "Full cut off" fixtures must be installed properly, so that the bottom of the fixture is level with the ground.
- “Fully Shielded” fixtures do not allow any light to be emitted above the lowest light emitting
- part, but do not restrict light output in the “glare” zone, 90-80 degrees below horizontal.



(III) Fixtures Distributions (Optical System):

- The Illuminating Engineering Society classified series of Fixture distribution patterns as Types I, II, III, IV, and V.



a) Type I (Two-way):

- The lateral distribution having a preferred lateral width of 15 degrees in the cone of maximum Lumen.
- **Illumination Pattern:** Narrow, symmetric luminance pattern.
- **Fixture Location:** This type is generally applicable to a luminaire location near the center of a roadway where the mounting height is approximately equal to the roadway width.
- **Type of Road:** The luminaire is placed on the side of the street or edge of the area to be lighted. Most 1or 2 Lane Road
- **Application:**

b) Type II (Two Way) :

- Light distributions have a preferred lateral width of 25 degrees.
- **Illumination Pattern:** Slightly wider illuminance pattern than Type I.
- **Fixture Location:** They are generally applicable to luminaires located at or near the side of relatively narrow roadways, where the width of the roadway does not exceed 1.75 times the designed mounting height.
- **Type of Road:** The luminaire is placed on the side of the street or edge of the area to be lighted. It produces a long, narrow, oval-shaped lighted area which is usually applicable to narrower streets.

c) Type III (Bat Wing) :

- Type III light distributions have a preferred lateral width of 40 degrees.
- **Illumination Pattern:** It produces an oval-shaped lighted
- **Fixture Location:** This distribution is intended for luminaires mounted at or near the side of medium width roadways, where the width of the roadway does not exceed 2.75 times the mounting height.
- **Type of Road:** The luminaire is placed on the side of the street or edge of area to medium width streets.

d) Type IV (Forward throw "Asymmetric"):

- Type IV light distributions have a preferred lateral width of 60 degrees.
- **Illumination Pattern:** Widest luminance pattern.
- **Fixture Location:** This distribution is intended for side-of-road mounting and is generally used on wide roadways where the roadway width does not exceed 3.7 times the mounting height.
- **Type of Road:** very wide roadway (4 to 6 Lane)
- **Applications**: Type IV often use at perimeters where Spill Light is required and there is no place to add Pole.

e) Type V:

- Type V light distributions have a circular symmetry of candlepower that is essentially the same at all lateral angles.
- **Illumination Pattern:** It produces a circular, wider lighted area and is usually applicable to wide streets.
- **Fixture Location:** The luminaries are mounting at or near center of roadways, center islands of parkway, and intersections.
- **Type of Road:** very wide roadway (4 to 6 Lane)
- **Applications**: Type V often applies to high-mast lighting.

GUIDE FOR LUMINAIRE LATERAL LIGHT TYPE AND PLACEMENT		
Pole Arrangement	**Road Width**	**Type of Distribution**
One Side or Staggered	up to 1.5 x Mounting Height	Types II-III-IV
Staggered or Opposite	Beyond 1.5 x Mounting Height	Types III & IV
Center of the Roadway Mounting	up to 2 x Mounting Height	Type I

Type of Classification	
AREA CLASSIFICATION	**CUTOFF TYPE**
Commercial	Full Cutoff or Semi Cutoff
Intermediate	Full Cutoff or Semi Cutoff
Residential	Full Cutoff

THE SELECTION OF LUMINAIRE MOUNTING HEIGHTS	
Lamp Lumens	**Mounting Height**
≤20,000 Lumen	≤35 Foot
20,000 To 45,000 Lumen	35 To 45 Foot
45,000 To 90,000 Lumen	45 To 60 Foot

Type of LED Luminaries	**Type of Road**	**Lamp mounting height from the floor level (Meters)**	**Minimum Illumination Level**	**Color of Illumination**

			(Lux) at centre of road	
250-260W		Above 18	(20 To 22)	5000K-6500K
190W	A1	Between 11 To 15	(20 To 22)	5000K-6500K
140-170W	A1	Between 9 To 15	(18 To 20)	5000K-6500K
90-120W	A2/B1	07 To 11	(15 To 18)	4300K-5600K
70-120W	A2/B1	07- To 11	(15 To 18)	4300K-5600K
70-120W	B1/B2	06 To 09	(15 To 18)	4300K-5600K
70-50W	B1/B2/C1	7 To 9	(12 To 15)	4300K-5600K
45-50W	B1/B2/C1	5 To 7	(12 To 15)	4300K-5600K
25-30W	B1/B2/C1	5 To 7	(10 To 12)	4300K-5600K

Relationship between mounting height and spacing							
Mounting Height	Width of road	6 Meter to 7 Meter		9 Meter to 10.5 Meter		12 Meter to 14 Meter	
	Pole arrangement	Cut-off Type	Semi Cutoff Type	Cut-off Type	Semi Cutoff Type	Cut-off Type	Semi Cutoff Type
8 Meter	Single side	24	28	-	-	-	-
	Staggered	24	28	-	-	-	-
	Opposite	-	-	28	28	-	-
10 Meter	Single side	30	30	-	-	-	-
	Staggered	35	35	30	35	-	-
	Opposite	-	-	35	40	30	35
12 Meter	Single side	42	48	36	42	-	-
	Staggered	-	-	36	42	36	42
	Opposite	-	-	42	48	42	48

GUIDE FOR LUMINAIRE LATERAL LIGHT TYPE AND PLACEMENT					
SIDE OF THE ROADWAY MOUNTING			CENTER OF THE ROADWAY MOUNTING		
One Side or Staggered	Staggered or Opposite	Local Street Intersection	Single Roadway	Twin Roadways (Median Mounting)	Local Street Intersections
Road Width up to 1.5 x Mounting Height	Road Width beyond1.5 x Mounting Height	Road Width up to 1.5x Mounting Height	Road Width up to 2x Mounting Height	Road Width up to 1.5x Mounting Height (each pavement)	Width up to 2.0x Mounting Height
Types	Types	Type	Type	Types	Types
II, III, IV	III & IV	II (4-way)	I	II & III	I (4-way) & V

(D) Lighting Factor:

(1) Maintenance Factor (Light Loss Factors) (MF)

- The Maintenance Factor (Light loss factor) is the combination of factors used to denote the reduction of the illumination for a given area after a period of time compared to the initial illumination on the same area.
- The efficiency of the luminaire is reduced over time. The designer must estimate this reduction to properly estimate the light available at the end of the lamp maintenance life.
- Luminaire maintenance factors vary according to the intervals between cleaning, the amount of atmospheric pollution and the IP rating of the luminaire.
- However, it is proposed to consider maintenance factor of not less than 0.5 for LED Road lighting installations for IP66 rated luminaires.
- The maintenance factor may range from 0.50 to 0.90, with the typical range between 0.65 To 0.75
- These maintenance factor values shall be adopted for the purposes of producing the lighting simulation design.
- The maintenance factor is the product of the following factors.
- **LLF = LLD x LDD x EF**

- Mostly We consider Maintenance factor from 0.8 to 0.9
- We have to choose Maintenance factor carefully by increasing maintenance factor 0.5 the spacing of pole increasing 2 meter to 2.5 meter

Maintenance Factor	Max. Spacing of Pole (Meter)
0.95	43
0.9	40.5
0.85	38
0.8	36

a) Lamp Lumen Depreciation Factor (LLD)

- As the lamp progresses through its service life, the lumen output of the lamp decreases. This is an inherent characteristic of all lamps. The initial lamp lumen value is adjusted by a lumen depreciation factor to compensate for the anticipated lumen reduction.
- This assures that a minimum level of illumination will be available at the end of the assumed lamp life, even though lamp lumen depreciation has occurred. This information should be provided by the manufacturer. For design purposes, a LLD factor of 0.9 to 0.78 should be used.

b) Luminaire Dirt Depreciation Factor (LDD).

- Dirt on the exterior and interior of the luminaries and to some on the lamp reduces the amount of light reaching the roadway.
- Various degrees of dirt accumulation may be anticipated depending upon the area in which the luminaire is located. Industry, exhaust of vehicles, especially large diesel trucks, dust, etc, all combine to produce the dirt accumulation on the luminaries.
- Higher mounting heights, however, reduce the vehicle-related dirt accumulations.
  LDD factor of 0.87 to 0.95 should be used. This is based on a moderately dirty environment and three years exposure time.

c) Equipment Factor (EF).

- Allows for variations inherent in the manufacture and operation of the equipment (i.e., luminaries, system voltage and voltage drop).
- It is generally assumed to be 95%.

(2) Coefficient of Utilization (CU):

- Coefficient of Utilization is the ratio of the luminous flux from a luminaire received on the surface of the roadway to the lumens emitted by the luminaire's lamps alone.
- Coefficient of Utilization should be maximum.
- Coefficient of Utilization differs with each luminaire type, and depends upon mounting height, road width, and overhang.
- The coefficient of utilization (K) should be over 30% or the utilance above 40% for the road, highway, square or enclosure. Luminaires or floodlights should not by placed far from the area to be lit or, where appropriate, light projection beyond the useful zone should be minimized (K = average maintained illuminance multiplied by the surface calculation and divided by the lumens installed).


Various Factors			
Type	**Luminaries Dirt Depreciation**	**Luminaire Lumen Depreciation**	**Total Light Loss Factor**
LED	0.9	0.85	0.765
HPS	0.9	0.9	0.81
LPS	0.9	0.85 (0.7 for 180W)	0.765 (0.63 for 180W)

Light Loss Factors		
Type of Lamp	**Laminar Dirt description**	**Light Loss Factor**
HPS	0.88	0.74
Induction	0.88	0.62
LED	0.88	0.72

Maintenance factors			
Cleaning intervals (months)	**Pollution category**		
	High	**Medium**	**Low**
12	0.53	0.62	0.82
18	0.48	0.58	0.8
24	0.45	0.56	0.79
36	0.42	0.53	0.78

Maintenance Factors for 36 month cleaning interval						
Factors	**IP5X**			**IP6X**		
	Pollution category			**Pollution category**		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**
LMF	0.88	0.82	0.76	0.9	0.87	0.83
LLMF	0.89	0.89	0.89	0.89	0.89	0.89
MF	**0.78**	**0.73**	**0.68**	**0.80**	**0.77**	**0.74**

(E) Lighting Uniformities

(I) Lighting Uniformities

- Uniformity is a description of the smoothness of the lighting pattern or the degree of the intensity of bright and dark areas on the road.
- Uniformity is a measure of how evenly distributed the light on the road is, which can be expressed as Overall Uniformity (UO) and Longitudinal Uniformity (UL).
- The uniformity ratio shall not exceed 4:1 and preferably should not exceed 3:1 except on residential streets, where 6:1 may be acceptable.

a) Overall uniformity:

- In design, the overall uniformity (UO) is expressed as a ratio of the minimum to the average luminance on the road surface of the carriageway within the calculation area.
- **UO=Lmin / Lave**

- It is a measure of how evenly or uniformly illuminate on the road surface.
- A good overall uniformity ensures that all spots and objects on the road are sufficiently lit and visible to the motorist.
- The industry accepted value for UO is **0.30 to 0.40.**

b) Longitudinal uniformity:

- The longitudinal uniformity (UL) is expressed as the ratio of the minimum to maximum luminance along the center line of a lane within the calculation area.

- **UL=Lmin / Lmax.**
- Longitudinal uniformity is a measure to reduce bright and dark bands of light appearing on road lit surfaces. The effect can be somewhat hypnotic and present confusing luminance patterns.

- It is a measure to reduce the intensity of bright and dark banding on road lit surface.
- A good level of longitudinal uniformity ensures comfortable driving conditions by reducing the Pattern of high and low luminance levels on a road (i.e. zebra effect).
- It is applicable to long continuous roads.
- **Combination of Overall Uniformity and Longitudinal Uniformity:**

- The picture on the left shows a road with good UO while the picture on the right has low level of UO. The Road is more visible in the road with higher UO. Having higher UO allows the motorist to see the road clearly and anticipate potential road hazards (e.g. open manholes, road excavations, sharp objects on the road, people crossing the street).
- The picture on the right shows a road with low level of UL demonstrating the 'Zebra Effect' while the picture on the left has high level of UL without 'Zebra Effect'.
- The 'zebra effect' can cause discomfort to motorists, posing a risk to road safety. Ensuring good level of uniformity can reduce the luminance level needed.

Lighting Levels				
Category	**Eave (LUX)**	**Emin LUX)**	**Uniformity ratios**	
			Emax : Emin	**Eave : Emin**
Express & Main street	30	15	3:01	2.5:1
Suburban shopping street	25	10	5:01	3:01
Subsidiary street	15	10	5:01	3:01
Other streets	15	5	10:01	5:01

Lux Level			
Road Classification	**Area Classification**	**Average Lux**	**Uniformity Ratio (Aver./Min.)**
Arterial (Minor & Major)	Commercial	12	3 to 1
	Intermediate	9	
	Residential	6	
Collector (Minor & Major)	Commercial	8	
	Intermediate	6	4 to 1
	Residential	4	
Local	Commercial	6	
	Intermediate	5	6 to 1
	Residential	3	

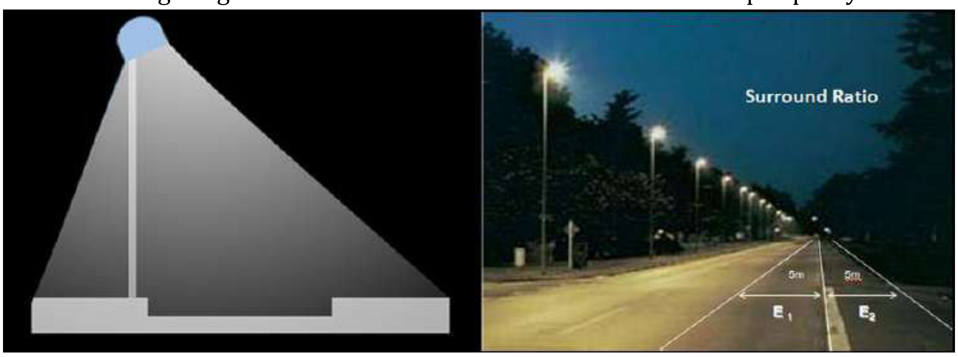
Alleys	Commercial	4	
	Intermediate	3	6 to 1
	Residential	2	
Sidewalks (Roadside)	Commercial	3	3 to 1
	Intermediate	6	4 to 1
	Residential	2	6 to 1
Pedestrian Ways		15	3 to 1

Illumination for Intersections				
Functional Classification	**Average Maintained Illumination at Pavement by Pedestrian Area Classification in Lumen**			**Uniformity Eavg/Emin**
	High	**Medium**	**Low**	
Major/Major	37	28	19	32
Major/Collector	31	24	16	32
Major/Local	28	22	14	32
Collector/Collector	26	19	16	43
Collector/Local	23	17	11	43
Local/Local	19	15	9	65

Illumination for Pedestrian Areas				
Maintained Illuminance Values for Walkways				
Area Classification	**Description**	**E avg (Lux)**	**EV min (Lux)**	**E avg/Emin**
High Pedestrian Conflict Areas	Mixed Vehicle and Pedestrian	22	11	43
	Pedestrian Only	11	5	43
Medium Pedestrian Conflict Areas	Pedestrian Areas	5	2	43
Low Pedestrian Conflict Areas	Rural/Semi-Rural Areas	2	1	108
	Low Density Residential (2 or fewer dwelling units per acre)	3	1	65
	Medium Density Residential (2.1 to 6.0 dwelling units per acre)	4	1	43
Pedestrian Portion of Pedestrian/Vehicular Underpasses	Day	108	54	43
	Night	43	22	32

(II) Surround Ratio (SR):

- Road lighting should be illuminate not only the road, but also the adjacent areas so motorists can see objects in the periphery and anticipate potential road obstructions (e.g., a pedestrian about to step onto the road).
- The SR is the visibility of the road's periphery relative to that of the main road itself.
- As per industry standards, SR should be at least **0.50.**
- Figure show how road lighting should illuminate both the main road and its periphery.



(F) Lighting Pollutions

- Light pollution is an unwanted consequence of outdoor lighting and includes such effects as sky glow, light trespass, and glare.
- 30 to 50% of all light pollution is produced by roadway lighting that shines wasted light up and off target.

(I) Glare:

- Glare is the condition of vision in which there is discomfort or a reduction in the ability to see significant objects. Glare affects human vision and it is subdivided into four components, Disability Glare, Discomfort Glare, Direct Glare and Indirect Glare.
- **By origin**

1. Direct Glare
2. Indirect (reflected) Glare

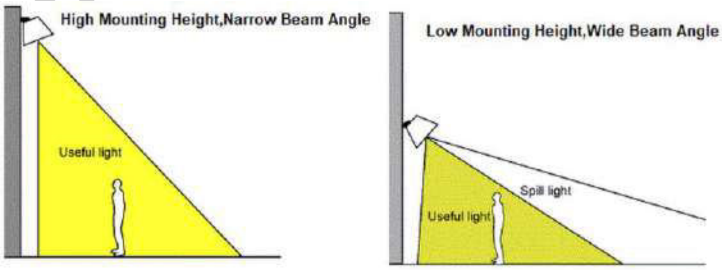
- **By effect on people**

1. Disability Glare
2. Discomfort Glare

- **Disability glare:**
- Disability glare is the glare that results in reduced visual performance and visibility.
- Since disability glare reduces the ability to perceive small contrasts.
- It can impair important visual tasks in traffic such as detecting critical objects, controlling headlights, and evaluating critical encounters, making glare a potential danger for road users.
- LED light sources can provide very high luminance levels which may cause glare. For this reason, LED lamps are commonly equipped with diffusers to reduce this luminance.
- Disability glare may vary for different individuals and it can be calculated objectively.
- In a particular illuminated environment, the human eye will be able to detect differences in luminance down to a certain threshold. This threshold can be compared for a situation in the same environment when a source of glare is added. By comparing these thresholds, the threshold increment can be derived.
- **Discomfort glare:**
- Discomfort glare is the glare producing discomfort. It does not necessarily interfere with visual performance or visibility.
- As vertical light angles increase, discomforting glare also increases
- Discomfort glare, on the other hand, is a subjective phenomenon and there is no method for its Rating.
- Although the 9-point De Boer scale (ranging from "1" for "unbearable" to "9" for "unnoticeable") is the most widely used in the field of automotive and public lighting.
- **Direct Glare:**
- Direct glare is caused by excessive light entering the eye from a bright light source. The potential for direct glare exists anytime one can see a light source. With direct glare, the eye has a harder time seeing contrast and details.
- A system designed solely on lighting levels, tends to aim more light at higher viewing angles, thus producing more potential for glare.
- Exposed bright light source, for example a dropped lens cobra head or floodlight causes of direct glare.
- Direct glare can be minimized with careful equipment selection as well as placement.

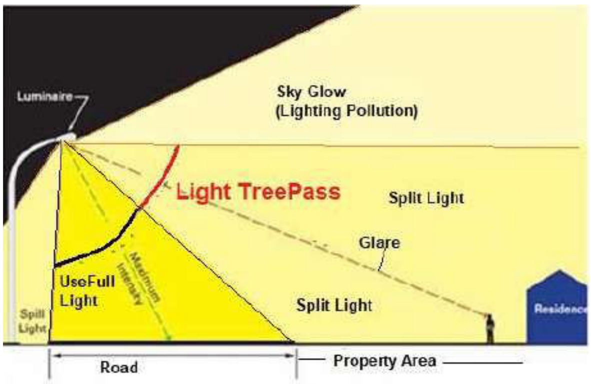
- **Figure illustrates two examples of exterior lighting that results in glare.**

- Fig shows how full cutoff luminaries (Shielded Luminaires) can minimize this direct glare. In exterior applications, use fully shielded luminaires that directs light downwards towards the ground.
- **Indirect Glare:**
- Indirect glare is caused by light that is reflected to the eye from surfaces that are in the field of view - often in the task area.
- Indirect Glare can be minimized with the type and layout of lighting equipment. Direct the light away from the observer with the use of low glare, fully shielded luminaries.
- As the uniformity ratio increases (poor uniformity), object details become harder to see.
- For roadway lighting, good uniformity shows evenly lighted pavement. However, to meet small target visibility criteria, a non uniform roadway surface may be better.
- There should be a balance between uniform perception and detecting objects on the road. Also, emphasis is put on horizontal surface uniformity. In reality, vertical surfaces may require more lighting in order to improve guidance.
- **How to Reduce Glare:**
- Glare and light trespass are more concern when installing floodlights.
- Use shielded Light should be use to reduce Glare.
- Higher mounting heights can more effective in controlling spill light, because floodlights with a more controlled light distribution (i.e., narrower beam) may be used, and the floodlights may be aimed in a more downward direction, making it easier to confine the light to the design area.
- Lower mounting heights increase the spill light beyond the property boundaries. To illuminate the space satisfactorily, it is often necessary to use floodlights with a broader beam and to aim the floodlights in directions closer to the horizontal than would occur when using higher mounting heights.
- Lower mounting heights make bright parts of the floodlights more visible from positions outside the property boundary, which can increase glare.



(II) Sky glow:

- Sky Glow is brightening of the night sky caused by outdoor lighting.
- Light that is emitted directly upward by luminaries or reflected from the ground is scattered by dust and gas molecules in the atmosphere, producing a luminous background. It has the effect of reducing one's ability to view the stars in Night.



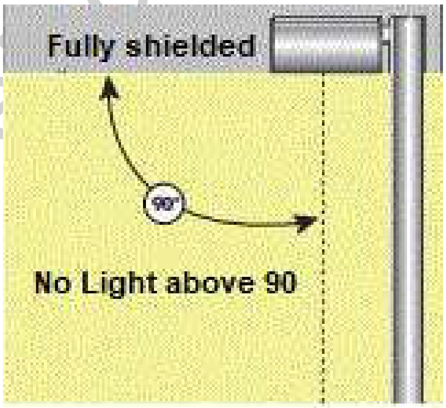
- **How to Reduce Sky Glow**
- While it is difficult to accurately model sky glow, at this point it is presumed that the most important factors are light output and lamp spectral characteristics, light distribution from the luminaire, reflected light from the ground, and aerosol particle distribution in the atmosphere.
- If the quantity of light going into the sky is reduced, then sky glow is reduced. Thus, to reduce sky glow by
- By using full cutoff luminaires to minimize the amount of light emitted upward directly from the luminaire.
- Reduce Lighting Level.
- Make practice to Turn off unneeded lights
- Limited Lighting hours in outdoor sales areas, parking areas, and signages
- Installing Low-Pressure Sodium light sources, which allow astronomers to filter the line spectra from telescopic images.

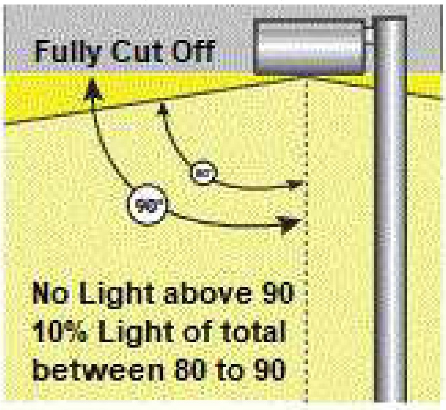
(III) Light trespass:

- Light trespass is condition when spill (Unwanted or Unneeded) light from a streetlight or floodlight enters a window and illuminates an indoor area.
- **How to Reduce Trespass**
- Select luminaries, locations, and orientations to minimize spill light onto adjacent properties.
- Use well-shielded luminaries.
- Keep floodlight aiming angles low so that the entire beam falls within the intended lighted area.

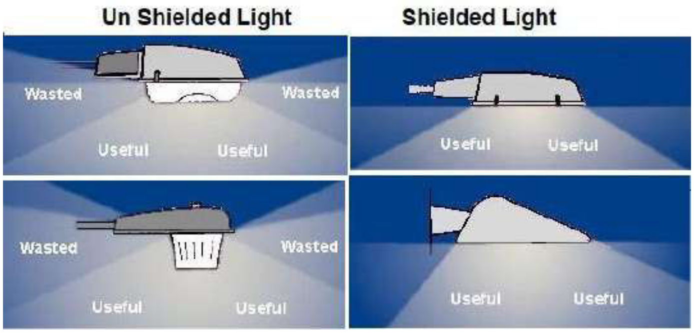
Difference between full cutoffs and fully shielded:

- The full cutoff has is luminaries that have no direct up light (no light emitted above horizontal) and 10% of light intensity between 80° and 90°.
- The term full cutoff is often substituted for the term fully shielded.
- The both terms are not equivalent. Fully shielded luminaires emit no direct up light, but have no limitation on the intensity in the region between 80° and 90°
- Luminaires that are full cutoff, cutoff, semi cutoff, and non cutoff , may also qualify as fully shielded.





- There is also a confusing assumption that a luminaire with a flat lens qualifies as a full cutoff luminaries. While this may be true or not in some Lighting Fixtures case.

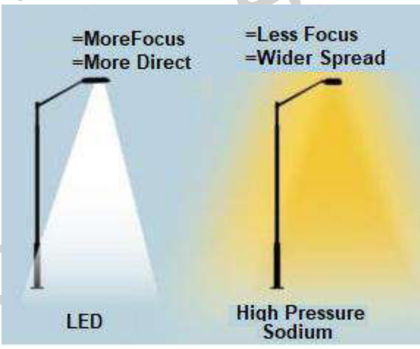


- Fully shielded means, a lighting fixture constructed in such a manner that the bulb should be fully recessed into Fixture so that all light is directed downward below the horizontal.
- The fixture is angled so the lamp is not visible below the barrier (no light visible below the horizontal angle).

(G) Selection of Luminas:

(1) Types of Lighting Source

- Street Lights are mostly Low-pressure sodium (LPS), High-pressure sodium (HPS), Metal halide and Light emitting diodes (LED).
- LPS is very energy efficient but emits only a narrow spectrum of pumpkin-colored light that some find to be undesirable.
- LPS is an excellent choice for lighting near astronomical observatories and in some environmentally sensitive areas.
- HPS is commonly used for street lighting in many cities. Although it still emits an orange-colored light, its coloring is more “true to life” than that of LPS.
- Where it’s necessary to use white light, there are metal halide and LEDs.



- High-pressure sodium lamps should be used for expressways, main roads, secondary roads and branch roads.
- Low-power metal halide lamps should be used in mixed traffic roads for motor vehicles and pedestrians in residential areas.
- Metal halide lamps can be used for motor vehicle traffic, such as city centers and commercial centers, which require high color identification.
- Metal halide lamps, CFL lamps are used at Pedestrian streets in industrial areas, sidewalks in residential areas, and sidewalks on both sides of motorway traffic.
- LED streetlights are more durable, longer lasting, efficiency, dimmable capacity and cost effective than traditional lights.
- LED also enhances public safety by delivering superior visible light while providing the environmental advantage of using less energy.

(2) Color Rendering Index (CRI):

- CRI Measures the ability of the artificial light to show or reproduce the colors of the road or objects on the road, relative to a natural light source.
- The natural light source (the sun) has CRI of 100. The higher
- **This index the better the visibility will be. For all types of road CRI ≥ 70 is recommended.**

(3) Efficacy

- At the low end LED efficacy starts at 70 lumens per watt (lm/W) and reaches as high as 150 lm/W.

- While the mean efficacy for outdoor area fixtures is slightly lower than common indoor fixtures such as troffers and linear lighting about 100 lm/W for area lights compared to about 110 lm/W for troffers and linear fixtures this difference is not significant. It may be the result of outdoor area lights requiring more precise luminous intensity distributions and other factors unique to outdoor lighting.

(4) Fixture Protection:

- When using sealed road lighting, the protection level of the light source cavity should not be lower than IP54.
- For roads and places with dangerous environmental pollution and heavy maintenance, the protection level of the light source cavity should not be lower than IP65.
- The degree of protection of the lamp electrical appliance cavity should not be lesser than IP43.
- Lamps with excellent corrosion resistance should be used in areas or places with high levels of corrosive gases such as acid and alkali in the air.

(H) Effective Road Lighting:

- Sufficient illumination.
- Good uniformity.
- No Glare.
- Low consumption.
- No Color Temperature abnormalities
- No Zebra effect
- Shielded lighting to ensure light is pointed downwards
- Completely uniform illuminance.
- No requirement for over lighting to obtain sufficient average illumination.
- Absence of glare.
- Absence of low angle radiation that causes sky glow.
- Control of light trespass.
- High redundancy.

Effective Road Lighting	
Features	**Benefits**
Proper pole height & spacing	Provide uniform light distribution
Proper Luminaire aesthetics	Blends in with the surroundings
Good maintenance	Reduce problems in lightning
High lamp efficiency	Minimize energy cost
Life of Luminaire	Reduce lamp replacement cost
Good color rendering	Helps object appear more natural
Proper light distribution	Provide required light on roads
Cost effectiveness	Lowers operating cost
Minimizing light pollution & glare	Reduce energy use

Effective Energy-efficient Street Lighting Systems (NYSERDA, 2002)	
Features	**Benefits**
Proper pole height and spacing	Provides uniform light distribution, which improves appearance for safety and security Meets recommended light levels Minimizes the number of poles, reducing energy and maintenance costs
Proper luminaire aesthetics	Blends in with the surroundings
High lamp efficacy and Luminaire efficiency	Minimizes Energy cost
Life of the luminaire and other components	Reduces lamp replacement costs
Cost effectiveness	Lowers operating cost
High Lumen Maintenance	Reduces lamp replacement costs

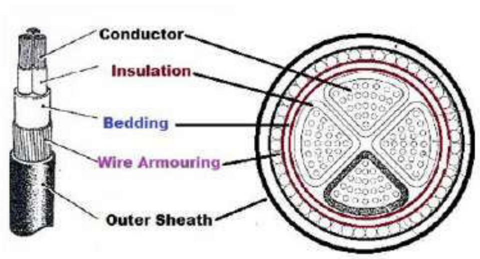
Good color rendering	Helps object appear more natural and pleasing to the public Allows better recognition of the environment, improves security
Short lamp Re strike	Allows the lamp to quickly come back after a power interruption
Proper light distribution	Provides required light on the roads and walkways
Proper Cutoff	Provides adequate optical control to minimize light pollution
Minimizing light pollution and Glare	Reduces energy use
Automatic Shutoff	Saves energy and maintenance costs by turning lamps off when not needed

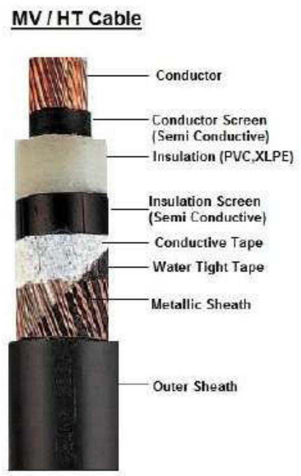
Minimum Value of Street Light Designing	
Descriptions	**Min Value**
Watt	400
Lumens Per Watt	80 To 140
Voltage	230Volt
Frequency	50 To 60Hz
Power Factor	More than 95
THD	< 20%
Life Hours	70,000 hours
Color Temperature	4000K To 5000K
CRI	More than 75
Beam Angle / Beam Pattern	Type 2,3,4,5
Operating Temperature	(-)25°C To (+)50°C
Working Humidity	10% To 90% RH
IP Rating	IP67
Dimmable	0-10V
Optic Lens Material	High Polycarbonate (PMMA)
Forward Current	>600mA
Housing	IP65 - Aluminum Alloy and PC Lens
Dimension	18.23" X 13.58" X 4.57"
Weight	15.30 lbs - 34.39 lbs
Warranty	10 Years

Cable Parts for Cable Construction:

- Following Parts are manily use for Cable

1. Conductor (For LV/MV/HT Cables)
2. Conductor Screen (For MV/HT Cables)
3. Filler & Binding Tapes (For LV/MV/HT Cables)
4. Insulation (For LV/MV/HT Cables)
5. Insulation Screen (For MV/HT Cables)
6. Separation Tape (For MV/HT Cables)
7. Bedding (Inner Sheath)
8. Metallic Sheen (For MV/HT Cables)
9. Armor (For LV/MV/HT Cables)
10. Outer Sheath (For LV/MV/HT Cables)
11. Water Blocking Tapes –Optional (For MV/HT Cables)
12. Insulation Tapes–Optional (For MV/HT Cables)



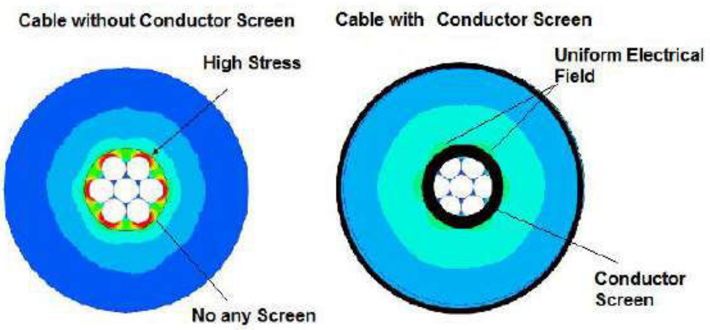


(1) Conductors:

- **Code:** IS:8130 / IEC 60228/ BS 6360
- **Material:** Class 2 - Annealed Plain / Tinned Copper / Aluminum.
- **Used for :** LV ,MV & HV Cables
- **Purpose:**
- Usually stranded copper (Cu) or aluminum (Al) is used.
- Copper is denser and heavier, but more conductive than aluminum.
- Electrically equivalent aluminum conductors have a cross-sectional area approximately 1.6 times larger than copper, but half the weight.
- The size of the copper / Aluminum conductor forming one of the cores of a cable is expressed in square millimeters (mm2), and the current rating of the cable is dependent upon the cross-sectional area of each core.
- Multi core Aluminum or copper conductor are produced by two Shapes
- **Circular Conductor:** multi layers of stranded wires are assembled together to make circular shape.
- To achieve a circular conductor, the number of strands follows a particular progression: 3, 7, 19, 37, 61, and 127 etc, the diameter of each strand being chosen to achieve the desired cross-sectional area of whole conductor.
- Circular Shape conductor is normally available used up to 200mm2
- **Segmental Conductor:** Five segments of compacted conductor in triangle shape of 72 degree are assembled together with separation of non metallic tapes to reduce the skin effect which reduce the AC conductor resistance.
- Larger sizes have conductors with the strands laid up in a segmental formation; this Cables achieves a better space factor and reduces the overall diameter of the cable. It also reduces the inductance of the cable due to decreased spacing between phases
- Segmental conductor is normally available from 1000 mm2 and above

(2) Conductor Screen (Semi Conductor Screen):

- **Code:** IS:7098/IEC:60502/ BS:6622/BS:7835
- **Material:** Extruded thermo set semi-conducting compound, Carbon paper and carbon loaded polymer.
- **Used for :** Cable from 6 to 30kV (MV & HV Cables)
- **Purpose:**
- This screen consists of a lapped copper tape or metallic foil usually less than 1.0mm in thickness, which is the interface between the conductor and the insulation (PVC, XLPE).
- The Main Purpose of Conductor Screen is to maintain a uniformly divergent electric field, and to contain the electric field within the cable core.
- Conductor Screen is semi-conducting material because Semi-conducting materials do not conduct electricity well enough to be a conductor but will not hold back voltage. It "smoothes" out the surface irregularities of the conductor. The conductor shield makes the voltage on the inside of the insulation the same
- Semiconducting screening materials are based on carbon black that is dispersed within a polymer matrix. The concentration of carbon black needs to be sufficiently high to ensure an adequate and consistent conductivity.
- The incorporation must be optimized to provide a smooth interface between the conducting and insulating portions of the cable.
- The smooth surface is important as it decreases the occurrence of regions of high electrical stress.
- **Control Electrical Field:** Conductor Screen is control the electric field within the insulation and thus the same voltage gradient across it. It also avoids any interaction of the electric stresses due to the voltages on different phase conductors within the same cable.
- **Reduce Voltage Stress** Conductor Screen helps to reduce voltage stress at the interface between the conducting and insulating components.
- A typical construction for a medium voltage cable consists of an aluminum conductor covered by a screening layer, then by a polyethylene or ethylene propylene rubber insulation followed by a further screening layer. The coefficient of expansion of the insulation layer is typically ten times greater than that of the aluminum and when the cable is at its maximum operating temperature of 90ºC, a large enough gap can formed to allow electrical discharges to occur. The semi-conducting layer then serves to even out the stresses associated with these discharges, which would otherwise attack the insulation at specific points.



- **Uniform Electrical Field:** A Black semi-conducting tape is used to maintain a uniform electric field and minimize electrostatic stresses in MV/HV power cables.
- The external surfaces of the conductor may not be smooth, particularly for stranded conductors, so this layer provides a smooth surface at the same potential as the conductor to keep the electric field consistent all the way around the surface. Without this layer, any small peaks or troughs could cause concentrations of electrical energy which could create small arcs, and over time could erode the insulation layer and cause failure of the cable.
- **Reduce Electrical Flux line around the each core: :** It Provide a cylindrical, smooth surface between the conductor and insulation
- Semi-conducting compounds also have the effect of filling in the interstices of the conductor giving a smooth surface for the insulation. This reduces the electrical flux lines around each individual wire that make up the conductor, which can reduce the stress by 10-15%.

(3) Filler & Binding Tap (Laying-Up):

- **Material:** Non Hygroscopic PVC / Poly propylene Fiber to maintain roundness of cable.
- **Used for :** LV,MV & HV Cables
- **Purpose:**

- In case of three core cables, the three cores are laid up with polymer compound or non-hygroscopic fillers like polypropylene (PP) fillers and a binder tape is applied with an overlap to provide a circular shape to the cable.
- These binder tapes can be of PVC or foamed Polyethylene.
- Inner Sheath (Bedding) for Armored Cables. Extruded layer of PVC or PE is applied over the laid up cores for armored cables.

(4) Insulation:

- **Code:** IS: 7098, 8130, 14494 / IEC: 60502 / BS: 6622/BS: 7835.
- **Material:** PVC, XLPE, Rubber, Elastomer, EPR.
- **Used for :** LV ,MV & HV Cables
- **Purpose:**
- Insulation main Purpose is to withstand the electrical field applied to the cable for its design life in its intended installed environment
- This will be an extruded layer of XLPE, Elastomer, Rubber or PVC applied over conductor screen under triple extrusion process along with conductor screen and insulation screen.
- There are different Type of Insulation Material used for cable but widely used are

(a) Cross-linked polyethylene: (XLPE)

- They are known as PEX or XLPE Cable. It is form of polyethylene with cross links.
- XLPE creates by direct links or bonds between the carbon backbones of individual polyethylene chains forms the cross linked polyethylene structure.
- The result of this linkage is to restrict movement of the polyethylene chains relative to each other, so that when heat or other forms of energy are applied the basic network structure cannot deform and the excellent properties that polyethylene has at room temperature are retained at higher temperatures.
- The cross linking of the molecules also has the effect of enhancing room temperature properties.
- The useful properties of XLPE are temperature resistance, pressure resistance (stress rupture resistance), environmental stress crack resistance (esc), and resistance to UV light, chemical resistance, oxidation resistance, room temperature and low temperature properties.
- XLPE cables work for the working voltage of 240 V to 500 KV.
- The Jacketing Material can be of PVC / Flame Retardant / Flame Retardant Low Smoke / Zero Halogen (LSOH).
- **Applications**: Fire Survival, Under Water Cables, Underground burial, installation on trays and ducts.

(b) Polyvinyl chloride (PVC)

- They are known as PVC insulated cables are widely used in various fields.
- PVC's relatively low cost, biological and chemical resistance and workability have resulted in it being used for a wide variety of applications.
- For electric cables the PVC is mixed up with plasticizers. PVC has high tensile strength, superior conductivity, better flexibility and ease of jointing.
- PVC is a thermoplastic material, therefore care must be taken not to overheat it; it is suitable for conductor temperatures up to 70°C. PVC insulated cables should not be laid when the temperature is less than 0ºC because it becomes brittle and is liable to crack.
- **Applications:** Low voltage copper conductor PVC cables are extensively used for domestic home appliances wiring, house wiring and internal wiring for lighting circuits in factories, power supply for office automation, in control, instrumentation, submarine, mining, ship wiring applications etc.

(c) Elastomer Insulated cable

- These cables are suitable for use where the combination of ambient temperature and temperature-rise due to load results in conductor temperature not exceeding 90°C under normal operation and 250°C under short-circuit conditions.
- This insulation shall be so applied that it fits closely on the conductor (with or without either separator or screen) but shall not adhere to it. The insulation, unless applied by extrusion, shall be applied in two or more layers and it is applicable to cables with a rated voltage up to 1 100 volts.
- **Applications**: Welding Cables, Ship wiring cables, Pressure Tight Cables and cables for submerged connection, Railways locomotives and coach wiring cables, Mining Cables.

(d) Polyvinyl chloride (EPR).

- For high-voltage cables the insulation is ethylene propylene rubber (EPR) and for low-voltage cables it is polyvinyl chloride (PVC).

- EPR has good electrical properties and is resistant to heat and chemicals; it is suitable for a conductor temperature up to 85 ºC.

(e) Rubber Insulated cable

- These are used in electric utilities such as the generation and transmission of electricity. Long service life under normal environment in Nuclear and conventionally powered generating stations plus safety considerations are the significant factors of these electric appliances.
- When exposed to fire, Silicon offers circuit integrity, low smoke evolution, and freedom from halogen acids.

(5) Insulation Screen:

- **Code:** IS:7098/IEC:60502/ BS:6622/BS:7835
- **Material:** Extruded thermo set semi-conducting compound, Carbon paper and carbon loaded polymer.
- **Used for :** Cable from 6 to 30kV (MV & HV Cables)
- **Purpose:**
- An extruded layer of semi conducting is applied over the insulation layer to insure that the electric stress is homogenous around the insulated core. The semi conducting layer shall be firmly bonded to the outer layer of the insulation layer.
- The Purpose of Insulation screen is same as Conductor Screen.
- The Purpose of Insulation Screen is to reduce voltage stress at the interface between the conducting and insulating component
- A cylindrical, smooth surface between the insulation and Metallic shield
- Insulation screen is a layer of black cross linked semi conductive compound of approx 1mm thickness and is either fully bonded to the insulation layer, or can be "cold strippable" by hand.
- When terminating or jointing the cables, it is necessary to remove a part of the insulation screen.

(6) Bedding (Inner Sheath):

- **Code:** IS: 7098, 1554 / IEC: 60502 / BS: 6622 / BS: 7835.
- **Material:** Thermoplastic material i.e. PVC, Polyethylene, thermosetting (CSP) compound
- **Used for** : LV, MV & HV Cables
- **Purpose:**
- It could be also called inner sheath or inner jacket, which serves as a bedding under cable armoring to protect the laid up cores and as a separation sheath.
- Inner sheath is over laid up of cores.
- It gives Circular Shape of the cable and it also provides Bedding for the armoring.
- IS:1554 permits following two methods of applying the Inner Sheath of thermoplastic material i.e. PVC, Polyethylene etc., Which is not harder than insulation.
- Inner sheath is provided by extrusion of thermoplastic over the laid up of cores
- Inner sheath is provided by wrapping at thermoplastic tape.
- All multi-core cables have either extruded PVC inner sheath or thermoplastic wrapped inner sheath, which is compatible to insulation material and removable without any damage to insulation. Single core cables have no inner sheath.

(7) Water blocking Taps:

- Water blocking is used to prevent moisture migration.
- Water blocking tapes or Swelling powder should be applied between the conductor strands to block the ingress of water inside the cable conductor (if required).
- Water blocking Methods to be considered are as follows.
- **Powders:** Swell able powders are used as longitudinal water blocks in cables to prevent longitudinal water penetration. These powders swell and expand sufficiently upon contact with water to form a gel-like material to block the flow of water.
- **Water-Blocking Tapes:** A water-blocking tape is usually a nonwoven synthetic textile tape impregnated with, or otherwise containing, a swell able powder.
- **Sealed Overlap:** To ensure a seal of the overlap, hot-melt adhesives can be used. These adhesives can be extruded or pumped into the overlap seam of a longitudinally formed metallic tape before the seam is closed during cable manufacture.

(8) Metallic Screen:

- **Code:** IS: 7098 /IEC:60502 / BS:6622/ BS:7835.

- **Material:** Nonmagnetic metallic materials Copper Wire / Tape or Aluminum Wire / Strip
- **Used for :** MV & HV Cables
- **Purpose:**
- Medium Voltage & High-voltage cables have an earthed metallic screen over the insulation of each core.
- This screen consists one or multi layers of a lapped Conductive copper wires, copper tape or metallic foil, lead, aluminum helically with overlap over insulation screen.
- The metallic shield needs to be electrically continuous over a cable length to adequately perform its functions of electrostatic protection, electromagnetic protection, and protection from transients, such as lightning and surge or fault currents.
- **(1) Shield Electromagnetic radiation:** A metallic sheath is used as a shield to keep electromagnetic radiation in the Cable.
- The main function of the metallic screen is to nullify the electric field outside of the cable – it acts as a second electrode of the capacitor formed by the cable. The screen needs to connect to earth at least at one point along the route.
- The capacitive charging current and induced circulating currents which are generated under normal operating conditions will be drained away through the screen.
- **(2) Earth Path:** It also provides a path for fault and leakage currents (sheaths are earthed at one cable end).
- The screen also drains the zero-sequence short circuit currents under fault conditions; this function is used to determine the required size of the metallic screen.
- Lead sheaths are heavier and potentially more difficult to terminate than copper tape, but generally provide better earth fault capacity.
- **(3) Water Blocking:** The other function of Metallic sheaths is to water block and form a radial barrier to prevent humidity from penetrating the cable insulation system.
- **(4) Mechanical Protection:** It also provides some degree of mechanical protection to cable.
- Cable shields are nonmagnetic metallic materials. The two materials typically used for metallic shields are aluminum and copper. Aluminum requires a larger diameter as a wire or a thicker cross section as tape to carry the same current as copper. At equivalent current-carrying capacity, an aluminum shield will be lighter in weight but about 40% larger in dimensions

Different Types of Metallic Screen:

Concentric Copper Wire screens /Tapes

- **Advantages:**
- Lightweight and cost effective design.
- High short-circuit capacity.
- Easy to terminate.
- **Drawbacks:**
- Low resistance of screen may necessitate need for special screen connections to limit the circulating current losses.
- Does not form a complete moisture barrier unless water swell able tapes are used under and/or over the copper wires.

(I) Aluminum foil laminate

- **Advantages:**
- Lightweight and cost effective design.
- Moisture proof radial barrier.
- **Drawbacks:**
- Low short circuit capacity.
- More difficult to terminate – requires special screen connections.

(II) Extruded lead alloy sheath

- **Advantages:**
- Waterproofing guaranteed by the manufacturing process.
- Excellent resistance to corrosion and hydrocarbons (suitable for oil and gas plants).
- **Drawbacks:**
- Heavy and expensive.
- Lead is a toxic metal whose use is being restricted in some countries.

- Limited capacity for short circuits.

(9) Armoring:

- **Code:** IS: 7098 / IS: 3975 / IEC:60502 / BS:6622/BS:7835.
- **Material:** metallic or non-magnetic Alumimium, Steel wire/strip.
- **Used for** : LV, MV & HV Cables
- The armor provides mechanical protection against crushing forces.
- Armor also can serve as an Earth Continuity Conductor (ECC).
- The armoring type could be:
- Mechanical protection of the cable is provided by a single layer of wire / Strip strands laid over the bedding. Steel wire / Strip is used for 3-core or 4-core cables, but single-core cables have aluminum wire armoring.
- When an electric current passes through a cable it produces a magnetic field (the higher the voltage the bigger the field). The magnetic field will induce an electric current in steel armor (eddy currents), which can cause overheating in AC systems. The non-magnetic aluminum armor prevents this from happening.
- **Magnetic Material's armoring for 3Ph System:** With 3-core or 4-core cables the vector sum of the currents in the conductors is zero, and there is virtually no resultant magnetic flux. In Multi-core armored cables have either single layer of Galvanized Steel wire Armor or Galvanized steel strip applied over inner sheath with left hand lay.
- **Non Magnetic Material's armoring for 1Ph System:** This is not so however for a single-core cable, where eddy-current heating would occur if a magnetic material was used for the armoring. The material has to be non magnetic for armoring as in this case of return current is not passing through the same cable. Hence it will not cancel the magnetic lines produced by current. These magnetic lines which are oscillating in case of A.C. systems will give rise to eddy currents in magnetic armoring and hence armoring will become hot, and this may lead to failure of the cable. Hence Single core cables for use on A.C systems are armored with single layer of nonmagnetic (Aluminum) material.
- Armoring is Mostly following Type
- SWA - Steel wire armor, used in multi-core cables (magnetic),
- AWA - Aluminum wire armor, used in single-core cables (non-magnetic).
- Tinning or galvanizing is used for rust prevention. Phosphor bronze or tinned copper braid is also used when steel armor is not allowed.
- As strip construction is economical, the manufacture always provides steel strip armoring unless wire armoring is specified.
- As per IS: 1554 Round Wire armoring is provided in cable where calculated diameter under amour is upto13mm. Above this the amour is either steel wire or steel strip of size 4.00X0.80mm.

(10) Over Sheath (Outer Jacket):

- **Code:** IS: IS:7098 / IEC:60502 / BS:6622/BS:7835.
- **Material:** PVC Flame Retardant / Flame Retardant Low Smoke / Zero Halogen (LSOH), High density Polyethylene HDPE, Halogen Free Flame Retardant (HFFR)
- **Used for** : LV, MV & HV Cables
- **Purpose:**
- It is the outer protection part of the cable against the surrounding environment.
- Protected against water ingress, Protection against termite, Protection against UV and Protection against differing soil compositions.
- It is applied over armoring in case of armored cable and over inner sheath in case of unarmored cable called as "Outer Sheath".
- The standard sheath color is Black other colors such as Red , Light Blue can also be provided
- High-voltage cables are identified by outer sheaths colored red; a black sheath indicates a low-voltage cable

- The following are the electrical property may be consider while selecting a outer Sheath Materials
- **Dielectric Strength**: Cable Sheath may be semiconducting or insulating.
- **Discharge and Tracking Resistance:** When a non shielded cable rests upon or comes into contact with a ground plane, the ground plane acts as the outer plate of the capacitor, made up of the conductor, insulation and the ground plane. Discharges and tracking may cause erosion of the Outer Sheath material.

- **Material:** A major consideration in selecting Outer Sheath may be a thermoplastic or thermosetting material. Mostly a thermoplastic jacket is less expensive. However, thermoplastics will melt at some elevated temperature and, thus, could run or drip from the cable under extreme conditions.
- Thermoset materials will not melt and run or drip at elevated temperatures.

Comparison of Cable:

(I) PVC Insulated Cable:

- PVC insulation becomes stiff making it difficult to fold and the soft PVC loosens its softening agent over years, making it brittle and prone to rip.
- Even at the time of disposing, burning PVC emits toxic dioxin, which is responsible for causing cancer and does, when dumped scantly dissolve
- PVC is thin insulation mainly used in LT side cables and XLPE is thick insulation used in MV & HT cables.

(II) XLPE Insulated Cable:

- **Higher Current Capacity:** XLPE has higher current carrying capacity as
- **Higher Temperature Withstand Capacity:** It can withstand higher temperature compared to PVC cable.
- **Higher Overload Capacity:** XLPE have high overload capacity.
- **Low Dielectric Constant:** XLPE has lower dielectric and constant power factor.
- **Light weight & Small Bending Radius :**XLPE cables are lighter in weight, has smaller bend radius, and hence lesser installation cost.
- **Higher Short Circuit Capacity:** XLPE has higher short circuit rating. XLPE can withstand higher & lower temperatures insulation is usually thinner but the resistance is higher.
- **Higher Moisture Resistance:** XLPE also has a higher moisture & chemical resistance.
- Cable Installation Job for XLPE is easier than PVC insulated cables because of less Wt, less Diameter and Less Bending radius.
- The Volume Resistivity (ohm-cm) for XLPE is way higher than the PVC cables which are of the order of XLPE cables has insulation resistance of 1000 times compared to PVC cables.

(III) Elastomer Insulated Cable:

- Elastomer cables are preferred for flexible application and in congested locations where the bending radius are very small. Elastomer cables are available from low voltage up to 33 kV grade.
- Elastomer cables are also available with rigid copper conductors and having properties like Fire Survival, Zero Halogen and Low toxicity FS properties.

(IV) Rubber Insulated Cable:

- Rubber insulation remains in the best condition after a long span of time,say,25-30 years and remain soft and pliable even when the temperature is low.
- Rubber Cables are predominantly used in special applications like, mining, ship wiring, transportation sector and Defense applications & earth moving machines.
- These materials have the potential to be recyclable since they can be molded , extruded and reused like plastics, but they have typical elastic properties of rubbers which are not recyclable owing to their thermosetting characteristics

Cable Selection Parameters:

(a) Voltage of Cable:

- The Nominal voltage is to be expressed with two values of alternative current Uo/U in V (volt)
- Uo/U : Phase to earth voltage
- Uo : Voltage between conductor and earth
- U : Voltage between phases (conductors)
- (i) Low-tension (L.T.) cables — upto 1000 V
- (ii) High-tension (H.T.) cables — upto 11,000 V
- (iii) Super-tension (S.T.) cables — from 22 kV to 33 kV
- (iv) Extra high-tension (E.H.T.) cables — from 33 kV to 66 kV
- (v) Extra super voltage cables — beyond 132 kV
- A low-voltage system usually has a solidly earthed neutral so that the line to earth voltage cannot rise higher than (line volts) ÷ √ 3. Cables for low-voltage use are insulated for 600V rms score to earth and 1000V rms core to core.

- High-voltage cables used in Shell installations are rated 19000/3300V or 3810/6600V or 6600/11000V, Phase/Phase.
- In selecting the voltage grade of cable, the highest voltage to earth must be allowed for. For example, on a normal 6.6kV unearthed system, a line conductor can achieve almost 6.6kV to earth under earth-fault conditions, to withstand this, a cable insulated for 6600/11000V must therefore be used.

(b) Current carrying capacity:

- The current carrying capacity of a cable is called Ampacity. Ampacity is defined as the maximum amount of electrical current a conductor or device can carry before sustaining immediate or progressive deterioration and is the rms electric current which a device or conductor can continuously carry while remaining within its temperature rating

(c) Short Circuit values:

- the "short-circuit current rating" is the maximum short-circuit current that a component can withstand. Failure to provide adequate protection may result in component destruction under short circuit conditions.
- Short circuits and their effects must be considered in selecting cables. These cables should have a short circuit rating which is the highest temperature the cable can withstand during an electrical short circuit lasting up to about half a second.

(d) Type of Conductor:

- Type of Conductor Material Copper or Aluminum is main criteria for selection of Cable

(e) No of Core:

- No of Core selection is depends upon Power System.
- For Single Phase Power Supply We can use 2 core Cable for Three phase supply we can use 3.5 Core or 4 Core Cable for HV supply We may be use Single Core Cable.

(f) Voltage drop:

- It is a primary concern when installing lengths of cables is voltage drop. The amount of voltage lost between the originating power supply and the device being powered can be significant. All cables have resistance, and when current flows in them this results in a volt drop.

(g) Type of Insulations:

- Type of Cable Insulation Material like, PVC, XLPE, Rubber
- PVC Cable is cheaper than XLPE Cable

(h) Method of Installation:

- If we lay cable in Ground Armor cable is required but If we lay cable in cable tray We may be used un armor cable to reduce cost of cable.
- I we lay cable on cable tray than shielded cable is required.
- Mutual heating effect due to cable group laying is also consider while selecting a cable. When multiple cables are in close proximity, each contributes heat to the others and diminishes the amount of external cooling affecting the individual cable conductors. Therefore cable de rating is necessary consideration for multiple cables in close proximity.

(i) Shielded Cable or unshielded Cable

- The choice of a shielded cable or non-shielded cable is depend upon some criteria.
- An area such as a production/factory floor where heavy equipment is being used is a prime example of a place where we might consider a shielded cable.
- Grounding can also be a concern in some installations. If shielded cable is used to connect equipment from two different circuits, a ground loop can occur causing noise on a network line. If the ground voltage difference is great enough it may even cause damage.
- Terminations of the shielded cable must also be made with care, to provide for a smooth dielectric transition from the shielded condition to the unshielded condition
- the substantial space required if shielded cables were used. Shielded cables require a significant amount of space at each end of the cable for installation of the stress cone kit. Also, the minimum bending radius for shielded cables is twelve times cable outside diameter, whereas the minimum bending radius for unshielded cables is only eight times outside diameter (and even less with extra-flexible appliance connection cables used in controllers).
- The two factors, high cost and large space requirements, preclude use of shielded cable in switchgear

(j) Economics:

- It is also an important factor for selecting the type of cable.
- It is to be kept in mind that the cost of the cable should not be such large that it causes loss and another cable may fetch the same results in low cost and loss.

(k) Environmental conditions:

- Cable operates at its best when it is installed in its optimum environmental conditions.
- For example, Elastomeric Cable is applied in trailing, coal cutter, wind mill, panel wiring, battery cable and such other areas. XLPE cables work good in areas where moisture content is good. Thus, proper cable should be selected so that the system becomes more efficient.

(l) Applications:

- Low voltage cables with both PVC and XLPE insulation are suitable for indoor and outdoor applications.
- Armored cables are not recommended for tray applications, as they are heavy in weight and extra loads are exerted on the tray.
- Unarmored cables are not recommended for direct buried applications, except if the quoted cables are designed and produced to pass direct burial test requirements (example, direct burial tests described in UL 1277 and UL 1581).
- A PVC jacket is a very stable material against a wide range of chemicals, while HDPE jacketed cables can serve better in wet locations.

Cable Core Colors Identification

- Single core **-** Natural
- Two core **-** Red, Black
- Three core **-** Red, Yellow and Blue
- Four core **-** Red, Yellow and Blue and Black
- Five core **-** Red, Yellow and Blue and Black and Green

Abbreviation for PVC & XLPE Cable

- A = Aluminum Conductor.
- Y = PVC Insulation or PVC Sheath
- 2X = Cross-linked Polyethylene Insulation
- W = Round Steel Wire Armoring
- WW = Double Round Steel Wire Armoring
- F = Formed Steel Wire (Strip) Armoring
- FF = Double Formed Steel Wire (Strip) Armouring
- C = Metallic Screening (Usually of Copper)
- CE = Metallic Screening (Usually of Copper) over each individual core.
- Gb = Holding Helix Tape (of Steel)
- Wa = Aluminum Round Wire & Aluminum Formed Wire (Strip) Fa Armouring.
- **Example:**
- **AYY:** Aluminum Conductor, PVC Insulated, PVC Outer Sheathed Heavy Duty Cables.
- **AYWY:** Aluminum Conductor, PVC Insulated, Round Steel Wire Armored and PVC Outer Sheathed
- **AYFY:** Aluminum Conductor, PVC Insulated, Flat Steel Wire (Strip) Armored and PVC Outer Sheathed
- **AYCY:** Aluminum Conductor, PVC Insulated, Metallic Screened and PVC Outer Sheathed
- **A2XCY:** Aluminium Conductor, XLPE Insulated, Metallic Screened and PVC Outer Sheathed

Cable Application Standard:

- IEC 60502 (Part 1)"PVC/ XLPE insulated cables" single core /multi-core
- BS 5467 for XLPE insulated armored cables
- BS 7889 for XLPE insulated single core unarmored cables

Chapter: 21 Difference between Unearthed & Earthed Cables

Introduction:

- In HT electrical distribution, the system can be earthed or unearthed. The selection of earthed/unearthed cable will depend on system. If distribution system is earthed then we have to use cable which is manufactured for earthed system. (Which the manufacturer specifies). If the system is unearthed then we need to use cable which is manufactured for unearthed system. The unearthed system requires high insulation level compared to earthed System.
- For earthed and unearthed XLPE cables, the IS 7098 part2 1985 does not give any difference in specification. The insulation level for cable for unearthed system has to be more.

Earthed System:

- Earlier the generators and transformers were of small capacities and hence the fault current was less. The star point was solidly grounded. This is called earthed system.
- In Three phases earthed system, phase to earth voltage is 1.732times less than phase to phase voltage. Therefore voltage stress on cable to armor is 1.732times less than voltage stress between conductors to conductor.
- In an earthed cable, the three phase of cable are earthed to a ground. Each of the phases of system is grounded to earth.**Examples are 1.9/3.3 KV, 3.8/6.6 KV system**
- Where in unearthed system, (if system neutral is not grounded) phase to ground voltage can be equal to phase to phase voltage. In such case the insulation level of conductor to armor should be equal to insulation level of conductor to conductor.

Unearthed System:

- Today generators of 500MVA capacities are used and therefore the fault level has increased. In case of an earth fault, heavy current flows into the fault and this lead to damage of generators and transformers. To reduce the fault current, the star point is connected to earth through a resistance.
- If an earth fault occurs on one phase, the voltage of the faulty phase with respect to earth appears across the resistance. Therefore, the voltage of the other two healthy phases with respect to earth rises by 1.7 times. If the insulation of these phases is not designed for these increased voltages, they may develop earth fault. This is called unearthed system.
- In an unearth system, the phases are not grounded to earth .As a result of which there are chances of getting shock by personnel who are operating it. **Examples are6.6/6.6 KV, 3.3/3.3 KV system.**
- Unearthed cable has more insulation strength as compared to earthed cable. When fault occur phase to ground voltage is $\sqrt{3}$ time the normal phase to ground voltage. So if we used earthed cable in unearthed System, It may be chances of insulation puncture. So unearthed cable are used. Such type of cable is used in 6.6 KV systems where resistance type earthing is used.

Nomenclature:

- In simple logic the 11 KV earthed cable is suitable for use in 6.6 KV unearthed system. The process of manufacture of cable is same. The size of cable will depend on current rating and voltage level.
- Voltage Grade (Uo/U) where Uo is Phase to Earth Voltage & U is Phase to Phase Voltage.
- **Earthed system has insulation grade of KV / 0.686 x KV.**
- For Earthed System (Uo/U): 1.9/3.3 kV, 3.8/6.6 kV, 6.35/11 kV, 12.7/22 kV and 19/33 kV.
- **Unearthed system has insulation grade of KV / KV.**
- For Unearthed System (Uo/U): 3.3/3.3 kV and 11/11 kV.
- 3 phase 3 wire system has normally Unearthed grade cables and 3 phase 4 wire systems can be used earthed grade cables, insulation used is less, and cost is less.

Thumb Rule:

- As a thumb rule we can say that 6.6KV unearthed cable is equal to 11k earthed cable i.e**. 6.6/6.6kvUnearthed cable can be used for 6.6/11kv earthed system**. because each core of cable have the insulation level to withstand 6.6kv so between core to core insulation level will be 6.6kv+6.6kv = 11kv
- For transmission of HT, earthed cable will be more economical due to low cost where as unearthed cables are not economical but insulation will be good.

- Generally, 6.6 kV and 11kV systems are earthed through a neutral grounding resistor and the shield and armor are also earthed, especially in industrial power distribution applications. Such a case is similar to an unearthed application but with earthed shield (some times called solid bonding). In such cases, unearthed cables may be used so that the core insulation will have enough strength but current rating is de-rated to the value of earthed cables.But it is always better to mention the type of system earthing in the cable specification when ordering the cables so that the cable manufacturer will take care of insulation strength and de-rating. Also it is better to use the cables for the type of system earthing they are meant for.

Chapter: 22 Low Voltage and High Voltage Cable Testing

Low Voltage XLPE Distribution Cable Testing:

1) Insulation Resistance:

- Cables shall be tested for insulation resistance with an insulation tester (i.e. Megger) at 1000 Volts for 1 minute.The minimum insulation resistance to earth or between phases shall be 100 meg-ohms.
- The instrument used for this measurement shall have a minimum resolution of 10 meg-ohms on the 0 to 500 meg-ohm range.
- At the conclusion of LV insulation resistance testing, the neutrals must be connected to the earth stakes.

2) Phasing Test:

- The correct phasing of all LV circuits shall be checked at all positions where the LV cables are terminated into fuse bases and where any LV cable is run from point to point.
- This test shall be performed with an instrument designed for the purpose. Mains frequency voltage of 240 Volts is not acceptable for this test.
- The neutral conductor shall be connected to the earth stake for this test.

3) Continuity Test (resistance of bolted connections):

- For loop LV systems, a continuity test shall be carried out on each LV circuit to ensure that all bolted connections are complete and adequate. The test shall be carried out as follows:
- At the transformer firmly bond all 4 conductors together
- Undertake a continuity test at every point where there is a service provision or open point. In a fused service pillar the bottom row of fuses bases must be the point at which the test is undertaken as that is the furthest extent of the network.
- The difference between the readings of each phase conductor and the neutral for each individual test shall not be greater than 10% of each other. Any difference greater than this may indicate a loose or dirty connection and will require further investigation.
- The instrument used for this measurement should have a resolution to the second decimal point in the 0 to 5 ohm range.A typical instrument would be the earth "Megger" type and taking into account the resistance values of the test leads.

4) Earth Resistance Test:

- In any overhead or underground network the earth resistance at any point along the length of a LV feeder is to have a maximum resistance of 10 ohms prior to connection to the existing network.
- In any overhead or underground network the overall resistance to earth Shall be less than 1 ohm prior to connection to the existing network.

11 KV & 33 KV XLPE Cable Testing:

1) Phasing Test

- The correct phasing of all HV circuits shall be checked at all positions where the HV cables have been terminated.
- This test shall be performed with an instrument designed for the purpose. 240 Volt mains frequency is not acceptable for the performance of this test. The test may be conducted on either the wire screens or the aluminum conductors.
- Where the test is performed on the wire screens, they shall be disconnected from earth.

2) Outer Sheath Insulation Resistance (Screen wire test)

- The purpose of the test is to determine soundness of the outer polyethylene sheath against water ingress, mechanical damage and termite attack.
- Values below 0.5 meg-ohms (500 kΩ) can indicate sheath damage. Values between 1.0 and 10 meg-ohms may not indicate damage in a single location. Fault finding can often be very difficult. In new cables, values of greater than 100 mega ohms are required.
- The integrity of the outer sheath shall be checked after cables have been buried by an insulation tester (Megger) at 1000 Volts.
- The test shall be conducted for 1 minute between each wire screen and earth after the cable has been jointed and terminations installed.
- For cables after repairs, the resistance must not be less than 10 meg-ohms.

- Where HV cable circuits are cut and joined to new circuits, sheath testing must be carried out on the existing old circuit prior to joining to the new cable.

3) HV test on XLPE cables already in service or previously energized (Except for New Cables, Testing at Voltage greater than 5.0KV is not permitted)

- Studies carried out on DC high voltage testing of XLPE cables now conclude that;
- DC testing above 5kV of field aged XLPE cables generally increases water tree growth and reduces service life.
- 5kV is not considered a "High Voltage DC Test". The test voltages for tests on XLPE cables is now limited to 5kV after in service repairs and 10kV for new installations.
- A 5kV Megger is suitable for a 5kV test on cables after repairs.
- The changes to this section will also make it possible for a repaired cable to be tested by repair crews and made available for immediate return to service.

Application	Test Voltage	Criteria
After repairs – Sheath	1kV Megger 1 minute	10 meg-ohms min.
After repairs - Insulation	5kV Megger 1 minute	1000 meg-ohms min.
After repairs - Insulation	5kV DC 1 minute	5.0 µA (micro-amps) max.

HV test on new XLPE cable:

- Prior to the performance of this test, the screen wires must be connected to the permanent earth position.
- The cable shall be tested at the test voltage and the pass criteria shall be in accordance with following

HV Cable Testing Voltage		
Application	**Test Voltage**	**Criteria**
New cables – Sheath	1kV Megger 1 minute	100 meg-ohms min.
New cables – Insulation	10kV DC 15 minute	1.0 µA (micro-amps) max
New cables – Insulation	10kV DC 15 minute	1000 meg-ohms min.

- If further repair works are undertaken, and they require additional joints to be installed, the complete HV testing procedure shall be repeated.
- **Alternative HV Test Requirement on Insulation for 11kV Cables**
- Where it is not practical to conduct a high voltage test, the test requirements for insulation (core to screen wire) may be limited to testing for the condition of "safe to energize". The following list of circumstances and conditions must be met as a minimum requirement:
- The cable circuit voltage shall be 11kV,
- The circuit outage duration shall be not more than 48 hours,
- The work shall involve extending or repairs to existing circuits,
- The insulation test shall be applied for 1 minute between each
- phase core and screen with a 1000 Volt minimum insulation tester (Megger),
- Typically the test result should be in the order of 1000 meg-ohms.

Paper Insulated Cable Testing:

1) Tests on LV Cables

- An insulation resistance test shall be conducted with a 1000 Volt megger. Test results as low as 10 meg-ohms on old cable circuits are common and therefore considered safe to energies.

2) Test on 11kV and 33kV Cables between Cores and Earth

- For three core belted cables, the test on any core shall be conducted between the core and lead sheath with the remaining two cores connected to earth.
- The test voltages and pass criteria shall be in accordance with the table below.

Application	Test Voltage	Criteria
11kV new cables	5kV Megger 1 minute	100 meg-ohms.
11kV after repairs	5kV Megger 1 minute	100 meg-ohms.
33kV - no TF's connected	5kV Megger 1 minute	1000 meg-ohms.
33kV - with TF's connected	5kV Megger 1 minute	15 meg-ohms.

66kV XLPE Cables Testing:

1) Core to Sheath Test after Repairs:

- After repairs have been carried out, the 66kV XLPE cable shall be energized at power frequency for 24 hours without load. DC testing is not permitted.
- The cable sheath link box/cross bonding system shall be put into its normal condition.

2) Outer Sheath Integrity Test:

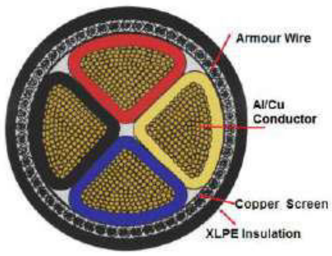
- An insulation resistance test between the metallic sheath and earth shall be conducted. The anti-termite barrier must be connected to the metallic sheath and the insulation test performed to earth.
- The test voltage applied for 1 minute shall be 5kV DC applied with either a high voltage test set or insulation resistance tester (Megger).

Introduction:

- In urban areas, high voltage underground cables are commonly used for the transmission and distribution of electricity. Such high voltage cables have metallic sheaths or screens surrounding the conductors, and/or armour and metallic wires surrounding the cables. During earth faults applied to directly earthed systems, these metallic paths are expected to carry a substantial proportion of the total fault current, which would otherwise flow through the general mass of earth, while returning to system neutrals. These alternative return paths must be considered when determining the extent of the grid potential rise at an electrical plant due to earth faults.
- For safety and reliable operation, the shields and metallic sheaths of power cables must be grounded. Without grounding, shields would operate at a potential considerably above ground. Thus, they would be **hazardous to touch and would cause rapid degradation of the jacket** or other material intervening between shield and ground. This is caused by the capacitive charging current of the cable insulation that is on the order of 1 mA/ft of conductor length.
- This current normally flows, at power frequency, between the conductor and the earth electrode of the cable, normally the shield. In addition, the shield or metallic sheath provides a fault return path in the event of insulation failure, permitting rapid operation of the protection devices.
- In order to reduce Circulating current and electric potential difference between the sheathings of single core three-phase cables, the sheathing is grounded and bonded at one or both ends of the cables. If the cable is long, double bonding has to be carried out which leads to circulating currents and increased total power loss. Raising the sheath's resistance, by decreasing its cross section and increasing its resistivity, can reduce this almost to the level of the core losses.
- However, in case of an earth fault, a considerable portion of the fault current flows through the increased sheath resistance, creating much higher power in the sheaths than in the faulty core. A simple solution, a conductor rod buried into the soil above or under the cable can divert this power from the sheaths.

Cable Screen:

(a) Purpose of cable screen:



- Cable screen controls the electric field stress in the cable insulation.
- Cable Screen Provides return path for Cable neutral and fault current.
- If the screen is earthed at two ends than it provides Shielding for electromagnetic radiation.
- Enclosing dangerous high voltage with earth potential for safety.

(b) Purpose of bonding cable screens at both ends:

- The electric power losses in a cable circuit are dependent on the currents flowing in the metallic sheaths of the cables so by reducing the current flows in metallic sheath by different methods of bonding we can increases the load current carrying capacity (ampacity) of the cable.
- It provides low impedance fault current return path and provides neutral point for the circuit.
- It provides shielding of electromagnetic field.

(c) Induced voltage & circulating circulating current in cable screen:

- Electromagnetic coupling between the core and screen Electromagnetic screen.
- If the cable screen is single point bonded, no electrical continuity and mmf generates a voltage.
- If the cable screen is bonded at both ends, the mmf will cause circulating current to flow if there is electrical continuity.
- The circulating current produces an opposing magnetic field.
- Suitable bonding method should be employed to meet the standing voltage limit and keep Circulating current to an acceptable level.

Laying Method of Cable:

- The three Single core cables in a 3-phase circuit can be placed in different formations. Typical formations include trefoil (triangular) and flat formations.

(I) Trefoil Formation:

- To minimize the electromechanical forces between the cables under short-circuit conditions, and to avoid eddy-current heating in nearby steelwork due to magnetic fields set up by load currents, the three single-core cables comprising the three phases of a 3-phase circuit are always run clamped in 'Trefoil' formation.
- **Advantage:**

1. This type of Formation minimizes the sheath circulating currents induced by the magnetic flux linking the cable conductors and metallic sheath or copper wire screens.
2. This configuration is generally used for cables of lower voltages (33 to 132kV) and of smaller conductor sizes.

- **Disadvantages:**

1. The trefoil formation is not appropriate for heat dissipation because there is an appreciable mutual heating effect of the three cables.
2. The cumulated heat in cables and cable trench has the effect of reducing the cable rating and accelerating the cable ageing.

(II) Flat Formation:

- This is a most common method for Laying LT Cable.
- This formation is appropriate for heat dissipation and to increase cable rating.
- The Formation choice is totally deepened on several factors like screen bonding method, conductor area and available space for installation.

Type of Core and Induced Voltage:

(a) Three Core Cable:

- For LT application, typically for below 11 kV.
- Well balanced magnetic field from Three Phase.
- Induced voltages from three phases sum to zero along the entire length of the cable.
- Cable screen should be earthed at both ends
- Virtually zero induced voltage or circulating current under steady state operation.

(b) Single Core Cable:

- For HV application, typically for 11 kV and above.
- Single–core cables neglect the use of ferromagnetic material for screen, sheath and armoring.
- Induced voltage is mainly contributed by the core currents in its own phase and other two phases. If cables are laid in a compact and symmetrical formation, induced in the screen can be minimized.
- A suitable screen bonding method should be used for single–core cables to prevent Excessive circulating current, high induced standing voltage.igh voltage.

Accessories for HT Cable Sheath Bonding:

(i) Function of Link Box?

- Link Box is electrically and mechanically one of the integral accessories of HV underground above ground cable bonding system, associated with HV XLPE power cable systems.
- Link boxes are used with cable joints and terminations to provide easy access to shield breaks for test purposes and to limit voltage build-up on the sheath

- Lightning, fault currents and switching operations can cause over voltages on the cable sheath. The link box optimizes loss management in the cable shield on cables grounded both sides.
- In HT Cable the bonding system is so designed that the cable sheaths are bonded and earthed or with SVL in such way as to eliminate or reduce the circulating sheath currents.
- Link Boxes are used with cable joints and terminations to provide easy access to shield breaks for test purposes and to limit voltage build-up on the sheath. The link box is part of bonding system, which is essential of improving current carrying capacity and human protection.

(ii) Sheath Voltage Limiters (SVL) (Surge Arrestors):

- SVL is protective device to limit induce voltages appearing on the bonded cable system due to short circuit.
- It is necessary to fit SVL's between the metallic screen and ground inside the link box. The screen separation of power cable joint (insulated joint) will be protected against possible damages as a result of induced voltages caused by short circuit/break down.

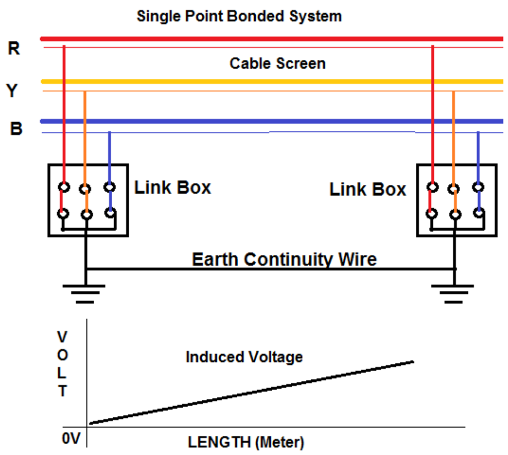
Type of Sheath Bonding for HT Cable:

- There is normally Three Type of Bonding for LT/HT Cable Screen.
- (I) Single Point Bonded.
- (a) One Side (Single Point)Bonded System.
- (b) Split Single Point Bonded System.
- (II) Both End Bonded System
- (III) Cross Bonded System

(I) Single point bonded system:

(a) One Side Single Bonded System:

- A system is single point bonded if the arrangements are such that the cable sheaths provide no path for the flow of circulating currents or external fault currents.
- This is the simplest form of special bonding. The sheaths of the three cable sections are connected and grounded at **one point only along their length**. At all other points there will be a voltage between sheath and ground and between screens of adjacent phases of the cable circuit that will be at its maximum at the farthest point from the ground bond.
- This induced voltage is proportional to the cable length and current. Single-point bonding can only be used for limited route lengths, but in general the accepted screen voltage potential limits the length



- The sheaths must therefore be adequately insulated from ground. Since there is no closed sheath circuit, except through the sheath voltage limiter, current does not normally flow longitudinally along the sheaths and no sheath circulation current loss occurs.
- Open circuit in cable screen, no circulating current.

- Zero volt at the earthed end, standing voltage at the unearthed end.
- Optional PVC insulated earth continuity conductor required to provide path for fault current, if returning from earth is undesirable, such as in a coal mine.
- SVL installed at the unearthed end to protect the cable insulation during fault conditions.
- Induced voltage proportional to the length of the cable and the current carried in the cable.
- Zero volt with respect to the earth grid voltage at the earthed end, standing voltage at the unearthed end.
- Circulating current in the earth–continuity conductor is not significant, as magnetic fields from phases are partially balanced.
- The magnitude of the standing voltage is depended on the magnitude of the current flows in the core, much higher if there is an earth fault.
- High voltage appears on the unearthed end can cause arcing and damage outer PVC sheath.
- The voltage on the screen during a fault also depends on the earthing condition.
- **Standing voltage at the unearthed end during earth fault condition**.
- During a ground fault on the power system the zero sequence current carried by the cable conductors could return by whatever external paths are available. A ground fault in the immediate vicinity of the cable can cause a large difference in ground potential rise between the two ends of the cable system, posing hazards to personnel and equipment.
- For this reason, **single-point bonded cable installations need a parallel ground conductor**, grounded at both ends of the cable route and installed very close to the cable conductors, to carry the fault current during ground faults and to limit the voltage rise of the sheath during ground faults to an acceptable level.
- The parallel ground continuity conductor is usually insulated to avoid corrosion and transposed, if the cables are not transposed, to avoid circulating currents and losses during normal operating conditions.
- Voltage at the unearthed end during an earth fault consists of two voltage components. Induced voltage due to fault current in the core.

Advantage:

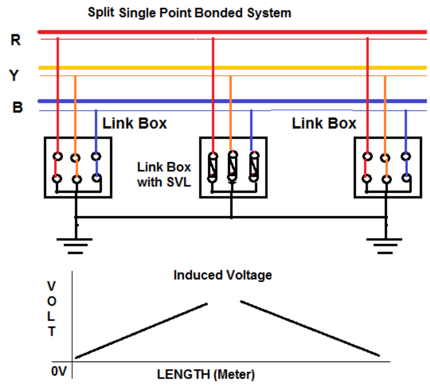
- No circulating current.
- No heating in the cable screen.
- Economical.

Disadvantage:

- Standing voltage at the un–earthed end.
- Requires SVL if standing voltage during fault is excessive.
- Requires **additional earth continuity conductor** for fault current if earth returned current is undesirable. Higher magnetic fields around the cable compared to solidly bonded system.
- Standing voltage on the cable screen is proportional to the length of the cable and the magnitude of current in the core.
- Typically suitable for cable sections less than **500 m, or one drum length**.

(b) Split Single Point-bonded System:

- It is also known as **double length single point bonding System**.
- Cable screen continuity is interrupted at the midpoint and SVLs need to be fitted at each side of the isolation joint.
- Other requirements are identical to single–point–bonding system like SVL, Earth continuity Conductor, Transposition of earth continuity conductor.
- Effectively two sections of single–point–bonding.
- No circulating current and Zero volt at the earthed ends, standing voltage at the sectionalizing joint.



Advantages:

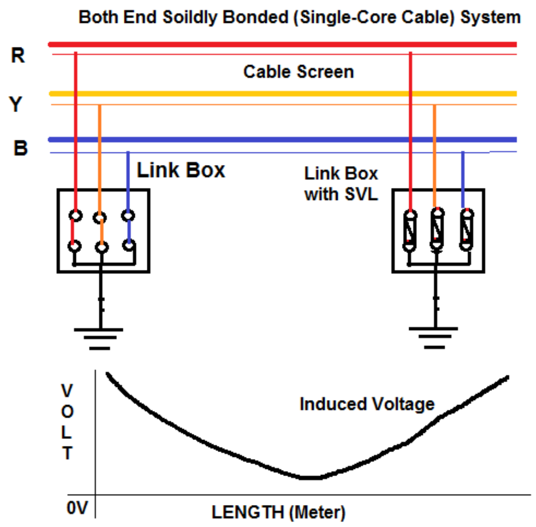
- No circulating current in the screen.
- No heating effect in the cable screen.
- Suitable for longer cable section compared to single–point–bonding system and solidly bonded single-core system.
- Economical.

Disadvantages:

- Standing voltage exists at the screen and sectionalizing insulation joint.
- Requires SVL to protect the un–earthed end.
- Requires separate earth continuity conductor for zero sequence current.
- Not suitable for cable sections over 1000 m.
- Suitable for 300~1000 m long cable sections double the length of single–point–bonding system.

(II) Both End Solidly Bonded (Single-core cable) systems.

- Most Simple and Common method.
- Cable screen is **bonded to earth grids at both ends (via link box).**
- To eliminate the induced voltages in Cable Screen is to bond (Earth) the sheath at both ends of the cable circuit.
- This eliminates the need for the parallel continuity conductor used in single bonding systems. It also eliminates the need to provide SVL, such as that used at the free end of single-point bonding cable circuits
- Significant circulating current in the screen Proportional to the core current and cable length and de rates cable.
- Could lay cable in compact trefoil formation if permissible.
- Suitable for route length of **more than 500 Meter**.
- Very small standing voltage in the order of several volts.



Advantages:

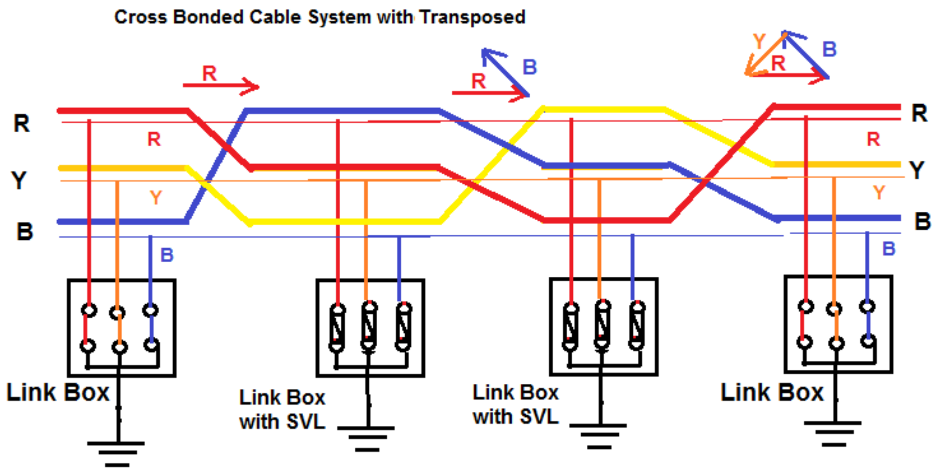
- Minimum material required.
- Most economical if heating is not a main issue.
- Provides path for fault current, minimizing earth return current and EGVR at cable destination.
- Does not require screen voltage limiter (SVL).
- Less electromagnetic radiation.

Disadvantages:

- Provides path for circulating current.
- Heating effects in cable screen, greater losses .Cable therefore might need to be de–rated or larger cable required.
- Transfers voltages between sites when there is an EGVR at one site.
- Can lay cables in trefoil formation to reduce screen losses.
- Normally applies to short cable section of tens of meters long. Circulating current is proportional to the length of the cable and the magnitude of the load current.

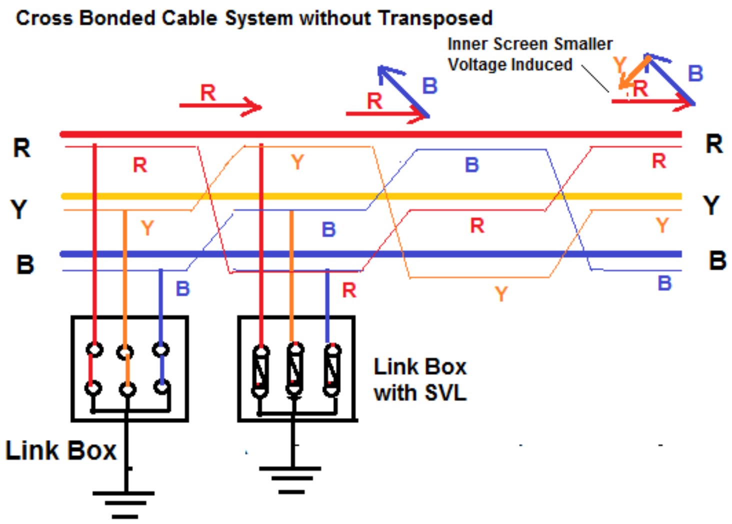
(III) Cross-bonded cable system.

- A system is cross-bonded if the arrangements are such that the circuit provides electrically continuous sheath runs from earthed termination to earthed termination but with the sheaths so sectionalized and cross-connected in order to reduce the sheath circulating currents.
- In This Type voltage will be induced between screen and earth, but no significant current will flow.
- The maximum induced voltage will appear at the link boxes for cross-bonding. This method permits a cable current-carrying capacity as high as with single-point bonding but longer route lengths than the latter. It requires screen separation and additional link boxes.
- For cross bonding, the cable length is divided into three approximately equal sections. Each of the three alternating magnetic fields induces a voltage with a phase shift of 120° in the cable shields.
- The cross bonding takes place in the link boxes. Ideally, the vectorial addition of the induced voltages results in U (Rise) = 0. In practice, the cable length and the laying conditions will vary, resulting in a small residual voltage and a negligible current. Since there is no current flow, there are practically no losses in the screen.
- The total of the three voltages is zero, thus the ends of the three sections can be grounded.
- Summing up induced voltage in sectionalized screen from each phase resulting in neutralization of induced voltages in three consecutive minor sections.
- Normally one drums length (500 m approx) per minor section.
- Sectionalizing position and cable jointing position should be coincident.
- Solidly earthed at major section joints.
- Transpose cable core to balance the magnitude of induced voltages to be summed up.
- Link box should be used at every sectionalizing joint and balanced impedance in all phases.
- Induced voltage magnitude profile along the screen of a major section in the cross–bonding cable system.
- Virtually zero circulating current and Voltage to the remote earth at the solidly earthed ends.
- In order to obtain optimal result, two "crosses" exist. One is Transposition of cable core crossing cable core at each section and second is Cross bond the cable screens effectively no transposition of screen.
- **Cross bonding of cable screen**: It is cancelled induced voltage in the screen at every major Section joint.
- **Transposition of cables:** It is ensure voltages to be summed up have similar magnitude .Greater standing voltage at the screen of the outer cable.
- Standing voltages exist at screen and majority of section joints cable and joints must be installed as an insulated screen system.



Requirement of transpose for cables core.

- If core not transposed, not well neutralized resulting in some circulating currents.
- Cable should be transposed and the screen needs to be cross bonded at each sectionalizing joint position for optimal neutralization



Advantage:

- Not required any earth continuity conductor.
- Virtually zero circulating current in the screen.
- Standing voltage in the screen is controlled.
- Technically superior than other methods.
- Suitable for long distance cable network.

Disadvantage:

- Technically complicated.
- More expensive.

Bonding Method Comparison:

Earthing Method	Standing Voltage at Cable End	Sheath Voltage Limiter Required	Application
Single End Bonding	Yes	Yes	Up to 500 Meter
Double End Bonding	No	No	Up to 1 Km and Substations short connections, hardly applied for HV cables, rather for MV and LV cables
Cross Bonding	Only at cross bonding points	Yes	Long distance connections where joints are required

Sheath Losses according to type of Bonding:

- Sheath losses are current-dependent losses and are generated by the induced currents when load current flows in cable conductors.
- The sheath currents in single-core cables are induced by “transformer” effect; i.e.by the magnetic field of alternating current flowing in cable conductor which induces voltages in cable sheath or other parallel conductors.
- The sheath induced electromotive forces (EMF) generate two types of losses: circulating current losses (Y**1**) and eddy current losses (Y2), so the total losses in cable metallic sheath are: **Y= Y1+Y2**
- The eddy currents circulating radially and longitudinally of cable sheaths are generated on similar principles of skin and proximity effects i.e. they are induced by the conductor currents, sheath circulating currents and by currents circulating in close proximity current carrying conductors.
- They are generated in cable sheath irrespective of bonding system of single core cables or of three-core cables
- The eddy currents are generally of smaller magnitude when comparing with circuit (circulating) currents of solidly bonded cable sheaths and may be neglects except in the case of large segmental conductors and are calculated in accordance with formulae given in the IEC60287.
- Circulating currents are generated in cable sheath if the sheaths form a closed loop when bonded together at the remote ends or intermediate points along the cable route.

- These losses are named sheath circulating current losses and they are determined by the magnitude of current in cable conductor, frequency, mean diameter, the resistance of cable sheath and the distance between single-core cables.

Conclusion:

- There is much disagreement as to whether the cable shield should be grounded at both ends or at only one end. If grounded at only one end, any possible fault current must traverse the length from the fault to the grounded end, imposing high current on the usually very light shield conductor. Such a current could readily damage or destroy the shield and require replacement of the entire cable rather than only the faulted section.
- With both ends grounded, the fault current would divide and flow to both ends, reducing the duty on the shield, with consequently less chance of damage.
- Multiple grounding, rather than just grounding at both ends, is simply the grounding of the cable shield or sheath at all access points, such as manholes or pull boxes. This also limits possible shield damage to only the faulted section.

References:

1. Mitton Consulting.
2. EMElectricals

What is HIPOT Testing (Dielectric Strength Test):

- Hipot Test is short name of high potential (high voltage) Teat and It also known as Dielectric Withstand Test. A hipot test checks for **"good isolation."** Hipot test makes surety of *no current* will flow from one point to another point. Hipot test is the opposite of a continuity test.
- Continuity Test checks surety of current flows easily from one point to another point while Hipot Test checks surety of current would not flow from one point to another point (and turn up the voltage really high just to make sure no current will flow).

Importance of HIPOT Testing:

- The hipot test is a non-destructive test that determines the adequacy of electrical insulation for the normally occurring over voltage transient. This is a high-voltage test that is applied to all devices for a specific time in order to ensure that the insulation is not marginal.
- Hipot tests are helpful in finding nicked or crushed insulation, stray wire strands or braided shielding, conductive or corrosive contaminants around the conductors, terminal spacing problems, and tolerance errors in cables. Inadequate creepage and clearance distances introduced during the manufacturing process.
- HIPOT test is applied after tests such as fault condition, humidity, and vibration to determine whether any degradation has taken place.
- The production-line hipot test, however, is a test of the manufacturing process to determine whether the construction of a production unit is about the same as the construction of the unit that was subjected to type testing. Some of the process failures that can be detected by a production-line hipot test include, for example, a transformer wound in such a way that creepage and clearance have been reduced. Such a failure could result from a new operator in the winding department. Other examples include identifying a pinhole defect in insulation or finding an enlarged solder footprint.
- As per IEC 60950, The Basic test Voltage for Hipot test is the **2X (Operating Voltage) + 1000 V**
- The reason for using 1000 V as part of the basic formula is that the insulation in any product can be subjected to normal day-to-day transient over voltages. Experiments and research have shown that these over voltages can be as high as 1000 V.

Test method for HIPOT Test:

- Hipot testers usually connect one side of the supply to safety ground (Earth ground). The other side of the supply is connected to the conductor being tested. With the supply connected like this there are two places a given conductor can be connected: high voltage or ground.
- When you have more than two contacts to be hipot tested you connect one contact to high voltage and connect all other contacts to ground. Testing a contact in this fashion makes sure it is isolated from all other contacts.
- If the insulation between the two is adequate, then the application of a large voltage difference between the two conductors separated by the insulator would result in the flow of a very small current. Although this small current is acceptable, no breakdown of either the air insulation or the solid insulation should take place.
- Therefore, the current of interest is the current that is the result of a partial discharge or breakdown, rather than the current due to capacitive coupling.

Time Duration for HIPOT Test:

- The test duration must be in accordance with the safety standard being used.
- The test time for most standards, including products covered under IEC 60950, is 1 minute.
- A typical rule of thumb is **110 to 120% of 2U + 1000 V for 1–2 seconds.**

Current Setting for HIPOT Test:

- Most modern hipot testers allow the user to set the current limit. However, if the actual leakage current of the product is known, then the hipot test current can be predicted.
- The best way to identify the trip level is to test some product samples and establish an average hipot current. Once this has been achieved, then the leakage current trip level should be set to a slightly higher value than the average figure.

- Another method of establishing the current trip level would be to use the following mathematical formula: **E(Hipot) / E(Leakage) = I(Hipot) / 2XI(Leakage)**
- The hipot tester current trip level should be set high enough to avoid nuisance failure related to leakage current and, at the same time, low enough not to overlook a true breakdown in insulation.

Test Voltage for HIPOT Test:

- The majority of safety standards allow the use of either ac or dc voltage for a hipot test.
- When using ac test voltage, the insulation in question is being stressed most when the voltage is at its peak, i.e., either at the positive or negative peak of the sine wave.
- Therefore, if we use dc test voltage, we ensure that the dc **test voltage is under root 2 (or 1.414) times the ac test voltage, so the value of the dc voltage is equal to the ac voltage peaks.**
- For example, for a 1500-V-ac voltage, the equivalent dc voltage to produce the same amount of stress on the insulation would be 1500 x 1.414 or 2121 V dc.

Advantage / Disadvantage of use DC Voltage for Hipot Test:

- One of the advantages of using a dc test voltage is that the leakage current trip can be set to a much lower value than that of an ac test voltage. This would allow a manufacturer to filter those products that have marginal insulation, which would have been passed by an ac tester.
- When using a dc hipot tester, the capacitors in the circuit could be highly charged and, therefore, a safe-discharge device or setup is needed. However, it is a good practice to always ensure that a product is discharged, regardless of the test voltage or its nature, before it is handled.
- It applies the voltage gradually. By monitoring the current flow as voltages increase, an operator can detect a potential insulation breakdown before it occurs. A minor disadvantage of the dc hipot tester is that because dc test voltages are more difficult to generate, the cost of a dc tester may be slightly higher than that of an ac tester.
- The main advantage of the dc test is DC Voltage does not produce harmful discharge as readily occur in AC.It can be applied at higher levels without risk or injuring good insulation. This higher potential can literally “sweep-out” far more local defects.
- The simple series circuit path of a local defect is more easily carbonized or reduced in resistance by the dc leakage current than by ac, and the lower the fault path resistance becomes, the more the leakage current increased, thus producing a “snow balling” effect which leads to the small visible dielectric puncture usually observed. Since the dc is free of capacitive division, it is more effective in picking out mechanical damage as well as inclusions or areas in the dielectric which have lower resistance.

Advantage / Disadvantage of use AC Voltage for Hipot Test:

- One of the advantages of an ac hipot test is that it can check both voltage polarities, whereas a dc test charges the insulation in only one polarity. This may become a concern for products that actually use ac voltage for their normal operation. The test setup and procedures are identical for both ac and dc hipot tests.
- A minor disadvantage of the ac hipot tester is that if the circuit under test has large values of Y capacitors, then, depending on the current trip setting of the hipot tester, the ac tester could indicate a failure. Most safety standards allow the user to disconnect the Y capacitors prior to testing or, alternatively, to use a dc hipot tester. The dc hipot tester would not indicate the failure of a unit even with high Y capacitors because the Y capacitors see the voltage but don’t pass any current.

Step for HIPOT Testing:

- Only electrically qualified workers may perform this testing.
- Open circuit breakers or switches to isolate the circuit or Cable that will be hi-pot tested.
- Confirm that all equipment or Cable that is not to be tested is isolated from the circuit under test.
- The limited approach boundary for this hi-pot procedure at **1000 volts is 5 ft. (1.53m)** so place barriers around the terminations of cables and equipment under test to prevent unqualified persons from crossing this boundary.
- Connect the ground lead of the HIPOT Tester to a suitable building ground or grounding electrode conductor. Attach the high voltage lead to one of the isolated circuit phase conductors.
- Switch on the HIPOT Tester. Set the meter to 1000 Volts or pre decide DC Voltage. Push the “Test” button on the meter and after one minute observe the resistance reading. Record the reading for reference.

- At the end of the one minute test, switch the HIPOT Tester from the high potential test mode to the voltage measuring mode to confirm that the circuit phase conductor and voltage of HIPOT Tester are now reading zero volts.
- Repeat this test procedure for all circuit phase conductors testing each phase to ground and each phase to each phase.
- When testing is completed disconnect the HIPOT Tester from the circuits under test and confirm that the circuits are clear to be re-connected and re-energized.
- To PASS the unit or Cable under Test must be exposed to a minimum Stress of pre decide Voltage for 1 minute without any Indication of Breakdown. For Equipments with total area less than 0.1 m2, the insulation resistance shall not be less than 400 MΩ. For Equipment with total area larger than 0.1 m2 the measured insulation resistance times the area of the module shall not be less than 40 MΩ·m2.

Safety precautions during HIPOT Test:

- During a HIPOT Test, there may be at some risk so to minimize risk of injury from electrical shock make sure HIPOT equipment follows these guidelines:

1. The total charge you can receive in a shock should not exceed 45 uC.
2. The total hipot energy should not exceed 350 mJ.
3. The total current should not exceed 5 mA peak (3.5 mA rms)
4. The fault current should not stay on longer than 10 mS.
5. If the tester doesn't meet these requirements then make sure it has a safety interlock system that guarantees you cannot contact the cable while it is being hipot tested.

- **For Cable:**

1. Verify the correct operation of the safety circuits in the equipment every time you calibrate it.
2. Don't touch the cable during hipot testing.
3. Allow the hipot testing to complete before removing the cable.
4. Wear insulating gloves.
5. Don't allow children to use the equipment.
6. If you have any electronic implants then don't use the equipment.

Chapter: 25 Cable Tray

Introduction:

- Today cable trays have become a necessary part of industrial and commercial construction by offering quick, economical and flexible solutions to these problems. Cable trays are capable of supporting all types of wiring:
  1. High Voltage Power Lines
  2. Power Distribution Cables
  3. Sensitive Control Wiring
  4. Telecommunication Wiring
  5. Optical Cables

Cable Tray Materials:

- Most cable tray systems are fabricated from a corrosion-resistant metal (low-carbon steel, stainless steel or an aluminium alloy) or from a metal with a corrosion-resistant finish (zinc or epoxy).
- The choice of material for any particular installation depends on the installation environment (corrosion and electrical considerations) and cost.

1) Aluminium

- Cable trays fabricated of extruded aluminium are often used for their high strength-to-weight ratio, superior resistance to certain corrosive environments, and ease of installation. They also offer the advantages of being light weight (approximately 50% that of a steel tray) and maintenance free, and since aluminium cable trays are non-magnetic, electrical losses are reduced to a minimum.
- Cable tray products are formed from the 6063 series alloys which by design are copper free alloys for marine applications. These alloys contain silicon and magnesium in appropriate proportions to form magnesium silicate, allowing them to be heat treated. These magnesium silicon alloys possess good formability and structural properties, as well as excellent corrosion resistance.
- The unusual resistance to corrosion, including weathering, exhibited by aluminium is due to the self-healing aluminium oxide film that protects the surface. Aluminium's resistance to chemicals in the application environment should be tested before installation.

2) Steel

- Steel cable trays are fabricated from structural quality steels using a continuous roll-formed process. Forming and extrusions increase the mechanical strength.
- The main benefits of steel cable tray are its high strength and low cost. Disadvantages include high weight, low electrical conductivity and relatively poor corrosion resistance.
- The rate of corrosion will vary depending on many factors such as the environment, coating or protection applied and the composition of the steel. T&B offers finishes and coatings to improve the corrosion resistance of steel.
- These include pre-galvanized, hot dip galvanized (after fabrication), epoxy and special paints.

3) Stainless Steel

- Stainless steel offers high yield strength and high creep strength, at high ambient temperatures.
- Stainless steel cable tray is roll-formed from AISI Type 316 stainless steel.
- Stainless Steel is resistant to dyestuffs, organic chemicals, and inorganic chemicals at elevated temperatures. Higher levels of chromium and nickel and a reduced level of carbon serve to increase corrosion resistance and facilitate welding. Type 316 includes molybdenum to increase high temperature strength and improve corrosion resistance, especially to chloride and sulfuric acid. Carbon content is reduced to facilitate welding.

Finishing of Cable Tray

(1) Galvanized Coatings

- The most widely used coating for cable tray is galvanizing. It is cost-effective, protects against a wide variety of environ mental chemicals, and is self-healing if an area becomes unprotected through cuts or scratches.
- Steel is coated with zinc through electrolysis by dipping steel into a bath of zinc salts. A combination of carbonates, hydroxides and zinc oxides forms a protective film to protect the zinc itself. Resistance to corrosion is directly related to the thickness of the coating and the harshness of the environ ment.

(2) Pre-Galvanized

- Pre-galvanized, also known as mill-galvanized or hot dip mill-galvanized, is produced in a rolling mill by passing steel coils through molten zinc. These coils are then slit to size and fabricated.
- Areas not normally coated during fabrication, such as cuts and welds, are protected by neighboring zinc, which works as a sacrificial anode. During welding, a small area directly affected by heat is also left bare, but the same self-healing process occurs.
- G90 requires a coating of .90 ounces of zinc per square foot of steel, or .32 ounces per square foot on each side of the metal sheet. In accordance with A653/A653M-06a, pre-galvanized steel is not generally recommended for outdoor use or in industrial environments.

(3) Hot-Dip Galvanized

- After the steel cable tray has been manufactured and assem bled, the entire tray is immersed in a bath of molten zinc, resulting in a coating of all surfaces, as well as all edges, holes and welds.
- Coating thickness is determined by the length of time each part is immersed in the bath and the speed of removal. Hot dip galvanizing after fabrication creates a much thicker coating than the pre-galvanized process, a minimum of 3.0 ounces per square foot of steel or 1.50 ounces per square foot on each side of the sheet (according to ASTMA123,grade 65).
- The process is recommended for cable tray used in most outdoor environments and many harsh industrial environment applications.

Type of Cable Trays:

- Cable trays are made of either steel, aluminium or fibber reinforced plastic (FRP) and are available in six basic types,

1. Ladder Type Cable Tray
2. Solid Bottom Cable Tray
3. Trough Cable Tray
4. Channel Cable Tray
5. Wire Mesh Cable Tray
6. Single Rail Cable Tray

(1) Ladder Cable Tray

- Generally used in applications with intermediate to long support spans—12 to 30 feet.
- Ladder cable tray is used for about 75 percent of the cable tray wiring system installations. It is the predominate cable tray type due to its many desirable features:
- A ladder cable tray without covers permits the maximum free flow of air across the cables. This allows the heat produced in the cable's conductors to effectively dissipate. Under such conditions, the conductor insulation in the cables of a properly designed cable tray wiring system will not exceed its maximum operating temperature. The cables will not prematurely age due to excessive operating temperatures.
- The rungs of the ladder cable trays provide convenient anchors for tying down the cables in the non-horizontal cable tray runs or where the positions of the cables must be maintained in the horizontal cable tray runs. This capability is a must for single conductor cable installations. Under fault conditions (short circuit), the magnetic forces produced by the fault current will force the single conductor cables from the cable tray if they are not securely anchored to the cable tray.
- Cables may exit or enter the ladder cable trays through the top or the bottom of the cable tray. Where the cables enter or exit conduit, the conduit to cable tray clamps may be installed upright or inverted to terminate conduits on the top or bottom of the cable tray side rail.
- Moisture can't accumulate in ladder cable trays.

- If cable trays are being installed where working space is a problem, hand access through the cable tray bottom may help to facilitate the installation of small diameter cables: control instrumentation, signal, etc.
- The most common rung spacing for ladder cable tray is 9 inches. This spacing may be used to support all sizes of cables. This spacing is desirable for the small diameter Type PLTC and TC cables as the support distance is such

that there is no visible drooping of the small cables between rungs. 12 or 18 inch rung spacing provides adequate cable support but the slight amount of small diameter cable drooping between rungs may be aesthetically objectionable for some installations. The maximum allowable distance between supports for 1/0 through 4/0 AWG single conductor cables is 9 inches [1993 NEC Section 318-3(b) (1)]

- **Ventilated Trough Cable Tray**
- The only reason to select a ventilated trough cable tray over a ladder type cable tray is aesthetics. No drooping of small cables is visible. The ventilated trough cable tray does provide more support to the cables than does the ladder cable tray but this additional support is not significant. It doesn't have any impact on the cables service record or life.
- **Characteristics:**
- Solid side rail protection and system strength with smooth radius fittings and a wide selection of materials and finishes
- Maximum strength for long span applications
- **Standard Dimension :**
- Standard widths of 6, 12, 18, 24, 30 & 36 inches ,depths of 3, 4, 5 & 6 inches, lengths of 10, 12, 20 & 24 feet
- Rung spacing of 6, 9, 12 & 18 inches.

(2) Solid Bottom Cable Tray

- Generally used for minimal heat generating electrical or telecommunication applications with short to intermediate support spans5 to 12 feet.
- The main reason for selecting solid bottom cable tray (with covers) is the concern of EMI/ RFI shielding protection for very sensitive circuits. A solid bottom steel cable tray with steel covers provides a good degree of shielding if there are no breaks or holes in the completed installation.
- The solid bottom cable tray system has a disadvantage in that moisture can build up in the cable trays. This can be controlled by drilling 1/4 inch drain holes in the bottom of the cable tray at three foot intervals (at the middle and very near the sides) if the cable tray is not being used for EMI/RFI shielding.
- Some engineers and designers specify solid bottom cable trays (often with covers) in the belief that all electrical circuits have to be totally enclosed by metal. The cable trays are just supporting cables that are designed for such installations. Cable failures in cable tray runs rarely happen. Cable failures due to cable support problems in cable trays are nonexistent.

- **Characteristics:**
- Non-ventilated continuous support for delicate cables with added cable protection available in metallic and fibreglass.
- Solid bottom metallic with solid metal covers for non-plenum rated cable in environmental areas.
- **Standard Dimension :**
- Standard widths of 6, 12, 18, 24, 30 & 36 inches , depths of 3, 4, 5 & 6 inches ,lengths of 10, 12, 20 & 24 feet.

(3) Trough Cable Tray

- Generally used for moderate heat generating applications with short to intermediate support of 5 to 12 feet

- **Characteristics**
- Moderate ventilation with added cable support frequency—with the bottom configuration providing cable support every four inches.
- Available in metal and non-metallic materials
- **Standard Dimension :**
- Standard widths of 6, 12, 18, 24, 30 & 36 inches , depths of 3, 4, 5 & 6 inches ,lengths of 10, 12, 20 & 24 feet

- Fixed rung spacing of 4 inches on centre.

(4) Channel Cable Tray

- Used for installations with limited numbers of tray cable when conduit is undesirable. Support frequency with short to medium support spans5 to 10 feet.
- **Characteristics:**
- Economical support for cable drops and branch cable runs from the backbone cable tray system.
- **Standard Dimension :**
- Standard widths of 3, 4, & 6 inches in metal systems and up to 8 inches in non-metallic systems
- Standard depths of 1 1/4 to 1 3/4 inches in metal systems and 1, 1 1/8, 1 5/8 & 2 3/16 inches in non-metallic systems
- Standard length of 10, 12, 20 & 24 feet.

(5) Wire Mesh Cable Tray

- Generally used for telecommunication and fibber optic applications, installed on short spans4 to 8 feet.
- **Characteristics:**
- A field adaptable support system primarily for low voltage, telecommunication and fibber optic cables. These systems are typically steel wire mesh, zinc plated.
- **Standard Dimension :**
- Standard widths of 2, 4, 6, 8, 12, 16, 18, 20 & 24 inches , depths of 1, 2 & 4 inches, length of about 10 feet.

(6) Single Rail Cable Tray

- Generally used for low voltage and power cable installations where maximum cable freedom, side fill and speed to install are factors.
- **Characteristics:**
- These aluminium systems are the fastest systems to install and provide the maximum freedom for cable to enter and exit the system
- Single hung or wall mounted systems in single or multiple tiers.
- **Standard Dimension :**
- Standard widths are 6, 9, 12, 18 & 24 inches, depths are 3, 4 & 6 inches , lengths are 10 & 12 feet.

Thermal Expansion and Contraction of Cable Tray:

- A cable tray system may be affected by thermal expansion and contraction, which must be taken into account during installation.
- To determine the number of expansion splice plates you need, decide the length of the straight cable tray runs and the total difference between the minimum winter and maximum summer temperatures.
- To function properly, expansion splice plates require accurate gap settings between trays.
- The support nearest the midpoint between expansion splice plates should be anchored, allowing the tray longitudinal movement in both directions.
- When a cable tray system is used as an equipment grounding conductor, it is important to use bonding jumpers at all expansion connections to keep the electrical circuit continuous.

MAX DISTANCE BETWEEN EXPANSION JOINTS (For 1” Movement)		
Temperature Differential (oF)	**Steel (Feet)**	**Aluminum(Feet)**
25	512	260
50	256	130
75	171	87
100	128	65
125	102	52
150	85	43
175	73	37

Chapter: 26 Cable Glands

Introduction:

- A device designed to permit the entry of cable in to electrical equipment which provide sealing ,retention and earthing, bonding, grounding, insulation, strain relief or combination of all these.
- Gland should maintain overall integrity of enclosure in to which it is to be fitted.

Selection of Gland

- Gland should be selected on following Points

(1) Type of Cable
(2) Gland Size
(3) Entry Type/Thread Specification of application
(4) Ingress Protection required.
(5) Material
(6) Type of Cable:

- **Unarmored:** Unarmored Cable will require outer seal within Gland to not only Provide ingress protection but also degree of retention.
- **Armoured:** Gland that required clamping mechanism to terminate the armored both mechanically and electrically.
- The Gland will usually be required to provide ingress protection by sealing outer sheath and retention by clamping amour.

Type of Glands:

1. Brass Indoor Type Gland
2. Brass Outdoor Type Gland
3. **Brass Straitening Unarmored Cable Gland**
4. **Brass Weather Proof Gland**
5. **PG Threaded Gland:**
6. Industrial Type Gland

(1) Brass Indoor Type Gland

- This Gland is quite handy in use with various types of cable whether plastic, rubberized, metal or any other.
- Application: Dry indoor, for use with all type of SWA cables, plastic or rubber sheathed cable.
- Brass indoor gland suitable for single wire armoured, plastic or rubber sheathed cable. Recommended to use with shroud for additional ingress protection.

- Cable Type: Steel Wire Amour.
- Amour Clamping: Two Part Amour Lock.

(2) Brass Outdoor Type Gland

- This come in stunning high quality material for use in outdoor or indoor application with various types of cables sheathed or unsheathed.
- Brass indoor and outdoor gland popularly used with single wire armored.
- Plastic or rubber sheathed cable. Terminates and secure cable armoringand outer seal grips sheath of cable thus ensuring mechanical strength and earth continuity.
- CW brass glands are also supplied with integral earth facilities.
- Recommended to use PVC shroud for additional ingress protection

- **Application:**

- Outdoor or indoor, for use with all type of SWA cables, plastic or rubber sheathed cable.
- Most suitable for SWA, plastic of rubber (Elastomeric) sheathed cables.
- Used in dry indoor conditions.
- No loose parts and easy to install.
- Save times & money.
- Gland size: 20 mm to 75 mm (S & L)
- Accessories:Earth Tag, PVC Shroud, Neo prime Rubber & LSF Rubber, PVC Washer, Brass Lock Nut.
- Cable Type: Wire Braid Armour.
- Armour Clamping: Three Parts (With Lock Nut).

(3) Brass Straitening Unarmored Cable Gland

- Nickel plated or natural brass type cable glands are used with variety of unarmored or rubber sheathed cables.
- Brass indoor and outdoor cable gland suitable for all types of unarmored cables, plastic or rubber sheathed cables.

- **Application:**
- For use with unarmored elastomeric and plastic insulated cables.
- Indoor & Outdoor whenever it is required to provide sealing on cable outer sheath.
- Size : Metric - 20mm to 75mm (S/L)
- Accessories: Earth Tag, PVC Shroud, Neo prime Rubber & LSF Rubber, PVC Washer, Brass Lock Nut.
- Cable Type : Unarmored

(4) Brass Weather Proof Gland

- Unlike other types of cable glands, This type cable gland is used precisely with single armored various types of swa cables whether plastic or rubber sheathed ones. this type cable gland is known for its uninterrupted services once the gland is fixed to the desired wires and wire components.
- Suitable for SWA or rubber sheathed cables.
- Outer seal grips bedding layer of cable for use in most climatic conditions.
- Weather proof and water proof.
- Design has separate armor lock rings. Can be supplied with integral earth facility.
- Gland size: 20 mm to 75 mm (S & L)

- **Application :**
- Outdoor or indoor, for use with single armored, all type of SWA cable, plastic or rubber sheathed cable.
- E1W Gland is Weatherproof & Waterproof Cable Gland
- **Cable Type :** Steel Wire Armour
- **Armour Clamping:** Three Part Armour Lock
- **Sealing Technique:** Compression & Displacement Type
- **Sealing Area(s):** Inner & Outer Sheath

(5) PG Threaded Gland:

- Nickel chrome plated PG threaded cable gland is a custom made threaded gland to meet the needs from the meet industries. Apart from the round headed PG threaded cable gland, we also offer hexagonal gland or any other like spherical rectangular or any other dimensional PG threaded cable gland as per the specification of the customer.

(6) Industrial Cable Gland:

- Brass gland suitable for wire braid armored, plastic or rubber sheathed cable. Terminates and secure cable armoring and outer seal grips sheath of cable thus ensuring mechanical strength and earth continuity.
- Recommended to use PVC shroud for additional ingress protection

- **Cable Type:** Wire Braid Armour
- **Armour Clamping :** Three Part (With Lock Nut)
- **Sealing Technique:** Compression Type.
- Brass gland suitable for steel tape armoured, plastic or rubber sheathed cables. Terminates and secure cable armouring and outer seal grips sheath of cable thus ensuring mechanical strength and earth continuity.
- **Recommended:** to use PVC shroud for additional ingress protection
- **Cable Type :** Steel Tape Armour
- **Armour Clamping :** Three Part (With Lock Nut)
- **Sealing Technique:** Compression Type.

Difference between Single Compression and Double Compression:

- Double compression glands provide extra support to the heavy armored cables entering or exiting the panel while single compression glands are used for light armored cables.
- Normal Cable Gland is also called Single Compression Cable Gland. As the name suggests, while you tighten the gland, the grip or compression is effected only at one p [lace (i.e.) at the cable armour only. There is scope for moisture and corrosive vapour to enter the gland and thus into the cable.
- Whereas in Double-Compression Gland, the compression happens both at the cable armour as well as at the inner sheath. This is sort of two sealing. Hence, chances of moisture or vapour entry are minimised. Hence these glands are also known as Weather-proof cable glands or Flame-proof cable glands.
- The basic difference between single and double compression

(1) Parts of Double comp

- Gland body / Gland body Nut / Cone / Cone Ring / Neopen Rubber seal / Rubber Washer /Check Nut.

(2) Single Comp Parts

- Gland body / Gland body Nut / Neopen Rubber seal / Rubber Washer / Check Nut / Flat washer
- The Basic difference between Single and Double Comp is in Single comp there no cone and cone ring.
- The mechanical support for the cable is only Neopen rubber seal, When u tighting the cable.
- In double camp gland the mechanical support to the cable only cone and cone ring. When doing glanding the cable armor sits on the cone and cone ring act as a lock for armor.
- Single compression and double compression glands are used on the basis of area classification. Those who are affiliatedwith oil and gas sector they will easily understand aboutarea classification.
- In zone 0 where the presence ofhydrocarbon is obvious (IIC) double compression gland is usedbecause the flame path in case of double compression glandis much more than in case of single compression gland.
- Thelogic behind this is that if there is any explosion insidethe terminal box of the motor no flame should be able tocome out through the cable gland in order to prevent firehazards but where there is no presence of hydrocarbons i.e.no danger of fire hazards (IIA/ IIB) single compression glands are used.
- It has nothing to do with mechanical strength. Even in case of lighting fixtures used in IIC zone double compression glands are used.

Chapter:27 Cable Tray Size as per National Electricity Code-392

No of Multi core Cables less than 2000 volts in the Cable Tray

(a) 120 Sq.mm Cable or Larger Cables:

- **The ladder cable tray:** Tray must have an inside available width equal to or greater than the sum of the diameters of the cables, which installed in a single layer.
- **Solid bottom cable tray:** the sum of the cable diameters is not to exceed 90% of the available cable tray width.

(b) Cables Smaller Than 120 Sq.mm

- **Ladder Type Cable Tray:** The total sum of the cross-sectional areas of all the cables to be installed in the cable tray must be equal to or less than the allowable cable area for the tray width, as per following Table.
- **Solid Bottom Cable Tray:** The allowable cable area is reduced by 22%.

Inside width of Cable Tray	Allowable Cable Area Sq.inch (Sq.mm)
152.5mm	4516 Sq.mm
228.6mm	6451 Sq.mm
304.8mm	9032 Sq.mm
457.2mm	13548 Sq.mm
609.6mm	18064 Sq.mm

(c) 120 Sq.mm or Larger Cables Installed with Cables Smaller than 120 Sq.mm

- **Ladder Type Cable Tray:** The ladder cable tray needs to be divided into two zones (a barrier or divider is not required but one can be used if desired) so that the No. 4/0 and larger cables have a dedicated zone, as they are to be placed in a single layer.
- A direct method to determine the correct cable tray width is to figure the cable tray widths required for each of the cable combinations per steps (2) & (3). Then add the widths in order to select the proper cable tray width.

(d) Multi conductor Control and Signal Cables Only

- **Ladder Type Cable Tray:** A ladder cable tray containing only control and/or signal cables may have 50% of its total available cable area filled with cable.
- **Solid Bottom Cable Tray:** When using solid bottom cable tray, the allowable cable area is reduced from 50% to 40%.

No of Single conductor Cables less than 2000 volts in the Cable Tray (NEC-392.12)

- All single conductor cables to be installed in the cable tray must be larger than 1/0 AWG (53.5 Sq.mm) and not to be installed with Solid Cable Tray.

(a) 1000 Kcmill (500 Sq.mm) or Larger Cables

- The sum of the diameters (Sd) for all single conductor cables to be installed shall not exceed the cable tray width as per following Table.

Inside width of Cable Tray	Allowable Cable Area Sq.inch (Sq.mm)
152.5mm	4194 Sq.mm
228.6mm	6129 Sq.mm
304.8mm	8387 Sq.mm
457.2mm	12258 Sq.mm
609.6mm	16774 Sq.mm
762mm	20968 Sq.mm
914.5mm	25161Sq.mm

(b) 120 Sq.mm to 500 Sq.mm Cables

- The total sum of the cross-sectional areas of all the single conductor cables to be installed in the cable tray must be equal to or less than the allowable cable area for the tray width, as given in following Table

Inside width of Cable Tray	Allowable Cable Area Sq.inch (Sq.mm)
152.5mm	4194 Sq.mm
228.6mm	6129 Sq.mm
304.8mm	8387 Sq.mm
457.2mm	12258 Sq.mm
609.6mm	16774 Sq.mm
762mm	20968 Sq.mm
914.5mm	25161Sq.mm

(c) 500 Sq.mm or Larger Cables Installed with Cables Smaller Than 500 Sq.mm

- The total sum of the cross-sectional areas of all the single conductor cables to be installed in the cable tray must be equal to or less than the allowable cable area for the tray width, as given in following Table

Inside width of Cable Tray	Allowable Cable Area Sq. inch (Sq.mm)
152.5mm	4194 Sq.mm
228.6mm	6129 Sq.mm
304.8mm	8387 Sq.mm
457.2mm	12258 Sq.mm
609.6mm	16774 Sq.mm
762mm	20968 Sq.mm
914.5mm	25161Sq.mm

(d) Single Conductor Cables 50Sq.mm to 120Sq.mm

- These single conductors must be installed in a single layer.
- Note: It is the opinion of some that this practice may cause problems with
- To avoid these potential problems due to unbalanced voltages, the individual conductors for this type of cable tray wiring system should be bundled with ties. The bundle should contain all of the three phase conductors with the neutral if used.

Single conductor Size	Cable Tray width				
	152mm	228mm	304mm	457mm	609mm
50Sq.mm	10	15	20	31	
70Sq.mm	9	14	19	29	
9550Sq.mm	8	13	17	26	
120Sq.mm	8	12	16		
120Sq.mm	11	18	24		
185Sq.mm	9	14	19		
240Sq.mm	7	11	14		
400Sq.mm	5	8	10		
500Sq.mm	4	6	8		

No of Cables more than 2.1 KV in the Cable Tray

- The sum of the diameters of all cables rated 2001 volts or over, is not to exceed the cable tray width.

Barrier Requirements (NEC 392.6)

- Barrier is used to separate cable systems, when Single Core cables are above and below 600 volts installed in the same cable tray. But when Multi Core type cables over 600 volts are installed in the same cable tray with cables rated 600 volts or less, no barriers are required.
- The barriers should be made of the same material as the cable tray and height must equal to the depth of the cable tray.

Chapter: 28 Method for Instalaltion of Cable & Wire

Purpose:

- The method explains the Procedures or activity for safely installation and Testing of MV cable in directly buries in ground, in trenches, in to cable trays or in underground ducts as per the standard Practice and Code.

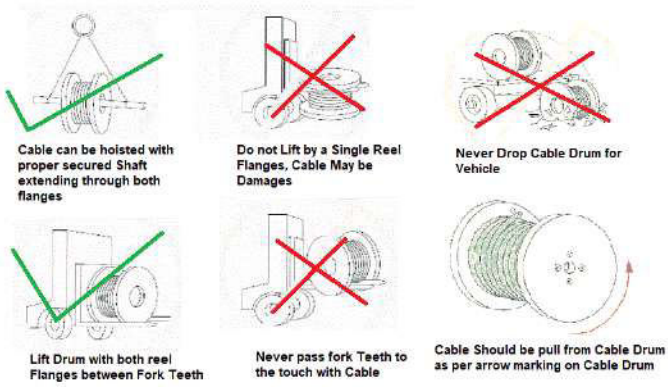
General Equipment & Tools:

- **Testing Equipment for Cable**

1) LV / HV Insulation Resistance tester (250V to 5KV)
2) Multi-meter
3) Continuity Tester
4) AC High Voltage Test Kit

Storage & Material Handling:

- The storage area must be free from dust and Water leakages / seepages.
- Manufacturer recommendation shall always be followed in loading/unloading and storing of Material.
- Material and its accessories shall be unloaded handle with care in designated area of the Store (Do not directly drop to Ground) to avoid any damages.
- Materials shall be stored in a dry place which is free from water or from weather effects and protection should be given to the material by means of covering the material with Tarpaulin sheet.
- The Material will be stacked / unload in the site store on a proper stand on wooden loft on a flat surface at a sufficient height from Ground.
- If Material are dispatch in packs or pallets, each pack or pallet shall be lifted individually with suitable lifting equipment.
- The material shall be transported / Shifted in their original packing to Site location.
- The cable drums shall be off-loaded at the site locations.



- The cable drum should be visually inspected for damage, which may have occurred during transport.
- During storage periodical rolling of drums once in 3 months done. Rolling shall be done in the direction of the arrow marked on the drum.
- It should be ensured that both ends of the cable are properly sealed to prevent ingress/absorption of moisture by the insulation.
- Protection from rain and sun shall be ensured. Sufficient ventilation between cable drums, should be ensured during storage.
- The drums shall always be rested on the flanges and not on the flat sides. f. Damaged battens of drums etc. should be replaced, if necessary.
- When cable drums have to be moved over short distances, they should be rolled in the direction of the arrow, marked on the drum
- While transferring cable from one drum to another, the barrel of the new drum shall have a diameter not less than that of the original drum.
- The manufacturer's seal on the inner and outer cable ends should be examined and the condition of the sheath inspected for mechanical damage.

- If the cable is found defective it shall not be installed and the cable shall be returned to the supplier for replacement.

Inspection of Materials:.

- Check The Material according to its Type, Size, Make
- **Inspection of Cable:**
- Type of Cable (HT /MV /LV)
- Cable Operating Voltage
- No of Cable Core (1 core,2core,3 core, 3.5 Core,4 core)
- Type of Cable Core (Cu, Alu)
- Type of Cable Material (PVC,XLPE)
- Size of Cable
- Length of Cable
- **Physical Damages Inspection:**
- Damage on Cable Drum
- Damage on insulation of Cable
- In case of any damages observed during inspection, the concern report will be issued and Material shall be returned to the supplier for replacement.

Testing and of Cable:

1) Insulation resistance test:

- Following Insulation resistance test will be carried out by approved calibrated equipment.
  1) At the Time of Cable drum receiving at the Store
  2) Before Installation of Cable on Site.
  3) After Installation of Cable on Site.
- The Insulation Resistance values will be noted for Core to Core and Armor by DC High Voltage Tester (Megger) before following activities.

Voltage Class	Test instrument	Acceptance Value
L/V Cable	1000 VDC	>20 Mega ohm
M/V Cable	5000 VDC	>100 Mega ohm
Control, Instrumentation, Communication cable	250 VDC	>1 Mega ohm

- The cables and conductors must discharged after Insulation Resistnce test.

2) The continuity test:

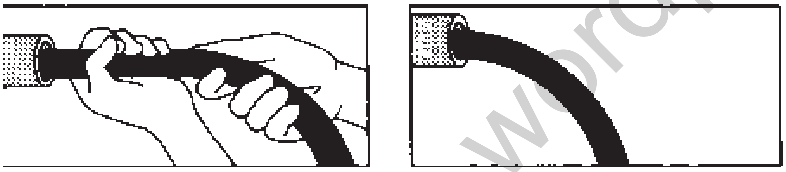
- The continuity test would be carried out between
  1) Phase to Phase,
  2) Phase to Neutral,
  3) Phase to earth and
  4) Neutral to Earth.
- The results would be recorded for records and future reference.
- After the test, the end of the cable shall be sealed to prevent the ingress of moisture.

General Steps for Cabling Laying:

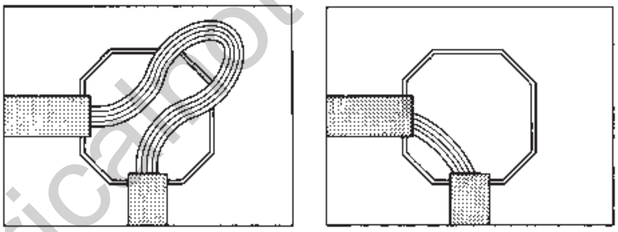
- **Shifting of Cable Drum at Working Location:**
- If a crane is used to unload / Shift cable, a shaft through the arbor hole or a cradle supporting both reel flanges should be used.
- Forklifts must lift the reel by contacting both flanges.
- Check and ensure that approved drawings, the correct size and type of Cable & accessories are ready for installation.
- Ensure that Cable and accessories received from site store for the installation are free of rusty parts and damages.
- **Installation of Cable Drum on Jacks:**
- Check and ensure that the Correct Size and Type of Cable Drum and accessories are transported at the Site locations.

- Ensure that cable and its accessories received from site store for the installation are free from rust, corrosion and damages
- Location of cable drum should be planned before transportation of cable drum. (Practically could differ at one or two places for easy installation of cable).
- The cable drums shall be un-packed.
- Depending on the weight and size of the drum, suitable size of the cable spindle shall be placed inside the central axis of the drum.
- Suitable jacks shall be placed firmly on the ground and jacked-up the Drum to allow sufficient clearance from the ground. Ensure that the cable drum on a jack is free for rotation.
- The cable drum will be correctly positioned and the direction of cable pulling as indicated by arrow on the drum shall be complied.
- **Drum control during pulling**
- Cable winch, if required, shall be positioned in proper place for cable pulling.
- The cable shall be fixed to the winch, if used, by means of a cable sock or gripper. Required number of persons will be posted at winch and near the drum.
- At all times during the pulling operation, at least one member of the team shall be stationed at the drum to control its rotation and check on the stability of the drum and jacks.
- **Cable Roller:**
- Cable rollers shall be placed as required on the cable route.
- Cable rollers will be placed not more than more than 3 meters apart under the M.V cable during pulling over longer distances and standoff rollers for acute bends to ensure that the cable is pulled with minimum effort and the cable outer jacket is free of scouring lines.
- **Cable Pulling Speed:**
- The required cable pulling speed and tension requirement shall be maintained according to the manufacturer's specification. If any problem arises during the pulling, the proceedings shall be stopped immediately and restarted only after the problem has been cleared.
- The pulling speed shall be controlled during the cable pulling and it will be assured by observing the indication of the tension meter.
- Cable pulling shall be done under strict supervision during the entire period of operation. Safety norms shall be observed and shall stick to the standard requirements
- **Identify Cable Laying Route:**
- Location of the panels / equipment shall be identified.
- Cable laying will generally start from one end of the route length or at any suitable point if required.
- In case of cable lengths which are more than one drum length, all cables which can be laid from original position will be completed. And then the cable pulling set-up will be re-positioned to the next location, from where the next length will be pulled.
- Cables shall be cut from the drums as per the actual cable length in accordance to the drum schedule and drum allocation sheets
- Before cutting the cable, both ends must be inspected to ensure sufficient length is for proper dressing and end termination.
- The cable schedule and drum schedule will be updated with the information on cable pulling.
- Cable rollers shall be positioned properly in to the cable trench. The intervals for the rollers are to be kept approximately 2 to 3 meters.
- The rollers shall be maintaining its smooth rotation. If the cable will run through the curves and edges the, curve rollers should be used at the proper position in order to keeps a safe cable bending.
- **Precaution while laying of Cable:**
- Where bends are encountered in a run, cables shall be lubricated with a cable pulling lubricant (without Petroleum based) to facilitate easy movement.
- Ensure excessive force and twisting of cables is avoided
- Proper spacing will be maintained between the cables
- Cables are protected from mechanical damage during pulling
- Protection shall be provided to the cables at crossings with pipes, civil works to prevent mechanical damage.

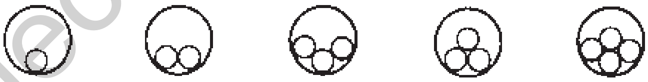
- PVC sleeves shall be installed for all cables passing through brick, block or concrete or similar structures in case there is need for future withdrawal.
- After the Insulation Resistance Test, the open ends of the cable will be sealed till termination to prevent entry of Moisture and water.
- After completion of all cables in the same route the cables shall be dressed and clamped.
- Unless the lengths exceed the maximum drum lengths joints shall be avoided. Joint markers indicating joint positions shall be provided above ground and also shown on the drawings.
- Empty cable drums will be transported back to stores.
- **Measure Insulation Resistance before Laying Cable**
- Insulation resistance of the cables shall be checked before laying cables.
- **Measure Insulation Resistance After Laying Cable**
- Soon after completion of every cable laying the cables will be tested for insulation resistance.
- **Cable Bending Radius:**
- During installation process cable can not be bent to a radius of less than 6D for unarmored cable and 8D for armored cable or bending radius of cables shall comply with cable manufacturer's recommendation. These conditions shall be strictly follow to, particularly where cables turn into road crossings, conduit entry etc
- **Eliminate Sharp Edge:**
- While pulling, in order to eliminate sharp bend and crossovers, always have a person feed the cable(s) straight into the conduit by hand or, for larger cables, over a large diameter sheave.



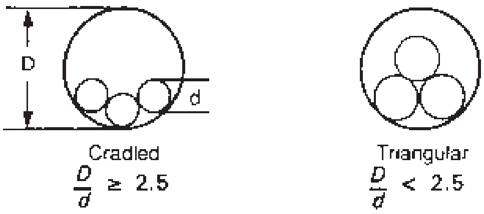
- Do not pull cable directly across short, sharp angles. After pulling completely out of one side of the enclosure, feed cable into the other side of the enclose and pull that segment.



- **Cable Laying Arrangements:**



- The configuration of three single-conductor cables in a conduit is determined by the ratio of the conduit inner diameter (D) to the outer diameter (d) of one of the single cables (D/d ratio).



- A cradled configuration develops when three single-conductor cables are pulled into a conduit where the D/d ratio is 2.5 or greater.
- A triangular configuration develops when three single conductor cables are pulled into a conduit where the D/d ratio is less than 2.5.
- These cables may be pulled from individual reels, tandem reels, or a single reel with parallel wound cables.

A. Cable Laying in Excavated Ground:

a) Formation of Cable Trench.

- Check the area of excavation by referring As Built drawing to find out crossing of any underground Services i.e. Gas Line, Water Line or other Cable. Check the indication marks, signs, manholes nearby area and find out the path of old services.
- If there are structures adjacent to the work area, proper temporary supports shall be provided to the adjacent structure prior to start excavation.
- Excavation near the existing electrical cables, instrumentation and control cables, sewer line, gas lines and any other service line shall take all necessary precautions to protect the services with proper supports & covers.
- Ensure the working area at any confined space is free from any Hazardous Gas by proper Gas testing using the Gas testing instrument.
- Required sign boards such as "DEEP EXCAVATION" "MEN WORKING", "DANGER" and warning boards will be placed to indicate the excavation work. The area of excavation will be cordoned by using safety barricading to stop trespassers.
- In open areas the excavation shall be carried out by using the machineries.
- If the excavation level is below the local water table level suitable dewatering system shall be designed and installed in such a way that alterations and extensions to the system during operations are possible.
- The width of the excavated Cable trench shall be as per specification or as per approved Drawings.
- The trench shall be excavated up to the required depth of 0.76 Meter from the existing ground level or as per Specification or as per approved Drawing.
- The Cable trench shall be kept dry during cable installation operation. The contractor shall deal with the dispose of water so as to prevent any risk to the cables and other materials.
- Debris, rocks and unusable materials shall be removed from Excavated Trench on daily basis and it will dump at the approved dumping Location of from the site.

b) First Layer of Sand:

- The bottom of the trench shall be backfilled with a layer of clean and fine sand bedding of 100mm thickness or as per the approved Drawing.
- The fill material shall be tamped. Any hard material which could damage the cable will be removed
- Inspection of sand bed will be carried out prior to commencement of cable pulling.

c) Cable Laying:

- Cables are laid over the clean and fine First Layer of sand bedding.
- Rollers must be used where cables are installed in an open trench using a pulling rope and eye; cable rollers are to be used at frequent intervals to support the cables and must never be more than 3 meters apart.
- Care must be taken to ensure that the cable does not enter or leave the rollers at an angle that exceeds the bending radius of the cable.
- The Pulling rope must be attached to the cable by a stocking grip with pulling eye.
- The cable shall be drawn into the trench manually, before the pull commences, to prevent the winch to move along with the cable.
- The cable shall be drawn into the trench smoothly with a minimum of stops and at an average speed of between 9 to 12 meters per minute, to avoid irregular movement.
- Cables shall be arranged properly to minimize crossovers, twists.
- All Cable shall be laying parallel to each other and cable dressing should be done properly
- Cable identification tags shall be installed on both end of cable after the cable pulling.

d) Second Layer of Sand:

- The cables shall be backfilled with approved clean and fine Sand / backfill Material of 100mm thickness or as per the approved Drawing.
- The fill material shall be tamped. Any hard material which could damage the cable will be removed
- Inspection of sand bed will be carried out prior to commencement of Cable Protection layer.

e) Cable Protection:

- Cable protection tiles / Bricks / Warning Taps are laid above the second layer of dune sand filling.

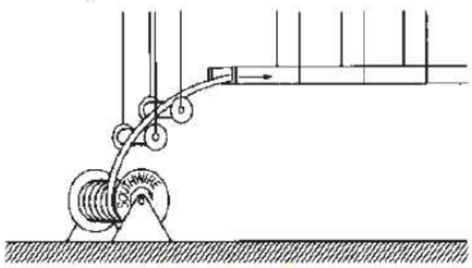
f) Back Filling:

- Backfilling materials shall be free from stones or rocks (larger than 50 mm), fossil content, vegetation and its roots, waste materials, Material containing gypsum or other soluble salts greater than the allowable limits which might prevent proper compaction or cause to inadequately of performance.

- Backfilling area shall be backfilled with approved material compacted in layers by suitable equipment like plate compactors, vibratory roller compactors, etc., until the specified density has been obtained.
- Sufficient Water is poured to match the required Moisture content.
- Intermediate cable markers to be firmly attached to the cables.
- The thickness of fill material shall not exceed 150 mm where manual compaction methods are adopted.

B. Cable Laying in Cable Tray / Trunking:

- Before laying of Cable , Cable Tray work should be completed form the one end to other end of the Cable route
- The cable tray must be cleaned and free from any dust or water dampness, before pulling the cables.
- Use cable rollers in cable trays to avoid damage on cables during the pulling process.
- From cable reel to cable tray, the cable is fed from the top of the reel to maintain required curvature. Sheaves, or a shoe, may be used to guide the cable into the tray.

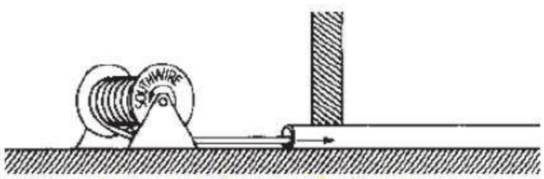


Cable Laying in Cable Tray

- Cable rollers shall be placed at every 6-12 meters or less if required to avoid touching of the cable to tray.
- Cable laying will generally start from one end of the route length from other suitable point if required.
- The number and size of cables drawn in to a particular cable tray shall not be exceed that allowed in specifications.
- At any time of Cable laying only one cable should be laid on cable tray, after laying first cable necessary dressing and cable tie should be fixed than after that second cable should be lay.
- Cut the cables to required length at both ends, seal the ends with adhesive insulation tape roll and keep in the box or enclosures to ensure no damage can occur to cables.
- Cables shall be arranged properly to minimize crossovers, twists
- Control cables will be laid along the LV cables. HV cables to be laid in separate trays
- All control cables will be installed at a minimum distance of 100mm from power cables unless otherwise agreed with consultant as per site conditions.
- After completion of all cables in the same route the cables shall be dressed and clamped.
- All cables in horizontal or vertical runs will be secured to the trays by nylon fasteners / ties.
- Cable identification tags as per specifications shall be installed on both end (at sending and receiving ends) of cable after the cable pulling.

C. Cable Laying in the Building

- In case of Cable lay inside the buildings, the drums will be placed outside the buildings and the cable pulled in the opposite direction. After reaching the other end the length of the cable required for reaching the location inside the building will be measured and then cut the cable.
- The cable is fed from the cable reel directly into the conduit at floor level.
- The cable is fed from the bottom of the reel so that its curvature is continuous with no reversed bends.



Cable Laying in Pipe at Ground Level

- Do not pull cable directly across short, sharp angles. After pulling completely out of one side of the enclosure, feed cable into the other side of the enclosure and pull that segment
- Unloading equipment should not come in contact with the cable or its protective covering.

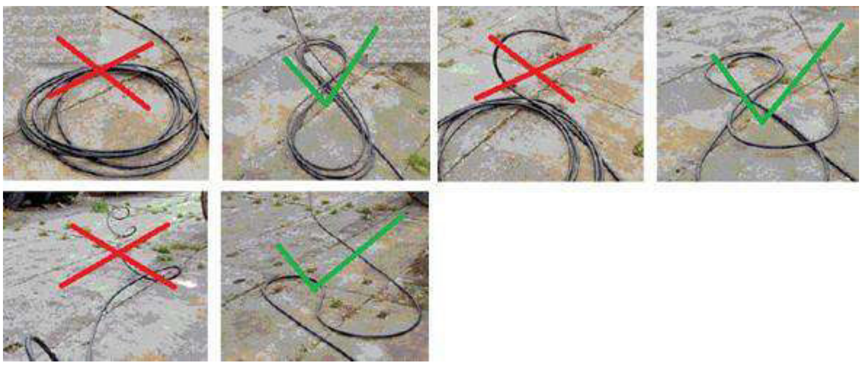
(1) Wires Pulling in Conduit:

- Proper marking / selection of location on site to be done prior to commencement of installation works.
- Complete a mockup installation before main works and get its approval.

- Make sure that all conduits and boxes in both ends are free from damages and blockages etc and installation is approved.
- Blockage shall be checked by inserting the draw wire and checking that it reaches to the other end without any disturbance.
- Use of Steel fish wire shall be made for drawing of wires. Wires shall be drawn with adequate care.
- Once the conduit is not blocked the wires shall be pulled using the draw wires while ensuring no damage occurs while pulling.
- Pulling compound or lubricant shall be used for pulling the wires where required.
- Use soap based pulling compound for short runs i.e. less than 20 meters for semi conductive insulated wires.
- Use wax based pulling compound for the runs greater than 20 meters for semi conductive insulated wires.
- While pulling the wires care should be taken to not insert the pull tension greater than the manufacturer allowed limits.
- Separate conduits shall be run for lighting and power circuits and also for telephone cables. To avoid any cross talk and extraneous interference in the telephone circuits, all telephone wiring conduits shall be run with a sufficient clearance from the power and lighting conduits.
- All separate circuits from DB's shall have separate neutral to the points. Common neutral between separate circuits are not permissible.
- As far as possible wiring shall be run in conduits. All conduit wiring shall be complete with continuous earth as per I.E.R.
- The wiring shall be carried out as specified. 'Power' and 'heating' wiring shall be kept separate and distinct from 'Lighting' wiring. The wiring shall be done on the distribution system with main and branch distribution boards at convenient physical and electrical centers and consideration shall be given for neatness and good appearance.
- The wiring shall be done in the 'Looping System. 'Phase' or 'live' conductors shall be looped at the switch box and neutral conductor can be looped from the light fan or socket outlets.
- 1.5 sq. mm PVC wires in green color are to be run continuously in conduits for continuous earthing. The earth wire should be connected to GI Switch boxes and DB boxes by tapped screws.
- No bare or twist joints shall be made at intermediate points in the through run of cables.
- Bare or twist joints shall be carried out with due care and preferably through proper junction boxes.
- If any joint becomes unavoidable such joints shall be made through proper cutouts or through proper junction boxes open to easy inspections.
- Electrical Load should be balance on all the three phases for an even distribution. Before commencement of work, the contractor shall seek the approval of the Consultants / Site Engineer on the distribution of balancing of loads and circuits. The wiring shall be done by the process of looping the live conductors and the neutral wires.
- Color coding of wires
- Phase : Red, Blue, Yellow,
- Neutral: Black,
- Earth: Green.
- Adequate extra length shall be left at termination points.

Excess or Spare Cable Storage:

- Store Cable reels on hard surface so that the flanges will not sink and allow reel weight to rest on cable.



Cables Identification / Marking of Cables:

- Install the tags / labels as per project specifications and as per approved material submittals.
- Cable marking shall be positioned properly to read and identify
- For Buried / Surface mounted cables tagging / Labeling will be corrosion resistant tags (with engraved or stamped for the identification number of the cable, voltage Rating, conductor size and make) or as per project specifications and as per approved material submittals.
- Cables shall be identified at feeders i.e. the sending and receiving ends (outgoing cables in SMDB's and final DB's) about 50mm below the gland.
- All termination shall be provided with tight fitting covering sleeves.

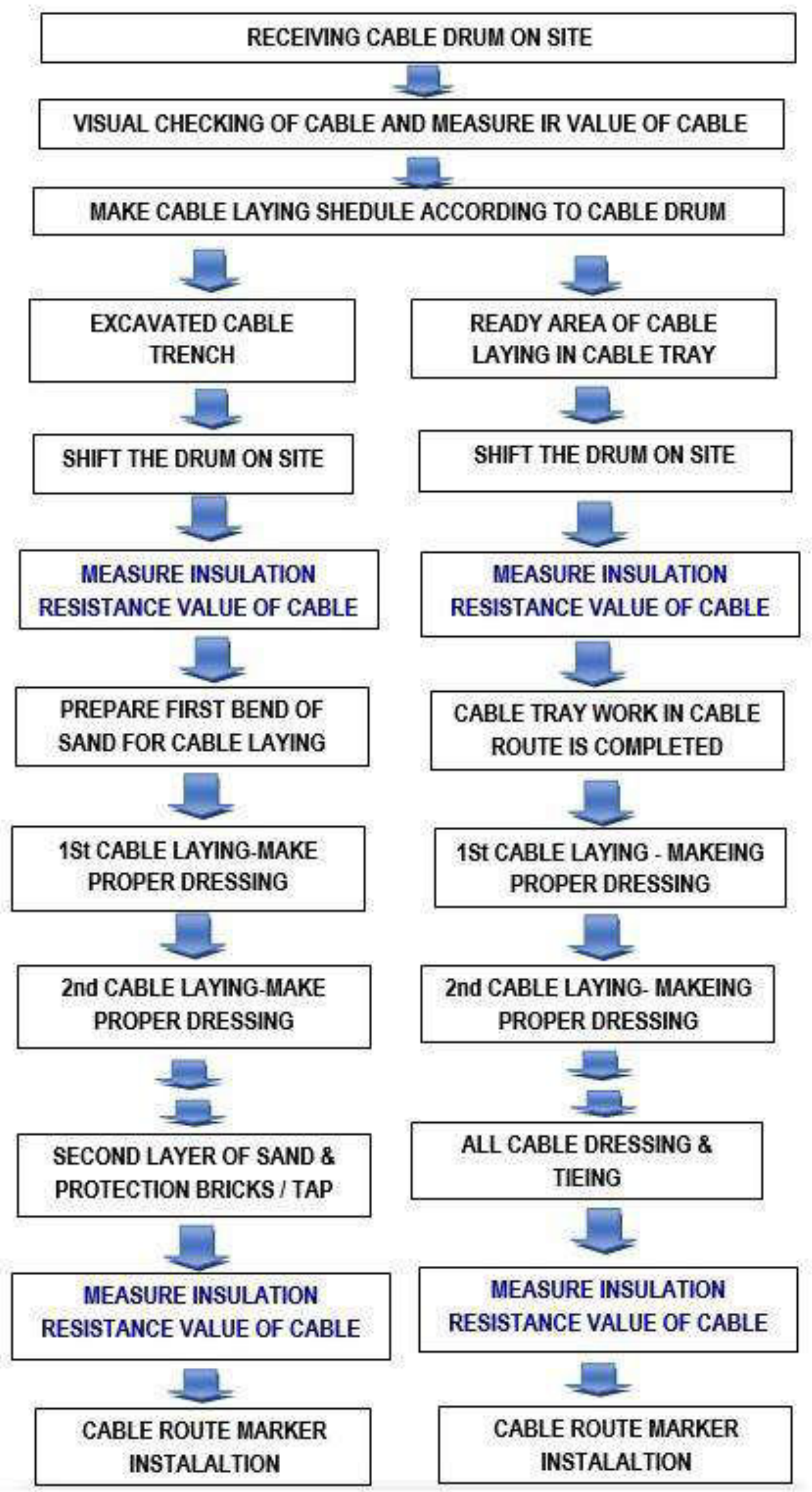
Duct Seals:

- After installation of all Cables, all cable ducts / Hume Pipes / Sleeves entering substations and buildings to be duct sealed to prevent the ingress of water and gas.

Reference:

- IEC 60228, BS 6360.
- BS 5467.

FLOW CAHRT OF CABLE LAYING IN GROUND / IN CABLE TRAY:



Chapter: 29 Method for Installation of Cable Tray

Purpose:

- This method explains the Procedures or sequence of activity for safely installation and Testing of cable tray, and it's accessories as per the standard Practice and Code.

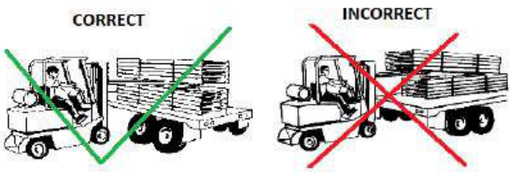
General Equipment & Tools:

- The equipment that will be engaged for Installation of Cable Tray will be

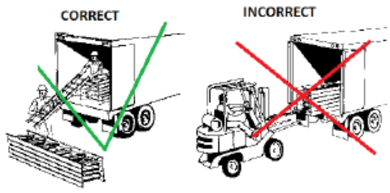
1) Tool Box with Screwdriver, Pliers, Spanner , Hammer
2) Drilling Machine with various Bits , Grinding & Cutting Machine
3) Electrical Tester , Continuity Tester ,Multi Meter
4) Cutter , Blower
5) Knockout punch and Flat File
6) Galvanizing paint
7) Marker, Measuring tape, Level gauge / Spirit level.
8) Ladder / Scaffolding / Mobile scaffold
9) Chain Block and Pipe Wrench
10) Portable Lights
11) Removable Barricades

Storage & Material Handling:

- The storage area must be free from dust and Water leakages / seepages.
- **Manufacturer recommendation shall always be followed in loading/unloading and storing of Material.**
- Material and its accessories shall be unloaded handle with care in designated area of the Store (Do not directly drop to Ground) to avoid any damages.
- Materials shall be stored in a dry place which is free from water or from weather effects and protection should be given to the material by means of covering the material with Tarpaulin sheet.
- The Material will be stacked / unload in the site store on a proper stand on wooden loft on a flat surface at a sufficient height from Ground.
- If Material are dispatch in packs or pallets, each pack or pallet shall be lifted individually with suitable lifting equipment.
- The material shall be transported / Shifted in their original packing to Site location.
- The Material should be visually inspected for damage, which may have occurred during transport.
- When bringing down materials, they should be handled with care and lowered carefully to the ground. They should not be dropped.



- To prevent damage to cable tray, never pull cable tray from a truck trailer by chaining to the bottom rung and dragging cable tray out of the trailer



- If the Material is found defective it shall not be installed and the cable shall be returned to the supplier for replacement.
- Cable Tray and its accessories (pre-galvanized, hot dipped galvanized) shall be stored in a dry place, fully enclosed / ventilated store.

Inspection of Materials:

- Check The Material according to its Type, Size, Make
- **Visual inspection:**
- Type of Cable Tray
- Type of Cable Tray Material
- Type of Cable Tray Coating
- Standard width of Cable Tray
- Standard length of Cable tray
- Cable Tray thickness
- Flange height of Cable Trays
- Proper painting / Galvanization and identification numbers of the cable trays
- **Physical Damages Inspection:**
- Damage on trays and ladders
- Damage on galvanizing
- Fittings and accessories are of proprietary type
- **Testing of galvanizing:**
- Uniformity of coating Thickness Test
- Electrical continuity of connection
- TRs not more than five year old from date of purchase order shall be reviewed for acceptance. Otherwise test shall be carried out.

BS EN ISO 1461	
Table-1 Control Sample Size Related to Lot Size	
Number of Lot	**Min. Sample**
1 To 3	All
4 To 500	3
501 To 1200	5
1021 To 3200	8
3201 To 10000	13
>10000	20
Inspection Lot: Single Order or Single Delivery Order	

ISO 1461:2009 TABLE-3				
Minimum coating thickness and mass on samples that are not centrifuged				
Article and its thickness	**Local coating thickness (minimum)µm**	**Local coating mass (minimum)g/m2**	**Mean coating thickness (minimum)µm**	**Mean coating mass (minimum)g/m2**
Steel > 6 mm	70	505	85	610
Steel > 3 mm to < 6 mm	55	395	70	505
Steel > 1.5 mm to < 3 mm	45	325	55	395
Steel < 1.5 mm	35	250	45	325
Casting > 6 mm	70	505	80	575
Castings < 6 mm	60	430	70	505
NOTE This table is for general use: individual product standards may include different requirements including different categories of thickness. Local coating mass and mean coating mass requirements are set out in this table for reference in such cases of dispute.				

Sequence of Cable Tray Installation Works:

(A) Installation of Cable Tray:

(1) Shifting of Cable Tray on Site

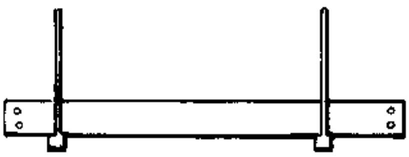
- Cable Tray shall be carefully unloaded or shifted to the site by using Crane/Hydra or by sufficient manpower and moved to a defined installation location.
- Remove the packing and ensure that the Cable Tray is free from transportation damages
- Check and ensure that approved drawings, the correct size and type of cable trays, trunking & accessories are ready for installation.
- Ensure that cable trays/trunking and accessories received from site store for the installation are free of rusty parts and damages.

(2) Marking the Route:

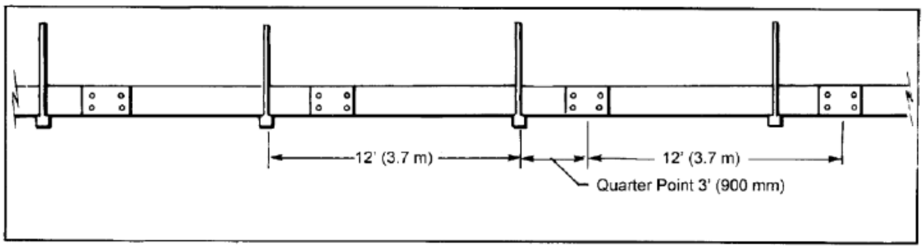
- Mark the route of Cable Tray and Trunking as per approved drawings with marking threads. The route of Cable Tray and Trunking need to be coordinated with other services and shall be confirmed by the Site Engineer.
- Minimum space from the building structure and other services to be maintained (**200 mm from the nearest point**) to facilitate easy handling and maintenance of cables.
- **If Possible, Do not install Cable trays below water/sewage pipes.**

(3) Hanging Support:

- The location of hangers and supports should be carefully marked as per the approved specifications and Drawings.
- Required sizes of holes should be marked and drilled by using a drilling machine.
- The threaded rod (**M12 steel**) or Specified rod should be fixed carefully into the anchor using clamping tools for a balance smooth twist. The threaded rod should be necessary thickness and length. Sizes should be as approved in the drawing. It should be done in such a way as to avoid damage to the threaded rod.
- When thread is done, a washer should be inserted into it. The washer should also be the required size and of quality. It should be fixed properly and the nut fastened tight to ensure that the threaded rod is strong and able to bare load.
- Trays and ladders shall be securely anchored to supports. They shall be secured such that the tray or ladder system will not move during cable installation.
- Ensure that rod is properly vertical under operating conditions.
- Tighten hanger load nut securely to ensure proper hanger performance.Tighten upper nut after adjustment
- **The distance between supports is called SPAN. The support span should not be greater than the length of the tray.** This will prevent two connecting points from being located within one support span.
- The support span should not be greater than the straight section length, or as recommended by the manufacturer, **to ensure that no more than one splice is located between supports.**

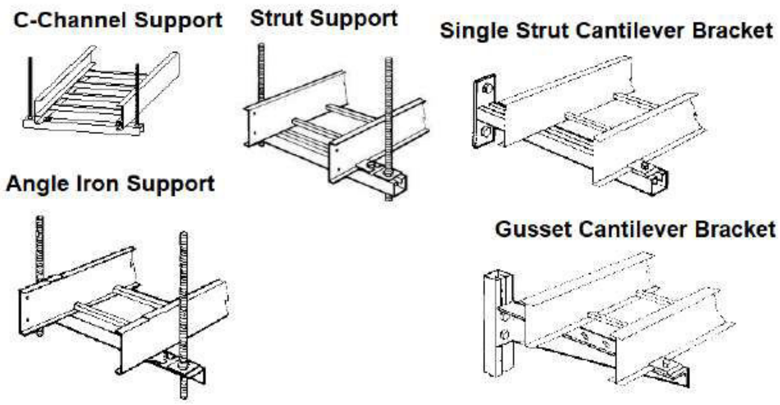


- Cable Tray and Trunking joints are to be positioned as close to the supports as possible, not more than **300 mm from either side.**
- Splice joints fall between the support and the quarter point. When installing a 12-foot long section, for example, a support spacing of 3.7 m (12 foot) causes the splice joints to fall at the same position every time.

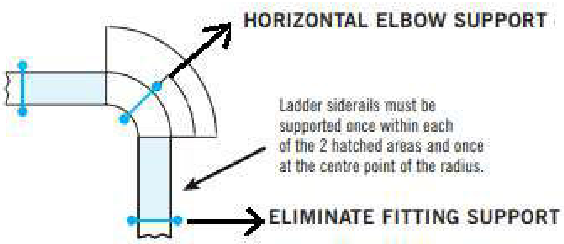


- The maximum tray overhang past the last support should not exceed 600 mm (2 ft).
- At every maximum of 1200 mm horizontally and 1500 vertically supports should be installed.
- Horizontal cable trays and ladders shall be supported by either wall mounted support bracket or a hanger rod system. The intervals between supports shall be as recommended by the manufacturer but this shall not exceed 1 meter for wall mounted support brackets, and 1.2 meter for the hanger rod system.

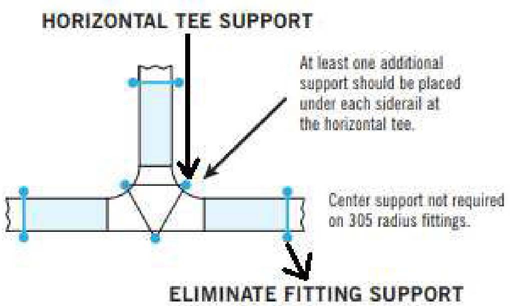
- The hanger, hanging support, cable tray bracket and the ladder should be trimmed to required size and galvanizing paint should be applied on the edges.
- Group parallel runs of trunking should be supported together where it is possible.



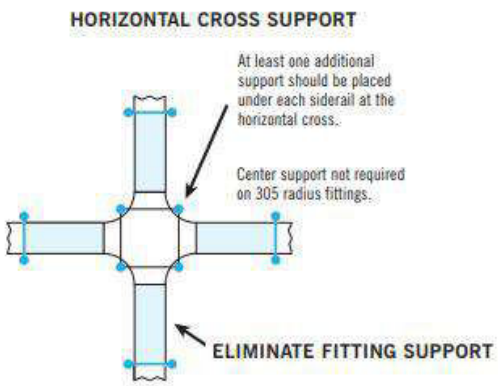
- For shaft cable trays and ladders that are vertical, all supports and fixings should be done as approved.
- Do not cut or drill structural building members (e.g., I-beams) without approval by the Main contractor.
- **Warning:** Do not use a cable tray as a walkway, ladder, or support for people; cable tray is a mechanical support system for cables and raceways. Using cable trays as walkways can cause personal injury and can damage cable tray and installed cables.
- **Horizon Fitting Support: NEMA Standard**
- Supports for horizontal fittings should be located at a distance, no greater than 610 mm (24") from each end of the fitting on the attached ladder.
- Fitting must also be supported at the radius center point on both sides of the fitting as per below:
- At the midpoint (45°) of the arc for a 90° elbow.
- At the midpoint (30°) of the arc for a 60° elbow.
- At the midpoint (22.5°) of the arc for a 45° elbow, excluded are 305 mm (12") radius fittings.
- At the midpoint (15°) of the arc for a 30° elbow, excluded are 305 mm (12") radius fittings.



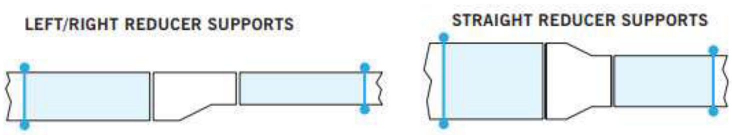
- **Horizon Tee Support: NEMA Standard**
- Supports for horizontal tee fittings should be located at a distance, no greater than 610 mm (24") from each end of the fitting on the attached ladder. Fitting should also be supported once on each side rail. For 305 mm (12") radius tees, place supports no greater than 610 mm (24") from each end of the fitting on the attached ladder.



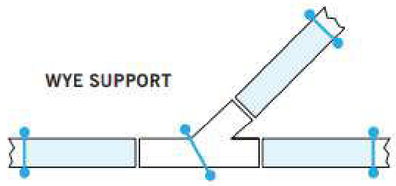
- **Horizon Cross Support: NEMA Standard**
- Supports for horizontal cross fittings should be located at a distance, no greater than 610 mm (24") from each end of the fitting on the attached ladder.
- Fitting should also be supported once on each side rail. For 305 mm (12") radius cross, place supports no greater than 610 mm (24") from each end of the fitting on the attached ladder.



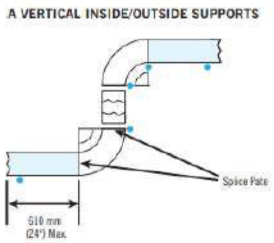
- **Reducer Support: NEMA Standard**
- Place horizontal supports (2) at a distance no greater than 610 mm (24") from each end.



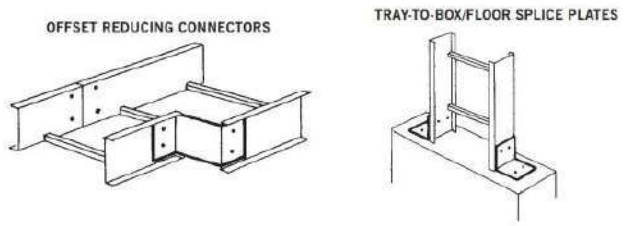
- **Horizontal Y Support: NEMA Standard**
- Place horizontal supports at a distance no greater than 610 mm (24") from each of the three openings and at the midpoint of the fitting at 22.5°



- **Vertical Inside / Outside Support: NEMA Standard**
- Vertical cable tray elbows at the top of runs should be supported at each end. At the bottom of runs, they should be supported at the top of the elbow and within 610 mm (24") of the lower extremity of the elbows. Both Inside and Outside Fittings should be additionally supported at a distance no greater than (24") from each end.



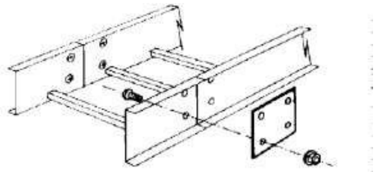
- **Offset Reducing Connection & Tray to Box / Floor Connection:**



(4) Cable Tray Installation:

- Ensure that the Cable Tray's, dimension, elevation and other fittings are properly leveled and that they are coordinated to the other services fixtures.
- The width of Cable Tray/trunking/ladder should have sufficient width to take the cable without crowding and shall allow for future 25% space. The cables should not be stacked together.

- If the conductors carried by trays or ladders are of various systems, the ELV and data processing or different insulation, the cable ladder or trays should be separate. Use insulating barriers where it is necessary. However, approval from the engineer is required.
- Earth continuity shall be ensured throughout the length of the Trays and Trunking
- **Cable Tray Installation on Roof / Floor:**
- Cable tray should not be laid directly on the floor or roof.
- Cable trays installed on roof shall be supported using Gl brackets or concrete blocks.
- It should be mounted far enough off the floor or roof to allow drainage of water.
- The cables to exit through the bottom of the cable tray.
- Where cable trays are installed in roof or exposed to sunlight, factory made cover shall be fixed to protect the cables from direct sunlight.
- Cable Trunking runs shall be arranged so that the lid is always on top or side. Lid shall be fixed to the trunking using factory made quick fix type clips.
- Open ends of the trays / trunkings shall be capped with purpose made end caps.
- **Cable Tray Accessories:**
- Where cutting of the trays is needed, circular saws will be used. Cable tray cut edges will be rasped or welded if it is necessary, galvanized points will be cleaned then it will be sprayed with galvanizing spray immediately.
- **Cut portion of Trays and Trunking, shall be made free of sharp edges by filing and coated with zinc rich and top coat and jointed using fish-plates with bolts and nuts.**
- Any cutting on the cable tray to be done along the solid area and not across the perforation of the cable tray. Burrs needs to be removed and cuts need to be protected with anti-rust galvanized paint to prevent rust.
- **The minimum radius of Cable Tray should equal the minimum bending radius of the cables.** Depending on the number of cables to be placed in the system it may be advantageous to use the next highest radius.
- **Installation of splice connectors**
- Splice connectors shall be located as recommended by the manufacturers.
- Splice joints should be designed and placed to maximize the rigidity of the cable tray.
- Splice connectors shall be attached by round / Hexa head bolts with the nuts and washers located on the outside of the tray or ladder unless otherwise specified by the manufacturer.
- Thermal expansion splices shall be installed wherever expansion joints occur.



- All straight joints, bends and offset connections shall be made neatly using standard fittings (fish plate and coupler). Only when these are inappropriate, fabricated bends/offsets shall be used.

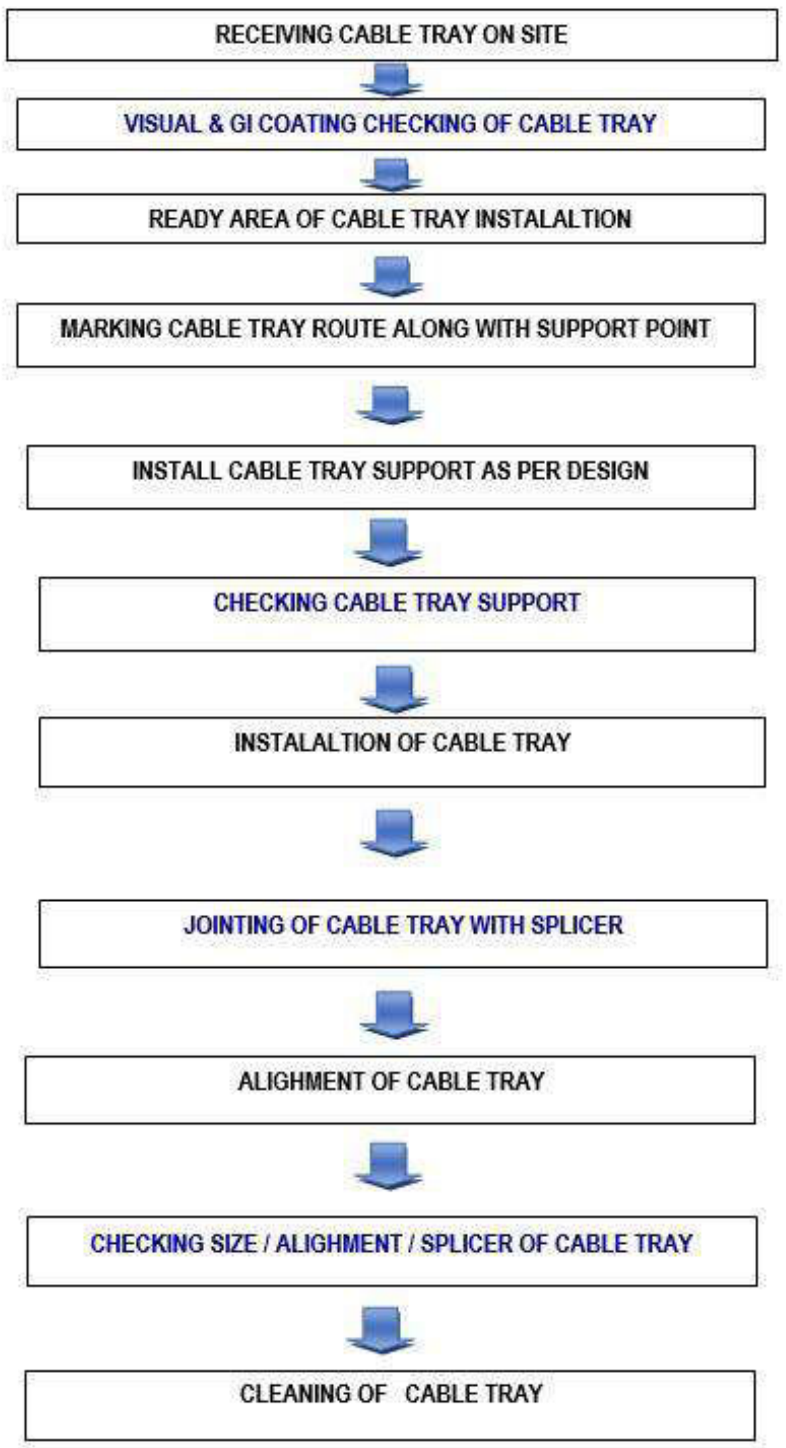
Cleaning of Work Area:.

- There should be a visual inspection of the trunking from inside side after installation. This is to be sure that it is free from Debris, burrs and waste materials.
- There are no sharp edges that could cause damage to the cables during installment.
- Galvanized coating damaged by excessively rough treatment during transit and erection shall be repaired using at least two coats of good quality zinc-rich paint complying with BS 4652.
- Upon completion of installation of cable trays/trunking in one area, the completed work shall be presented for Inspection and shall be protected by providing polyethylene sheet cover.

Codes and Standards:

1) IS 4759: Hot-dip zinc coatings on structural steel and other allied products
2) IS 2629: Recommended Practice for Hot-Dip Galvanizing of Iron and Steel
3) IS 2633: Methods for testing uniformity of coating of zinc coated articles
4) IEC 61537 Cable Management- Cable Tray System and Cable Ladder System
5) BS 4652 Specification for zinc-rich priming paint
6) National Electrical Manufacturers Association (NEMA) Standard

Flow Chart of Cable Tray Installation:



Chapter: 30 Method for Installation of Conceal & Surface Conduits

Purpose:

- This method explains the sequence of activity for safely installation of PVC / GI Conduits and it's accessories in the concrete slabs / columns, in block works and on Surface as per the standard Practice and Code.

Storage & Material Handling:

- The storage area must be free from dust and Water leakages / seepages.
- **Manufacturer recommendation shall always be followed in loading/unloading and storing of Material.**
- Material and its accessories shall be unloaded handle with care in designated area of the Store (Do not directly drop to Ground) to avoid any damages.
- Materials shall be stored in a dry place which is free from water or from weather effects and protection should be given to the material by means of covering the material with Tarpaulin sheet.
- The Material will be stacked / unload in the site store on a proper stand on wooden loft on a flat surface at a sufficient height from Ground.
- If Material are dispatch in packs or pallets, each pack or pallet shall be lifted individually with suitable lifting equipment.
- The material shall be transported / Shifted in their original packing to Site location.
- The Material should be visually inspected for damage, which may have occurred during transport.
- If the Material is found defective it shall not be installed and the cable shall be returned to the supplier for replacement.

Inspection of Materials:.

- Check The Material according to its Type, Size, Make
- **Visual inspection:**
- Type and Make of Conduit and Accessories Material
- Length , Width and thickness of PVC / GI / MS Conduit Material and Accessories
- **Physical Damages Inspection:**
- Damage on Material and it's Accessories
- In case of any damages observed during inspection, the concern report will be issued and Material shall be returned to the supplier for replacement.

Concealed Conduit in Slab / Column:

1. Shifting Material to Working Area:

- PVC Conduit and its accessories shall be carefully unloaded or shifted to the site by using Crane/Hydra or by sufficient manpower and moved to a defined installation location.
- Remove the packing and ensure that the material is free from transportation damages
- Check and ensure that approved drawings, the correct size and type of Conduit & its accessories are ready for installation.
- Ensure that Conduit and its accessories received from site store for the installation are free of rusty parts and damages.

2. Marking Electrical Point / Wall Conduit Drop on Slab:

- Ensure that the civil activities are finished I,e Slab Shuttering Work and Steel Work and Site is ready for Electrical Work on Slab.
- After completing the first layer of steel, start marking of Ceiling Points and Wall Drop Points on Slab as per approved Site Drawings.
- Mark first the wall location for lower floor in slab as per latest Architecture layout so that it will be easy to locate the drops for switch, Wall Light Points and any other drops required for electrical system.
- Mark the opening size in Slab or in Beam i.e window, door and shaft as per approved electrical drawing to avoid passing wall conduit drop on that area.
- Mark the Electrical points on the slab, Wall Conduit Drop in Beam as per approved Electrical Shop Drawing.
- **Make sure that marking of Wall conduit drop is placed in center of wall, it is not out from wall or not move to any face of wall.**

- For initially use marker / Chalk for making location of electrical point on slab and wall drop after that apply oil paint on that location before conducting work so after de shuttering ,the JB or conduit drop is easily visible on slab or on beam.

3. Installation of Junction Box and Conduit:

- Chalk will be used to mark the PVC conduit route. Make sure that size of conduit is as per approved Electrical Shop Drawing.
- Ceiling Conduits shall be laid on the prepared shuttering work of the ceiling slab before concrete is poured. The conduits, boxes, accessories, joints, etc. shall be laid along with the conduits.
- Use Deep Junction Box for surface mounted lighting Fixtures and for Cable Pulling.
- Use long radius bend or make as per site requirement by using PVC Conduit bending spring.
- Joints between PVC conduit + fittings shall be made with suitable adhesive.
- Try to avoid the overlapping of conduits and keep some distance between the conduits for low current and power/Lights.
- **To maintain at least 20mm spacing gap between PVC conduits running in parallel. To allow adequate / sufficient space between formwork and conduit so that embedded conduit is fully covered by concrete and will not result in any honeycomb or structural defects in the future.**
- Concealed conduits in slabs shall be brought out as vertical drops in beams, wherever such drops are required. All vertical conduits in beams shall be left protecting from the bottom of the beam. All such ends of conduits protecting from bottom of beams shall be provided with couplings to receive extension.

4. Fixing of Conduit & Accessories:

- The conduits shall be adequately fixed to prevent excessive movement and damage during the pouring and setting of concrete and shall be protected from mechanical damage.
- For Double layer of rebar, PVC conduits shall be secured to the bottom of Top layer rebar and for Single Layer rebar, PVC Conduit should be secure at top of rebar with binding Steel Wire.
- After completing the work, tight the conduits with binding wire .PVC Conduit should be bound at intervals of not more than **1 meters by binding** short lengths of steel wire, of not less than 2mm diameter twisted around the conduit and reinforcing steel. Additional Steel bonding Wire also provide near each PVC Conduit Coupler, PVC Bends and near Junction Box
- Check there is no damage in PVC Conduit and it's accessories before concrete is poured.
- The open ends of Conduit should be protected during concreting by caps or plugs to prevent the ingress of building material.
- All Junction Box, Fan Box should be protected during concreting by filling thermo coal Sheets to prevent the ingress of building material.
- Ensure conduits are not concealed until works has been inspected and approved.
- Before the concrete pouring the PVC conduit installation to be inspected and approved by consultant/client/contractor.
- **During concrete pouring, keep electricians for taking care of conduit to avoid any damage by others or dislocation of joints.**

Recess / Concealed Conducting in Wall.

- Ensure that bricks / Block masonry work is complete, and Site is given for electrical works.
- Check the required reference markings are available for FFL (finished floor levels).
- All required materials shall be shifted and stored under safe custody near workplace on daily basis as per planned quantity.
- In the case of building under construction, conduit shall be buried in the wall before plastering and shall be finished neatly after erection of conduit.
- In case of exposed brick/rubble masonry work, special care shall be taken to fix the conduit and accessories in position along with the building work.

1. Marking of Switch Box and Light Points:

- Mark the location of switch/socket and conduit route on proper height based on approved shop drawing.
- No conduit smaller than 20mm in diameter or larger than 32mm diameter shall be used.
- Mark the location of Switch Box, DB, and Junction Box for Light Point on the wall from FFL.

2. Wall Chasing:

- After marking of conduit and Switch Box location, Wall chasing shall be done using wall cutting machine.

- Hammer and chisel will be used on the chased portion to get uniform depth of **50 mm or as per standard specifications.**
- All chases, grooves shall be neatly made to proper dimensions to accommodate the required number and size of conduits and staples. The outlet boxes, point control boxes, inspection and draw boxes shall be fixed as an when conduit is being laid. The recessing of conduits in walls shall be so arranged as to allow **at least 12 mm plaster over the same.**
- The chase in the wall shall be neatly made and of ample dimensions to permit the conduit to be fixed in the manner desired.
- Wherever the length of conduit run is more than 10 meters, then circular junction box shall be provided to permit periodical inspection and of facilitate replacement of wires, if necessary. These shall be mounted flush with the wall.
- In place where the conduit is crossing at different ceiling height, uniform bending shall be done. The bending of conduit shall be done using proper bending springs.
- Conduits will be cleaned with a round file from inside and outside of the pipe after cutting.
- Connect the conduit by using PVC solvent with an adaptor to the junction box. Apply PVC Solvent cement on the portion of conduit entering into coupler wherever applicable.
- PVC Conduits shall be duly fixed by using a hook or Nail. Distance of GI hook / Nail shall be maintained at **500 mm at intervals.**
- Embedded back box, JB shall be protected by covering with brown tape filled with jute/gunny bag.

3. Installation of the Box / Enclosure:

- At Planning and Designing Level, always Select DB Wall block work thickness should be **200 mm instead of 100 mm for easy DB installation**.
- For Properly Installation of DB and Switch Box, locate plaster level points near DB or Switch Board.
- The mounted height of the Switch Board is generally 1200mm (Bottom of Switch Box) in all rooms ,300 mm near Bed and for DB it is generally 1800mm (bottom of panel) or as per approved Drawings.
- Ensure the box size and accordingly cut a bit larger size of box in marked place of block wall with sufficient depth.
- Fix the GI Metal box of appropriate size and level with the help of spirit level.
- Installed the Switch Box and DB with the use of cement mortar around the box. Make sure that it is flush with finished plaster level.

- The bottom portion of box should match the marked level as per consultant approved height for switch/ socket and/or as per local applicable wiring regulation requirements.
- Apply cement filler to fix the box properly and leave for setting, insert the required lengths of conduits on their paths and don't connect with boxes until next day.
- Next day, after setting of box connect the dropped conduits for switch/socket to the box.
- The switch box shall be flush with the plaster. The height of the switch boxes shall be as indicated in the drawings. The switch boxes should be sufficient depth to give minimum 20 mm plaster cover to conduits embedded.
- Distribution board interiors will not be installed in cabinets until all conduits connections to the cabinet have been completed.
- Trim for flush mounted cabinets will be installed in plaster frame, flushed with furnished wall.

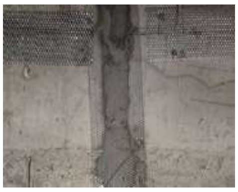
4. Filling Chasing Area:

- All grooves, chases shall be properly filled and concreted and finished up to the wall surface before plastering of walls is taken up. The conduit boxes, accessories, joints, etc. shall be laid along with the conduits. The chases shall be sufficiently deep and properly filled with cement mortar.
- Where conduits pass through expansion joints in the building, adequate expansion fittings or other approved services shall be used to take care of any relative movement. As far as possible, chasing of wall to embed the conduits to be avoided.

- Chasing is filled by Cement mortar 1:5 ratio(1 portion of the cement+5 portion of sand) shall be used for patchwork in chased area and its surface is rough so main plaster will easily joint on chasing area.
- Curing shall be carried out for a minimum of three days.
- Make sure the conduits are not visible from outside their route which could lead to improper plastering.

5. Wire Mesh:

- After chasing area is filled by mortar, Chicken (wire) mesh and GI nails shall be applied on chasing area to avoid hair crack in plaster.



- Width of Chicken Mesh is slightly larger than chasing Area. After installation of Chicken mesh final Plaster should be done. Make Sure that Nails for Wire Mesh should not damage the Buried PVC Conduit.

Surface Conducting:.

- Take the approved Drawings of Electrical conduit Shop Drawing with section details, MEP coordination drawing with section details and Architectural Drawings.
- Ensure that the civil people have finished block wall and Plastering with adequate curing and clearance is given to proceed for electrical works.
- Check the required reference markings are available for FFL (finished floor levels).
- All required materials shall be shifted and stored under safe custody near workplace on daily basis as per planned quantity.

1) Marking of Conduits:

- Site Engineer will carry out a site survey where the PVC Conduit will be installed as per approved shop drawings.
- Mark the exact position of the conduit route with the blue marker string and then install conduit saddles.
- All runs must be installed as a complete system before any conductors are pulled into them. In other words, a run of conduit (to include conduit, fittings, and supports) must be complete before the conductors are installed.
- A run of conduit should be as straight and direct as possible. When a number of conduit runs are to be installed parallel and next to each other, install them all at the same time.

2) Installation of Conduits:

a) PVC Conduit and Accessories:

- Conduits shall run vertically or horizontally only for surfaced run conduits.
- Install the correct Type and size of the conduits as per approved Specification and drawing.
- Conduit pipes shall be fixed by heavy gauge saddles, secured to suitable wood plugs or other approved plugs with screws in an approved manner **at an interval of not more than 1 meter** but on either side of the couplers or bends or similar fittings, saddles shall be fixed at 30cm **from the center of such fittings.**
- The saddles should not be less **than 19MM (width) of 24 gauge for conduits up to 25 mm dia and not less than 25mm (width) of 20 gauge for larger diameter conduits.**
- Where conduit pipes are to be laid along the trusses, steel joint etc. the same shall be secured by means of special clamps made of MS. Where as it is not possible to drill holes in the trusses members suitable clamps with bolts and nuts shall be used.

- Where conduit pipes are to be laid above false ceiling, either conduit pipes shall be clamp to false ceiling frame work or suspended with suitable supports from the ceiling slab.
- For conduit pipe run along with wall, the conduit pipe shall be clamped to wall above false ceiling in uniform pattern with special clamps if required to be approved by the Engineer-In-Charge at site.
- Check to ensure no sharp edges within the conduit joints for surfaced conduit and to ensure proper bonding for all conduit joint for concealed PVC conduit by foreman / skill worker / sub-contractor.
- All joints in PVC conduits, other than screwed joints, shall be cemented with a waterproof adhesive. This adhesive shall be as recommended by the conduit manufacturer.

- All saddles, tubes and boxes must be in perfect alignment to avoid any appearance of warping when the installation is complete. Saddles should not be so tight as to prevent expansion of the conduit.
- Power conduit and LV conduit need to be separate. Power, Lighting Circuit should be run in separate conduit than LV circuit (Data wire, Telephone wire, TV wire) conduit.
- Conduits shall **not be run closer than 0.15m to any steam or hot water pipes** and shall be run underneath such pipes rather than over them.
- Conduits should not also be run closer than **0.05m to any telephone, bell or other signaling circuit.**
- Particular care shall be taken to ensure that no grout or other foreign materials enters the conduit system through joints, or through surface openings.
- All conduits shall be run as far as possible along the walls and ceiling and above false ceilings so as to be easily accessible for inspection if need be. While the Architects drawings indicate the distribution for light and power points
- PVC conduits shall be ISI grade and it shall be rigid type. Where conduits are laid in straight run, draw boxes shall be provided at intervals not exceeding 10 meters. Between two consecutive draw boxes the right angle bends shall not exceed two in number.
- Drawn-in boxes must be provided to give access to all conduit for the drawing-in or out of any cable after the installation is completed.
- Terminations of PVC conduits into switch boxes, DBs, etc. shall be with adapters. PVC conduits shall be fixed to accessories such as coupler, circular boxes, etc. with vinyl cement.

b) GI / Steel Conduit and Accessories:

- GI Conduiting layout complete with MEP coordination and Architectural Drawing complete with section details.
- Check the route of GI Conduiting free from debris and no obstruction of any other activity.
- Arrange scaffolding of sufficient height approved by HSE officer.
- Mark the reference points on wall/ column as per civil architectural drawing.
- Identify the circuit start point and end & mark GI Conduiting route as per approved drawings.
- Prior to erection, all burrs and sharp edges shall be removed from the conduit together with any dirt, oil or paint which may be present.
- Standard length of conduits shall be cut to the required length.
- For GI Conduits threading shall be done using a threading tools and appropriate die-set. Thread will be kept to a minimum from coupling and boxes. Zink rich paint to be applied to the exposed thread part of GI conduit.
- Where required conduits shall be bent to the required radius using manual bending machines.
- Conduits are fixed to the building fabric by means of distance saddle with appropriate metal screws will be allowed.
- Spacer bar are fixed in regular interval not exceeding 1000mm and the distance from either side of ay box or bend to the nearest spacer bar shall not be more than 150mm.
- All terminal boxes area marked on the appropriate location (wall/ceiling) as per approved shop drawing and fixed with metal screws and plug. Suitable bushes are used where conduit enters the boxes to avoid any damage to the wires.
- Wherever necessary ropes shall be pulled into conduit runs ending and kept at pull boxes for the future purpose. Ensure that sufficient number of pull boxes is installed.
- Metallic conduit boxes shall be sued throughout metallic conduit raceway system.
- GI flexible conduits shall be used to make connections from un-accessible location and end connections to terminal boxes.
- All pull boxes, junction boxes fixed on the wall in the route of steel conduit shall be provided with GI cover after pulling the wires.
- Steel conduiting shall be conforming to relevant IS specifications (IS 9537). All steel conduits shall be of heavy gauge, welded and threaded type. Conduit accessories such as boxes, bends, inspection bends, boxes, elbows, reducers, etc. shall conform to relevant standards. As far as possible, boxes shall have internally tapped spouts to receive the conduits.
- Where conduits are installed in straight run, draw boxes shall be provided at intervals not exceeding 30 feet (9 meters). Between two consecutive draw boxes, the right angle bends shall not exceed two in number. Conduits shall be properly threaded and screwed in to the accessories.
- The minimum size of conduits used shall be 20 mm. The minimum thickness of the conduits shall be 16 SWG.

- Wherever steel conduits terminate into points control boxes, distribution boards, etc. conduits shall be rigidly connected to the boxes, boards, etc. with check nuts on either side of the entry to ensure electrical continuity and with PVC or Bakelite bushes. Turning joints in conduits wherever necessary shall be rigidly held in aligned position by check nut tightened on the running side.
- After conduits, junction boxes, outlets, etc. are fixed in position, their outlets shall be properly plugged with PVC stop cover or with any other suitable material so that water, mortar, vermin or any other foreign material do not enter into the conduit system.

Maximum number of PVC insulated 650/1100 V Copper conductor cable conforming to IS: 694-1990

Conduit size	20mm		25mm		32mm		40mm		50mm	
Wire Size (Sq.mm)	S	B	S	B	S	B	S	B	S	B
1.5 Sq.mm	7	5	12	10	20	14	-	-	-	-
2.5 Sq.mm	6	5	10	8	18	12	-	-	-	-
4 Sq.mm	4	3	7	6	12	10	-	-	-	-
5 Sq.mm	3	2	6	5	10	8	-	-	-	-
10 Sq.mm	2	-	4	3	6	5	8	6	-	-
16 Sq.mm	-	-	2	-	4	3	7	6	-	-
25 Sq.mm	-	-	-	-	3	2	5	4	8	6
The columns heads 'S' apply to runs of conduits which have distance not exceeding 4.25 m between draw in boxes and which do not deflect from the straight by an angle of more than 15 degrees.										
The columns heads 'B' apply to runs of conduit which deflect from the straight by an angle of more than 15 degrees.										

Bending of Conduit:

- It may be necessary to create bends in the field by heating and deforming rigid conduit.
- For heating the rigid conduit, use a heat gun or some other flameless heat source. Do not use an open flame to heat the conduit. The rigid conduit must be heated to approximately 125°C in order to bend without kinking.
- Heat a length of conduit equal to approximately 10 times the rigid conduit nominal diameter.
- Once the rigid conduit has been adequately heated, bend it to the required angle plus 3 extra degrees. The additional angle will accommodate the "spring back" which will occur during cooling.
- After bending of the conduit is completed, immediately cool the bend using water or cold air.

Conduit Bending Radius

Size of Conduit	Radius to Center of Conduit
12 mm	100 mm
20 mm	112 mm
25 mm	144.8 mm
30 mm	183.9 mm
40mm	208 mm
50 mm	238 mm
63 mm	266 mm
75 mm	330 mm
88 mm	370 mm
100 mm	403 mm
127 mm	609 mm
152 mm	762 mm

Reference:

1) IS 3854 1966: Switches for domestic and similar purpose.
2) IS 1293 1967: Three pin plug and socket outlets.
3) IS 4614 1968: Switch Socket outlet (non-interlocking type)
4) IS 6538 1971: Three pin plugs made of resistant materials.
5) IS 9537-3 (1983): Rigid plain conduits of insulating materials.
6) IS 3419 (1989): Fittings rigid non-metallic conduits

Chapter: 31 Difference between Fault Current & Short Circuit Current

Introduction:

- There is a difference between "Fault Current" and "Short Circuit Current" in electrical system. Both parameters are important while selecting an Equipment or designing a Network, however both terms are misled in Electrical engineering.
- In very simple language "Short" means less (shortest distance, time or circuit), Short circuit Fault means least resistance or no resistance in circuit and Current is high due to less resistance. This high current convert into heat energy. The opposite of a short circuit is an "open circuit", which is an infinite resistance between two nodes.
- While Fault means wrong. Fault Current means Current pass in to wrong path.

What is Fault Current

- A fault current is a current which takes the wrong path instead of using the normal conducting path during Fault condition.
- Under normal condition, the electric equipment operate at normal voltage and current ratings. Once the fault occurs in a circuit or device, voltage and current value deviates from their nominal Value. This may be high or Low Values.
- The fault may be occurred due to insulation failures, Wrong Connection or conducting path failures, which further convert in Open Circuit, Short Circuit and Ground Fault.
- **A fault current can either current being more or less than the normal rated current.**
- In Three phase power system, there are basically three types of Fault Current.
  1) Open Circuit Faults
  2) Short Circuit Faults (L-L / L-L-L)
  3) Ground Circuit Faults (L-G / L-L-L-G)

What is Short Circuit Current:

- When a two or more conductors of differential potential comes to contact with each other (one phase comes in contact with other Phase, Neutral or Earth) gives the electricity to a path of less resistance hence a large current flow in the un-faulted phases, such current is called the **short circuit current.**
- When Short circuit occurs, current returns to its source without passing to the load. It caused zero or very little resistance and No Voltage drop in that circuit.
- **This Current will be the maximum that the source can deliver for a very small time before the protection device operates**. The current is limited only by the resistance of the rest of the circuit.
- We know that V (Voltage) =I (current) x R (resistance of Circuit).
- When short circuit occur, resistance is very small and can be considered as negligible. We can consider R=0. This means I = V/0, which means infinite current will Flow so the conductor must have the capacity to allow this huge current to flow. In most of the cases breakdown happens.
- The resistance when short circuit occur is very small and can be considered as negligible. We can consider R=0.
- This means V=Ix0, which means Voltage at Short circuit is very Less.
- **V(drop)=0 and current(I)=infinite**
- Short circuit gives thousands time larger Current than the normal current and Zero Voltage at Fault Point. This will produce more heat and result in burns and fires.
- Short circuit faults are also called as Shunt faults.
- **Causes:**
- **Over Loading of Equipment:** Overloading of equipment and insulation failure due to lighting surges and mechanical damage.
- **Loose Connections:** Due to Loose Connections, Sometimes Neutral and Phase wires to touch.
- **Faulty or Wrong Connections:** Wrong Connections make Short circuit in Circuit.
- **Failure / Ageing of Insulation:** Old or damaged insulation makes neutral and Phase wires to touch, which can cause a short circuit. Punctures in Insulation can damage insulation and makes short circuit.
- **Harmful Effects:**

- The short-circuit produces the arc that causes the major damage of equipment such as transformers and circuit breakers.
- The short circuit causes a heavy current in the power system which produces excessive heat and hence results in fire or explosion.
- The short circuit affects the stability of the network which disturbs the continuity of the supply.
- The operating voltages of the system can go below or above their acceptance values that creates harmful effect to the service rendered by the power system.

Open Circuit Faults:

- Open Circuit Faults occur due to the Failure / Open of one or more Phase Conductors in Circuit.
- In Open Circuit Fault, Current cannot flow hence Current is Zero and Voltage become Infinite.
- **V(drop)=infinite and current(I)=0**
- Open circuit faults are also called as series faults. These are unsymmetrical or unbalanced type of faults except three phase open fault.
- **Causes:**
- Broken Conductor, Failure of Conductor Joints and malfunctioning of circuit breaker in one or more phases.
- **Harmful Effects:**
- Abnormal operation of the system.
- Danger to the Human and Animals.
- Exceeding the voltages beyond normal values in certain parts of the network, which leads to insulation failures and developing of short circuit faults.

Difference between Fault Current and Short Circuit Current:

- **Circuit Resistance:**
- A short circuit has zero resistance between two Wires / Circuits / Systems, on the other hand a Fault current has a resistance that draws current. The amount of resistance decides how much current is drawn and is usually caused by a breakdown in the insulation of a system.
- **Amount of Current:**
- **Fault Current:** it is the current exceeding the equipment current rating e.g. motor rated 25A, then more than this will be the fault current.
- **Short Circuit current:** it is the maximum current which can flow when the equipment is short circuited & it can withstand. above this the current will damage the equipment.
- Fault current is the current that flows during an Open Circuit or Short Circuit Fault condition so each time it is not necessary that Fault Current is a Short Circuit Current (It may be Open Circuit Fault).
- A short-circuit current will flow when there is short-circuit in the system, and it will represent the highest possible fault current that a system can experience.
- **Therefore, a fault current can be less that the short-circuit current, and a short-circuit current will represent the highest fault current in the system.**
- **A fault current can either current being more or less than the normal current while Shor Circuit Current is higher than Normal Current.**
- **A Fault Current is not necessary a short circuit Current but Short Circuit Current is always a Fault Current.**

Comparison of Fault Current -Short Circuit Current

Basis For Comparison	Fault Current (Open Circuit Fault)	Short Circuit Fault	Overload
Meaning	In the Open circuit the voltage at the fault point is high up to infinite and current is zero through the faulty point of the network.	In the short circuit the voltage at the fault point decreases to zero and current of irregular high value flow through the faulty point of the network.	The overload means that load greater than the desired value have been imposed on the system.
Resistance	High	Zero	
Current	Zero	High	Low as compared to short

			circuit.
Voltage	High	Zero	The voltage becomes low, but cannot be zero.
Occur	It occurs when the neutral and live wire Break or Open.	It occurs when the neutral and live wire touch each other.	It occurs when a large number of devices are joint in a single socket.

Importance of Fault Current and Short circuit Current for designing of System or Panel.

- The safety of the system is decided by short-circuit current rating (SCCR) of the Equipment with the reference of the available fault current where the Equipment is installed.
- The short circuit current rating gives a baseline for the fault current that an equipment can withstand for a specific amount of time, or until it clears the circuit with opening of a circuit breaker.
- The short circuit current rating of a panel is the amount of energy, usually expressed as a value in kilo-Amperes (kA), that the panel can handle without causing fire, a shock hazard, or explosive danger.
- In equipment with higher short-circuit current ratings compared to Fault Current is not an issue.
- The available fault current of panel can be decided by the size of the upstream transformer, size of the electrical conductors / Cables up to the Equipment.
- If the System Fault Current at the Location is 20KA to 50KA and if we use Equipment having short circuit current of 5KA to 10KA may cause damages of equipment or network in fault condition.
- If the System Fault Current at the Location is 5KA to 10KA and if we use Equipment having short circuit current of 65KA to 100KA will not create any issue but it will unnecessarily increase the price of equipment hence **short circuit level of the equipment is not too much high with respect of fault current.**
- **We must ensure that the Short Circuit Current is equal or more than Fault Current available at the point of Equipment.**

Chapter: 32 Difference between PVC- LSF-LSHF- FR- FRLS - FRLSH and FS cables.

Introduction:

- Due to lack of standardization and lack of awareness. While selecting of Cable, there is a lot of confusion and misunderstanding regarding the terminology associated with cables in terms of "LSF / LS" (Low Smoke), "LSZH / LSHF (Low Smoke Halogen Free)," FR" (Fire Retardant),"FR" (Fire Resistance) "FRLS" (fire resistant, low smoke), "FRLSZH" (Fire retardant Halogen-Free).

Cable / Wire Terminology

- According to type of Insulation Material around the conductor, we can classify Cables / Wire in Three main Categories PVC, Zero Halogen and Fire Retardant.
- According to application we can mainly classified in to Two categories

(A) Non-Fire Rated Cable

1. PVC = Polyvinyl Chloride
2. LS / LSF = Low Smoke / Low Smoke Fume
3. LSHF / LSZH / LSNH = Low Smoke Halogen Free / Low Smoke Zero (No) Halogen
4. LH / HF = Low Halogen / Halogen Free

(B) Fire Rated Cable

5. FR =Fire Retardant
6. FR =Fire Resistance
7. FRLS = Fire Resistant, Low Smoke
8. FRLSH= Fire Resistant, Low smoke, Low Halogen
9. FRLSZH / NHFR / ZHFR / HFFR = Fire Retardant Low Smoke Zero Halogen / Non (Zero) Halogen Free, Fire retardant
10. HRFR=Heat Resistance Fire Retardant

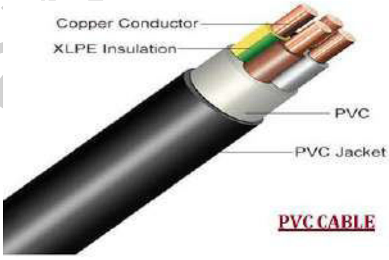
- PVC, FRLS and FP cables, have conductors and insulation to manage the electrical current and voltage. Some also have extra physical protection, like steel wire armour.
- PVC and FRLSH cables are different insulating materials around conductors for different application and performance.
- The properties that distinguish one electrical insulation from the other are
- (1) dielectric strength or break down voltage
- (2) maximum permissible temperature
- (3) dielectric loss
- (4) permittivity; and some special properties to suit the application.
- FRLS / FRLF is the quality of insulating material. It may be PVC or XLPE.

(A) Non-Fire Rated Cable

(1) PVC Cable:

- PVC (Polyvinyl Chloride) cables is usually made up of a PVC compound as an insulating Material.
- PVC insulation has a temperature limit of about 70°C. From the point of view of maximum permissible temperature, it belongs to the lowest class of insulation, yet it serves the purpose as the voltages and power ratings involved are relatively low.
- While burring of PVC in case of Fire produces dense of black smoke and produce large amount of toxic gas and cocktail of harmful chemicals.
- **Smoke:**
- Burning PVC has been **reduced visibility in the surrounding area** by 50% within 10 minutes. After 30 minutes, visibility can be reduced by as 90%
- This reduced visibility could make it very difficult to escape a burning Area / Building.
- The smoke and fumes produced during a fire can be more dangerous to people than the fire itself.
- **Toxic Chemicals:**

- Burning PVC produces a number of toxic chemicals, but the most problematic is hydrogen chloride (HCl). **PVC emits approximately 28% of Hydrogen Chloride (HCI)**.
- In natural state HCL is a pungent, almost colourless gas, which forms into white vapor clouds on contact with air.
- Furthermore, when mixed with water it changes state yet again to form Hydrochloric Acid, whether it's in gaseous, vaporized or liquid state it's a highly toxic and corrosive substance.
- There are numerous harmful effects that HCl can have on a person. If inhaled the lining of the throat can be irritated to such an extent that it swells, making breathing extremely difficult.
- Contact with the eyes can be responsible for anything from severe irritation to permanent damage to the corneas. Similarly, lips and mucous membranes may be burned or even ulcerated, the severity dependent on the concentration of HCl and length of exposure.
- Taking into account the combined effects on someone of the smoke and HCl produced during the burning process, it's difficult to see and the victims have been rendered unconscious long before the flames have reached them.
- **Some extent Fire Retardant property:**
- PVC is resistant to Fire ignition.
- PVC (polyvinyl chloride) is naturally Fire Retardant due to chlorine base. It contains a large number of chlorine ions in the molecular structure, and these are particularly difficult to break off when exposed to heat.
- If it does catch fire, PVC has a particularly slow spread of flame. PVC has one of the lowest flames spread ratings, meaning that it won't typically contribute to the spread of a fire
- The temperature required to ignite rigid PVC is more than 150 deg C higher than that required to ignite wood. **The ignition resistance of common flexible PVC formulations is lower, but with specialized formulations it may be significantly increased.**
- The fire in the gets extinguished immediately on removal of the fire source.
- In the Plant or Building, PVC cables are bunched in the cable shaft or on cable trays. In case of fire in these cables the fire becomes self-sustaining.
- Moreover, due to the burning of PVC a dense corrosive smoke is emitted which makes firefighting very difficult, due to poor visibility and toxic nature of the smoke. HCL content of the smoke, not only damages other costly equipment lying nearby, but also penetrates the RCC and corrodes the steel reinforcement.
- **PVC have some Fire-retardant Property due to halogen even though it may create an extensive damage to the property and harmful for human**.



Advantage:

- PVC is Cheap.
- PVC offers greater flexibility and robust
- PVC have a relatively long working life

Disadvantage:

- When PVC insulated cable burns it gives off a cocktail of chemicals and dense black smoke.

Application:

- PVC cables are used for non-essential services that do not need to operate in case of fire
- Mostly use for Domestic, Office for general lighting.
- They are ideal for low-risk buildings, not generally for public or large commercial buildings.

(2) LS / LSF (Low Smoke & Fume) Cables:

- LSF is also manufactured using PVC compounds.
- LSF cables are usually made up of a modified PVC compound (varying degrees dependent on the manufacturer's) which produces somewhat less HCI gas and smoke on burning than PVC.
- However, it still produces **15% to 22 % (depending on quality) of HCI gas** and due to the presence of PVC can still emit dense black smoke and HCl emissions.

- It does contain halogen, so it shouldn't be confused or similar with Low Smoke Halogen Free (LSHF) cables.
- The amount of PVC present in these cables can differ from manufacturer to manufacturer which makes installing LSF cables in public places.

Advantage:
- These cables are often purchased to cut cost or in confusion with LSHF cables.
- They should be considered to be a small improvement over PVC cables.

Dis Advantage:
- These cables are not recommended for public, large commercial buildings, near sensitive electronic equipment and where escape is limited in case of fire.

Application:
- Mostly use for Domestic, Office for general lighting.

(3) LSHF / LSZH / LS0H (Low Smoke Halogen Free) Cables

- LSHF cables are made up of halogen free compounds that are good fire retardants but emit less than **0.5% hydrogen chloride** gas and smoke when burnt.
- In case of fire, LSHF cable produces only small amounts of light grey smoke and miniscule amounts of HCl, which as a result greatly increases a person's chances of escape from a burning building in which it's installed.
- The reason LSHF products react so differently when exposed to fire in comparison to PVC & LSF cables is the complete absence of PVC.
- The outer sheath / Jacketing and conductor insulation of these products are often made from polyethylene which contains little by way of chlorine, and low chlorine means low HCl and Low nontoxic gases emissions.
- **It emits <0.5 % of HCL gas thus providing a safer environment in the event of a fire.**
- There's no PVC in these cables, hence no harmful fumes or dense black smoke are given off in case of fire and generation ensures evacuation routes and signage remain visible during a fire.
- In Some Manufacture's LSHF Cable use standard PVC cables over-sheathed with an LSHF jacket or cables with PVC insulation. When the jacket burns through, the PVC inner sheath or insulation will give off poisonous gases in just the same way as PVC Cable.

Advantage:
- LSHF cables use in applications where smoke emission and toxic fumes could a risk to human health and essential equipment in the event of a fire.

Disadvantage:
- Costly compare to PVC and LSF
- Not Flexible compared to PVC

Application:
- Because of their low smoke and toxicity benefits, LSHF cables are often chosen for various Public, non / Poor ventilated Place and Essential applications.
- Public space, Building like Railway and subway stations and cars, buses and bus stations, airplanes and airports, Carrier Ships, other mass transit facilities.
- Any public underground or poorly ventilated location like elevators, subways
- Public entertainment and sports facilities
- Apartment buildings and hotels
- Hospitals

- Computer/data centres

Difference between PVC vs LSF vs LSZH

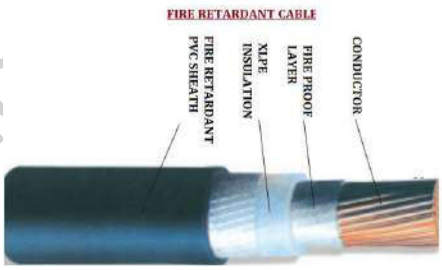
- LSF cables are flexible and low-cost alternative to PVC cables but made from a modified version of PVC and can still produce a dangerous amount of toxic gas and **large amounts of black smoke and hydrogen chloride gas when burned.**
- Black smoke can obscure exit routes in the event of a fire and hydrogen chloride gas can be deadly to both people and sensitive equipment.
- Whereas LSHF cables are less flexible and a higher cost but due to absent of PVC reduce significant of toxic gas, smoke and no more than 0.5% HCL when burned. So in a high risk populated area where escape is limited, LHSF cables are strongly recommended.
- But in low-risk areas where the evacuation is easy and high flexibility is required, PVC could still be a good choice.
- One common misunderstanding is that LSF or LSHF cable is also flame retardant. This is not necessarily true. The cables may spread the fire even though minimal fumes are being emitted

(B) Fire Rated Cable (Retardant / Resistance Cable)

- Fire is one of the biggest risks in factories, public place and a majority of them occur due to electrical faults.
- The terms Fire Resistant and Fire Retardant (both are commonly referred to as FR) terms are very similar and misused or confusing a lot.
- Both are different in structure, in materials, in Application and react even differently in the event of a fire. If we required one but select other can lead the problem.

(1) Fire Retardant Cables

- Insulating Material of Fire Retardant Cable is chemically treated to Retard or Slowdown ignition or Burning of Fire hence **slow down the spreading of fire.** It also actually self-extinguishes when exposed to an open flame.
- **Flame-retardant Cable is characterized by delaying the spread of flame along the cable so that the fire does not expand.**
- Fire-resistant cables and flame-retardant cables are different in structure and materials.
- The basic structure of the flame retardant cable is:
- The insulation layer uses flame retardant.
- The inner sheath and outer sheath are made of flame retardant.
- The tape and filling use of flame retardant material.



Advantage:

- Low Cost compared to Fire Resistance Cable.
- Produce Low Smoke

Disadvantage:

- **By Adding Fire Retardant Material / Filler in PVC it decreases insulation property at least 10% compare to normal PVC**, however its conductor temperature withstanding capability (during overload) remains only at 70 deg C same as ordinary PVC cables.

Applications:

- Control Wiring of Building
- Fire Alarm Circuit

(2) Fire Resistant cables

- The Fire resistance materials (non-flammable.) are designed to prevent / Resist the spread of fire (self-extinguishing) and will not melt or drip when in close proximity to a flame.
- Because it self-extinguishes once the source of ignition is removed and does not melt or drip. **Fire-resistant cables can maintain normal operation for a certain period under flame burning conditions and maintain**

the Circuit integrity and continue to work for a specified period of time under defined conditions hence improving the chances of escape and survival.

- Because of Fire resistant fabrics are not usually made from 100% flame resistant materials, they will burn, but will do so very, very slowly and are often self-extinguishing.
- A Fire-resistant cable is a cable that can maintain safe operation for a certain period under flame-burning conditions. Fire-resistant wires are widely used in high-rise buildings, subways, underground shopping malls, power stations, and important industrial and mining enterprises related to fire safety and fire rescue. For example, power supply wires and control wires for firefighting facilities.
- Fire-resistant cable is divided into class A and class B.
- **Class B:** Class B cable can be in 750 °C to 800 °C flame and rated voltage to withstand burning for at least 90min, and the cable is not broken.
- In the refractory layer to improve the manufacturing process and increase the refractory layer and other methods based on
- **Class A:** Class A fire rated cable can be 950 °C to 1 000 °C flame and rated voltage to withstand burning for at least 90min and the cable is not punctured.
- Class A fire-resistant cable fire performance is better than class B.
- **Mineral Insulated Cable (MI):** mineral insulated cable is a better performance of fire-resistant cables made of copper core, copper sheath, magnesium oxide insulation material processing, referred to as MI (mineral insulated cables) cable.
- MI cable has good fire resistance characteristics and can work for a long time under 250 °C high temperature, but also explosion-proof, strong corrosion-resistance, high flow rate, radiation resistance, high mechanical strength, small size, lightweight, long life, and smokeless. However, the price is high. The process is complicated, the construction is difficult in the oil irrigation area, important public buildings, high-temperature places, and other fire-resistant requirements, and the economy can accept the occasion and use fire-resistant cable.

Advantage:

- Produce Low Smoke compared to Fire Retardant Cable.

Disadvantage:

- High Cost compared to Fire Resistance Cable.
- By Adding Fire Retardant Material / Filler in PVC it decrease insulation property at least 10% compare to normal PVC, However its conductor temperature withstanding capability (during overload) remains only at 70 deg C same as ordinary PVC cables.

Applications:

- In Fire Fighting System,
- In Fire Alarm Circuit

(3) FRLS (Fire Retardant Low Smoke)

- To overcome these deficiencies of FR Cable, FRLS Cable was developed.
- FRLS has special flame retardant, low smoke emitting and toxic fumes suppressing properties.
- In FRLS Cable, inner sheath and/or outer sheath is made material of Polyethylene Material having Fire Retardant Properties.
- In the Case of fire, convectional PVC insulated wires give out thick black smoke and toxic fumes of hydrochloric acid gas. This impairs visibility and hampers rescues operations. But in FRLS Cable not only emits very little smoke and toxic gases, but also retards the spreading of fire. It is thus ideal of concealed and conduit wiring in multi-storied high-rise buildings such as hotels, banks, hospitals, factories, commercial complexes and residential apartments, etc

Advantages

- Excellent flame-retardancy
- Low smoke generation
- Low toxic gas emission

(4) FRLSZH/ NHFR / ZHFR (Fire Retardant Low Smoke Halogen Free)

- FRLSZH, Halogen Free Flame Retardant non-toxic smoke house wires for building wiring.
- FRLSZH Wires are recommended especially in a situation where high degree of safety of personnel and equipment are obligatory like Hotels, Theatres, Hospitals, High-rise buildings, Commercial complexes, Centrally A.C. offices, Residential properties etc.
- Owing to its special insulation characteristics the wires continue to provide uninterrupted power supply even during fire – keeping alive fire alarm circuits, exit lights, Lifts & other emergency Circuits.
- As part of sustainable green building technology, to bringing down the use of hazardous PVC from green building. Normal PVC cables will be replaced with Green Cable.

Advantages

- Excellent flame-retardancy
- Halogen Free
- Low smoke generation
- Low toxic gas emission
- Better visibility help easy for people escape
- Environment friendly
- Benefit to environment
- PVC is not only hazardous during the manufacturing process but also potential risk in case of fire. Green Cable is superior performance cable with utmost quality which is replacement for PVC cables.
- Generally used where green environment and higher safety is expected for Human life and valuables

Disadvantages

- Costly Compare to FR and FRLS Cables

Applications:

- Airports
- Centrally A. C. Buildings
- Complexes
- Educational Institutions
- General House wiring

- Green Buildings
- High Raise Building
- Hospitals
- Hotels
- Public Places, Theaters
- **Flame retardant (FR) or FRLS compounds are not suitable for building wires for the following reasons:-**
- FR & FRLS PVC compounds are said to be flame retardant because they have better LOI (Limiting Oxygen Index) and TI (Temperature Index) than ordinary PVC, but, only better LOI & TI does not guarantee better flame retardant properties. LOI & TI are only quality control tests and flame retardant testing is incomplete without finished cable testing as per IEC 332-1 &3.
- Moreover, all the FR and FRLS PVC compounds contain Antimony Trioxide which is a probable carcinogen. When inhaled, ATO can cause irritation of the respiratory track, mouth, nose & stomach. It may also cause the heart to beat irregularly or even stop.
- The use of FR & FRLS PVC compounds does not solve the issues of dense black smoke and HCL acid gas emitting from burning which are the main cause of loss of human lifes during fire accidents.
- All PVC,FR & FRLS compounds also contain phthalate plasticizers. These plasticizers leach out of PVC compound after some time and results in PVC loosing its flexibility and other properties. Moreover most of the phalates presently used have been identified as suspected endocrine disrupters and reproductive toxicants

Difference between Fire Resistant vs. Fire Retardant Cable

- **Fire Resistant** and **Fire Retardant cables** are being used increasingly due to their usefulness in the event of fire. However, though they both sound similar, they have vastly different uses and react differently in the event of a fire.
- **Heat resistant:** It will operate as normal at high temperatures, but may not operate as normal in the event of a fire.
- **Fire retardant:** It will not operate as normal within fire conditions, but will actively prevent the fire from spreading.
- **Fire resistant:** It can operate as normal within fire conditions.
- **Conclusion:**
- In brief, Fire retardant cables are designed to resist the spread of fire into a new area. It would not maintain circuit continuity for Work.
- Fire resistant or fire rated cables are designed to maintain circuit integrity and continue to work, allowing power to be transferred through it under defined for a specified period of time and conditions.
- The distinction between the two is crucial when it comes to maintaining critical circuits required for life safety or for a safe and immediate plant shutdown.
- Fire resistant cables are used in critical electrical circuits, such as safety circuits and life support circuits which are required to function in the case of emergencies.
- Flame retardant cables on the other hand are used in all other circuits so if there's a fire, they can curb its spread. A flame resistant cable will be passed as per IEC 60331 and are encased in a red outer sheathes. Flame retardant cables behavior under fire is predefined as per passing the IEC 60332 and are encased in a grey or black outer sheathe.

Fire resistant (fire rated) cables	Continues to operate in the presence of fire, hence their reference as Circuit Integrity cables.
Flame retardant cables	Fire performance limited to not propagating fire

Difference between FR vs PVC vs LSF vs LSHF Cables

- **FR Cables:**
- Fire resistant and fire retardant cable sheaths are design to resist combustion and limit the propagation of flames.
- **Fire Retardant (FR):** Designed for use in fire situations where the spread of flames along a cable route needs to be retarded
- **Fire Resistant (FR):** cables are designed to maintain circuit integrity of those vital emergency services during the fire

- **FR is for essential services such as fire alarms, emergency lighting, life safety and firefighting applications.**
- These systems have to operate during a fire to detect the fire, alert people and help them evacuate and also help emergency services do their job.
- These circuits need to function fully and retain circuit integrity in the event of fire.
- In case of fire, it does not emit toxic or corrosive gases, thereby protecting public health and avoiding any possible damage to electronic equipment
- **LSF, LSHF and PVC Cables**
- Low smokes cables have a sheath designed to limit the amount of smoke and toxic halogen gases given off during fire situations
- **Low Smoke and Fume (LSF):** burns with very little smoke and fumes compared to standard PVC, fumes may contain halogens
- **Low Smoke Zero Halogen (LSZH):** when burns there is very little smoke and fumes contains no Halogen (compared to standard PVC)
- **LSHF and PVC cables are used for non-essential services that do not need to operate in a fire.**
- These include all the usual power circuits in buildings for services such as general lighting or kitchen and office appliances like cookers or photocopiers.
- These circuits are not essential for the safety of the public; they can fail in a fire with no increase in danger so they do not need to be fire resistant.
- For public buildings however, all cables need to be low smoke and zero halogen type but in domestic premises and for buried cables they do not, so PVC is acceptable
- Both LSZH and LSF are used to limit smoke, fumes and halogen given off in fire conditions.
- In the event of a fire, both types will emit very low levels of smoke. LSF cable will emit toxic gases while LSZH will limit the emission of these (typically under 0.5% hydrogen chloride emission). In addition to being toxic, hydrogen chloride is corrosive to equipment. The use of LSZH cables protect both people and limit the amount of equipment damage during a fire situation.

Comparison of various cable

Comparison of various cable					
Feature	**Normal PVC Wire**	**Heat Resistant HR PVC**	**Fire Retardant FR - PVC**	**Fire Retardant Low Smoke FRLS**	**Zero Halogen Low Smoke ZHFR**
Insulation Material	PVC	PVC	Special PVC	Special PVC	Special Polymer
Insulation Property	Normal	Good	Good	Good	Very Good
Temperature Rating	70^0 C.	85^0 C.	70^0 C.	70^0 C.	85^0 C.
Thermal Stability	Normal	Very Good	Good	Good	Very Good
Flam Retardancy	Good	Good	Very Good	Very Good	Excellent
Safety During Burning	Average	Average	Good	Good	Excellent
Requirement of Oxygen to Catch Fire	> 21%	> 21%	> 30%	> 30%	> 35%
Temperature Required to catch fire (with 21% oxygen)	Room Temp.	Room Temp.	> 250^0 C.	> 250^0 C.	> 300^0 C.
Visibility during Cable burning	< 20%	< 20%	< 35%	< 40%	< 80%
Release of Halogen Gas during burning	< 20%	< 20%	< 20%	< 20%	0%

Abrasion Resistance during Installation	Good	Good	Good	Good	Good

Comparison various Specification's of Cable					
Test	**Function**	**Specification**	**Values of FRLS Compound**	**Values of Halogen Free Compound**	**Values of PVC**
Critical Oxygen Index	To Determine % of Oxygen Required For Supporting Combustion of Insulating Material at room temperature.	ASTM–D-2863	> 29%	More than 29%	23%
Temperature Index	To determine at What Temperature Normal Oxygen Content of 21% In Air will Support Combustion of Insulating Material	ASTM–D-2863	> 250^0 C.	More than 250^0 C.	150^0 C.
Smoke density Rating (Light Transmission)	To Determine the visibility (Light Transmission) under Fire of Insulating Material	ASTM-D-2843	> 40 %	More than 80 %	10-15 %
Acid Gas Generation	To ascertain the amount of Hydrochloric Acid Gas Evolved from insulation of Cable Under Fire.	IEC – 754 - 1	< 20 %	Less than 0.5 %	45-50 %

International Standards

Halogen & Smoke Emission, Corrosively & Toxicity Standards

- IEC 60754-1/BS6425-1 - emission of halogen
- IEC 60754-2 – corrosivity , Acid gas emission
- IEC 61034-1/ ASTM E662 - emission of smoke
- ISO4589-2/ BS2863 - oxygen index LOI
- ISO4589-3/ BS2782.1 - temperature index TI
- ASTM – D – 2863- Oxygen index
- ES713 - toxicity index

Flame Retardant Standards

- IEC 60332-1 / BS 4066-1 - flame test on single vertical insulated wires/cables
- IEC 60332-3 / BS 4066-3 - flame test on bunched wires/cables
- UL Standard for Fire Retardant Cable
- NFPA -262 =CMP (Plenum Flame Test/ Steiner Tunnel Test)
- UL1666=CMR (Riser Flame Test)
- UL 1581=CM (Vertical Tray Flame Test)
- UL1581=CMG (Vertical Tray Flame Test)
- UL1581=CMX (Vertical Wire Flame Test)

Fire Resistance Standards

- IEC 60331 - fire resistance test
- BS 6387 / BS 8491: BS 8434/2 - fire resistance test (more stringent than IEC 60331)

Chapter: 33 HV Cable Termination Method and Precaution

Introduction:

- Power cable is most important part of power transmission and distribution systems.
- Terminations and joints are the essential part for the power cables. It makes connections between Cable or between Cable and electrical apparatus.
- Cable terminations make physical and electrical connections between the cable and the equipment to flow electricity in the desired manner.
- Cable terminations are weak parts for electrical system and most of the cable faults happen at this section, hence the quality of cable terminations directly affects the safe operation of the cable lines. The mistake will cause troubles, widespread power outages and cause great loss of finance, the people's life and property.
- There are three types of cable terminations. it can be heat-shrink type, cold-shrink type or pre-moulded push on type cable terminations.

Type of Cable Termination:

- There are various types of High / Medium Voltage cable termination for substation switchgears, transformer, poles, and cable boxes.
- Termination Kit are classified by its application.
- It can be pre-moulded push-on, cold shrink or heat shrinkable type.
- Selecting the appropriate termination method is essential for maintaining the mechanical integrity of the cable and it depends on the cable types, operating parameters, voltage applications and site conditions.
- Each technology has specific advantages depending on the needs of the user.

(1) Heat shrinkable terminations:

- It names suggests that it required Heat and have shrinkable type tubing.
- when we applied heat (with an electric or gas heat gun) to shrink tube. It expanded shrinkable tubes to the size of the substrate beneath and enabling quick and easy installation.
- **Material:**
- Heat shrinkable products are usually made from polyolefin type plastics which have been modified to give additional properties such as improved weathering and enhanced insulation levels.
- Heat Shrink is resistant to most chemicals. It will become rigid once it has been recovered and making it a good option for mechanical protection.
- **Application:**
- Use on low and medium voltage cables,
- Heat shrink termination kits can be used for XLPE cable in both indoor and outdoor applications, even for extreme hazardous atmospheric conditions.
- The cable terminations provide non-tracking stress control connections for medium to high voltage cables with water, UV, erosion and corrosion resistant performance.
- **Advantage:**
- When stored correctly, there is unlimited shelf life for the product.
- **Drawback:**
- the Material rigidity prevents flexing with the cable during normal operation hence an effective environmental seal cannot be maintained without the mastic tapes.

(2) Cold shrink terminations:

- It names suggests that it does not require heat.
- They can be used for medium-high cable installations which do not require naked flame or heat source to install especially in explosive atmospheres.
- By removing the supporting cord during the installation process causes the tube to shrink so that it fits onto the desired place.
- The cold shrinkable cable terminal offers excellent insulation and high resilience.
- **Material:**
- Cold Shrinkable products are made from elastomeric materials such as Silicon or EPDM rubbers, which are pre-stretched onto a tubular hold-out made from plastic tape in a tight spiral.
- By unwinding the spiral tube, the material recovers to its original size.

- **Application**
- The cold shrinkable cable joints are especially suitable for installation in hazardous environment, such as coal mine, oil field etc, where fire is strictly prohibited.
- **Advantage:**
- The Cold Shrink eliminate any heat source required for installation.
- The rubber material will follow the normal expansion and contraction of cables without need for additional adhesives or mastics.
- **Disadvantage:**
- Care is needed to store product and there is a finite shelf life.

(3) Push On type termination:

- Similar to Cold Shrink, these are made from elastomeric material and are not expanded before installation.
- The product is applied by sliding onto cable cores with the use of silicone grease as a lubricant.
- It has similar benefits to Cold Shrink, but with restricted application diameter range.

Parts of Termination Kit

(A) Environment Sealing Shrinkable Tubes:

1) Breakout Boot
2) Anti-tracking Heat Shrink Sleeve Tubes
3) Stress Control Tubes
4) Lug Sealing Tubes
5) Rain Sheds

(B) Mastic Taps:

1) Stress Control Yellow Mastic
2) Red Sealing Mastic
3) Black Sealing Mastic
4) PVC Insulation Tape

(c) Earthing:

5) Worm Clips:
6) Tinned Copper Braid
7) Copper Binding Wire / Small Copper Braid

(D) Cleaning Accessories

1) Cleaning Solvent
2) Aluminium Oxide Tape
3) Silicon Grease

(E) Other:

4) Lugs
5) Nylon Thread

(1) Heat Shrinkable Breakout Boot

- **Purpose:** Breakouts Boot is used to provide insulation and protection against binding force. It also provides sealing over the crutch of three core cables at the branching point.
- They are coated internally with waterproof, non-tracking rubber based red sealant.
- When heat is applied to the heat shrink tubing, the adhesive material inside of the tube is activated and shrink the boot which provide protection to the crutch of three core.

- **Installation Location:** It normally installed on over the crutch of multi-core cables to provide protection to Cable termination earthing assembly.

- **Materials** The base material of the breakouts is thermally stabilized, cross linked polyolefin. Which offer resistance against UV radiation, oxidation, ozone and other environmental effects.

(2) Anti-tracking Heat Shrink Sleeve Tubes

- **Purpose:** Heat shrinkable Sleeve Protects cables from harmful elements such as water, oils, acids, and other environmental hazards.
- When heat is applied to the heat shrink tubing, the adhesive material inside of the tube is activated, which shrink and provide protection to the cable.
- A common gas torch is required to heat and recover the tubes onto the power cables or accessories. It has a high shrink ratio which allows it to be used with a wide range of cable sizes.

- **Installation Location:** It is normally used as an integral part of cable joints for protection & insulation.
- Non tracking tube (red) is used as an external protective covering for the core for both indoor and outdoor applications.
- Minimum length of the non-tracking tube depends on the system voltage and it's application (Indoor or Outdoor).
- **Materials :** The material of the Anti-tracking Sleeve is thermally stabilized, cross linked blended polyolefins which has high insulation, non-tracking, erosion resistant, weather proof and flame-retardant properties.
- It has excellent insulating properties combined with toughness, resistance to impact and abrasion thus providing mechanical protection.
- It offers good protection from environmental effects, ultra violet radiation and also resistant to oil and solvent attacks

(3) Stress Control Tube:

- **Purpose:** Stress control tube (black) is used to control the high electrical stress present at the end of the semi conductive screen of the cable.
- Suitable size of heat shrinkable stress control tubes is to be used to reduce stress at cut back of screen.
- The minimum length of the stress control tube is 130 MM for 12 kV, 190 MM for 24 kV and 260 MM for 36 kV for effective stress control of Cable.

- **Installation Location:** The heat shrinkable semi conductive stress control tubes cover the earth connection point to the conductive screen end. It should not be extended further this point onto the outer cable sheath.
- Ensure the tubes are wrinkle free and have an even wall thickness.
- **Material:** Polyolefin is the most popular material for shrink tubing due to its thermal resistance and has a combination of resistive and capacitive characteristics.

(4) Lug Sealing Tubes

- **Purpose:** To protect the interface between the termination lug and the cable core covered by the non-tracking Lug Sealing tube

- **Installation Location:** At the end of XLPE insulation area near Cable Lugs.

- **Material:** It is made from the same material as the non-tracking tube i,e Polyolefin and coated internally with the red sealant.

(5) Rain Sheds

- **Purpose:** Heat Shrink Single Sheds are used for extending the creepage path for the medium voltage cable termination, thereby saving the length of the cable and reducing the size of the switch gear cabinet required for this purpose.

- **Installation Location:** On anti-tracking Heat Shrinkable Sleeve near Cable Lugs.
- The minimum number of sheds designed to be used in the termination system depends on system voltage and whether the application is indoor or outdoor.
- **Typical Applications:**
- Single sheds are suitable for termination of the complete range of electrical cables of XLPE and PILC types. The rubber based red sealant seals the single shed to the cable insulation.
- **Materials:** The base material of the HV sheds is thermally stabilized, cross linked blend of polyolefin and a compatible grade of synthetic rubber.
- The properties of the HV Sheds are electrical insulation, non-tracking, erosion resistant, weather proof and flame retardant.
- HV Sheds are internally coated with waterproof, non-tracking, butyl rubber based red sealant mastic

(6) Stress Control mastic (Yellow Mastic)

- **Purpose:** Stress Control mastic is used in MV terminations for providing stress relief of the electric field.
- It also serves purpose of filling all the gaps and uneven surfaces.
- The mastic is water resistant and has high adhesion property.
- The colour of the stress grading mastic is yellow.
- **Installation Location:** Conductive paint / Stress grading mastic is applied around the step formed at the screen-cut point i.e., at end of the semi-con screen and start of the XLPE insulation of the cable.

- **Material:** The base material is thermally stabilized, blended polyolefins.
- The basic resin is mixed with chemical additives offering electrical stress control properties.

(7) Non-Tracking – Water Sealing Mastic (Red Mastic)

- **Purpose:** Anti-tracking / Weather Resistance red mastic sealants Tapes are used in MV terminations on breakout boots, non-tracking tube and on lugs for sealing, insulation, and waterproofing.
- The red sealant also acts as a filler and insulating material to fill in the step formed at the end of conductor insulation.
- It forms a waterproof seal at the end of the termination, which is essential for the long service life of the termination.
- **Installation Location:** Red sealant is applied around the base of the terminal lug where it is crimped to the cable conductor.

- **Materials:** The base material is thermally stabilized, blended rubber.
- The base rubber is mixed with chemical additives offering non-tracking and insulating properties.

(8) Insulation-Sealing Mastic (Black Mastic)

- **Purpose:** Black mastic is suitable for LV and MV applications. It is used for sealing and waterproofing of electrical installations such as joints and terminations.
- Insulating mastic is used in joints to protect the heat shrink material by covering the **sharp edges of metallic parts and for filling voids and irregular shapes**.
- It also acts as an environmental seal to **prevent ingress of water and moisture** and other environmental contaminants
- **Installation Location:** To protect the cable breakout, PVC tape/black mastic is required to be applied over earthing arrangement (worm drive clip installed over copper braid and armour) for suitable length of the termination part.

- **Materials:** base material of the black insulating mastic is thermally stabilized, blended rubber. The base rubber is mixed with chemical additives offering good insulating properties
- The black insulating mastic provides excellent sealing and insulating functions.
- These offer excellent adhesion to rubbers, synthetic cables, metals, and jackets

(9) PVC Insulation Tape,

- **Purpose:** PVC Insulation tape is used for Insulation ,sealing of electrical installations such as joints and terminations. PVC Insulation Tap covers the **sharp edges of metallic parts and for filling voids and irregular shapes**.

- **Installation Location:** To protect the cable breakout, PVC tape is required to be applied over earthing arrangement (worm drive clip installed over copper braid and armour) for suitable length of the termination part.
- **Materials :** PVC

(10) Lugs:

- **Purpose:** Cable lugs are connectors that used to connect/terminate cables

- **Installation Location:** At the end of Cable Termination.
- **Material:** copper or aluminium or their respective alloys

(11) Cleaning Solvent Pouches:

- **Purpose:** To clean the XLPE insulation surface.

- **Installation Location:** It is applied on XLPE Insulation to Clean XLPE Insulation Surface.
- To clean the XLPE insulation surface.

- **Material:** Isopropyl Alcohol solution

(12) Worm Clips:

- **Purpose:** Worm drive clip (jubilee/hose clips) for tightly securing the earthing braid.

- **Installation Location:** On Copper Wire of Copper Screen and armour at crutch of three core cables at the branching point.
- **Material:** The material of support ring to be steel (G.I.) or Aluminium.

(13) Tinned Copper Braid:

- **Purpose:** Earth Continuity between armour and earth to be provided by tinned copper braid of adequate cross section.
- This is required for proper earthing of the Cable termination.
- This armour earthing arrangement provides sound electrical contacts at armour bonding points and handling large current and low voltage to avoid excessive temperature rise during earth faults.

- **Installation Location:** Earth Continuity between armour and earth to be provided by tinned copper braid of adequate cross section.
- **Material:** Copper.

(14) Aluminium Oxide Tapes

- **Purpose:** For cleaning of cores, removing burrs and roughness of XLPE insulation.
- **Installation Location:** It used to smooth surface of XLPE Insulation.

- **Material:** Abrasive Material on Textile Backing

(15) Silicone Grease

- **Purpose:** The use of insulating silicone grease in MV Cable termination for high-voltage resistance, waterproof and anti-creep performance.
- It is used to smoothen out any uneven insulation surfaces of XLPE Insulation of cables and to lubricate mount moulded parts of cables termination.
- Cuts and scratches on the XLPE insulation may cause electric discharge under the stress control tube. Application of a thin layer of silicone-based discharge suppression compound will make it free of partial discharge.

- **Installation Location:** It applied on XLPE Insulation and other parts of Cable Termination for insulation, sealing, lubrication purpose.
- **Material:** Insulating silicone grease is an insulating paste made from modified silicone oil.

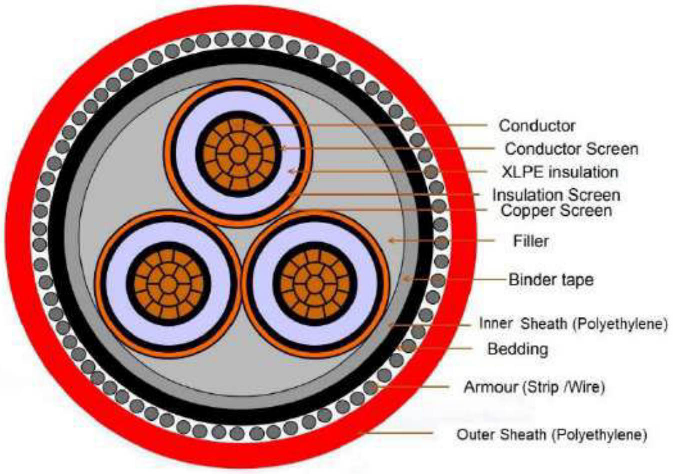
(16) Copper Binding Wire / Cooper Strips:

- **Purpose:** It is used to provide earth connectivity between copper screen to armour of cable to earth

- **Installation Location:** Between Copper Screen and armour of cable
- **Material:** Copper

Basic Structure of High Voltage Cables

- High-voltage cables generally consist of nine layers.



- The basic structure of high voltage cables is

1. Outer Sheath:
- It protects cable from the moisture and environment. It also provides protection against mechanical impact on cable.
- Outer sheath material is mostly Polyethylene

2. Armor Layer.
- Armor provides mechanical Strength to the cable, certain resistance to external force, and prevents animal bite, external mechanical impact on cable.

3. Inner Sheath:
- Inner protective sheath can keep Cable XLPE Insulation layer away from water, air and other objects, avoiding moisture and mechanical injury on internal insulation layer.
- It protects the cable core.
- Inner Sheath Material is same as outer sheath material, mostly Polyethylene

4. Package and Filler Layer.
- It helps to organizes several cable cores into circular shape, for the convenience of packaging and cabling.
- It also provides protection to the cable Core.

5. Copper Shielding screen.
- The main function of copper screen is to equalize the electric field and help improve the electric field distribution.
- The other function is to ground the short circuit current.
- When cable is charged it's produced strong electrical filed around the core, Copper Shielding equalize this electrical filed and improve uniformity of electrical field distribution surrounding the core which restrict the interference of strong electric field around on core in the cable.
- Hence, if copper shielding layer in cable doesn't exist, then insulation breakdown between core and core will be damaged.

6. Semi Conductive Layer (Outer Semi Con Layer).
- There may be small clearance or air gap between in XLPE insulation and copper shielding screen which is one of the main factors causing partial discharge.
- Semi Conductive material have good contact properties hence semiconductive layer is provided between XLPE Insulation and copper screen to avoid the partial discharge between insulation layer and protective layer.

7. XLPE Insulation Layer.

- The cable insulation provides electrical insulation to the conductor at voltage from the outer screens at ground potential.
- The insulation will be of sufficient thickness to withstand the electric field under the rated and transient operating conditions.
- XLPE (cross-linked polyethylene) is good insulating materials.
- XLPE has high breakdown strength, high insulation resistance, low dielectric loss, excellent tree discharge-resistance performance and long insulation performance period, etc.

8. Conductor Shielding Layer (Inner Semi Con Layer).

- Conductor shielding layer can improve the electric field distribution.
- This layer reduces the probability of occurrence of partial discharge.
- The cable conductor is made stranding of wires hence it surface is not smooth which creates air gap between insulation layer and conductor. This will cause the concentration of electric field.
- Conductor is covered by Inner Conductor shielding layer of semiconductor materials on the surface of the conductor for good contact with insulation layer.

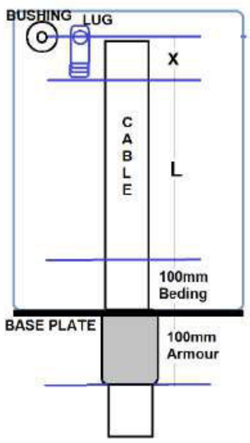
HV Cable Termination Procedure:

General Instructions

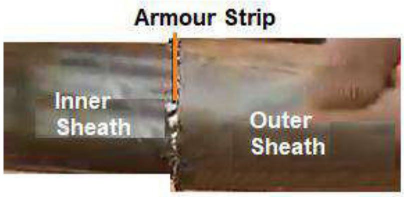
- Use a propane gas torch with a soft yellow flame for shrinking components.
- Avoid a pencil type flame which is caused by unregulated supply
- Keep the flame on the moving direction to ensure even shrinkage of all the materials and also helps to reduce scorching
- Ensure that all components are kept clean and grease free during installation
- Allow to cool before applying any mechanical strain
- Read the instructions carefully before starting.
- Clean and degrease all parts which will be in contact with tapes and adhesives.
- Personnel should be proficient and knowledgeable for preparing and installing medium voltage terminations.

(1) Remove Outer Cable Insulation Sheath:

- Calculate approximate Terminate length of Cable from following Table.



Voltage	Indoor (L)	Outdoor (L)	x
7.2KV	650mm	700mm	Length Of Lugs +5mm
12KV	650mm	700mm	
17.5KV	650mm	700mm	
24KV	700mm	800mm	
36KV	800mm	900mm	
The “L” dimension should not be longer than the distance between bushing centres and base plate.			



- Strip of and removed Outer Sheath of Cable for Length “L”.
- Removed Armoured from Length “L”.
- Make smooth edge of Sharp armour.
- Bend / Fold Armour up to 50mm.
- Bind Armour on the outer sheath with use of Copper Wire / Clamp.

(2) Remove Inner Cable Insulation Sheath:

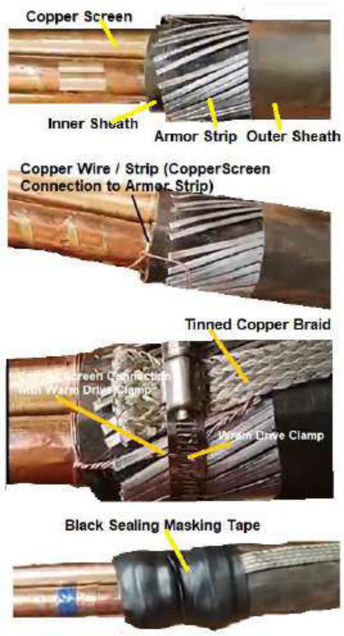
- Removed Inner Cable Sheath 10mm length from Armour with the help of knife.
- Removed extra parts of cable which used to make cable round, i.e., Filler, Binding rope / Strip

(3) Earthing arrangement of Copper Screen.

- Marking with the help of tape from100mm length from inner sheath on Cu Screen.
- Removed extra Copper Screen from this marking tap to cable end.
- Make sure that cu screen is not damage during this process.
- Some Manufacture provides small Copper Braid but if not provided than make it by use of copper wire provided with the kit (Twist together to form a conductor)
- Tight Copper Braid / Copper Wire to Cu screen. Make sure Connection should not be loose.
- Ensure that Free end of copper braid / wire extended up to armour wires or up to tinned copper braid.

(4) Earthing arrangement of Armour.

- Installed Long Tinned copper braid on Armour with used of Warm drive clamp.
- Extend the small copper braid (Strip) / copper wire which are already fixed on copper screen to the Tinned copper braid.
- Make sure this connection should be over lapping to each other.
- Firmly tight these arrangement with the use of Warm drive clip.
- Wrap Black sealing masking Tape around Sharpe edge and over the earthing assembly.
- Further after completion of Cable termination, these braids will either be bonded to the earth gland or other suitable earth point.

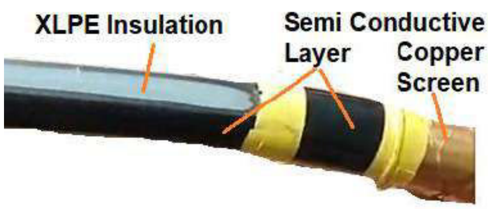


(5) Installation of Heat Shrinkable boot on earthing arrangement

- Slide the three-legged adhesive-coated breakout over the cores and pull it as far down into the crutch as possible.
- Apply heat to heat shrinkable Boot by use of gas torch with a soft flame.
- Keep the flame on the move to ensure even shrinkage of all the materials and also helps to reduce scorching.
- Shrink the breakout into place starting at the centre. Work first towards the lower end, then shrink the turrets onto the cores.
- Make sure that there is no any void or air is remaining inside boot during this process and shrinkable boot is firmly tight fixed with the earthing assembly.
- Make sure that Tube is shrink uniformly and free from void and wrinkles.

(6) Removing Semi Conductive Layer.

- Remove the semi-conductive screen layer using a suitable tool to a point 50 mm above the copper tape screen.
- **It is very important that the screen is removed leaving a clean straight cut and that no scoring or damage is done to the XLPE Insulation (Primary insulation).**



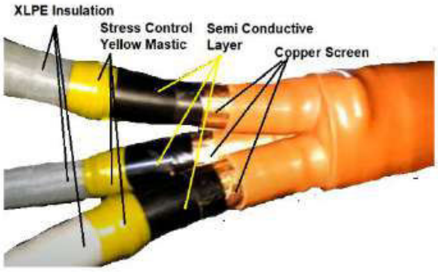
(7) XLPE Insulation Grinding, Polishing & Cleaning

- The cable insulation surface must be smooth to avoid air gaps where discharges can occur.
- Cable Surface can be smooth by use of grinding (abrasive) paper.
- The Cable grinding / Polishing process must be carried out carefully to avoid damage to the cable insulation screen.
- After grinding / Polishing Cable Insulation must be clean by approved Cable Cleaner solution. **Cable Insulation should be clean by using a motion of travel towards the insulation screen.**
- Never use the same side of a cleaning tissue twice and the insulation must be clean of conductive particles and dirt.

- After Proper Cleaning, Cable Cleaning Wipes are used to remove all traces of the semi-conducting screen from the cable end towards the cable termination/joint point. The cable XLPE Insulation must be wiped along the available length to ensuring complete removal of contaminants.
- It is recommended that a non-flammable cable cleaning solvent be used. Any solvent that leaves a residue should be avoided. **Do not use excessive amounts of solvent as this can saturate the semi-con layer and render it non-conductive.**

(8) Apply Stress Control Mastic Tape

- Stretch Stress Control Mastic around the core.
- Start 20mm from Sem conductive Layer to extend onto the XLPE Insulation (Primary insulation) by 10mm.
- Secure copper screen end on semi conductive layer by use of PVC Tape or binding with copper wire.
- Apply thin film of silicon grease on the XLPE Insulation.



(9) Heat Shrinkable Stress Control Tube

- Insert stress control tubes over core and position lower end of stress control tube 10mm from copper screen.
- Start shrinking the tube from the lower end and process upward. Shrink tube one at a time.
- Make sure that Tube is shrink uniformly and free from void and wrinkles.

(10) Installation of Lugs

- Insert Terminal Lug on end of core and clip it properly as per standard practice.
- In case of outdoor termination insert the rain sheds before crimping the lug.
- **Remove any burrs or sharp points that may be present during clipping process.**

(11) Apply Red Sealant Mastic Tape

- Fill the gap between insulation and terminal lug with the help of red mastic tape.
- Red Sealant Tape over the Lug barrel and extend onto the Insulation by approximate 10mm.

(12) Heat Shrinkable Anti Tracking Tube

- Insert Anti tracking heat shrinkable tube over each core.
- Position the anti-track tubes so that they cover the turrets of the breakout boot and the barrels of the lugs.
- Make sure that tube cover the fingers of breakout by 25mm at least.
- **Start shrinking the anti-tracking tube from bottom end of tube and proceed upward to avoid any air void.**

- Make sure that Tube is shrink uniformly and free from void and wrinkles.

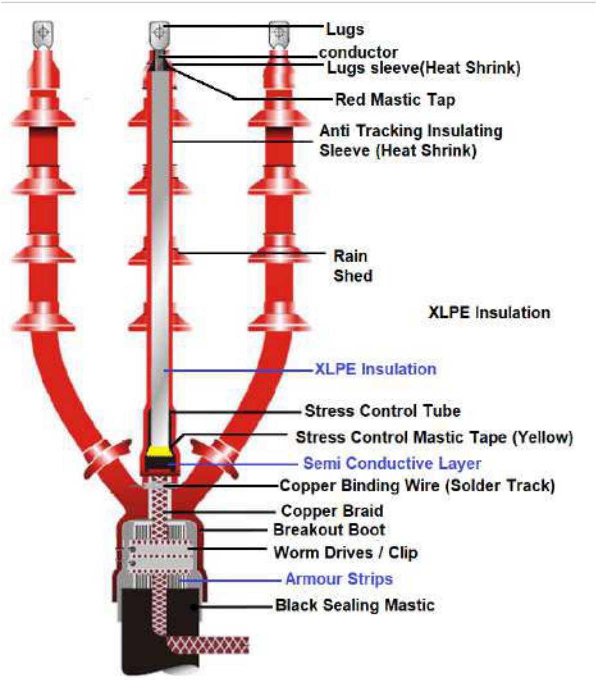
(13) Lug Sleeve

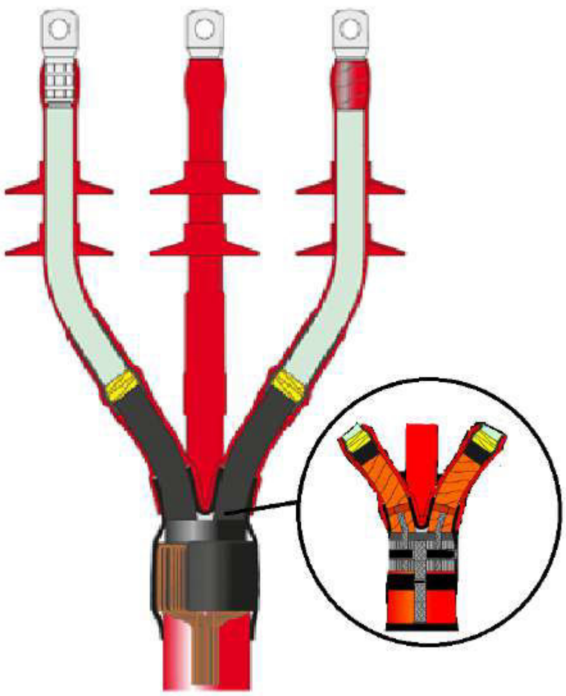
- Remove released paper which is inside the lug sleeve.
- Insert Lug sleeve on core. Make the position of lug sleeve so that it covers Lug barrel and core equally.
- **Start shrinking sleeve from top and proceed downwards**

(14) Rain sheds

- For outdoor application insert Rain shed on each core and keep 150mm distance from cable end and shrink it on the core.
- Make distance of 80mm on next rain sheds.

HT Termination kit





Chapter: 34 Reasons for HV Cable Termination Kit Failure.

Introduction:

- High voltage cables are used in Electrical Network for Power Transmission and distribution.
- Cable termination failure / faults are major problem in electrical networks.
- Power cable joints and terminations are the weakest link in Electrical Network. The higher the voltage the more complexity in the cable joints and terminations hence more difficult to control thermal and electrical stresses.
- There are many reasons that cause breakdown in cable termination. Like Poor Termination, Poor preparation of Semiconductive layer, Moisture, partial discharge, excessive bending, Not following instruction of Cable Termination kit's manufacture.

Main Reason for HT Termination Failure:

(A) Workmanship Error / Assembly Errors

1. Excessive Bending of Cable
2. Crossing of Cable Core to each other
3. Sharp Corners
4. Not Proper Heating of Heat Shrinkable Sleeves
5. Excess Heating of Heat Shrinkable Sleeves
6. Loose Connections
7. Poor Installation of Mastic Tapes.
8. Not following Manufacture's Instruction.

(B) Poor Earthing of Cable

1. Poor Termination of Steel wire Armoured
2. Poor Earthing of Cable

(C) Poor Preparation of Semi Conductive Layer

1. Damaged of XLPE Insulation.
2. Damaged of Semi Conductive Insulation.
3. Incomplete removal of Semi conductive layer
4. Not Radial edge of Semi conductive layer
5. Wrong Cutback Length of Insulation / Semi conductive layer
6. Not Proper installation of Stress Control Tubes.
7. Extreme rough Surface of XLPE Insulation.
8. Not Proper Cleaning of XLPE Insulation Surface

(D) Damage of Cable

1. Damaged of Cable during Cable Termination Process

(E) Worse environment condition

1. Contamination of salt, dust, ash on Cable

(A) Workmanship Error / Assembly Errors

(I) Excessive Bending of Cable

- Excessive bending of the cable creates stress on the entire cable core, from the conductor to the shielding end.
- This stress can cause micro voids in the insulator which become larger as stress is increased and lead to an eventual corona failure or dielectric breakdown.

(II) Cross over Cable Core / Not proper distance between each core.

- **Cable entry points through the cable gland plate to cable termination should be centralized / straight.**

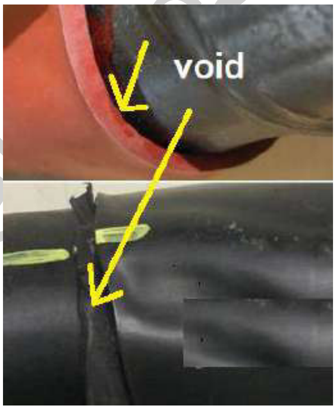
- Crossing of cores to each other will increase stress over insulation and partial discharge will occur at the crossed cores of the HV cable causing failure of the cable termination.
- if cores are too close and cross to each other at unscreened area results in the air "breaking down" at approximately 4kV on an 11kV cable, 6kV on a 24kV cable and 9kV on 36kV cable.
- The anti-track heat shrink material then begins to erode due to the ionisation of the air, which over time will inevitably cause failure of the cable termination
- Required to use proper Phase out the cable sections in the box.

(III) Sharp Corners (at Armor or at Lugs):

- **Sharp corners generate highly stressed area which will be subjected to electrical discharge.**
- Normally Sharp edge will occur at armour bending or at Location of Lug's crimping.

(IV) Not Proper application of Heat-on-Heat Shrinkable Sleeves

- Proper Amount Heat and direction of applied Heat is very important during Installation of Heat shrinkable Sleeve.
- Some Sleeve need to be heated from central to both up and down direction while in some sleeve heat should be applied from bottom of sleeve to end termination direction.
- Heating process firmly joint one layers (silicon rubber) to the others layer (XLPE, semiconductor and etc).



- If during heating, voids remain between the layers, The voids may contain air, wet or contaminations which change equivalent circuit and formation of electric field distribution.
- Electric field increases in the void or the layer of air and makes a high potential difference between both sides of the void. Insulation endurance weakness in the layer of air causes Partial Discharge (PD) and breakdown.
- Make sure that the tubes are shrunk free from wrinkles

(V) Excess Heat on Heat Shrinkable Sleeves

- Excessive Heat may damage the heat shrinkable sleeve.

(VI) Loose Connections

- **20% to 25% of electrical failures due to poor termination and loose connections.**
- The poor termination / loose connection in an electrical system causes overheating at the joints which further leads to failure.
- Loose connection is mostly raised due to Using improperly crimped tool / die for the cables.
- Lugs of higher than recommended size used for termination will also in results of loose cable to lug joint.

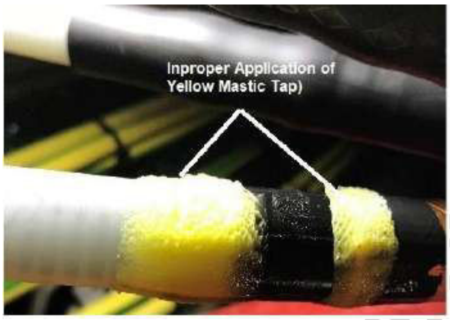
(VII) Poor Installation of Mastic Tapes.

- **Anti-Tracking mastic sealing tape is used in HV and MV terminations for providing a water-tight seal between heat shrink components and the cable parts.**

- Wrapping mastic tape around crotch and under lead cut on core to eliminate air and moisture.
- Any improper wrapping of Mastic Tap leads the path for moisture and Air which result in high electrical stress and partial discharge.

(VIII) Not following Manufacture's Instruction.

- In HV Cable Termination each and every stage is crucial hence cable jointer should strictly follow manufactures instruction.
- **Not following manufacture's instruction regarding length, dimension and sequence of stage will create cable termination failure.**
- In flowing image, Cable Termination Kit Manufacture clearly indicate that 5mm of yellow mastic is to be installed on the copper tape screen and to continue over the semi conductive layer and then finish 10mm onto the cable installation.
- The yellow mastic is used to fill voids and provides stress relief from electrical fields so it is **essential** this is installed correctly but Cable Jointer applied it at wrong location.



(B) Poor Earthing of Cable

(1) Poor Termination of Steel wire Armoured

- Poor termination of the Cable armour strip/ Wire is one of the reasons for failure of Cable Termination Kit.
- When terminating cables with heat shrink cable terminations there is a need to ensure safe earthing and termination of the armour wires (SWA steel wire armour) using cable glands.
- In most HV cable installations the cable gland body can be installed after completion of the Cable terminations. Completion of the final 11kV connections should be done before bolting the cable gland into place on the 11kV cable box.

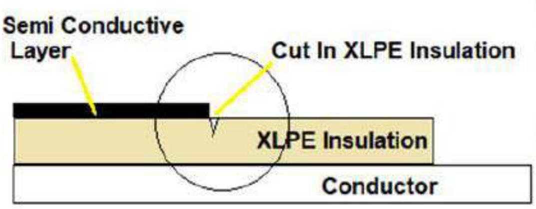
(2) Not proper earthing of Cable

- Earthing must be provided to carry any circulating currents to core screens, metal sheaths and armour wires.
- It must also have the ability to carry fault current. On indoor MV HV cable terminations the use of tin-plated copper, solder-blocked braids, metal canisters, armour support, clamps and a complete corrosion protection system should be employed.

(C) Poor Preparation of Semi Conductive Layer

A) Damage of XLPE Insulation:

- When unguarded knife or Glass is used for removing Semiconductor layer, there is a significant risk of cutting into the insulation at the screen edge.
- **Deep and dirty cuts and burrs in the insulation causing the XLPE insulation to be over stressed and this was ultimately caused the insulation failure.**
- A knife cut may be invisible but will certainly become a future failure, possibly immediately the cable system is energised but certainly after several months or years. The knife cut will likely be a point of partial discharge activity which leads to cable frailer.
- Installers must be aware of this and pay great attention to this stage of the accessory installation process.
- NEVER use an unguarded knife. This includes broken glass and any other object with a sharp unguarded edge.



- make sure that there are no deep dents formed on XLPE Insulation.

B) Damaged Semi Conductive Layer

- When unguarded knife or Glass is used for removing Insulation layer, there is a significant risk of cutting of Semiconductive layer of the Cable.

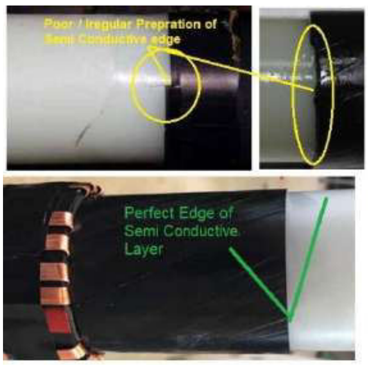
C) Incomplete Removal of Semi Conductive Layer:

- Correct / proper removal of the black conductive semi conductive screen layer covering the insulation is a critically and important stage in the preparation of cables Termination.
- This is most important factor controlling the service life of a cable joint or termination.
- The cable jointer should carefully examine the surface of the MV-HV cable insulation to ensure all black particles are removed.
- **The semi-con screen layer of MV-HV cable construction provides a smooth transition from the cable insulation to the metallic screen.**
- This semi conductive screen layer is extruded together with the insulation and the inner conductor screen. Its thickness is generally between 0.3 mm and 0.6 mm.
- Here in figure, the semi conductive layer has been left (Not Properly removed) on the 11kV XLPE insulation which can cause surface tracking and eventual flash over. This occurred on 2 out 5 cable termination breakdowns

- **Irregularities in removal of semi conductive screen can cause surface tracking, raise electric stress and eventual flash over the Cable.**

D) Irregular / Sharp (Not Radial) edge of Semiconductor Layer

- The quality of the screen edge is very important for the performance of MV Cable in service.
- **Sharp edges in the insulation screen are a common error. The transition between the screen and the insulation must be smooth, achieved by a straight final cut.**
- Irregularities of semi conductive edge on the insulation are raised electric stress which will result of Cable Failure.

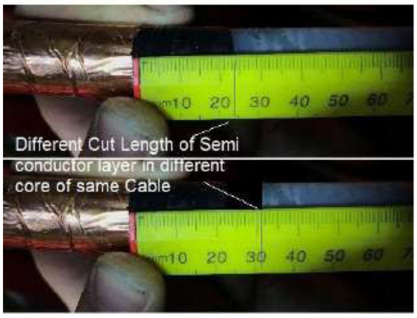


- Non-radial, rough and jagged semi conductive screens with protruding points at the cutback will cause cable termination or joint failure.

E) Wrong Cutback Length of Insulation / Semi conductive layer

- The most common issue for Cable Termination failure is the incorrect insulation / semi conductive cutback dimensions.
- **The semi conductive cutback is the point of highest electrical stress in the termination.**
- Jointer should strictly follow the manufacturer's instructions Manual for dimension of cutback length from the end of the insulation to the semi conductive layer.

- If This length is either more or less caused the termination kit's electrical stress control Tube and void filling compound to fall well below the semi conductive cutback.



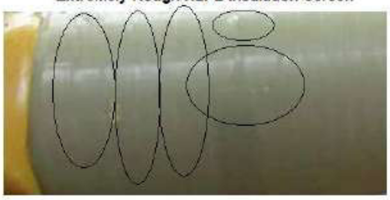
F) Not Proper installation of Stress Control Tubes.

- Stress control tube is used to achieve more uniform distribution of the Electrical field lines. It should be installed at correct location of cut back as per Instruction manual of Termination Kit's manufacture. Any deviation in location would lead to Cable termination frailer.

G) Rough Surface of XLPE Insulation.

- **The XLPE insulation surface must be smooth to avoid sir gaps where partial discharge can occur.**
- Use long and thin strips of grinding paper. Perform carefully and do not extremely grind the insulation screen.
- It is good practice to smooth any minor surface roughness using abrasive cloth (preferably aluminium oxide type).

Extremely Rough XLPE Insulation Screen



H) Not Proper Cleaning of XLPE Insulation Surface:

- **Insulation layers should be cleaned during installation, because any conductive particles to spread all over the insulation, causing partial discharges.**
- Wet or polluted surface of XLPE Insulation may cause a fault in cable terminations.
- The jointer should move the cable's wipe away from the cable end towards the semi-con screen to remove fine particles on the edge of the cable screen, not on the insulation otherwise conductive particles or dirt could be dragged to the insulation and cause discharge.
- Never use the same side of a cleaning tissue twice. The insulation must be clean of conductive particles and dirt.
- Emery paper should not be used due to metal particle content. The surface of the MV cable insulation should be cleaned using a cable cleaning wipe.

Not Proper Cleaning of XLPE Surface

(D) Worse environment condition

- Surface contamination (Salt, dust, coal dust ash) attract moisture and degrade insulation of Cable.
- High humidity and temperature fluctuations can cause condensation that hastens the deterioration of insulation materials. which can create excessive electrical stress and cause the sheathing to crack.

HV Cable Termination Failure Rate:

(1) At Various Stage of Cable Termination

- Lug problem = 7%
- Contamination / Partial Discharge = 7%
- Poor Cutback= 8%
- Damage to cable / insulation=9%
- Poor Moisture Seal=9%

- Improper/missing materials=10%
- Missing putty/mastic /grease=10%
- poor heat shrink technique=9%
- Poor Ground connection=6%
- Assembly Mistake=25%

(2) Due to Process and other factor

- Workmanship error =66%
- Due to Cable Termination Age= 10%
- Application error= 4%
- Externally caused damage =4%
- manufacture defect in accessory =16%

Chapter: 35 CO Detection and Control Systems for Basement Parking

Introduction

- Carbon Monoxide (CO), one of the most toxic components of vehicle exhaust and it is a significant safety concerns in Basement Parking area. When concentrations of CO approach unsafe levels, the ventilation system must be activated to normalize Co level of the Parking area.

What is carbon monoxide

- Carbon monoxide gas has a simple molecule one part carbon and one part oxygen.
- Carbon monoxides produce due to incompletion combustion (Fails to burn due to not enough Oxygen) of carbon containing compounds like wood, gasoline, coal, propane, natural gas, and heating oil.
- CO produce when there is not enough oxygen to produce carbon dioxide (CO_2) such as when operating a combustion engine in an enclosed space.
- These carbon-containing compounds aren't dangerous when it burns them in an open area with plenty of ventilation. But carbon monoxide is hazardous in confined spaces like basements, kitchens, garages, or campers.
- Carbon monoxide is hard to detect without a sensor, which is one of the reasons it's so dangerous.
- Carbon Monoxide (CO) is dangerous for human beings and will cause even death within minutes. This is mainly formed in underground parking, basements etc.
- The level of CO concentration is measured in parts per million (ppm). For example, 100 ppm CO

Effects of Carbon Monoxide

- Carbon monoxide (CO) is a colorless, odorless and tasteless gas that is highly toxic for humans and animals; it bonds with hemoglobin and reduces the oxygen-carrying capacity of blood in the body.

How Carbon Monoxide is generated in Basement:

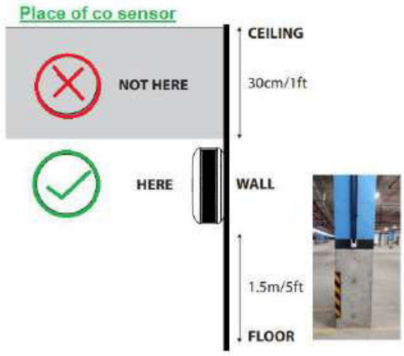
- In a basement of a building, oxygen levels may not be sufficient, and the combustion may not be complete. This can occur in vehicles exhaust, gas stoves, boilers, coal heaters etc. which are operated in the basements. Under such conditions, Carbon Monoxide is generated. The occupants of the area will be unaware of the same and hence it becomes a dangerous environment. Hence continuous Carbon Monoxide (CO) monitoring is important for such area.

Components of CO Monitoring system for Car Parking

- The following components are essentially form a CO detection & CO monitoring system for a basement car parking.

1) CO sensors

- A CO sensor is used to detect the level of CO and give an output signal. The number of required sensors is decided based on the size of the area or car park.
- All sensors will be wired to the common PLC panel.
- **Location of CO Sensor:**
- The distance between the Co sensor and the source of CO is important. The air polluted with hazardous gases have to be in physical contact with the gas sensors. Because carbon monoxide is slightly lighter than air and it may be found with warm rising air Hence, CO Sensor is fitted at 3 **feet to 5 feet from the ground surface.**



- Do not place the detector right next to or over a fireplace or flame-producing appliance
- Each CO sensor can cover approximately 5,000 to 10,000 sq ft of open space. CO gas will disperse and flow with natural air current and car movement.
- Using the average of 7,500 sq ft per sensor and a circular radius of 49 feet, the sensors area coverage could be scaled and placed on the Basement layout to cover the open floor area. Based on the number of CO sensors and the location of the exhaust fans and make-up air handlers.
- The most practical mounting location for a CO sensor within a basement area is the side of the support column away from traffic.
- CO sensors will be more effective if placed in areas where CO levels are likely to be high. For example, do not place sensors adjacent to the fresh air intake.

2) Programmable Logic Controller (PLC) panel

- All the inputs from the CO sensors are connected to a PLC (Programmable Logic Controller) for proper control functioning. The PLC will provide output signals to the VFD based on the inputs from the sensors.

3) Variable Frequency Drive (VFD)

- A VFD is used to operate a motor at different speeds. This VFD will be controlled by the PLC and will control the exhaust fans. If the CO content is more, the exhaust fan operates at a faster speed.

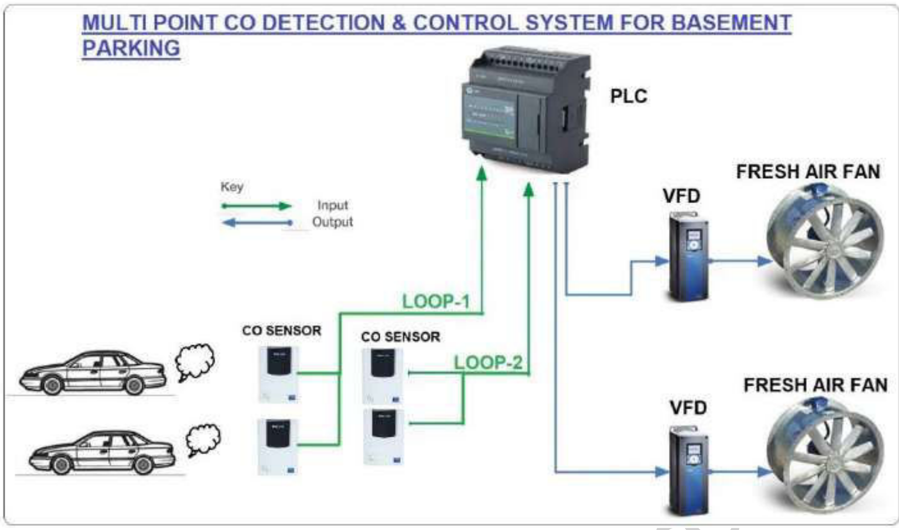
4) Exhaust Fans / Fresh Air Fans

- The number of required Exhaust / Fresh Air fans will be decided based on the size and shape of the area. The Exhaust Fresh Air Fans are controlled by the VFD. Basically, the Exhaust Fans / Fresh Air Fan have to remove the contaminated air at a fast rate.

Working Principle and System Architecture:

- A number of CO monitoring sensors are installed at various points of the basement car parking. The number of required sensors is decided based on the size of the area or car parking.
- All CO sensors are wired to the common PLC panel to VFD to Exhaust Fan operations.
- CO sensors detect various types of smoke, Smoke radicals, and fumes and generates a control signal according to PPM level.
- This Control signal continuously feed to PLC panel.
- The PLC continuously takes inputs from all sensors. In case any of the sensors have high pre-defined value, the PLC gives an output signal to the VFD.
- The VFD then operates (ON) the Exhaust Fan / Fresh Air Fan.
- The Exhaust Fan / Fresh Air Fan immediately remove the contaminated air from the area and brings Fresh Air in Basement.

- Normally VFD control is preferred so that we can control the speed of the Exhaust Fan / Fresh Air Fan based on the ppm level.
- As soon as the CO content is reduced as predefined PPM Value, the exhaust fan stops after a certain time delay.
- Based on pre-defined logic, it will operate, regulate, stop-start ventilation Fan system, dampers etc.
- Underground car parking CO detection system is installed for energy cost saving and environmental protection. Ventilation rates can be decreased to save energy if there is no exhaust gas pollution present.



STANDARDS FOR BASEMENT CAR PARKING	
NATIONAL BUILDING CODE OF INDIA –2005	CO level- within 25 ppm with Peak level not to exceed 125 ppm
As per ASHRAE	Max Level for CO
	8 hrs exposure – 25ppm
	1 Hour exposure- 35 ppm
NATIONAL BUILDING CODE OF INDIA –2005	Air change requirement 9 to 12 ACPH under normal conditions
	30 ACPH in case of fire emergency

Logic Diagram of Fresh Air System:

- Low setpoint of 26 ppm and a high of 75 ppm. When any CO sensor exceeds a threshold (ppm level in air) the following shall happened:

1) Threshold # 1= Lower than 26ppm (OFF)

- Exhaust Fan / Fresh Air is in OFF Condition.

2) Threshold # 2= 26ppm (START)

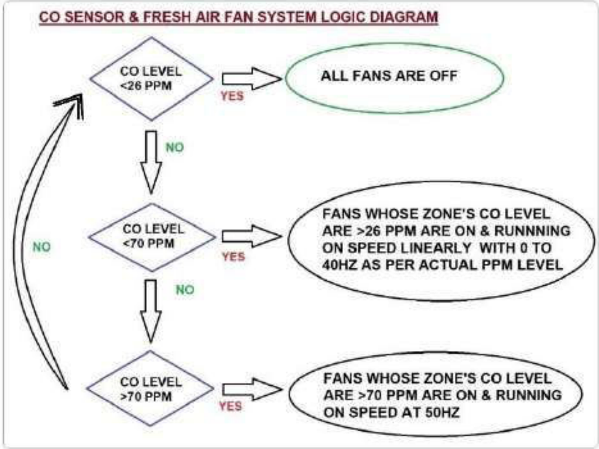
- Whose Zone's CO level is 26ppm, Start the Exhaust Fan / Fresh Air of that Zone at minimum speed to bring in fresh air and reduce the CO level.

3) Threshold # 3= Higher than 26ppm but Low than 75 ppm (RUNNING)

- The Zone's CO level is 26ppm but less than 75ppm.Fan Speed of that Zone is linearly / proportionally with 0 to 40hz according to Actual ppm Level.
- This will run Fan on Low to Normal to High speed according to ppm Level to increase more fresh Air in contaminated Zone.

4) Threshold # 4=Higher than 75ppm (Full Speed)

- Fan runs on 50hz at 100% Speed. This High Speed brings more fresh air and reduce the CO level.



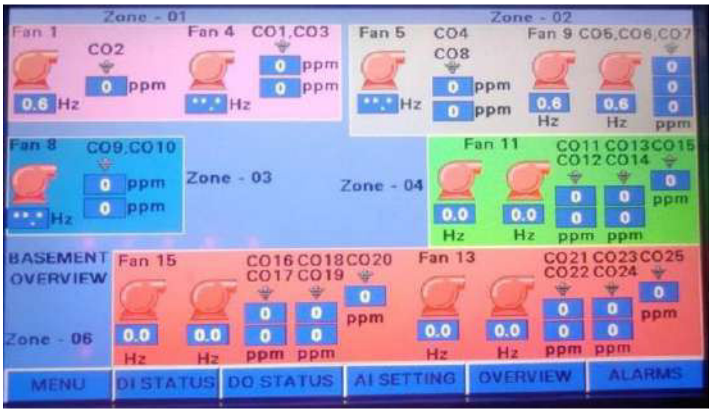
Operation of Basement Ventilation system:

- The Basement ventilation system shall comprise of Supply of Air, Make-up of Air and Exhaust of Air by Natural ventilation or by Mechanically ventilation Method (By Fresh Air Fans).

- During normal mode, these Fans will Run on lower speed based on **CO concentration** in the Basement Area. During high CO level / fire conditions, fans shall run on higher speed to meet 12 ACPH.
- Since ventilation fan shall work round the clock, it is desirable to provide VFD to conserve the energy. The fan shall be operated through VFD actuated by Carbon Monoxide (CO) sensor.
- In Basement area there are various number of Fresh Air Fans are available. Zone for Each Fan should be decided as per capacity of Fan.
- Fresh Air Fan through VFD is run according to CO Level of Basement Car Parking from 0% to 100% as per PPM Level. It also run 100% in case of Fire due to increase level of CO.

Basement Ventilation in Day-to-Day Condition:

- For day-to-day operation, Various CO Sensors generates output signal as per the PPM Level. These Signal continuously feed to PLC Panel.
- The PLC continuously takes inputs from all sensors. and gives an output signal to the VFD.
- Following condition's for VFD Automatic operation:
  - i) When the Carbon Monoxide (CO) level less than 25 ppm all fan will switched to OFF conditions.
  - ii) When the CO level raise above (26 ppm to 70 ppm) then one Fresh Air Fan ON / RUN as per Normal mode to modulate as per PPM level in basement.
  - iii) When the CO level reach above (70ppm) then Fresh Air Fan (FAF) shall be achieved 100% speed.



Routine Check List:

Co Detection System Routine Check List			
Inspection	**Equipment**	**Task**	**Description**
Daily Inspection	PLC Panel	Visual	Confirm that Panel Indicate all Censors "Normal / Healthy " State.
	PLC Panel	Entry in Log Book	if not, that any fault indicated should be attended and recorded in the log book.
Weekly Inspection	Co Sensor	Operation / Testing	Trigger any CO device on one zone circuit should be operated to test the ability of the control and indicating equipment to receive a signal and operate particular FAN.
	Co Sensor	Entry in Log Book	An entry should be made in the log book indicating the particular trigger device that has been used to initiate the test.
Quarterly Inspection	Log Book	Checking	Entries in the log book since the previous inspection should be checked and any necessary action taken.
	PLC Panel	Operation / Testing	The PLC function of control and indicating equipment should be checked by the operation of a Co device in each zone
	Co Sensor	Visual	A visual inspection should be made that structural or occupancy changes have not affected the requirements for the sting of trigger of CO Sensor.
	Co Sensor	Visual	The visual inspection should also confirm that a clear space of at least 750 mm radius is preserved in all directions below every detector, that the detectors are preferably sited and that all manual call points remain unobstructed and conspicuous.
Annual Inspection	Devices	Operation / Testing	Operation of All CO detectors in an installation should be checked each year
	Cable	Visual	Visual inspection should be made to confirm that all cable fittings and equipment are secure, undamaged and adequately protected.
	PLC Panel	Entry in Log Book	On completion of the annual inspection, the entry should be made in register in respect of defects found.

Chapter: 36 Method of Statement For Installation of Earthing Strip / Wire

Purpose:

- This method of statement explains the Procedures or sequence of activity for safely installation and Testing of Earthing Strip / Wire as per the standard Practice and Code.

General Equipment & Tools:

- The equipment that will be engaged for Installation of Cable works will be
- Drilling Machine with various Bits , Grinding Machine , Cutting Machine
- Welding Machine
- Electrical Tool Box, Cable Cutter, Screwdriver, Pliers, Spanner.
- Galvanizing paint ,Bitumius Paint
- Ladder , Scaffolding / Mobile scaffold
- Marker , Leveling device , Tape measure
- Removable Barricades
- Portable Lights

Storage & Material Handling:

- The storage area must be free from dust and Water leakages / seepages.
- **Manufacturer recommendation shall always be followed in loading/unloading and storing of Material.**
- Material and its accessories shall be unloaded handle with care in designated area of the Store (Do not directly drop to Ground) to avoid any damages.
- Materials shall be stored in a dry place which is free from water or from weather effects and protection should be given to the material by means of covering the material with Tarpaulin sheet.
- The Material will be stacked / unload in the site store on a proper stand on wooden loft on a flat surface at a sufficient height from Ground.
- If Material are dispatch in packs or pallets, each pack or pallet shall be lifted individually with suitable lifting equipment.
- The material shall be transported / Shifted in their original packing to Site location.
- The Material should be visually inspected for damage, which may have occurred during transport.
- If the Material is found defective it shall not be installed and the cable shall be returned to the supplier for replacement.
- Earthing Strip and Accessories (pre-galvanized, hot dipped galvanized) shall be stored in a dry place, fully enclosed / ventilated store.

Inspection of Materials: .

- Check The Material according to its Type, Size, Make

(a) Visual inspection:

- Type of Earthing Strip and Accessories Material
- Length , Width and thickness of Earthing Strip and Accessories
- Galvanization thickness
- Galvanization tests to be conduct.
- Proper painting / Galvanization and identification numbers of the Earthing Strip and Accessories
- The GS Flat to be supplied in 5.5 meters to 13 meters lengths.
- The weighment of GS Flat shall be witnessed by the consignee at the time of receiving delivery.
- MS flat shall conform to IS 2062 & its latest amendments for steel & Galvanization as per IS 4759 & its Latest amendments

Weight of G.I Flat Strip (IS:1730) (Tolerance : +5%&-3%)		
Sizes in mm (HxW)	**Kgs/Per meter**	**Application**
20x3	0.471	Lighting Arrestor
20x4	0.628	

20x5	0.785	
20x6	0.980	PLC Panel
25x3	0.589	
25x4	0.785	
25x5	0.981	
25x6	1.180	Control & Relay Panel
35x3	0.824	
35x4	1.100	
35x5	1.370	Lighting Panel & Local Panel
35x6	1.650	Distribution Board
40x3	0.942	Motors 5.5kw-55Kw
40x4	1.260	
40x5	1.570	
40x6	1.880	
50x3	1.180	
50x4	1.570	HT switchgear, structures, cable trays & fence, rails, gate and steel column
50x5	1.960	
50x6	2.360	
50x10	3.930	
65x10	5.100	Transformers Substations
75x10	5.890	
75x12	7.070	

Weight of G.I. wire (Steel Tube India)		
Guage Gms.	**mm**	**Weight Kg / Meter.**
4	5.892	0.216
6	4.876	0.148
8	4.064	0.103
10	3.251	0.066
12	2.641	0.045
14	2.032	0.026
16	1.625	0.017

(b) Physical Damages Inspection:

- Damage on Earthing Strip and Accessories
- Damage on galvanizing
- In case of any damages observed during inspection, the concern report will be issued and Material shall be returned to the supplier for replacement.

Testing and of Earthing Strip

- **Uniformity of coating Thickness Test**
- Test Report is not more than five year old from date of purchase order shall be reviewed for acceptance. Otherwise, test shall be carried out.
- **Uniformity Weight Test**
- The unit Weight Test Report would be carried out and results would be recorded for records and future reference.

Hot dip galvanization. (IS 2629)		
Galvanizing	**Minimum thickness:**	**Min. weight:**
MS flats 5mm thick & over	75 microns (minimum)	610 gms. / sq. mtr.
MS flats under 5mm thickness	60 microns (minimum)	460 gms. / sq. mtr.
Pipes/ conduits with thickness over 5 mm	75 microns (minimum)	610 gms. / sq. mtr
Pipes/ conduits with thickness under 5mm	60 microns (minimum)	460 gms. / sq. mtr
GI Wire	20 Microns (Medium coated)	150 gms. / sq. mtr.

Earthing Strip Laying.

(a) Shifting of Earthing Strip at Working Location:

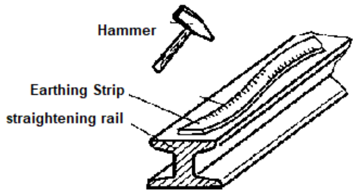
- Use Crain, Hydra or Sufficient Manpower to shift Earthign Strip from Site Store to Working area of Site.
- Remove the packing and ensure that the Earthing Strip is free from transportation damages
- Check and ensure that approved drawings, the correct size and type of Earthing Strip & accessories are ready for installation.
- Ensure that Earthing Strip and accessories received from site store for the installation are free of rusty parts and damages.

(b) Marking the Route:

- Mark the route of Earthing Strip as per approved drawings with marking threads.
- The route of Earthing Strip to be coordinated with other services and shall be confirmed by the Site Engineer.
- Minimum space from the building structure and other services to be maintained **(200 mm from the nearest point)** to facilitate easy handling and maintenance.

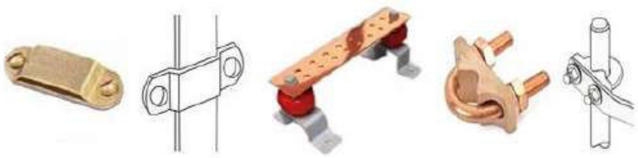
(c) Satiating of Earthing Strip / Electrode:

- Hot-dip galvanized strip steel is aligned on simple straightening machines or on a parallel by hammer.



(d) Earthing Strip Installation on Wall / Ground:

- GI strips used for earthing shall be minimum 6 mm thick and hot dip galvanized.
- If round GI conductors are used it shall have double the calculated area of cross-section.
- For installing earth leads on walls, special clamps are employed. They firmly accommodate the earth leads and are easily mounted. They are directly inserted in the wall or screwed to the wall. Fixing should be spaced not more than **1 meter apart**.
- Joints and junctions of earth leads and earthing concentration leads are to warrant a durable, safe and electrically well conductive connection.



- Where a Copper conductor is to be joined to GI, the joints should be tinned to prevent electrolytic action.
- If atmosphere is corrosive, GI conductors shall not be used for earthing.
- Earthing strips may be placed together with underground cables in cable Trench, but the heat from the cable must not be able to dry out the soil.
- Earth conductors in trenches having power or multi-core cables should be fixed to the walls near the top (for example, **100 mm from the top**).
- Copper earth strip supported from or in contact with galvanized steel should be tinned to prevent electrolytic action.
- Sharp bends required in aluminum strip should be formed by the use of a bending machine.
- Earthing Strip which install below ground should be covered adequate insulating Sleeve for avoid corrosion.
- Aluminum or copper conductors should not be drilled for fixing to structures. Clips should be used that prevent contact between conductor and structure and which are of suitable material so that there is no electrolytic action between clip and conductor.
- Fixings should be spaced not more than 1 m apart. Earth conductors in trenches containing power and/or multi-core cables should be fixed to the walls near the top (e.g. 100 mm from the top).
- Copper earth strip supported from or in contact with galvanized steel should be tinned to prevent electrolytic action. If sharp bends are required in aluminum strip they should be formed by the use of a bending machine to avoid stress concentration. Aluminum is prone to corrosion when in contact with Portland cement and mortar

mixes. Contact of aluminum conductors with such materials should, therefore, be avoided by the use of stand-off fixings.

(e) Earthing Electrode (Plate / Pipe):

- Minimum distance between earthing electrode (Plate /Pipe) and **adjacent civil structure shall be 1.5 meter.**
- Earthing grid should be run at a **minimum depth of 50 cm below the ground**.
- Since earthing electrodes will be damaged by corrosion, they are not to be placed in aggressive soil, in the vicinity of rubbish or in running waters.
- Transformer and generator neutral shall be double earthed. One independent earth electrode shall be provided for neutral earthing
- Earth electrodes (Plate /Pipe) shall be embedded as far apart as possible from each other. Mutual separation between them shall usually be not less twice the length of the electrode and are to be arranged in such a way as to prevent them from affecting each other.
- All material, fitting etc. used for earthing and earthing pit should be of IS specified make and standards. Two separate and distinct connections shall be taken out from plate earthing.

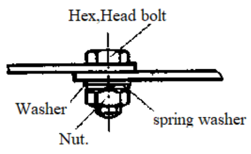
(f) Earthing Bus-Bar:

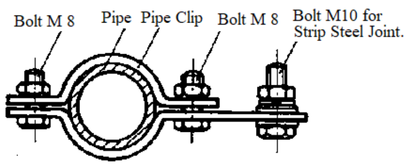
- As far as possible, all earth connections shall be visible for inspection.
- All connections shall be carefully made, if they are poorly made or inadequate for the purpose for which they are intended, loss of life or serious personal injury may result.
- No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and the live conductors,
- All earth electrodes shall be interconnected using the conductors of largest size in the earthing system.
- All non-current carrying metal parts of equipments shall be double earthed using conductors of adequate size.
- Earthing bus bars for screwing on wall / other constructions, **distance of bores 35 mm**.
- For connecting Flat strip with bore by flat head screws **M10 (with anti-rotation feature)**, nuts and spring washer

- Connection of Earthing Strip / Wire in Earthing Bus-Bar or to the body of equipment etc, such that it should be easily disconnected for testing purpose.
- By welding and drilling the zinc layer on the steel is damaged leading to stronger corrosion at the defective points.
- Welded joints are to be thoroughly cleaned from scale by means of a welder's hammer prior to applying the anti-corrosive tape.

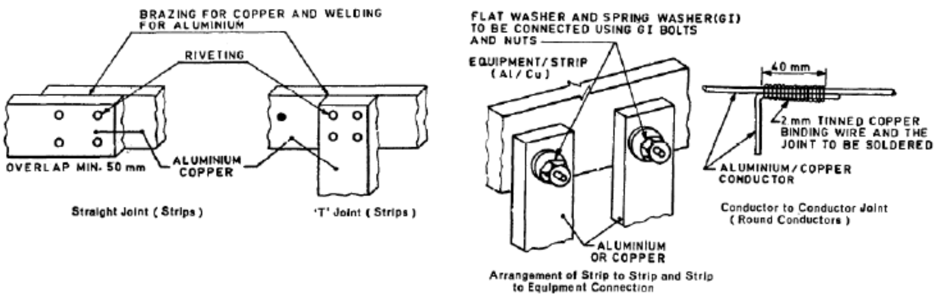
(g) Earthing Strip / Wire Jointing:

- Bolted, welded and pressed joints are permitted, In this case welded joints are being preferred Joints must be protected from corrosion.
- All Earthing Strip joined together with minimum two bolt arrangement, cutting, bending, shaping jointing with nut bolts & lap welding joints at all junctions. All connection made by electric arc welding with low hydrogen content electrodes.
- **Overlapping of Earthing Strip for Jointing:**
- **While jointing two earthing Strip or wire overlapping should be at least width of Strip or Conductor.**
- Joints shall be allowed to cool down gradually to atmospheric temperature before putting any load on it. All oxide films that may have formed during welding must be removed from the welded joints
- Joints should be provided with coating alternative layers of red oxide and aluminum. Joints are to be covered with **hot bitumen.**
- The interfaces of all 'mechanical' joins. Should be protected with a suitable electrical joint compound, particularly any bimetallic joints. All bimetallic joints should then be encapsulated in a grease impregnated tape, mastic compound or bitumastic paint, etc., to exclude moisture, In general, aluminum should only be used above ground and the connections to earth electrodes made above ground with bimetallic joints.





- Joints using GI conductors should be welded as far as possible and kept separated from air by a thick coating of tar or similar non-hygroscopic materials.
- In case bolted joints cannot be avoided than there should be a minimum of 2 bolts for sizes up to 25 mm x 6 mm, 3 bolts for sizes up to 31 mm x 6 mm and zig-zag bolting for large sizes.
- When making a bolted type joint the surface of the Aluminium strip should be cleaned thoroughly by wire brushing and greased or an approved jointing compound applied immediately to both mating surfaces. Bolts should then be tightened and all excess grease or compound wiped off and discarded.
- All crossings of conductors in the main earth grid should be jointed. Compression type joints may be used for stranded conductors.
- **Earthing (Non-conductor) strip should be drilled for a bolt having a diameter greater than one-third of the width of the strip. If this diameter will be exceeded, than a wider flag should be jointed to the strip**.
- In case of bolted joints, **at least a bolt M 10** has to be taken. For joining the earth lead to the auxiliary earthing electrode in case of applying the protective measure "voltage-operated earth-leakage protection" **a bolt M 6 will suffice (Always hardened and tempered bolts with hexagonal head are to be used).**
- Connections to natural earthing electrodes are preferably to be made outside the soil. At points where this is impossible and at joining faces being not metallic-bright, toothed lock-washers are to be used. At joining faces being metallic-bright, joints between earthing electrodes may be made by applying spring lock washer resp. plain lock washers. At the joints of earthing electrodes protection against corrosion is of utmost importance. It must be durable and fully effective.



OVERLAPING OF EARTHING STRIP		
SR.NO	**SIZE OF EARTHING STRIP**	**MIN.OVERLAPING**
1	20x3	20MM
2	20x6	20MM
3	25x3	25MM
4	25x6	25MM
5	32x6	25MM
6	40x5	50MM
7	40x6	50MM
8	50x6	50MM
9	50x10	50MM
10	75x6	50MM
11	75x10	50MM

NO'S AND SIZE OF NUT BOLT FOR JOINTING EARTHING STRIP			
SR.NO	**SIZE OF EARTHING STRIP**	**MIN.NUT BOLT REQUIRED**	**MIN.SIZE OF NUT BOLT**
1	20x3	2 NO'S	8X25MM
2	20x6	2 NO'S	8X25MM
3	25x3	2 NO'S	8X25MM
4	25x6	2 NO'S	8X25MM
5	32x6	2 NO'S	8X25MM
6	40x5	4 NO'S	8X25MM

7	40x6	4 NO'S	8X25MM
8	50x6	4 NO'S	10X25MM
9	50x10	4 NO'S	10X25MM
10	75x6	4 NO'S	10X25MM
11	75x10	4 NO'S	10X25MM

(h) Jointing conductors:

- **Aluminum to aluminum:** When possible, joints on strip conductor should be bolted or arc welded using either the tungsten inert-gas arc (TIC) or metal inert gas arc (MIG) techniques. Oxy-acetylene gas welding or brazing may also be used.
- Rectangular Strip can be joined or terminated by drilling and bolting.
- When making a bolted type joint, the surface of the aluminum should be cleaned thoroughly by wire brushing and greased or an approved jointing compound applied immediately to both mating surfaces. Bolts should then be tightened and all excess grease or compound wiped off and discarded. To ensure adequate contact pressure and avoid overstressing, torque spanners should be used. The conductor manufacturer's literature should be consulted for further details for the joints and procedures.
- **Aluminum to copper:**
- Joints between aluminum and copper should be of the bolted type and be installed in the vertical plane at a minimum distance of 150 mm above ground level.
- The rating surface of the aluminum should he cleaned thoroughly by wire brushing and greased or an approved jointing compound applied and the copper tinned. Grease or an approved jointing compound should be applied to the melting surface of the aluminum.
- After bolt tightening by torque spanner, excess grease or compound should be wiped off and discarded, and the joint protected from the increase of moisture by the application of suitable plastics compound or irradiated polyethylene sleeve with mastic lining. Alternatively, the joint may be protected by a bitumastic paint.
- Aluminum conductor connections to equipment should, where possible, be in the vertical plane. Surface preparation of the aluminum and the making of the joint should be as previously described. The finished joint should be protected by a bitumastic paint.
- Earthing strip shall not have any cut-outs or switches or links. Interconnection of earth and main branch of earth should be made in such a way that reliable and good electrical contact is established. The path of earthing strip should be minimum as possible, be out of reach of any person.
- Anti-corrosive measures: Earth strip should be protected against mechanical damages and corrosion. Fittings should be resistant to the corrosive agencies or be otherwise suitably protected. Joints and bonds may be protected with bitumen or embedded in plastic compound according to the local conditions.

Reference:

- IS 3043 Code of Practice for Earthing (first revision)
- IS 2062 Hot rolled carbon sheets & strips.
- IS 2629 Recommended practice for hot dip galvanized of Iron Earthing Strips
- IS 2633Testing of zinc coating
- IS 3203 Specification for Electroplating
- IS 4759 Specification for hot dip Zinc coating on structural & other allied products
- IS 5358 Specification for hot dip galvanized coating on fastness
- IS 4826 Hot dipped galvanized coating on round steel wires
- IS 6745 Determining of mass of zinc coating
- Indian Electricity Rules :1956 (latest edition)
- National Electrical Code :1985 of Bureau of Indian Standards
- IEEE Guide for safety in a. c. substation grounding. No. ANSI/IEEE Standard 80-1986

Chapter: 37 What is Earthing

Introduction:

- The main reason for doing earthing in electrical network is for the safety. When all metallic parts in electrical equipments are grounded then if the insulation inside the equipments fails there are no dangerous voltages present in the equipment case. If the live wire touches the grounded case then the circuit is effectively shorted and fuse will immediately blow. When the fuse is blown then the dangerous voltages are away.

Purpose of Earthing:

(I) Safety for Human life/ Building/Equipments:

- To save human life from danger of electrical shock or death by blowing a fuse i.e. To provide an alternative path for the fault current to flow so that it will not endanger the user
- To protect buildings, machinery & appliances under fault conditions.
- To ensure that all exposed conductive parts do not reach a dangerous potential.
- To provide safe path to dissipate lightning and short circuit currents.
- To provide stable platform for operation of sensitive electronic equipments i.e. To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment .

(II) Over voltage protection:

- Lightning, line surges or unintentional contact with higher voltage lines can cause dangerously high voltages to the electrical distribution system. Earthing provides an alternative path around the electrical system to minimize damages in the System.

(III) Voltage stabilization:

- There are many sources of electricity. Every transformer can be considered a separate source. If there were not a common reference point for all these voltage sources it would be extremely difficult to calculate their relationships to each other. The earth is the most omnipresent conductive surface, and so it was adopted in the very beginnings of electrical distribution systems as a nearly universal standard for all electric systems.

Conventional methods of earthing:

(I) Plate type Earthing:

- Generally for plate type earthing normal Practice is to use
- Cast iron plate of size 600 mm x600 mm x12 mm. OR
- Galvanized iron plate of size 600 mm x600 mm x6 mm. OR
- Copper plate of size 600 mm x 600 mm x 3.15 mm
- Plate burred at the depth of 8 feet in the vertical position and GI strip of size 50 mmx6 mm bolted with the plate is brought up to the ground level.

(J) Pipe type Earthing:

- For Pipe type earthing normal practice is to use
- GI pipe [C-class] of 75 mm diameter, 10 feet long welded with 75 mm diameter GI flange having 6 numbers of holes for the connection of earth wires and inserted in ground by auger method.
- These types of earth pit are generally filled with alternate layer of charcoal & salt or earth reactivation compound.

Method for Construction of Earthing Pit (Indian Electricity Board):

- Excavation on earth for a normal earth Pit size is 1.5M X 1.5M X 3.0 M.
- Use 500 mm X 500 mm X 10 mm GI Plate or Bigger Size for more Contact of Earth and reduce Earth Resistance.
- Make a mixture of Wood Coal Powder Salt & Sand all in equal part
- Wood Coal Powder use as good conductor of electricity, anti corrosive, rust proves for GI Plate for long life.
- The purpose of coal and salt is to keep wet the soil permanently.
- The salt percolates and coal absorbs water keeping the soil wet.
- Care should always be taken by watering the earth pits in summer so that the pit soil will be wet.
- Coal is made of carbon which is good conductor minimizing the earth resistant.
- Salt use as electrolyte to form conductivity between GI Plate Coal and Earth with humidity.

- Sand has used to form porosity to cycle water & humidity around the mixture.
- Put GI Plate (EARTH PLATE) of size 500 mm X 500 mm X 10 mm in the mid of mixture.
- Use Double GI Strip size 30 mm X 10 mm to connect GI Plate to System Earthling.
- It will be better to use GI Pipe of size 2.5″ diameter with a Flange on the top of GI Pipe to cover GI Strip from EARTH PLATE to Top Flange.
- Cover Top of GI pipe with a T joint to avoid jamming of pipe with dust & mud and also use water time to time through this pipe to bottom of earth plate.
- Maintain less than one Ohm Resistance from EARTH PIT conductor to a distance of 15 Meters around the EARTH PIT with another conductor dip on the Earth at least 500 mm deep.
- Check Voltage between Earth Pit conductors to Neutral of Mains Supply 220V AC 50 Hz it should be less than 2.0 Volts.

Factors affecting on Earth resistivity:

(1) Soil Resistivity:

- It is the resistance of soil to the passage of electric current. The earth resistance value (ohmic value) of an earth pit depends on soil resistivity. It is the resistance of the soil to the passage of electric current.
- It varies from soil to soil. It depends on the physical composition of the soil, moisture, dissolved salts, grain size and distribution, seasonal variation, current magnitude etc.
- In depends on the composition of soil, Moisture content, Dissolved salts, grain size and its distribution, seasonal variation, current magnitude.

(2) Soil Condition:

- Different soil conditions give different soil resistivity. Most of the soils are very poor conductors of electricity when they are completely dry. Soil resistivity is measured in ohm-meters or ohm-cm.
- Soil plays a significant role in determining the performance of Electrode.
- Soil with low resistivity is highly corrosive. If soil is dry then soil resistivity value will be very high.
- If soil resistivity is high, earth resistance of electrode will also be high.

(3) Moisture:

- Moisture has a great influence on resistivity value of soil. The resistivity of a soil can be determined by the quantity of water held by the soil and resistivity of the water itself. Conduction of electricity in soil is through water.
- The resistance drops quickly to a more or less steady minimum value of about 15% moisture. And further increase of moisture level in soil will have little effect on soil resistivity. In many locations water table goes down in dry weather conditions. Therefore, it is essential to pour water in and around the earth pit to maintain moisture in dry weather conditions. Moisture significantly influences soil resistivity

(4) Dissolved salts:

- Pure water is poor conductor of electricity.
- Resistivity of soil depends on resistivity of water which in turn depends on the amount and nature of salts dissolved in it.
- Small quantity of salts in water reduces soil resistivity by 80%. common salt is most effective in improving conductivity of soil. But it corrodes metal and hence discouraged.

(5) Climate Condition:

- Increase or decrease of moisture content determines the increase or decrease of soil resistivity.
- Thus in dry whether resistivity will be very high and in monsoon months the resistivity will be low.

(6) Physical Composition:

- Different soil composition gives different average resistivity. Based on the type of soil, the resistivity of clay soil may be in the range of 4 – 150 ohm-meter, whereas for rocky or gravel soils, the same may be well above 1000 ohm-meter.

(7) Location of Earth Pit :

- The location also contributes to resistivity to a great extent. In a sloping landscape, or in a land with made up of soil, or areas which are hilly, rocky or sandy, water runs off and in dry weather conditions water table goes down very fast. In such situation Back fill Compound will not be able to attract moisture, as the soil around the pit would be dry. The earth pits located in such areas must be watered at frequent intervals, particularly during dry weather conditions.

- Though back fill compound retains moisture under normal conditions, it gives off moisture during dry weather to the dry soil around the electrode, and in the process loses moisture over a period of time. Therefore, choose a site that is naturally not well drained.

(8) Effect of grain size and its distribution:

- Grain size, its distribution and closeness of packing are also contributory factors, since they control the manner in which the moisture is held in the soil.
- Effect of seasonal variation on soil resistivity: Increase or decrease of moisture content in soil determines decrease or increase of soil resistivity. Thus in dry weather resistivity will be very high and during rainy season the resistivity will be low.

(9) Effect of current magnitude:

- Soil resistivity in the vicinity of ground electrode may be affected by current flowing from the electrode into the surrounding soil.
- The thermal characteristics and the moisture content of the soil will determine if a current of a given magnitude and duration will cause significant drying and thus increase the effect of soil resistivity

(10) Area Available:

- Single electrode rod or strip or plate will not achieve the desired resistance alone.
- If a number of electrodes could be installed and interconnected the desired resistance could be achieved. The distance between the electrodes must be equal to the driven depth to avoid overlapping of area of influence. Each electrode, therefore, must be outside the resistance area of the other.

(11) Obstructions:

- The soil may look good on the surface but there may be obstructions below a few feet like virgin rock. In that event resistivity will be affected. Obstructions like concrete structure near about the pits will affect resistivity. If the earth pits are close by, the resistance value will be high.

(12) Current Magnitude:

- A current of significant magnitude and duration will cause significant drying condition in soil and thus increase the soil resistivity.

Measurement of Earth Resistance by use of Earth Tester:

- For measuring soil resistivity Earth Tester is used. It is also called the “MEGGER”.
- It has a voltage source, a meter to measure Resistance in ohms, switches to change instrument range, Wires to connect terminal to Earth Electrode and Spikes.
- It is measured by using Four Terminal Earth Tester Instrument. The terminals are connected by wires as in illustration.
- P=Potential Spike and C=Current Spike. The distance between the spikes may be 1M, 2M, 5M, 10M, 35M, and 50M.
- All spikes are equidistant and in straight line to maintain electrical continuity. Take measurements in different directions.
- **Soil resistivity =2πLR.**
- R= Earth resistance in ohm, L=Distance between the spikes in cm, π = 3.14,
- P = Earth resistivity ohm-cm.
- Earth resistance value is directly proportional to Soil resistivity value
- **Measurement of Earth Resistance (Three-point method):**
- In this method earth tester terminal C1 & P1 are shorted to each other and connected to the earth electrode (pipe) under test.
- Terminals P2 & C2 are connected to the two separate spikes driven in earth. These two spikes are kept in same line at the distance of 25 meters and 50 meters due to which there will not be mutual interference in the field of individual spikes.
- If we rotate generator handle with specific speed we get directly earth resistance on scale.
- Spike length in the earth should not be more than 1/20th distance between two spikes.
- Resistance must be verified by increasing or decreasing the distance between the tester electrode and the spikes by 5 meters. Normally, the length of wires should be 10 and 15 Meter or in proportion of 62% of ‘D’.
- Suppose the distance of Current Spike from Earth Electrode D = 60 ft, Then, distance of Potential Spike would be 62 % of D = 0.62D i.e. 0.62 x 60 ft = 37 ft.
- **Measurement of Earth Resistance (Four point method):**

- In this method 4 spikes are driven in earth in same line at the equal distance. Outer two spikes are connected to C1 & C2 terminals of earth tester. Similarly inner two spikes are connected to P1 & P2 terminals. Now if we rotate generator handle with specific speed, we get earth resistance value of that place.
- In this method error due to polarization effect is eliminated and earth tester can be operated directly on A.C.

GI Earthing Vs Copper Earthing:

- As per IS 3043, the resistance of Plate electrode to earth **(R) = (r/A) X under root(P/A).**
- Where r = Resistivity of Soil Ohmmeter.
- A=Area of Earthing Plate m3.
- The resistance of Pipe electrode to earth **(R) = (100r/2πL) X loge (4L/d).**
- Where L= Length of Pipe/Rod in cm
- d=Diameter of Pipe/Rod in cm.
- The resistivity of the soil and the physical dimensions of the electrode play important role of resistance of Rod with earth.
- Material resistivity is not considered important role in earth resistivity.
- Any material of given dimensions would offer the same resistance to earth. Except the sizing and number of the earthing conductor or the protective conductor.

Pipe Earthing Vs Plate Earthing:

- Suppose Copper Plate having of size 1.2m x 1.2m x 3.15mm thick. soil resistivity of 100 ohm-m,
- The resistance of Plate electrode to earth (R)=(r/A)X under root(π/A) = (100/2.88)X(3.14/2.88)=**36.27 ohm**
- Now, consider a GI Pipe Electrode of 50 mm Diameter and 3 m Long. soil resistivity of 100 Ohm-m,
- The resistance of Pipe electrode to earth (R) = (100r/2πL) X loge (4L/d) = (100X100/2X3.14X300) X loge (4X300/5) =**29.09 Ohm.**
- From the above calculation the GI Pipe electrode offers a much lesser resistance than even a copper plate electrode.
- **As per IS 3043 Pipe, rod or strip has a much lower resistance than a plate of equal surface area.**

Length of Pipe Electrode and Earthing Pit:

- The resistance to earth of a pipe or plate electrode reduces rapidly within the first few feet from ground (mostly 2 to 3 meter) but after that soil resistivity is mostly uniform.
- After about 4 meter depth, there is no appreciable change in resistance to earth of the electrode. Except a number of rods in parallel are to be preferred to a single long rod.

Amount of Salt and Charcoal (more than 8Kg):

- To reduce soil resistivity, it is necessary to dissolve in the moisture particle in the Soil.
- Some substance like Salt/Charcoal is highly conductive in water solution but the additive substance would reduce the resistivity of the soil, only when it is dissolved in the moisture in the soil after that additional quantity does not serve the Purpose.
- 5% moisture in Salt reduces earth resistivity rapidly and further increase in salt content will give a very little decrease in soil resistivity.
- The salt content is expressed in percent by weight of the moisture content in the soil. Considering 1M3 of Soil, the moisture content at 10 percent will be about 144 kg. (10 percent of 1440 kg). The salt content shall be 5% of this (i.e.) 5% of 144kg, that is, about 7.2kg.

Amount of Water Purring:

- Moisture content is one of the controlling factors of earth resistivity.
- Above 20 % of moisture content, the resistivity is very little affected. But below 20% the resistivity increases rapidly with the decrease in moisture content.
- If the moisture content is already above 20% there is no point in adding quantity of water into the earth pit, except perhaps wasting an important and scarce national resource like water.

Length Vs Diameter of Earth Electrode:

- Apart from considerations of mechanical strength, there is little advantage to be gained from increasing the earth electrode diameter with the object in mind of increasing surface area in contact with the soil.
- The usual practice is to select a diameter of earth electrode, which will have enough strength to enable it to be driven into the particular soil conditions without bending or splitting. Large diameter electrode may be more difficult to drive than smaller diameter electrode.
- The depth to which an earth electrode is driven has much more influence on its electrical resistance characteristics than has its diameter.

Maximum allowable Earth resistance:

Equipment	Earth Resistance Value
Major power station	0.5 Ohm
Major Sub-stations	1.0 Ohm
Minor Sub-station	2.0 Ohm
Neutral Bushing	4.0 Ohm
Service connection	2.0 Ohm
Medium Voltage Network	4.0 Ohm
L.T Lightening Arrestor	5.0 Ohm
L.T Pole	0.5 Ohm
H.T Pole	10 Ohm
Tower	20 to 30 Ohm

Treatments to for minimizing Earth resistance:

- Remove Oxidation on joints and joints should be tightened.
- Poured sufficient water in earth electrode.
- Used bigger size of Earth Electrode.
- Electrodes should be connected in parallel.
- Earth pit of more depth & width- breadth should be made.

Chapter: 38 Difference between Bonding-Grounding- Earthing

Introduction:

- One of the most misunderstood and confused concept is difference between Bonding, Grounding and Earthing. Bonding is more clear word compare to Grounding and Earthing but there is a micro difference between Grounding and Earhing.
- **Earthing and Grounding are actually different terms for expressing the same concept**.Ground or earth in a mains electrical wiring system is a conductor that provides a low impedance path to the earth to prevent hazardous voltages from appearing on equipment. Earthing is more commonly used in Britain, European and most of the commonwealth countries standards (IEC, IS), while Grounding is the word used in North American standards (NEC, IEEE, ANSI, UL).
- We understand that Earthing and Grounding are necessary and have an idea how to do it but we don't have crystal clear concept for that. We need to understand that there are really two separate things we are doing for same purpose that we call Grounding or Earthing.
- The Earthing is to reference our electrical source to earth (usually via connection to some kind of rod driven into the earth or some other metal that has direct contact with the earth).
- The grounded circuits of machines need to have an effective return path from the machines to the power source in order to function properly (Here by Neutral Circuit).
- In addition, non-current-carrying metallic components in a System, such as equipment cabinets, enclosures, and structural steel, need to be electrically interconnected and earthed properly so voltage potential cannot exist between them.However, troubles can arise when terms like “bonding,” “grounding,” and “earthing” are interchanged or confused in certain situations.
- In TN Type Power Distribution System, in US NEC (and possibly other) usage: Equipment is earthed to pass fault Current and to trip the protective device without electrifying the device enclosure. Neutral is the current return path for phase. These Earthing conductor and Neutral conductor are connected together and earthed at the distribution panel and also at the street, but the intent is that no current flow on earthed ground, except during momentary fault conditions. Here we may say that Earthing and grounding are nearly same by practice.
- But In the TT Type Power Distribution System (In India) Neutral is only earthed (here it is actually called Grounding) at distribution source (at distribution transformer) and Four wires (Neutral and Three Phase) are distributed to consumer. While at consumer side all electrical equipments body are connected and earthed at consumer premises (here it is called Earthing). Consumer has no any permission to mix Neutral with earth at his premises here earthing and grounding is the different by practice.
- But in both above case Earthing and Grounding are used for the same Purpose. Let’s try to understand this terminology one by one.

Bonding:

- Bonding is simply the act of joining two electrical conductors together. These may be two wires, a wire and a pipe, or these may be two Equipments.
- Bonding has to be done by connecting of all the metal parts that are not supposed to be carrying current during normal operations to bringing them to the same electrical potential.
- Bonding ensures that these two things which are bonded will be at the same electrical potential. That means we would not get electricity building up in one equipment or between two different equipment. No current flow can take place between two bonded bodies because they have the same potential.
- **Bonding, itself, does not protect anything.** However, if one of those boxes is earthed there can be no electrical energy build-up. If the grounded box is bonded to the other box, the other box is also at zero electrical potential.
- It protects equipment & Person by reducing current flow between pieces of equipment at different potentials.
- The primary reason for bonding is personnel safety, so someone touching two pieces of equipment at the same time does not receive a shock by becoming the path of equalization if they happen to be at different potentials.
- The Second reason has to do with what happens if Phase conductor may be touched an external metal part. The bonding helps to create a low impedance path back to the source. This will force a large current to flow, which in turn will cause the breaker to trip. In other words, bonding is there to allow a breaker to trip and thereby to terminate a fault.

- Bonding to electrical earth is used extensively to ensure that all conductors (person, surface and product) are at the same electrical potential. When all conductors are at the same potential no discharge can occur.

Earthing:

- Earthing means connecting the dead part (it means the part which does not carries current under normal condition) to the earth for example electrical equipment's frames, enclosures, supports etc.
- The purpose of earthing is to minimize risk of receiving an electric shock if touching metal parts when a fault is present. Generally green wire is used for this as a nomenclature.
- Under fault conditions the non-current carrying metal parts of an electrical installation such as frames, enclosures, supports, fencing etc. may attain high potential with respect to ground so that any person or stray animal touching these or approaching these will be subjected to potential difference which may result in the flow of a current through the body of the person or the animal of such a value as may prove fatal.
- To avoid this non-current carrying metal parts of the electrical system are connected to the general mass of earth by means of an earthing system comprising of earth conductors to conduct the fault currents safely to the ground.
- Earthing has been accomplished through bonding of a metallic system to earth. It is normally achieved by inserting ground rods or other electrodes deep inside earth.
- **Earthing is to ensure safety or Protection of electrical equipment and Human by discharging the electrical energy to the earth.**

Grounding:

- Grounding means connecting the live part (it means the part which carries current under normal condition) to the earth for example neutral of power transformer.
- Grounding is done for the protections of power system equipment and to provide an effective return path from the machine to the power source. For example grounding of neutral point of a star connected transformer.
- Grounding refers the current carrying part of the system such as neutral (of the transformer or generator).
- Because of lightening, line surges or unintentional contact with other high voltage lines, dangerously high voltages can develop in the electrical distribution system wires. Grounding provides a safe, alternate path around the electrical system of your house thus minimizing damage from such occurrences.
- Generally Black wire is used for this as a nomenclature.
- All electrical/electronic circuits (AC & DC) need a reference potential (zero volts) which is called ground in order to make possible the current flow from generator to load. **Ground is May or May not be earthed.** In Electrical Power distribution it is either earthed at distribution Point or at Consumer end but it is not earthed in Automobile(for instance all vehicles' electrical circuits have ground connected to the chassis and metallic body that are insulated from earth through tires).There may exist a neutral to ground voltage due to voltage drop in the wiring, thus **neutral does not necessarily have to be at ground potential.**
- In a properly balanced system, the phase currents balance each other, so that the total neutral current is also zero. For individual systems, this is not completely possible, but we strive to come close in aggregate. This balancing allows maximum efficiency of the distribution transformer's secondary winding

Micro Difference between earthing & Grounding:

- There is no major difference between earthing and Grounding, both means "Connecting an electrical circuit or device to the Earth". This serves various purposes like to drain away unwanted currents, to provide a reference voltage for circuits needing one, to lead lightning away from delicate equipment. Even though there is a micro difference between grounding & earthing.

Difference in Terminology:

- In USA term Grounding is used but in UK term Earthing is used.

Balancing the Load Vs Safety:

- Ground is a source for unwanted currents and also as a return path for main current some times. While earthing is done not for return path but only for protection of delicate equipments. It is an alternate low resistance path for current.
- When we take out the neutral for a three phase unbalanced connection and send it to ground, it is called grounding. Grounding is done to balance unbalanced load. While earthing is used between the equipment and earth pit so as to avoid electrical shock and equipment damage.

Equipment Protection Vs Human Safety:

- Earthing is to protect the circuit elements whenever high voltage is passed by thunders or by any other sources while Grounding is the common point in the circuit to maintain the voltage levels.
- **Earth is used for the safety of the human body in fault conditions while Grounding (As neutral earth) is used for the protection of equipments.**
- **Earthing is a preventive measure while Grounding is just a return path**
- The ground conductor provides a return path for fault current when a phase conductor accidentally comes in contact with a grounded object. This is a safety feature of the wiring system and we would never expect to see grounding conductor current flow during normal operation.
- **Do not Ground the Neutral Second time When It is grounded either at Distribution Transformer or at Main service Panel of Consumer end.**
- **Grounding act as neutral. But neutral cannot act as ground.**

System Zero Potential Vs Circuit Zero Potential:

- Earthing and Grounding both is refer to zero potential but the system connected to zero potential is differ than Equipment connected to zero potential .If a neutral point of a generator or transformer is connected to zero potential then it is known as **grounding.**At the same time if the body of the transformer or generator is connected to zero potential then it is known as **earthing.**
- The term "Earthing means that the circuit is physically connected to the ground and it is Zero Volt Potential to the Ground (Earth) but in case of "Grounding" the circuit is not physically connected to ground, but its potential is zero(where the currents are algebraically zero) with respect to other point, which is also known as **"Virtual Grounding."**
- **Earth** having zero potential whereas **neutral** may have some potential. That means neutral does not always have zero potential with respect to ground.In earthing we have Zero Volt potential references to the earth while in grounding we have **local Zero Volt potential reference to circuit**. When we connect two different Power circuits in power distribution system, we want to have the same Zero Volt reference so we connect them and grounds together. This common reference might be different from the earth potential.

Illegal Practice of interchange Purpose of Grounding wire and earthing wire

- Neutral wire in grid connections is mandatory for safety. Imagine a person from 4th floor in a building uses plumbing or Earth wire (which is earthed in the basement at Basement) as neutral to power his lights. Another Person from 2nd floor has a normal setup and uses neutral for the same purpose. Neutral wire is also earthed at the ground level (as per USA practice Neutral is Grounded (earthed) at Building and as per Indian Practice it is Grounded (earthed) at Distribution Transformer). However, ground wire (Neutral wire) has a much lower electrical resistance than plumbing (Earthing) which results in a difference of electrical potential (i.e. voltage) between them. This voltage is quite a hazard for anyone touching a water tap as it may have several tens of volts.
- The second issue is legality. Using ground wire instead of neutral makes you an energy thief as the meter uses only the Phase and neutral for recording your energy consumption. Many Consumers make energy theft by using Earthing wire as a Neutral wire in an Energy meter.

Conclusion:

- Ground is a source for unwanted currents and also as a return path for main current. While earthing is done not for return path but only for protection of delicate equipments. It is an alternate low resistance path for current.Earth is used for the safety of the human body in fault conditions while Grounding (As neutral earth) is used for the protection of equipments.

Chapter: 39 Methods of Earth Resistance Testing

Introduction:

- The measurement of ground / Earth resistance for an earth electrode is very important for not only for human safety but also for preventing damages of equipments, industrial plants and to reduce system downtime.
- It also provides protection against natural phenomenon such as lightning stock by providing path to the lightning current to the ground.
- Ground resistance is the measurement of the resistance between conducting connection and earth Soil.
- Earth Resistance should be Low as possible to provide low resistance path to leakage current to the earth.
- Ground resistance depends on grounding electrode selection, soil resistivity, soil contact, and other factors

Difference between Ground Resistance and Ground Resistivity

- **Ground / Earth Resistance:**
- Ground Resistance is the resistance (Which oppose of current flow) of an installed earthing electrode system.
- It is the resistance between a buried electrode and the surrounding soil.
- It is measured in **Ohms.**
- Ground Resistance is measured with a four-point, three-point or clamp on tester.
- **Ground / Earth Resistivity:**
- Ground resistivity is a measurement of how much the soil resists the flow of electricity.
- Ground resistivity is the electrical properties of the soil for conducting current.
- It indicates how good the soil /Earth conducts electric currents. For the lower the resistivity, the lower the earth electrode resistance at that location.
- Ground resistivity is theoretical resistance of a cylinder of earth Piece having a cross-section area of 1 Sq. meter.
- Ground resistivity (ρ) is measured in **Ohm centimeters.**
- Ground resistivity has nothing to deal with any installed electrical structure, but is a pure measurement of the electrical conductivity of the soil itself.
- Ground resistivity is measured with a four-point tester.
- Ground resistivity varies significantly according to the region, season and the type of soil because it depends on the level of humidity and the temperature (frost or drought increase it).

Purpose of Measurement of Earth Resistivity:

- Earth resistivity measurements have a Main three purpose.
- Earth resistivity data is used to use survey for Surface of Land to identifying locations, depth to bedrock and other geological phenomena.
- Earth resistivity data is used for protective anticorrosion treatment of underground pipelines, because Earth resistivity is direct related on the degree of corrosion of underground pipelines. Lower in resistivity increase in corrosion of Underground Pipes.
- Earth resistivity directly affects the design of an Earthing system. When we design an Earthing system, it is advisable to locate the area of lowest soil resistivity to achieve the most economical grounding installation. If the lower the soil resistivity value, the lower the grounding electrode resistance.

Earth Resistivity depends on:

- There are various that affect the ground resistance of a ground system

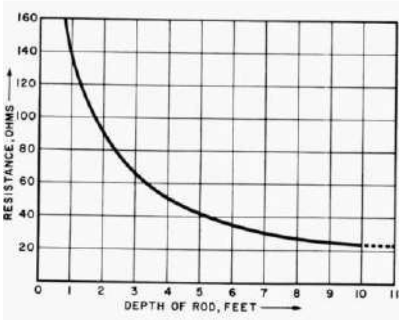
(1) Diameter of Ground Rod:

- Increasing the diameter of the ground electrode has very little effect in lowering the resistance.
- Doubling diameter of ground rod reduces resistance only **10%.**
- Using larger diameter ground rods is mainly a strength issue. In rocky conditions, a larger diameter ground rod might be advantageous.

(2) Depth of Ground Rod:

- As per NEC code minimum ground electrode length of 2.5 meters (8.0 feet) to be in contact with the soil.
- Doubling depth of Rod theoretically reduces resistance **40%.**
- Earthing Spike (electrodes) deeper is a very effective way to lower Earthing resistance.
- Actual reduction of resistance depends on soil resistivity encountered in multi-layered soils.

- The resistance decreases rapidly as the length of the electrode increases and less rapidly as the diameter increases.



(3) Spacing of Ground Rod:

- Earth resistance decrease when distance between adjustments earthing Rod is twice the length of the rod in Ground (in good soil).

Probe Spacing		
Probe distance (m)	**Soil resistance, Re (Ω)**	**Soil resistivity, ρρ (Ω m)**
0.3	14.75	27.79
0.6	7.93	29.88
0.9	6.37	36.00
1.2	4.36	32.86
1.5	4.31	40.60

(4) No of Ground Rods:

- Using multiple ground electrodes provides another way to lower ground resistance.
- More than one electrode is driven into the ground and connected in parallel to lower the resistance.
- The spacing of additional rods must be at least equal to the depth of the driven rod.
- Two well-spaced rods driven into the earth provide parallel paths and act as two resistances in parallel. However the rule for two resistances in parallel does not apply exactly so the resultant resistance is not one-half the individual rod resistances.
- The reduction in Earth resistance for equal resistance rods is
- 40 % for 2 rods
- 60 % for 3 rods
- 66 % for 4 rods

(5) Material & Surface Condition of Ground Rod:

- Grounding electrodes are usually made of a very conductive metal (stainless steel, copper or copper clad) with adequate cross sections so that the overall resistance is negligible.
- The resistance between the electrode and the surrounding earth is eligible if the electrode is not free of paint, grease, or other coating, and not firmly packed with earth.
- If the electrode is free from paint or grease, and the earth is packed firmly, contact resistance is negligible.
- Rust on an iron electrode has little or no effect .But if an iron pipe has rusted through, the part below the break is not effective as a part of the earth electrode

(6) Moisture

- Low-resistivity soils are highly influenced by the presence of moisture.
- The amount of moisture and salt content of soil affects its resistivity.
- Actually, pure water has an infinitely high resistivity. Naturally occurring salts in the earth, dissolved in water, lower the resistivity. Only a small amount of salt can reduce earth resistivity quite a bit.

(7) Temperature

- Increase in temperature will decrease resistivity
- Increase in temperature markedly decreases the resistivity of water.
- When water in the soil freezes, the resistivity jumps appreciably; ice has a high resistivity. The resistivity continues to increase a temperatures go below freezing.

(8) Soil type

- Some soils such as sandy soils have high resistivity that conventional ground.
- Frozen and very dry soils are good insulators and have high resistivity.
- In low resistivity soils, the corrosion rate is often greater than in high resistivity soils

- The resistivity is much lower below the subsoil water level than above it. In frozen soil, as in a surface layer in winter, it is particularly high.

(9) Choosing Proper Instrument:

- Use a dedicated ground tester for measuring earth resistance.
- Do not use a generalized ohmmeter, multi meter or Megger for that.

Soil Resistivity (approximate ohm-meters)			
Soil Description	**Minimum**	**Median**	**Maximum**
Topsoil, loam	1	26	50
Inorganic clays of high plasticity	10	33	55
Fills – ashes, cinders, brine wastes	6	38	70
Gravelly clays, sandy clays, silty clays, lean clays	25	43	60
Slates, shale	10	55	100
Silty or clayey fine sands with slight plasticity	30	55	80
Clayey sands, poorly graded sand-clay mixtures	50	125	200
Fine sandy or silty clays, lean clays	80	190	300
Decomposed gneisses	50	275	500
Silty sands, poorly graded sand-silt mixtures	100	300	500
Clayey gravel, poorly graded gravel, sand-clay mixture	200	300	400
Well graded gravel, gravel-sand mixtures	600	800	1000
Granites, basalts, etc.	-	1000	-
Sandstone	20	1010	2000
Poorly graded gravel, gravel-sand mixtures	1000	1750	2500
Gravel, sand, stones, little clay or loam	590	2585	4580
Surface limestone	100	5050	10000

Soil Resistivity Ranges	
1000 Ohm cm	Wet organic soil
10000 Ohm cm	Moist soil
100000 Ohm cm	Dry soil
1000000 Ohm cm	Bed rock
590 to 7000 Ohm cm	Ashes, cinders, brine, waste
340 to 1630 Ohm cm	Clay, Shale, Loam
59000 to 458000 Ohm cm	Gravel , Sand , Stone with little Clay
300 to 500 Ohm meter	Concrete
900 to 1100 Ohm meter	Granite
20 to 2000 Ohm meter	Sand Stone
100 - 15,000 Ohm cm	Standard Design OK
15,000- 25,000 Ohm cm	Standard Design Maybe
25,000 - 50,000 Ohm cm	Special – Contact the carrier, owner or engineering firm
50,000 + Ohm cm	Very Special - Perhaps not practical

Ground Resistance Values	
Industrial plant:	5 Ω
Chemical plant:	3 Ω
Computer System	3 Ω
Lighting Protection	1 Ω
Generating station:	1 Ω
Large HV sub-station, Generating Station (IEEE Std 142 clause 4.1.2)	1 Ω
Small Distribution sub-station (IEEE Std 142 clause 4.1.2)	5 Ω
Telecommunication facilities	<5 Ω
Water pipe ground should	<3 Ω

Can we use an Megger or Multimeter for earth resistivity Testing

- We cannot use Megger or Mulitimeter for Earth resistivity Testing.
- **Insulation Tester (Megger):**
- Insulation testers are designed to measure at the opposite end of the resistance by inserting high DC Voltage.
- Insulation testers use high test voltages in the kilovolt range. The area between electrode and ground is charged with high DC Voltage and we do not want grounds that measure in megohms.
- Ground testers use Low Voltage for testing for operator safety, to low voltages.
- **Multimeter:**
- However, a Multimeter or continuity test can use very low Voltage between an installed electrode and a reference ground, which is assumed to have negligible.
- Low voltage DC can produce a resistance reading between ground and an earth electrode but it is not an accurate measurement.
- Multimeter measurement may not be reliable, since reading can be influenced by soil transients, the electrical noise that is generated by utility ground currents trying to get back to the transformer, as well as other sources.

Can Earth resistance reduce by pouring Water around Test Earth Probe?

- Never. By pouring water is near test probe reduce contact resistance of between probe and ground at some extent.
- If there is sufficient contact between probe and ground then pouring water near test probe is never decrease earth resistance of the system.
- Earth resistance is the resistance of the ground electrode that is being measured, not that of the test probe. The Test probe is a tool to use measurement of earth resistance.
- If the test setup has adequate spacing, the probes will be far enough away outside of the electrical field of the test ground so that watering them has no influence on the test result.

Test Methods for Measuring Earth Resistance

- There are six basic test methods to measure earth resistance

1. Four Point Method (Wenner Method)
2. Three-terminal Method (Fall-of-potential Method / 68.1 % Method))
3. Two-point Method (Dead Earth Method)
4. Clamp-on test method
5. Slope Method
6. Star-Delta Method

(A) Four Point Method (Wenner Method):

- This method is the most commonly used for **measuring soil resistivity**,

Required Equipments:

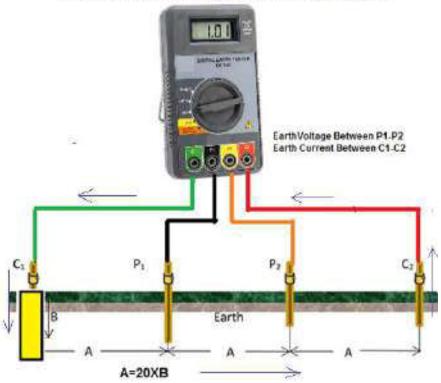
- Earth Tester (4 Terminal)
- 4 No's of Electrodes (Spike)
- 4 No's of Insulated Wires
- Hammer
- Measuring Tap

Connections:

- First, isolate the grounding electrode under measurement by disconnecting it from the rest of the system.
- Earth tester set has four terminals, two current terminals marked C1 and C2 and two potential terminals marked P1 and P2.
- P1 = Green lead, C1 = Black lead, P2 = Yellow lead, C2 = Red lead
- In this method, **four small-sized electrodes** are driven into the soil at the **same depth and equal distance from one another** in a straight line.
- The distance between earth electrodes should be at least **20 times greater** than the electrode depth in ground.
- Example, if the depth of each earth electrode is 1 foot then the distance between electrodes is greater than 20 feet.
- The earth electrode under measurement is connected to **C1** Terminal of Earth Tester.
- Drive another potential Earth terminal **(P1)** at depth of 6 to 12 inches from some distance at **C1** Earth Electrode and connect to **P1** Terminal of Earth Tester by insulted wire.

- Drive another potential Earth terminal **(P2)** at depth of 6 to 12 inches from some distance at **P1** Earth Electrode and connect to **P2** Terminal of Earth Tester by insulted wire.
- Drive another Current Electrode **(C2)** at depth of 6 to 12 inches from some distance at **P2** Earth Electrode and connect to **C2** Terminal of Earth Tester by insulted wire.
- Connect the ground tester as shown in the picture.

Four Point Earth Resistance Testing Method



Testing Procedure:

- Press START and read out the resistance value. This is the actual value of the ground Resistance of the electrode under test.
- Record the reading on the Field Sheet at the appropriate location. If the reading is not stable or displays an error indication, double check the connections. For some meters, the RANGE and TEST CURRENT settings may be changed until a combination that provides a stable reading without error indications is reached.
- The Earthing Tester has basically Constant Current generator which injects current into the earth between the two current terminals C1 (E) and C2 (H).
- The potential probes P1 & P2 detect the voltage ΔV (a function of the resistance) due to the current injected in the earth by the current terminals C1 & C2.
- The test set measures both the current and the voltage and internally calculates and then displays the resistance. R=V/I
- If this ground electrode is in parallel or series with other ground rods, the resistance value is the total value of all resistances.
- Ground resistance measurements are often corrupted by the existence of ground currents and their harmonics. To prevent this it is advisable to use Automatic Frequency Control (AFC) System. This automatically selects the testing frequency with the least amount of noise enabling you to get a clear reading.
- Repeat above steps by increasing spacing between each electrode at equal distance and measure earth resistance value.
- Average the all readings
- An effective way of decreasing the electrode resistance to ground is by pouring water around it. The addition of moisture is insignificant for the reading; it will only achieve a better electrical connection and will not influence the overall results. Also a longer probe or multiple probes (within a short distance) may help.

Application:

- It is advisable for Medium or Large electrode System.
- It is use for Multiple Depth Testing

Advantage:

- This is most accurate Method.
- It is Quick, easy method.
- Extremely reliable conforms to IEEE 81;

Disadvantage:

- There need to turn off the equipment power or disconnect the earth electrode.
- One major drawback to this method is that it requires a large distance for measurement.
- This distance can range up to 2,000 feet or more for ground systems covering a large area or of very low resistance.
- Time consuming and labor intensive

(B) Three Point (Fall-of-potential) Method.

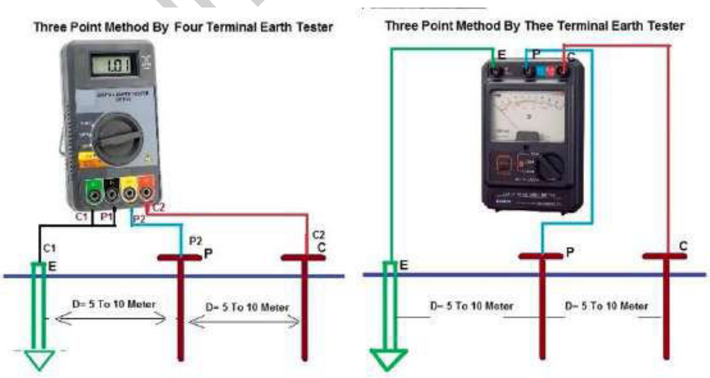
- The Fall-of-Potential method or Three-Terminal method is the most common way to measure earth electrode system resistance, but it requires special procedures when used to measure large electrode systems
- There are three basic fall-of-potential test method.
- **Full fall-of-Potential:** A number of tests are made at different spaces of Potential Probe “P” and the resistance curve is plotted.
- **Simplified Fall-of-Potential:** Three measurements are made at defined distance of Potential Probe ”P” and mathematical calculations are used to determine the resistance.
- **61.8% Rule**: A single measurement is made with Potential Probe “P” at a distance 61.8% (62%) of the distance between the electrode under test and “C”.

Required Equipments:

- Earth Tester (4 Terminal or 3 Terminal) / 4 No’s of Electrodes (Spike) / 4 No’s of Insulated Wires
- Hammer / Measuring Tap

Connections:

- First, isolate the grounding electrode under measurement by disconnecting it from the rest of the system.
- **For Small System:**
- For 4 Terminal Earth Tester Short Current Terminal **(C1)** and Potential Terminal **(P1)** together with a short jumper on the earth tester and connect it to earthing electrode under test.
- For 3 Terminal Earth Tester Connect current terminal **(C1)** to the earth electrode under measurement.
- Drive another Current Electrode **(C2)** into the earth 100 to 200 feet at depth of 6 to 12 inches from the center of the electrode and connect to **C2** Terminal of earth tester.
- Drive another potential terminal **(P2)** at depth of 6 to 12 inches into the earth midway between the Current Electrode **(C1)** and Current Electrode **(C2)** and connect to Earth Tester on **P2** Terminal.
- **For Large System**
- Place the current electrode **(C2)** 400 to 600 feet from the measuring Earth Current Electrode **(C1)**
- Place the potential electrode **(P1)** 61.8% of the distance from the Earth Current Electrode (C1)
- Measure the resistance
- Move the current electrode (C2) farther 50 to 100 Feet away from its present position.
- Place the potential electrode (P2) 61.8% of the distance from the Earth Current Electrode (C1).
- Spike length in the earth should not be more than 1/20th distance between two spikes.



Testing Procedure:

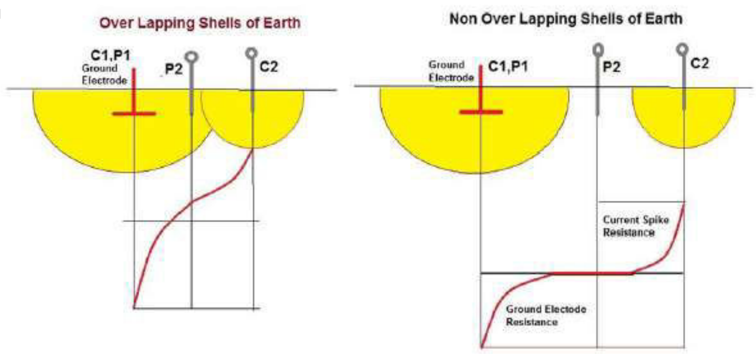
- Press START and read out the resistance value. This is the actual value of the ground electrode under test.
- Move the potential electrode 10 feet farther away from the electrode and make a second Measurement.
- Move the potential probe 10 feet closer to the electrode and make a third measurement.
- If the three measurements agree with each other within a few percent of their average, then the average of the three measurements may be used as the electrode resistance.
- If the three measurements disagree by more than a few percent from their average, then additional measurement procedures are required.
- The electrode center location seldom is known. In this case, at least three sets of measurements are made, each with the current probe a different distance from the electrode, preferably in different directions.
- When space is not available and it prevent measurements in different directions, suitable measurements can be made by moving the current probe in a line away from or closer to the electrode.

- For example, the measurement may be made with the current probe located 200, 300 and 400 feet along a line from the electrode.
- Each set of measurements involves placing the current probe and then moving the potential probe in 10 feet increments toward or away from the electrode.
- The starting point is not critical but should be 20 to 30 feet from the electrode connection point, in which case the potential probe is moved in 10 feet increments toward the current probe, or 20 to 30 feet from the current probe, in which case the potential probe is moved in 10 feet increments back toward the electrode.
- The spacing between successive potential probe locations is not particularly critical, and does not have to be 10 feet, as long as the measurements are taken at equal intervals along a line between the electrode connection and the current probe.
- Larger spacing means quicker measurements with fewer data points. Smaller spacing means more data points with slower measurements.
- Once all measurements have been made, the data is plotted with the distance from the electrode on the horizontal scale and the measured resistance on the vertical scale.

Importance of Position of Current Electrode (C2):

- **Fall-of-Potential measurements are based on the distance of the current and potential probes from the center of the electrode under test.**
- For highest degree of accuracy, it is necessary that the probe is placed outside the sphere of influence of the ground electrode under test and the auxiliary earth.
- If we Place Current Electrode (C2) too near to Earth Electrode (C1) then the sphere of influence, the effective areas of resistance will overlap and invalidate measurements taken.
- For the accurate results and to ensure that the ground stakes are outside the spheres of influence.
- Reposition the inner Potation Electrode (P1) 1meter in either direction and take a fresh measurement. If there is a significant change in the reading (30 %), we need to increase the distance between the ground rod under test, the inner stake (probe) and the outer stake (auxiliary ground) until the measured values remain fairly constant when repositioning the inner stake (probe).
- **The best distance for the current probe is at least 10 to 20 times the largest dimension of the electrode.**
- Because measurement results are often distorted by underground pieces of metal, underground aquifers, etc so re measurements are done by changing axis of earth spike by 90 degrees, by changing the depth and distance several times, these results can be a suitable ground resistance system.
- The table is a guide for appropriately setting the probe (inner stake) and auxiliary ground (outer stake).

Depth of the ground electrode	Distance to the inner stake	Distance to the outer stake
2 m	15 m	25 m
3 m	20 m	30 m
6 m	25 m	40 m
10 m	30 m	50 m



/

Application:

- It is advisable for High Electrical Load.
- It is suitable for small and medium electrodes system (1 or 2 rods/plates). .
- It is useful for homogeneous Soil

Advantage:

- The three-point method is the most reliable test method;

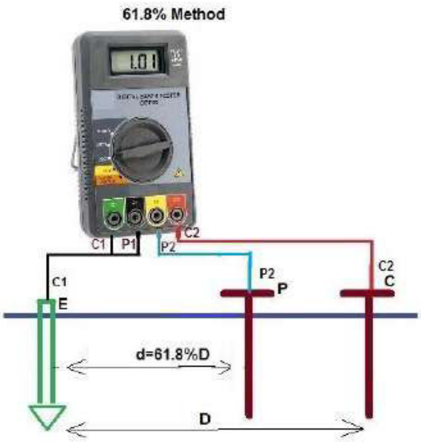
- This test is the most suitable test for large grounding systems.
- Three-terminal is the quicker and simpler, with one less lead to string Spacing For Current Probe

Disadvantage:

- Individual ground electrodes must be disconnected from the system to be measured.
- It is extremely time consuming and labor intensive.
- There are situations where disconnection is not possible.
- Knowledge of location of center probe is necessary
- Time consuming and labor intensive Ineffective if the electrical center is unknown.
- If less measurements are being made then less accurate than full Fall of Potential

61.8% Rule:

- It is proven that the actual electrode resistance is measured when the potential probe is located 61.8% of the distance between the center of the electrode and the current probe. For example, if the current probe is located 400 feet from the electrode center, then the resistance can be measured with the potential probe located 61.8% x 400 = 247 feet from the electrode center.
- The 61.8% measurement point assumes the current and potential probes are located in a straight line and the soil is homogeneous (same type of soil surrounding the electrode area and to a depth equal to 10 times the largest electrode dimension).
- The 61.8% measurement point still provides suitable accuracy for most measurements.



- Suppose, the distance of Current Spike from Earth Electrode D = 60 ft, Then, distance of Potential Spike would be 62 % of D = 0.62D i.e. 0.62 x 60 ft = 37 ft.

Application:

- It is suitable for small and medium electrodes system.
- It is useful for homogeneous Soil

Advantage:

- Simplest to carry out.
- Required minimum calculation;
- Fewest number of test probe moves.

Disadvantage:

- Soil must be homogeneous.
- Less accurate
- Susceptible for non-homogeneous soil

(C) Two Point (Dead Earth) Method.

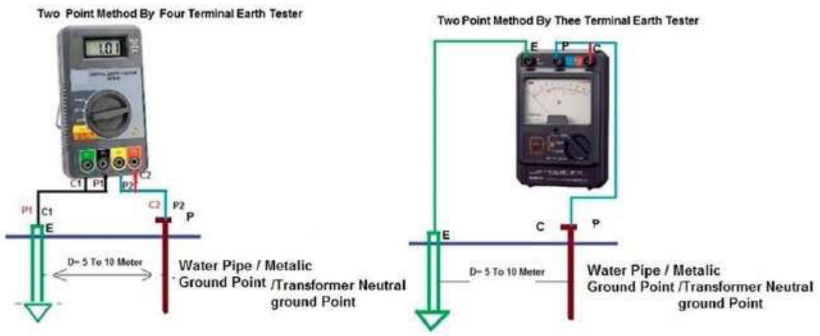
- This method is used where the driving of ground spike is neither practical nor possible
- To perform this test we have access to a good known ground such as an all metal water pipe. The water pipe should be extensive enough and be metallic throughout without any insulating couplings or flanges.
- This method is not as accurate as three-point methods (62% method), as it is particularly affected by the distance between the tested electrode and the dead ground or water pipe

Required Equipments:

- Earth Tester (4 Terminal or 3 Terminal) / 2 No's of Insulated Wires / Hammer

Connections:

- In This method, the resistance of two electrodes in a series is measured by connecting the P1 and C1 terminals to the ground electrode under test; P2 and C2 connect to a separate all-metallic grounding point like a water pipe or building steel.
- The earth electrode under test must be far enough away from the secondary grounding point to be outside its sphere of influence.



Testing Procedure:

- Press START and read out the resistance value. This is the actual value of earthing resistance of the ground electrode under test.
- Record the reading on the Field Sheet at the appropriate location. If the reading is not stable or displays an error indication, double check the connections.
- Two terminals testing of earth resistance is appropriate for most general purpose testing in normally conductive soil.
- Two terminal measurements include less test lead and contact resistance in the measurement and the result will be a reading slightly higher than the true earth resistance.
- When measured results are higher than desired or if measurement directives require multi terminal techniques, switch to the 3 or 4 terminal techniques as needed.

Advantage:

- It does Not Require Disconnecting Equipment
- This is the simplest way to obtain a ground resistance reading.
- It is most effective for quickly testing the connections and conductors between connection points.
- Required Less Test Lead.
- Required small area for Measurement.

Disadvantage:

- This is not as accurate as the three-point method and should only be used as a last resort.
- Non-metallic (high resistance) return Resistance areas should not overlap.

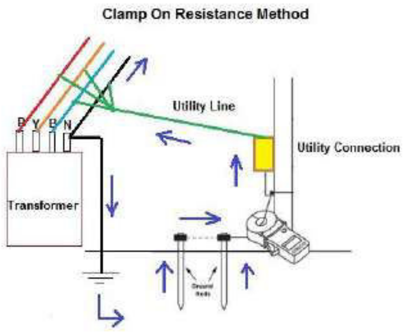
(D) Clamp-on test method

- For the clamp-on method to be effective there must be a complete grounding circuit in place. The tester measures the complete resistance path (loop) that the signal is taking. All elements of the loop are measured in series.
- The Induced Frequency testing or commonly called the "Clamp-On" test is one of the newest test methods for measuring the resistance-to-ground of a grounding system or electrode.
- This is Convenient, Quick ,easy and safe Method
- It does Not Require Disconnecting Equipment

Required Equipments:

- Clamp-on Ground Resistance Meter. / 2 No's of Insulated Wires

Connections setup:



- **Testing Procedure:** Press START and read out the resistance value. This is the actual value of earthing resistance of the ground electrode under test.
- The clamp-on methodology is based on Ohm's Law (R=V/I).
- The source coil inside the clamp of the earth tester inducing the voltage. This voltage is inductively applied to a complete circuit .The resulting current flow in the earthing circuit due to the induced voltage is measured by the current coil installed in the same clamp of the earth tester.
- The resistance of the circuit can then be calculated by taking the ratio of the induced voltage and the circulated current in the earthing circuit.
- It has to be ensured that the earthing system under test is included in the current circulation loop. The clamp-on earth tester measures the resistance of the path traversed by the induced current.
- All elements of the loop are measured in series. This method assumes that only the resistance of the earthing system under test contributes significantly.
- A low return path is required for readings. A high resistance return path will yield high readings.

Advantage

- There is no need to turn off the equipment power or disconnect the earth rod.
- Not disconnecting the connections between the earthed body and the metal work of the electrical Earthing Point.
- Not dangerous to human life because no any DC current injected in Probe.

Disadvantages:

- If the frequency of AC current injected into the earth by the tester is the same as that of disturbance current in the earth then accuracy of the readings are seriously affected.
- The mutual inductance between the voltage and current loops of the clamp tester may affect accuracy of the readings.
- The clamp-on method is only effective in situations with multiple earthing electrodes are in parallel and a closed circuit is available for the current circulation.
- It cannot be used on isolated grounds, as there is no return path.
- Measurement of low earth resistance (0.5Ω) is difficult with this method.
- This method id effective only in situations with multiple grounds in parallel.
- This method cannot be used on isolated grounds, not applicable for installation checks or commissioning new sites.
- This method cannot be used if an alternate lower resistance return exists not involving the soil, such as with cellular towers or substations.

(E) Star Delta Method:

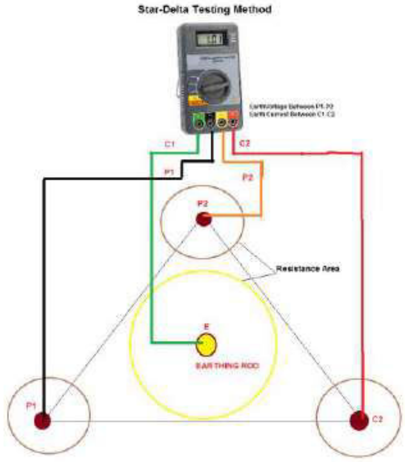
- If the testing area is so limited that an required spacing cannot be found then it may be necessary to use the Star-Delta Method. Named for the configuration of the test probes and lines of measurement (a graphic of it resembles the familiar symbols for "delta" and "star" windings).
- This method saves space by employing a tight configuration of three probes around the test ground

Required Equipments:

- Earth Tester (4 Terminal or 3 Terminal) / 2 No's of Insulated Wires /Hammer

Connections:

- The ground electrode under test (E) is connect to C1 Terminal of Tester.
- Three Potential and current probes (P2, P3 and P4) are placed equidistant from "E" with a 120º angle between them. Separation of potential and current circuits is abandoned, and a series of two-point measurements made between all pairs of probes, and probes to the ground under test.



- **Testing Procedure:** Press START and read out the resistance value. This is the actual value of earthing resistance of the ground electrode under test.
- **Application:** Ground systems located in congested urban areas or rocky area where probe positioning is difficult where required probe positioning is difficult
- **Advantage:** Knowledge of electrical center not necessary
- **Disadvantage:** Number of calculations required
- Long distances to test probes is still required.

(F) Slope Method

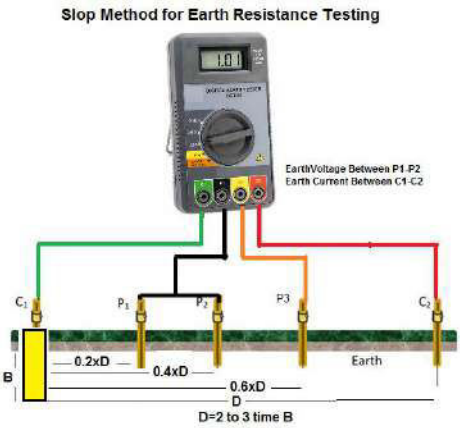
- If soil is non homogenous Soil Slope Method is useful for earth resistance measurement.

Required Equipments:

- Earth Tester (4 Terminal or 3 Terminal)
- 4 No's of Insulated Wires
- Hammer
- Measuring Tap

Connections:

- First, isolate the grounding electrode under measurement by disconnecting it from the rest of the system.
- The earth electrode under measurement (E) is connected to C1 Terminal of Earth Tester.
- E is either one of many paralleled rods forming the complex earth system.
- Insert the current probe C2 at a distance (D) from E (distance D is normally 2 to 3 times the maximum dimension of the system).
- Insert potential probes P1,P2 and P3 at distances equal to 20% of D, 40% of D and 60% D.



Testing Procedure:

- Press START and read out the resistance value. This is the actual value of earthing resistance of the ground electrode under test.

Chapter: 40 Working Principle of ELCB & RCCB

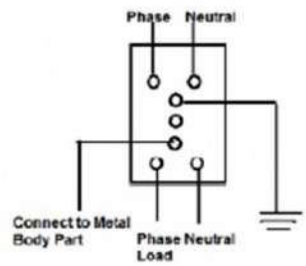
Introduction:

- **A**n Earth Leakage Circuit Breaker (ELCB) is a device used to directly detect currents leaking to earth from an installation and cut the power and mainly used in TT earthing systems.
- **There are two types of ELCB:**
  1. Voltage Earth Leakage Circuit Breaker (voltage-ELCB)
  2. Current Earth Leakage Current Earth Leakage Circuit Breaker (Current-ELCB).
- Voltage-ELCBs were first introduced about sixty years ago and Current-ELCB was first introduced about forty years ago. For many years, the voltage operated ELCB and the differential current operated ELCB were both referred to as ELCBs because it was a simpler name to remember. But the use of a common name for two different devices gave rise to considerable confusion in the electrical industry. If the wrong type was used on an installation, the level of protection given could be substantially less than that intended. To ignore this confusion, IEC decided to apply the term Residual Current Device (RCD) to differential current operated ELCBs. Residual current refers to any current over and above the load current

Type of ELCB:

(1) Voltage Base ELCB:

- Voltage-ELCB is a voltage operated circuit breaker. The device will function when the Current passes through the ELCB. Voltage-ELCB contains relay Coil which it being connected to the metallic load body at one end and it is connected to ground wire at the other end.
- If the voltage of the Equipment body is rise (by touching Phase to metal Part or Failure of Insulation of Equipment) which could cause the difference between earth and load body voltage, the danger of electric shock will occur. This voltage difference will produce an electric current from the load metallic body passes the relay loop and to earth. When voltage on the equipment metallic body rose to the danger level which exceed to 50Volt, the flowing current through relay loop could move the relay contact by disconnecting the supply current to avoid from any danger electric shock.
- The ELCB detects fault currents from live to the earth (ground) wire within the installation it protects. If sufficient voltage appears across the ELCB's sense coil, it will switch off the power, and remain off until manually reset. A voltage-sensing ELCB does not sense fault currents from live to any other earthed body.



- These ELCBs monitored the voltage on the earth wire, and disconnected the supply if the earth wire voltage was over 50 volts.
- These devices are no longer used due to its drawbacks like if the fault is between live and a circuit earth, they will disconnect the supply. However, if the fault is between live and some other earth (such as a person or a metal water pipe), they will NOT disconnect, as the voltage on the circuit earth will not change. Even if the fault is between live and a circuit earth, parallel earth paths created via gas or water pipes can result in the ELCB being bypassed. Most of the fault current will flow via the gas or water pipes, since a single earth stake will inevitably have a much higher impedance than hundreds of meters of metal service pipes buried in the ground
- **The way to identify an ELCB is by looking for green or green and yellow earth wires entering the device.** They rely on voltage returning to the trip via the earth wire during a fault and afford only limited protection to the installation and no personal protection at all. You should use plug in 30mA RCD's for any appliances and extension leads that may be used outside as a minimum.

Advantages:

- ELCBs have one advantage over RCDs: they are less sensitive to fault conditions, and therefore have fewer nuisance trips.
- While voltage and current on the earth line is usually fault current from a live wire, this is not always the case, thus there are situations in which an ELCB can nuisance trip.
- When an installation has two connections to earth, a nearby high current lightning strike will cause a voltage gradient in the soil, presenting the ELCB sense coil with enough voltage to cause it to trip.
- If the installation's earth rod is placed close to the earth rod of a neighboring building, a high earth leakage current in the other building can raise the local ground potential and cause a voltage difference across the two earths, again tripping the ELCB.
- If there is an accumulated or burden of currents caused by items with lowered insulation resistance due to older equipment, or with heating elements, or rain conditions can cause the insulation resistance to lower due to moisture tracking. If there is a some mA which is equal to ELCB rating than ELCB may give nuisance Tripping.
- If either of the earth wires become disconnected from the ELCB, it will no longer trip or the installation will often no longer be properly earthed.
- Some ELCBs do not respond to rectified fault current. This issue is common for ELCBs and RCDs, but ELCBs are on average much older than RCB so an old ELCB is more likely to have some uncommon fault current waveform that it will not respond to.
- Voltage-operated ELCB are the requirement for a second connection, and the possibility that any additional connection to earth on the protected system can disable the detector.
- Nuisance tripping especially during thunderstorms.

Disadvantages:

- They do not detect faults that don't pass current through the CPC to the earth rod.
- They do not allow a single building system to be easily split into multiple sections with independent fault protection, because earthling systems are usually use common earth Rod.
- They may be tripped by external voltages from something connected to the earthing system such as metal pipes, a TN-S earth or a TN-C-S combined neutral and earth.
- As electrically leaky appliances such as some water heaters, washing machines and cookers may cause the ELCB to trip.
- ELCBs introduce additional resistance and an additional point of failure into the earthing system.

Can we Check healthiness of Our Electrical System by only Pressing ELCB Test Switch?

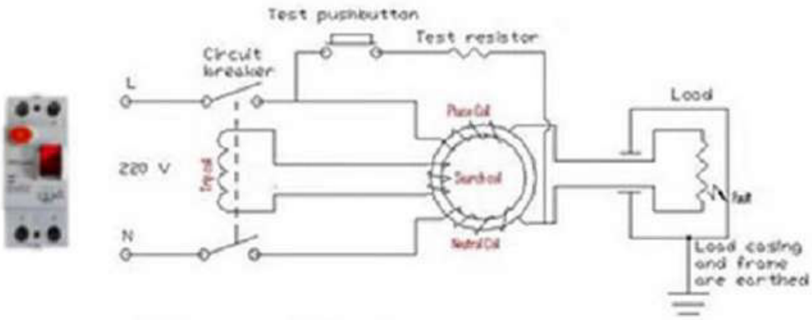
- Checking the health of the ELCB is simple and you can do it easily by pressing TEST Push Button Switch of ELCB. The test push-button will test whether the ELCB unit is working properly or not.
- Can we assume that If ELCB is Trip after Pressing TEST Switch of ELCB than your system is protected against earth protection? Then you are wrong.
- The test facility provided on the home ELCB will only confirm the health of the ELCB unit, but that test does not confirm that the ELCB will trip when an electric shock hazard does occur. It is a really sad fact that all the while this misunderstanding has left many homes totally unprotected from the risk of electric shocks.
- This brings us or alarming us to think over second basic requirement for earth protection. The second requirement for the proper operation of a home shock protection system is electrical grounding.
- We can assume that the ELCB is the **brain for the shock protection**, and the grounding as the backbone. Therefore, without a functional grounding (Proper Earthing of Electrical System) there is totally no protection against electrical shocks in your house even if You have installed ELCB and its TEST switch show proper result. Looking after the ELCB alone is not enough. The electrical Earthing system must also be in good working order for the shock protection system to work. In addition to routine inspections that should be done by the qualified electrician, this grounding should preferably be inspected regularly at shorter intervals by the homeowner and need to pour Water in Earthing Pit at Regular interval of Time to minimize Earth Resistance.

(2) Current-operated ELCB (RCB):

- Current-operated ELCBs are generally known as Residual-current devices (RCD). These also protect against earth leakage. Both circuit conductors (supply and return) are run through a sensing coil; any imbalance of the currents means the magnetic field does not perfectly cancel. The device detects the imbalance and trips the contact.
- When the term ELCB is used it usually means a voltage-operated device. Similar devices that are current operated are called residual-current devices. However, some companies use the term ELCB to distinguish high sensitivity

current operated 3 phase devices that trip in the milliamp range from traditional 3 phase ground fault devices that operate at much higher currents.

Typical RCB Circuit:



- The supply coil, the neutral coil and the search coil all wound on a common transformer core.
- On a healthy circuit the same current passes through the phase coil, the load and return back through the neutral coil. Both the phase and the neutral coils are wound in such a way that they will produce an opposing magnetic flux. With the same current passing through both coils, their magnetic effect will cancel out under a healthy circuit condition.
- In a situation when there is fault or a leakage to earth in the load circuit, or anywhere between the load circuit and the output connection of the RCB circuit, the current returning through the neutral coil has been reduced. Then the magnetic flux inside the transformer core is not balanced anymore. The total sum of the opposing magnetic flux is no longer zero. This net remaining flux is what we call a residual flux.
- The periodically changing residual flux inside the transformer core crosses path with the winding of the search coil. This action produces an electromotive force (e.m.f.) across the search coil. An electromotive force is actually an alternating voltage. The induced voltage across the search coil produces a current inside the wiring of the trip circuit. It is this current that operates the trip coil of the circuit breaker. Since the trip current is driven by the residual magnetic flux (the resulting flux, the net effect between both fluxes) between the phase and the neutral coils**, it is called the residual current devise.**
- With a circuit breaker incorporated as part of the circuit, the assembled system is called residual current circuit breaker (RCCB) or residual current devise (RCD). The incoming current has to pass through the circuit breaker first before going to the phase coil. The return neutral path passes through the second circuit breaker pole. During tripping when a fault is detected, both the phase and neutral connection is isolated. o RCD sensitivity is expressed as the rated residual operating current, noted **IΔn**. Preferred values have been defined by the IEC, thus making it possible to divide RCDs into three groups according to their IΔn value.
- High sensitivity (**HS**): 6- 10- 30 mA (for direct-contact / life injury protection)
- Standard IEC 60755 (General requirements for residual current operated protective devices) defines three types of RCD depending on the characteristics of the fault current.
- Type **AC**: RCD for which tripping is ensured for residual sinusoidal alternating currents

Sensitivity of RCB:

- Medium sensitivity (**MS**): 100- 300- 500- 1000 mA (for fire protection)
- Low sensitivity (**LS**): 3- 10- 30 A (typically for protection of machine)

Type of RCB:

(1) Type A: RCD for which tripping is ensured

- for residual sinusoidal alternating currents
- for residual pulsating direct currents
- For residual pulsating direct currents superimposed by a smooth direct current of 0.006 A, with or without phase-angle control, independent of the polarity.

(2) Type B: RCD for which tripping is ensured

- as for type A
- for residual sinusoidal currents up to 1000 Hz
- for residual sinusoidal currents superposed by a pure direct current
- for pulsating direct currents superposed by a pure direct current

- for residual currents which may result from rectifying circuits o three pulse star connection or six pulse bridge connection
- two pulse bridge connection line-to-line with or without phase-angle monitoring, independently of the polarity

Break time of RCB:

- **G (general use) for instantaneous RCDs (i.e. without a time delay)**
- **Minimum break time:** immediate
- **Maximum break time:** 200 ms for 1x $I\Delta n$, 150 ms for 2x $I\Delta n$, and 40 ms for 5x $I\Delta n$
- **S (selective) or T (time delayed) for RCDs with a short time delay (typically used in circuits containing surge suppressors)**
- **Minimum break time:** 130 ms for 1x $I\Delta n$, 60 ms for 2x $I\Delta n$, and 50 ms for 5x $I\Delta n$
- **Maximum break time:** 500 ms for 1x $I\Delta n$, 200 ms for 2x $I\Delta n$, and 150 ms for 5x $I\Delta n$

Chapter: 41 Difference between MCB-MCCB-RCB-RCCB-ELCB

(1) MCB (Miniature Circuit Breaker)

- **Rated current**: Not more than 100 A.
- **Trip characteristics:** Normally not adjustable.
- Thermal or thermal-magnetic operation.

(2) MCCB (Moulded Case Circuit Breaker):

- **Rated current:** up to 1000 A.
- **Trip characteristics:** may be adjustable.
- Thermal or thermal-magnetic operation.

(3) Air Circuit Breaker:

- **Rated current:** up to 10,000 A.
- **Trip characteristics:** fully adjustable including configurable trip thresholds and delays.
- Usually electronically controlled—some models are microprocessor controlled.
- Often used for main power distribution in large industrial plant, where the breakers are arranged in draw-out enclosures for ease of maintenance.

(4) Vacuum Circuit Breaker:

- **Rated current:** up to 3000 A,
- These breakers interrupt the arc in a vacuum bottle.
- These can also be applied at up to 35,000 V. Vacuum breakers tend to have longer life expectancies between overhaul than do air circuit breakers.

(5) RCD (Residual Current Device) / RCCB (Residual Current Circuit Breaker) :

- Phase (line) and Neutral both wires connected through RCD.
- It trips the circuit when there is earth fault current.
- The amount of current flows through the phase (line) should return through neutral.
- It detects by RCD. any mismatch between two currents flowing through phase and neutral detect by RCD and trip the circuit within 30Miliseconed.
- If a house has an earth system connected to an earth rod and not the main incoming cable, then it must have all circuits protected by an RCD (because u mite not be able to get enough fault current to trip a MCB)
- The most widely used are 30 mA (milliamp) and 100 mA devices. A current flow of 30 mA (or 0.03 amps) is sufficiently small that it makes it very difficult to receive a dangerous shock. Even 100 mA is a relatively small figure when compared to the current that may flow in an earth fault without such protection (hundred of amps)
- A 300/500 mA RCCB may be used where only fire protection is required. eg., on lighting circuits, where the risk of electric shock is small
- RCDs are an extremely effective form of shock protection

- ## Limitation of RCCB:

- **Standard electromechanical RCCBs are designed to operate on normal supplywaveforms** and cannot be guaranteed to operate where none standard waveforms are generated by loads. The most common is the half wave rectified waveform sometimes called pulsating dc generated by speed control devices, semi conductors, computers and even dimmers.
- Specially modified RCCBs are available which will operate on normal ac and pulsating dc.
- **RCDs don't offer protection against current overloads**: RCDs detect an imbalance in the live and neutral currents. A current overload, however large, cannot be detected. It is a frequent cause of problems with novices to replace an MCB in a fuse box with an RCD. This may be done in an attempt to increase shock protection. If a live-neutral fault occurs (a short circuit, or an overload), the RCD won't trip, and may be damaged. In practice, the main MCB for the premises will probably trip, or the service fuse, so the situation is unlikely to lead to catastrophe; but it may be inconvenient.
- It is now possible to get an MCB and and RCD in a single unit, called an RCBO (see below). Replacing an MCB with an RCBO of the same rating is generally safe.

- **Nuisance tripping of RCCB:** Sudden changes in electrical load can cause a small, brief current flow to earth, especially in old appliances. RCDs are very sensitive and operate very quickly; they may well trip when the motor of an old freezer switches off. Some equipment is notoriously `leaky', that is, generate a small, constant current flow to earth. Some types of computer equipment, and large television sets, are widely reported to cause problems.
- **RCD will not protect against a socket outlet being wired with its live and neutral terminals** the wrong way round.
- **RCD will not protect against the overheating** that results when conductors are not properly screwed into their terminals.
- **RCD will not protect against live-neutral shocks**, because the current in the live and neutral is balanced. So if you touch live and neutral conductors at the same time (e.g., both terminals of a light fitting), you may still get a nasty shock.

(A) ELCB (Earth Leakage Circuit Breaker):

- Phase (line), Neutral and Earth wire connected through ELCB.
- ELCB is working based on Earth leakage current.
- **Operating Time of ELCB:**
- The safest limit of Current which Human Body can withstand is 30ma sec.
- Suppose Human Body Resistance is 500Ω and Voltage to ground is 230 Volt.
- The Body current will be 500/230=460mA.
- Hence ELCB must be operated in 30maSec/460mA = 0.65msec

(B) RCBO (Residual Circuit Breaker with Over Load):

- It is possible to get a combined MCB and RCCB in one device (Residual Current Breaker with Overload RCBO), the principals are the same, but more styles of disconnection are fitted into one package

Difference between ELCB and RCCB:

- ELCB is the old name and often refers to voltage operated devices that are no longer available and it is advised you replace them if you find one.
- RCCB or RCD is the new name that specifies current operated (hence the new name to distinguish from voltage operated).
- The new RCCB is best because it will detect any earth fault. The voltage type only detects earth faults that flow back through the main earth wire so this is why they stopped being used.
- The easy way to tell an old voltage operated trip is to look for the main earth wire connected through it.
- RCCB will only have the line and neutral connections.
- ELCB is working based on Earth leakage current. But RCCB is not having sensing or connectivity of Earth, because fundamentally Phase current is equal to the neutral current in single phase. That's why RCCB can trip when the both currents are deferent and it withstand up to both the currents are same. Both the neutral and phase currents are different that means current is flowing through the Earth.
- Finally both are working for same, but the thing is connectivity is difference.
- RCD does not necessarily require an earth connection itself (it monitors only the live and neutral).In addition it detects current flows to earth even in equipment without an earth of its own.
- This means that an RCD will continue to give shock protection in equipment that has a faulty earth. It is these properties that have made the RCD more popular than its rivals. For example, earth-leakage circuit breakers (ELCBs) were widely used about ten years ago. These devices measured the voltage on the earth conductor; if this voltage was not zero this indicated a current leakage to earth. The problem is that ELCBs need a sound earth connection, as does the equipment it protects. As a result, the use of ELCBs is no longer recommended.

MCB Selection:

1) Over Load Characteristic:

- The first characteristic is the overload which is intended to prevent the accidental overloading of the cable in a no fault situation. The speed of the MCB tripping will vary with the degree of the overload. This is usually achieved by the use of a thermal device in the MCB.

2) Magnetic fault protection:

- The second characteristic is the magnetic fault protection, which is intended to operate when the fault reaches a predetermined level and to trip the MCB within one tenth of a second. The level of this magnetic trip gives the MCB its type characteristic as follows:

Type	Tripping Current	Operating Time
Type B	3 To 5 time full load current	0.04 To 13 Sec
Type C	5 To 10 time full load current	0.04 To 5 Sec
Type D	10 To 20 time full load current	0.04 To 3 Sec

3) Short circuit protection:

- The third characteristic is the short circuit protection, which is intended to protect against heavy faults maybe in thousands of amps caused by short circuit faults.
- The capability of the MCB to operate under these conditions gives its short circuit rating in Kilo amps (KA). In general for consumer units a 6KA fault level is adequate whereas for industrial boards 10KA fault capabilities or above may be required.

Fuse and MCB characteristics:

- Fuses and MCBs are rated in amps. The amp rating given on the fuse or MCB body is the amount of current it will pass continuously. This is normally called the rated current or nominal current.
- Many people think that if the current exceeds the nominal current, the device will trip, instantly. So if the rating is 30 amps, a current of 30.00001 amps will trip it, right? This is not true.
- The fuse and the MCB, even though their nominal currents are similar, have very different properties. For example, for 32Amp MCB and 30 Amp Fuse, to be sure of tripping in 0.1 seconds, the MCB requires a current of 128 amps, while the fuse requires 300 amps.
- The fuse clearly requires more current to blow it in that time, but notice how much bigger *both* these currents are than the `30 amps' marked current rating.
- There is a small likelihood that in the course of, say, a month, a 30-amp fuse will trip when carrying 30 amps. If the fuse has had a couple of overloads before (which may not even have been noticed) this is much more likely. This explains why fuses can sometimes `blow' for no obvious reason
- If the fuse is marked `30 amps', but it will actually stand 40 amps for over an hour, how can we justify calling it a `30 amp' fuse? The answer is that the overload characteristics of fuses are designed to match the properties of modern cables. For example, a modern PVC-insulated cable will stand a 50% overload for an hour, so it seems reasonable that the fuse should as well.

Typical methods of provision of the main earthing terminal:

- **Supply type: TN-S: Supplier** provides a separate earth connection, usually direct from the distribution station and via the metal sheath of the supply cable.
- **Supply type: TN-C-S:**Supplier provides a combined earth/neutral connection; your main earth terminal is connected to their neutral
- **Supply type: TT:** Supplier provides no earth; you have an earth spike near your premises.

Chapter: 42 What is Correct Method of MCB Connections

Introduction:

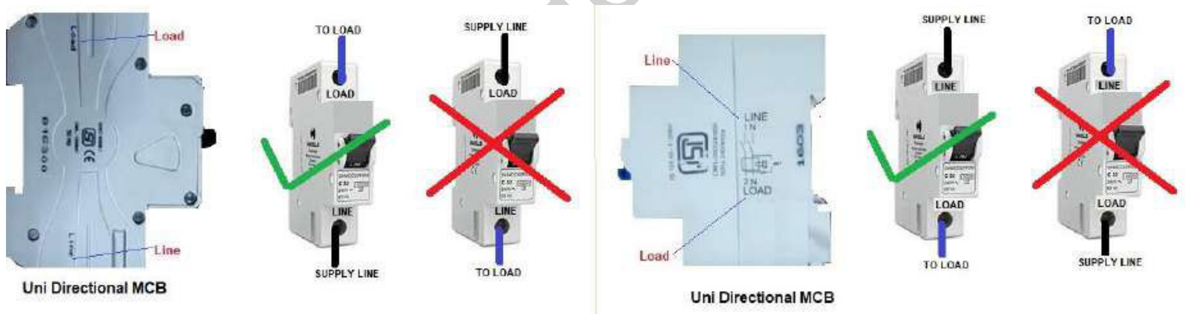
- MCB is a mechanical switching device which can carry and break currents under normal circuit conditions and also under specified abnormal conditions, such as overload and short circuit.
- The MCB can provide protection until and unless we have install input power (LINE) connection and Output (LOAD) connections in proper Terminals of MCB.
- Electrical engineers seem to be confused to indentify where is the Line and Load terminal of an MCB (on the top or on the bottom).

Terminal Marking of MCB:

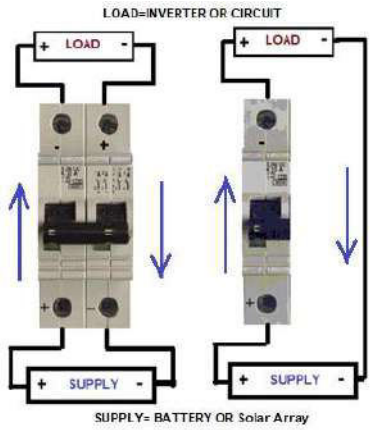
- There are two type of MCB available in market.
- MCB having terminal marking (LINE / LOAD Marking) (Polarized MCB)
- MCB having No terminal marking (No any Marking) (Non Polarized MCB)
- Some manufacture clearly indicates where to apply Input Power and where to connect Load on MCB while some manufacture does not indicate such Terminal Marking.
- The constructions of both MCB are almost same even though we need to understand difference between them.

(1) LINE / LOAD Terminal Marking on MCB (Polarized MCB)

- **For AC Circuit:**
- If manufactures indicate Input (LINE) making on MCB then we have to give Supply at "LINE" Terminal and Load at "LOAD" Terminal for perfect operation of MCB.
- If we do wrong connection than MCB may or may not give proper protection in fault Condition.
- As Per UL 489 Paragraph 9.1.1.13: It is clearly indicate that **"Circuit breakers shall be marked "Line" and "Load" unless the construction and test results are acceptable with the line and load connections reversed. This marking requirement specifies that UL MCB shall be marked with the word "Line" on one end of the circuit breaker and the word "Load" on the other end",** as shown in Figure



- If MCB is not live (ON) from long time (in Cold state) than there is possibility of MCB to not operate in fault conditions.
- In MCB ,The fixed contact is encompassed by the arc chute, and the arc products are de ionized, cooled and ejected uneventfully when the incoming power is on "Line" Terminal (when the fixed contact is 'live' or 'hot').There is less chance to re strike arc again.
- If the power is applied to moving contact ,"Load" Terminal, the flexible connector, the trip system, everything is live/hot after the arc is quenched. Chances of restrike/flashover are much higher.
- **For DC Circuit:**
- The polarized DC MCB have a marking of '+' and '–' symbol
- If Polarized DC MCB are wired incorrectly, they are a possibility of hazard and When we turned off under load, the MCB might not be able to extinguish the arc and the circuit breaker will burn out.
- Polarized DC MCB use a small magnet to direct the arc away from the contacts and up into the arc shoot and arc disrupter cage. If the direction of current flow through the unit is reversed, then the magnet directs the arc away from the arc shoot and into the mechanism of the unit thus destroying it.



(2) No Terminal Marking on MCB (Non Polarized MCB)

- **For AC Circuit:**
- If manufacture has not indicated any Terminal Marking than we are free to connect line or load at any side as we wish.
- If construction / Operating principle of both MCB are same then what are the different between them.
- Without Terminal Marking MCB has following additional features.
- (1) By Design improvement (Manufacture has provided some more provision for quenching of arc (So it cannot reproduce it again).
- (2) By doing some more extra test as per IEC 60947-2 and UL 489

- The performance of single-break circuit breakers is slightly different when the "LINE" and "LOAD" feed either from the bottom or Top hence IEC 60947-2 specifies that one additional SC test be carried out with connections required when the terminals are not specifically marked 'Line' and/or 'Load'

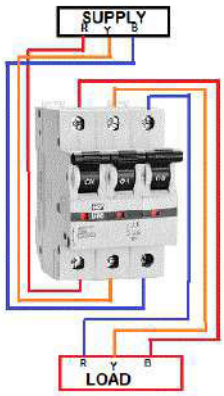
Table 10- Number of samples for test (IS / IEC 60947-2)

Test Sequences	Terminal Marking (Line / Load)		No of Sample For Testing	Sample For *
	YES	NO		
In	√	√	1	**1**
Ics (Rated service short-circuit breaking capacity) (Ics=25%Icu)	√		2	1
				2
		√	3	1
				2
				3
	√	√	3	1
				2
				3
	√	√	4	1
				2
				3
				4
Icu (Rated	√		2	1

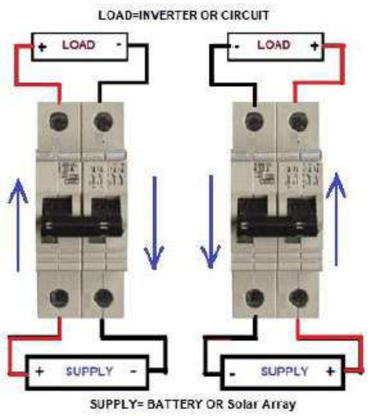
ultimate short-circuit breaking capacity)				2
		√	3	1
				2
				3
	√	√	3	1
				2
				3
	√	√	4	1
				2
				3
				4

***Sample For Indications**	
1	In of a given frame size.
2	This sample is omitted in the following cases:
	A circuit-breaker having a single non-adjustable current setting for a given frame size;
	A circuit-breaker provided only with a shunt release (i.e. without an integral over current release);
	A circuit-breaker with electronic over current protection, of a given frame size, having an adjustable current rating by electronic means only (i.e. without change of current sensors).
3	Connections reversed.
4	Connections reversed, if terminals unmarked.

- As Per UL 489, Paragraph 7.1.1.18: **"if a circuit breaker is not marked "Line" and "Load," one sample of each set tested, or one additional sample, shall be connected with the line and load connections reversed during the overload, endurance and interrupting tests".**
- This UL test requirement specifies that for MCC to be UL Listed for reverse-feed applications, samples shall be tested with the line and load terminals reverse-fed, as shown in Figure, **and that the test results shall be the same as those of "normally" fed circuit breakers.** Depending on the design configuration and construction, the circuit breaker may or may not be affected by the application of power in a reverse-feed connection during these tests.



- If Line / Load are not marked, we can connect Line or Load either on Top or bottom of MCB. However, it is a good practice to keep the fixed contact side connected to the bus bar.
- **For DC Circuit:**
- The Non polarized DC MCB have a No marking of '+' and '–' symbol
- Non polarized DC MCB operate safely as load breaking isolators and for fault current protection regardless of the direction of current flow through them.



Conclusion:

- When a MCB are marked "Line" and "Load," the power supply conductors must be connected to the marked "Line." These MCB cannot be reverse-fed.
- If "Line" and "Load" are not marked on MCB, the power supply conductors may be connected to either end. These devices are suitable for reverse-feed applications.

Type of breakers based on number of poles:

- Based on the number of poles, the breakers are classified as

1. SP – Single Pole
2. SPN – Single Pole and Neutral
3. DP – Double pole
4. TP – Triple Pole
5. TPN – Triple Pole and Neutral
6. 4P – Four Pole

(1) SP (Single Pole) MCB:

- In Single Pole MCCB, switching & protection is affected in only one phase.
- **Application:** Single Phase Supply to break the Phase only.

(2) DP (Double Pole) MCB:

- In Two Pole MCCB, switching & protection is affected in phases and the neutral.
- **Application:** Single Phase Supply to break the Phase and Neutral.

(3) TP (Triple Pole) MCB:

- In Three Pole MCB, switching & protection is affected in only three phases and the neutral is not part of the MCB.
- 3pole MCCB signifies for the connection of three wires for three phase system (R-Y-B Phase).
- **Application:** Three Phase Supply only (Without Neutral).

(4) TPN (3P+N) MCB:

- In TPN MCB, Neutral is part of the MCB as a separate pole but without any protective given in the neutral pole (i.e.) neutral is only switched but has no protective element incorporated.
- TPN for Y (or star) the connection between ground and neutral is in many countries not allowed. Therefore the N is also switches.
- **Application:**Three Phase Supply with Neutral

(5) 4 Pole MCB:

- 4pole MCCB for 4 wires connections, the one additional 4th pole for neutral wire connection so that between neutral and any of the other three will supply.
- In 4-Pole MCCBs the neutral pole is also having protective release as in the phase poles.
- **Application:** Three Phase Supply with Neutral

Difference between TPN and 4P (or SPN and DP):

- TPN means a 4Pole device with 4th Pole as Neutral. In TPN opening & closing will open & close the Neutral.
- For TPN, protection applies to the current flows through only 3 poles (Three Phase) only; there is no protection for the current flow through the neutral pole. Neutral is just an isolating pole.
- TP MCB is used in 3phase 4wire system. It is denoted as TP+N which will mean a three pole device with external neutral link which can be isolated if required.
- For the 4 pole breakers, protection applies to current flow through all poles. However when breaker trips or manually opened, all poles are disconnected.
- Same type of difference also applies for SPN and DP.

Where to Use TP, TPN and 4P in Distribution panel:

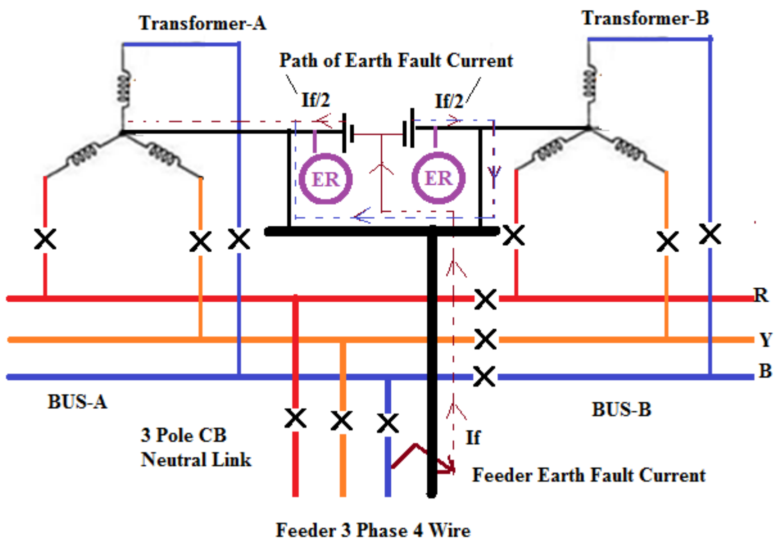
- For any Distribution board, the protection system (MCB) must be used in the incomer. For a three phase distribution paneleither TP or TPN or 4P can be used as the incoming protection.
- **TP MCB:** It is most commonly used type in all ordinary three phase supply.
- **TPN MCB**: It is generally used where there are dual sources of incomer to the panel (utility source and emergency generator source).
- **4P MCB:** It is used where is the possibility of high neutral current (due to unbalance loads and /or 3rd and multiple of 3rd harmonics current etc) and Neutral / Earth Protection is provided on Neutral.

Where to use 4 Pole or TPN MCB instead of 3 Pole (TP) MCB.

- **Multiple Incoming Power System:**
- When we have a transformer or a stand-by generator feeding to a bus, it is mandatory that at least either of the Incomers or the bus coupler must be TPN or 4-Pole Breaker please refers IS 3043.
- In multi incomer power feeding systems, we cannot mix up the neutrals of incoming powers to other Power Source so we can use TPN or 4P breakers or MCB instead of TP MCB to isolate the Neutral of other power sources from the Neutral of incomer power in use.
- We can use 4 Pole ACB instead of TP for safety reasons .If there is power failure and DG sets are in running condition to feed the loads, if there is some unbalance in loads(which is practically unavoidable in L.V. distribution system), depending of quantum of unbalance, there will be flow of current through Neutral. During this time, if Power Supply Utility Technicians are working, and if they touch the neutral conductors(which is earthed at their point) they will likely to get electric shock depending on the potential rise in common neutral due flow of current through Neutral conductor as stated above. Even fatal accident may occur due the above reason. As such, it is a mandatory practice to isolate the two Neutrals.
- We can use 4-pole breakers or TPN Breakers when the system has two alternative sources and, in the event of power failure from the mains, change-over to the standby generator is done. In such a case, it is a good practice to isolate the neutral also.
- 4 pole circuit breakers have advantages in the case when one of the poles of the device will get damage, and it also provides isolation from neutral voltage.
- Normally, Neutral is not allowed to break in any conditions, (except special applications) for human & equipment safety. Sofor single incomer power fed systems, 3P breaker is used, whereonly phases are isolated during breaking operations.
- Where We have dual Powerlike in DG & other electricity supply sources ,it is required to isolate neutral, where neutral needs to be isolated in internal network TPN MCB or 4P MCB can be used.

Where to use 4 Pole MCB instead of TPN MCB

- **Any Protection Relay used on Neutral (Ground Fault Protection of Double ended System):**
- The use of four poles or three poles CB will depend on system protection and system configuration.
- Normally in 3phase with neutral we just use 3pole CB and Neutral is connected on common Neutral Link but if application of 3pole will affect the operation of protective relay then we must use 4pole CB.
- System evaluation has to be required to decide whether three-pole circuit breakers plus neutral link can be used or four-pole breakers are required.
- If unrestricted ground fault protection is fitted to the transformer neutral, then the bus section circuit breaker should have 4-poles and preferably incomer circuit breakers should also have 4-polesbecause un cleared ground fault located at the load side of a feeder have two return paths. As shown in fig a ground fault on a feeder at the bus section "A" will have a current return path in both the incomers, thus tripping both Bus.The sensitivity of the unrestricted ground fault relay is reduced due to the split current paths.



- **For System Stability :**
- In an unbalanced 3phase system or a system with non-linear loads, the neutral gives the safety to the unbalanced loads in the system and therefore Itmust not be neglected. In perfectly balanced conditions the neutral functions as a safety conductor in the unforeseen short-circuit and fault conditions. Therefore by using 4-pole MCB will enhance the system stability.
- 4 Poles will be decided after knowing the Earthing Systems (TT, TN-S, TN-C, IT).
- **IT (with distributed neutral) System:**
- The Neutral should be switched on & off with phases.
- Required MCB: TPN or 4P MCB.
- **IT (without distributed neutral) System:**
- There is no neutral.
- Required MCB: TP MCB.
- **TN-S System:**
- Required MCB: TP MCB because even when neutral is cut off system remains connected with Ground.
- **TN-C System:**
- Required MCB: TPN or 4P only, because we cannot afford to cut neutraldoing so will result in system loosing contact with Ground.
- **TN-C-S System:**
- Neutral and Ground cable are separate
- Required MCB: TP MCB Because Neutral and Ground cable are separate.
- **TT System:**
- Ground is provided locally
- Required MCB: TP MCBbecause ground is provided locally.
- **Conclusion:** Its compulsory to use TPN in TN-C system rest everywhere you can use MCB.

Nomenclature of Distribution Board:

- Distribution Box can be decided by "way" means how many how many single phase (single pole) distribution. Circuit and Neutral are used.

1) SPN Distribution Board (Incoming+ Outgoing)

- 4way (Row) SPN = 4 X 1SP= 4Nos (Module) of single pole MCB as outgoing feeders.
- 6way (Row) SPN = 6 X 1SP= 6Nos (Module) of single pole MCB as outgoing feeders.
- 8way (Row) SPN = 8 X 1SP= 8Nos (Module) of single pole MCB as outgoing feeders.
- 10way (Row) SPN = 10 X 1SP= 10Nos (Module) of single pole MCB as outgoing feeders.
- 12way (Row) SPN = 12 X 1SP= 12Nos (Module) of single pole MCB as outgoing feeders.
- Normally single phase distribution is mainly used for small single phase loads at house wiring or industrial lighting wiring.

2) TPN Distribution Board (Incoming, Outgoing)

- 4way (Row) TPN = 4 X TP= 4nos of 3pole MCB as outgoing feeders =12 No of single pole MCB.
- 6way (Row) TPN = 6 X TP=6nos of 3pole MCB as outgoing feeders =18 No of single pole MCB.
- 8way (Row) TPN = 8 X TP=8nos of 3pole MCB as outgoing feeders =24 No of single pole MCB.
- 10way (Row) TPN = 10 X TP=10nos of 3pole MCB as outgoing feeders =30 No of single pole MCB.
- 12way (Row) TPN =12 X TP=12nos of 3pole MCB as outgoing feeders =36 No of single pole MCB

Chapter: 44 Type and Specification of Fuse

What is Fuses

- A fuse is a device that protects a circuit from an over current condition only. It has a fusible link directly heated and destroyed by the current passing through it. A fuse contains a current-carrying element so that the heat generated by the flow of normal current through it doesnot cause it to melt the element; however, when an over current or short-circuit current flowsthrough the fuse, the fusible link will melt and open the circuit.
- The Underwriter Laboratories (UL) classifies fuses by letters e.g. class CC, T, K, G, J, L, R, and so forth. The class letter may designate interrupting rating, physical dimensions, and degree of current limitation.

Construction of Fuse:

- The typical fuse consists of an element which is surrounded by filler and enclosed by the fuse body. The element is welded or soldered to the fuse contacts (blades or ferrules).
- **The Element:**The element provides the current path through the fuse. It generates heat at a rate dependent on its resistance and the load current.
- **Filler Materials:** The heat generated by the element is absorbed by the filler and passed through the fuse body to the surrounding air. The filler material, such as quartz sand, provides effective heat transfer and allows for the small element cross-section typical in modern fuses. The effective heat transfer allows the fuse to carry harmless overloads .The small element cross section melts quickly under short-circuit conditions. The filler also aids fuse performance by absorbing arc energy when the fuse clears an overload or short circuit.

Inverse Time Characteristic of Fuse:

- When a sustained overload occurs, the element will generate heat at a faster rate than the heat can be passed to the filler. If the overload persists, the element will reach its melting point and open. Increasing the applied current will heat the element faster and cause the fuse to open sooner. Thus, fuses have an inverse time current characteristic: that is **the greater the over current, the less time required for the fuse to open the circuit.**
- This characteristic is desirable because it parallels the characteristics of conductors, motors, transformers, and other electrical apparatus. These components can carry low-level overloads for relatively long periods without damage. However, under high-current conditions, damage can occur quickly. Because of its inverse time current characteristic, a properly applied fuse can provide effective protection over a broad current range, from low-level overloads to high-level short circuits.

Commonly Terms Used for Fuse:

(a) I2t (Ampere Square second):

- A measure of the thermal energy associated with current flow.
- **I2t = (I RMS) 2 X t,** where is the duration of current flow in seconds.
- A measure of thermal energy associated with current flow. It can be expressed as melting I2t, arcing I2t or the sum of them as Clearing I2t.
- Clearing I2t is the total I2t passed by a fuse as the fuse clears a fault, with t being equal to the time elapsed from the initiation of the fault to the instant the fault has been cleared.

(b) Melting I2t:

- Melting I2t is the minimum I2t required to melt the fuse element

(c) Clearing I2t:

- The total I2t passed by a fuse as the fuse clears a fault, with being equal to the time elapsed from the initiation of the fault to the instant the fault has been cleared.
- The minimum I2t required melting the fuse element.

(d) Interrupting Rating (Abbreviated I.R.)

- Same as breaking capacity or short circuit rating.
- The maximum current a fuse can safely interrupt at rated voltage. Some special purpose fuses may also have a "Minimum Interrupting Rating". This defines the minimum current that a fuse can safely interrupt.

- Safe operation requires that the fuse remain intact. Interrupting ratings may vary with fuse design and range from 35 amperes AC for some 250V metric size (5 x 20mm) fuses up to 200,000 amperes AC for the 600V industrial fuses.

(e) Ampere Rating:

- The continuous current carrying capability of a fuse under defined laboratory conditions. The ampere rating is marked on each fuse.

(f) Available Fault Current:

- The maximum short-circuit current that can flow in an unprotected circuit.

(g) Current limiting Range:

- Currents a fuse will clear in less than ½ cycles, thus limiting the actual magnitude of current flow.

(h) Element:

- A calibrated conductor inside a fuse that melts when subjected to excessive current. The element is enclosed by the fuse body and may be surrounded by an arc quenching medium such as silica sand. The element is sometimes referred to as a link.

(i) Fast acting Fuse:

- This is a fuse with no intentional time-delay designed into the overload range. It is sometimes referred to as a "single-element fuse" or "non-delay fuse."

(j) Fault Current:

- Short-circuit current that flows partially or entirely outside the intended normal load current path of a circuit component. Values may be from hundreds to many thousands of amperes.

(k) Current limiting Fuse:

- A fuse that meets the following three conditions:
- Interrupts all available over currents within its interrupt rating.
- Within its current limiting range, limits the clearing time at rated voltage to an interval equal to, or less than, the first major or symmetrical current loop duration.
- Limits peak let-through current to a value less than the available peak current. The maximum level of fault current that the fuse has been tested to safely interrupt.

(l) Arcing time

- The amount of time from the instant the fuse link has melted until the over current is interrupted.

(m) Clearing time

- The total time between the beginning of the over current and the final opening of the circuit at rated voltage by an over current protective device. Clearing time is the total of the melting time and the arcing time.

(n) Fast acting fuse

- A fuse which opens on overload and short circuits very quickly. This type of fuse is not designed to withstand temporary overload currents associated with some electrical loads. UL listed or recognized fast acting fuses would typically open within 5 seconds maximum when subjected to 200% to 250% of its rated current. IEC has two categories of fast acting fuses:
- F= quick acting, opens 10x rated current within 0.001 seconds to 0.01 seconds
- FF = very quick acting, opens 10x rated current in less than 0.001 seconds

(o) Overload

- Can be classified as an over current which exceeds the normal full load current of a circuit by 2 to 5 times its magnitude and stays within the normal current path.

(p) Resistive load

An electrical load which is characterized by not drawing any significant inrush current. When a resistive load is energized, the current rises instantly to its steady state value, without first rising to a higher value.

(q) RMS Current

- The R.M.S. (root mean square) value of any periodic current is equal to the value of the direct current which,flowing through a resistance, produces the same heating effect in the resistance as the periodic current does.

(r) Short circuit

- An over current that leaves the normal current path and greatly exceeds the normal full load current of the circuit by a factor of tens, hundreds, or thousands times.

(s) Time delay fuse

- A fuse with a built-in time delay that allows temporary and harmless inrush currents to pass without operating,but is so designed to open on sustained overloads and short circuits. UL listed or recognized time delay fuses typically open in 2 minutes maximum when subjected to 200% to 250% of rated current. IEC has two categories of time delay fuses:
- T= time lag, opens 10x rated current within 0.01 seconds to 0.1 seconds
- TT = long time lag, opens 10x rated current within 0.1 seconds to 1 second

(t) Voltage rating

- A maximum open circuit voltage in which a fuse can be used, yet safely interrupt an over current. Exceeding the Voltage rating of a fuse impairs its ability to clear an overload or short circuit safely.

(u) Over current

- A condition which exists in an electrical circuit when the normal load current is exceeded. Over currents take on two separate characteristics-overloads and short circuits.

(v) Threshold Current:

- The magnitude of symmetrical RMS available current at the threshold of the current-limiting range, where the fuse becomes current-limiting when tested to the industry standard.

(w) Threshold ratio:

- A threshold ratio is a relationship of threshold current to a fuse's continuous current rating.
- **Threshold Ratio = Fuse Threshold Current / Fuse Continuous Current.**
  Maximum threshold ratio for various types of fuses:

Fuse Class	Ratio
CLASS RK5	65
CLASS RK1	30
CLASS J	30
CLASS CC	30
CLASS L	30 (601-1200 Amps)
CLASS L	35(1201-2000 Amps)
CLASS L	40 (2001-4000 Amps)

- The current limiting characteristic depends on the threshold ratio and available fault current.
- Let's consider an example of 1500 kVA radial service feeding a fusible switchboard with 2000 amps class L fuses. As per ANSI C 57 [3] standard, a typical impedance value for this size of a transformer is 5.75%;
- All utility's network provides a specific fault current at a specific location which depends on various factors, e.g.; cable lengths, cable size, X/R ratio and etc. If we ignore this limitation and assume that there is an unlimited fault current available from a utility, then let's calculate short circuit current from a 1500 kVA transformer at 480 volts
- The formula to calculate short circuit current (Isc)
- **ISC = (KVA X 10,000) / (1.732 X VOLT X %Z).**
- ISC = 1500 X 10,000 / 1.732 X 480 X 5.75
- ISC = 31378.65 Amp.

Types of Fuse:

- A fuse unit essentially consists of a metal fuse element or link, a set of contacts between which it is fixed and a body to support and isolate them. Many types of fuses also have some means for extinguishing the arc which appears when the fuse element melts. In general, there are two categories of fuses.
- (1) Low voltage fuses.
- (2) High voltage fuses.
- Usually isolating switches are provided in series with fuses where it is necessary to permit fuses to be replaced or rewired with safety.
- In absence of such isolation means, the fuses must be so shielded as to protect the user against accidental contact with the live metal when the fuse is being inserted or removed.

(1) Low Voltage Fuse:

- Low voltage fuses can be further divided into two classes namely
- (a) Semi-enclosed (Rewireable type / Kit Kat Fuse).
- (b) Totally enclosed (Cartridge type).

a) Semi enclosed (Re wire able Type Fuse / Kit Kat Fuse):

- The most commonly used fuse in 'house wiring' and small current circuit is the semi-enclosed or rewire able fuse. (Sometime known as KIT-KAT type fuse). It consist of a **porcelain base** carrying the fixed contacts to which the incoming and outgoing live or phase wires are connected and a **porcelain fuse carrier** holding the fuse element, consisting of one or more strands of fuse wire, stretched between its terminals.
- The fuse carrier is a separate part and can be taken out or inserted in the base without risk, even without opening the main switch. If fuse holder or carrier gets damaged during use, it may be replaced without replacing the complete unit.

- **Fuse Element:**The fuse wire may be of lead, tinned copper, aluminium or an alloy of tin lead.
- The actual fusing current will be about twice the rated current. When two or more fuse wire are used, the wires should be kept apart and a de rating factor of 0.7 to 0.8 should be employed to arrive at the total fuse rating.
- The specification for re wire able fuses are covered by IS: 2086-1963. Standard ratings are 6, 16, 32, 63, and 100A.
- **A fuse wire of any rating does not exceeding the rating of the fuse.** We use 80 A fuse wire in a 100 A fuse, but not in the 63 A fuse. On occurrence of a fault, the fuse element blows off and the circuit is interrupted. The fuse carrier is pulled out, the blown out fuse element is replaced by new one and the supply can is resorted by re-inserting the fuse carrier in the base.
- **Advantages:**
- Easily removal or replacement without any danger of coming into the contact with a lie part.
- Negligible replacement cost
- **Disadvantages:**
- Unreliable Operations.
- Lack of Discrimination.
- Small time lag.
- Low rupturing capacity.
- No current limiting feature.
- Slow speed of operations.

b) Totally Enclosed(Cartridge Type Fuse)

- The fuse element is enclosed in a totally enclosed container and is provided with metal contacts on both sides. These fuses are further classified as

(i) D- Type Cartridges Fuses

- It is a non interchangeable fuse comprising fuse base, adapter ring, cartridge and a fuse cap. The cartridge is pushed in the fuse cap and the cap is screwed on the fuse base. On complete screwing the cartridge tip touches the conductor and circuit between the two terminals is completed through the fuse link. The standard ratings are 6, 16, 32, and 63 amperes.

- **Breaking or rupturing capacity**: 4k A for 2 and 4 ampere fuses the 16k A for 63 A fuses.
- **Ratings of D Type Cartridge fuses**: 2, 4, 6, 10, 16, 25, 30, 50, 63
- D-type cartridge fuse have none of the drawbacks of the re wire able fuses. Their operation is reliable. Coordination and discrimination to a reasonable extent and achieved with them.

(ii) Link type Cartridge or High Rupturing Capacity (HRC)

- Where large numbers of concentrations of powers are concerned, as in the modern distribution system, it is essential that fuses should have a definite known breaking capacity and also this breaking capacity should have a high value.

- High rupturing capacity cartridge fuse, commonly called HRC cartridge fuses, have been designed and developed after intensive research by manufactures and supply engineers in his direction.

- The usual fusing factor for the link fuses is 1.45. The fuses for special applications may have as low as a fusing factor as 1.2.
- **Knife Blade Type HRC Fuse:**

- It can be replaced on a live circuit at no load with the help of a special insulated fuse puller.
- **Bolted Type HRC Link Fuse:**

- It has two conducting plates on either ends. These are bolted on the plates of the fuse base. Such a fuse needs an additional switch so that the fuse can be taken out without getting a shock.
- **Ratings of HRC fuses**: 2, 4, 6, 10, 16, 25, 30, 50, 63, 80, 100, 125, 160, 200, 250, 320, 400, 500, 630,800, 1000 and 1,250 amperes.

Fuse Selection Guide:

- The fuse must carry the normal load current of the circuit without nuisance openings. However, when an over current occurs the fuse must interrupt the over current, limit the energy let-through, and withstand the voltage across the fuse during arcing. To properly select a fuse the followings must be considered:
- **Normal operating current**: The current rating of a fuse is typically de rated 25% for operation at 25C to avoid nuisance blowing. For example, a fuse with a current rating of 10A is not usually recommended for operation at more than 7.5A in a 25C ambient.
- Overload current and time interval in which the fuse must open.
- Application voltage (AC or DC Voltage).
- Inrush currents, surge currents, pulses, start-up currents characteristics.
- Ambient temperature.
- **Recommended UL Current Limiting Fuse Classes:**

TIME DELAY FUSE TYPE		
Class	**Voltage**	**Current**
Class-L (LCL)	600V AC	601 – 6000A
Class RK1 (LENRK)	250V AC	0.6 -600A
Class RK1 (LESRK)	600V AC	0.5 -600A
Class RK5 (ECNR)	250V AC	0.1 -600A
Class RK5 (ECSR)	600V AC	0.1 -600A
Class J (JDL)	600V AC	1 -600A
Class CC (HCTR)	600V AC	0.25 -10A

FAST ACTING TYPE FUSE (Non/time-delay)		
Class	**Voltage**	**Current**
Class-T (TJN)	300V AC	1 – 800A
Class-T (TJS)	600V AC	1 – 800A
Class-L (LCU)	600V AC	601– 6000A
Class-RK1(NCLR)	250V AC	1 – 600A
Class-RK1(SCLR)	600V AC	1 – 600A
Class J (JFL)	600V AC	1 -600A
Class CC (HCLR)	600V AC	0.1 -30A

Fuse Class:

1) Class L, fuses – (Safety where your circuit starts).

- They provide a minimum time delay of 4 seconds at 500% of their rated current to handle harmless inrush currents, plus they are 20% more current limiting than any other Class L fuse.
- That means optimal over current protection for service entrances, large motors, feeders and other circuits.
- Range from 601 to 6000 amperes, 600V AC, 300kA
- I.R., and an exclusive 500V DC, 100kA I.R., through 3000A.
- **Features**
- Fastest operation under short circuit conditions
- Most current limiting for lowest peak let-thru current
- Replaces all older Class L fuses
- Pure silver links for long fuse life
- AC and DC ratings
- High-grade silica filler for fast arc quenching
- **Applications**
- Mains and feeders , Large motors , Lighting, heating and general loads , Power circuit breaker backup
- UPS DC links, battery disconnects and other DC applications

2) Class J, fuses – (Compact fuses, big protection).

- The most current-limiting UL-class fuse, provide optimal performance, prevent interchange ability with old fuses, and save valuable panel space. So you can use smaller, more economical fuse blocks to provide superior protection for dedicated or combined motor, lighting, heating and transformer loads.
- Plus their time delay characteristic allows for use in a wide range of applications.
- Rated from 1 to 600 amperes, 600V AC, 300kA I.R., and 500V DC, 100kA I.R., listed to UL 248-8, they're the right fuses for any new installation.
- **Features**
- Most current-limiting UL-class fuses
- Timesaving Smart Spot™ indicator
- Unique dimensions prevent misapplications
- Optional mechanical indicator available on 70A to 600A AJT fuses
- **Applications**
- Motor circuits
- Mains and feeders
- Branch circuits
- Lighting, heating and general loads
- Transformers and control panels
- Circuit breaker backup
- Bus duct
- Load centres
- **Application notes**
- Mains and feeders: Can size at 125% of load for NEC and CEC code compliance.
- Motor starters: For typical starting duty and optimal coordination, fuse rating should not exceed 150% of motor FLA. Where "no-damage" tests have been conducted, follow the control gear manufacturer's fuse ampere rating recommendations.
- Lighting, heating and general loads: Can size at 125% of combined load for NEC and CEC code compliance.
- Transformers: Due to the high inrush currents that can be experienced with transformers, size fuse to carry 12 times transformer full load for 0.1 second and 25 times full load for 0.01 second.

3) Class RK1 fuses – (Upgrade to advanced technology).

- Significantly more current limiting than Class RK5, K and H fuses, upgrading your existing feeder and branch circuits to arc flash category "0". They also offer plenty of application flexibility, with ratings from 1/10A to 600A (250V or 600V), 300kA I.R.
- **Features**
- Highly current limiting to achieve HRC "0"

- Timesaving Smart Spot™ indicator
- Brass end caps (blade style) for cooler operation and superior performance
- Rejection-style design
- **Applications**
- Motors , Safety switches , Transformers , Branch circuit protection , Disconnects ,Control panels
- General-purpose circuits
- **Application notes**
- Mains and feeders: Can size at 125% of load for NEC and CEC code compliance.
- Motor starters: For typical starting duty and optimal coordination, fuse rating should not exceed 150% of motor FLA. Where “no damage” tests have been conducted, follows the control gear manufacturer’s fuse ampere rating recommendations.
- Lighting, heating and general loads: Can size at 125% of combined load for NEC and CEC code compliance.
- Transformers :Due to the high inrush currents that can be experienced with transformers, size fuse to carry 12 times transformer full load for 0.1 second and 25 times full load for 0.01 second.

4) Class CC, fuses – (Best small-motor protection).

- Choose our highly current-limiting fuses when you need maximum fault protection for sensitive branch circuit components and small motors. They deliver the best time delay characteristics and exceptional cycling ability for frequent motor starts and stops without nuisance opening. They’re available in 1/4A to 30A, 600VAC, 200kA I.R.
- **Features**
- Highly current limiting
- Best time-delay characteristics in a Class CC fuse
- Exceptional cycling ability for frequent motor stops and starts
- Rejection-style design
- **Applications**
- Small motors , Contactors , Branch circuit protection
- **Application notes**
- Motor starters: for typical starting duty. Where “no damage” tests have been conducted, follows the control gear manufacturer’s fuse ampere rating recommendations.
- Lighting, heating and general loads: Can size at 125% of combined load for NEC and CEC code compliance.

5) Class CC, fuses – (Optimal TC protection in the smallest package).

- Class CC fuses provides the time delay needed to handle the high inrush currents of control transformers, solenoids, and similar inductive loads.
- They’re available in 1/10A to 30A, 600V AC, 200kA I.R.
- **Features**
- Highly current limiting
- Rejection-style design
- Special time-delay characteristics for transformer loads
- **Applications**
- Control transformers , Solenoids , Inductive loads , Branch circuit protection
- **Application notes**
- Control transformers, solenoids and similar inductive loads: For control transformers 600V AC or less with ratings up to 2000VA.fuses are designed to handle 40 times the transformer’s primary full load amperes for 0.01 second.
- Lighting, heating and general loads: Can size at 125% of combined load for NEC and CEC code compliance.

6) Class RK5, fuses

- **Voltage / Ampere:** 250V (1A to 200Amp), 600V (3A to 200A)
- **Description:**
- The time delay characteristics of these fuses typically allows them to be sized closer to the running ampacity of inductive loads to reduce cost and improve over current protection
- **Application:**
- Use in AC power distribution system mains, feeders, and branch circuits.

- Recommended for high inrush inductive loads, like motors and transformers, and non inductive loads like lighting, and heating loads.

7) Class Midget fuses (600V, 0.5To 50A)

- **Description:**
- Provides supplemental protection to end-use equipment with a 100KA interruption rating, 600VAC. Fast acting design responds quickly to both overloads and short-circuit protection.
- **Application:**
- Recommended for control circuits, street lighting, HID lighting, and electronic equipment protection

8) Class Midget fuses (250V, 0.5To 50A)

- **Description:**
- Provides supplemental protection to end-use equipment with a 10,000A interruption rating, economical laminated paper tube
- **Application:**
- Recommended to use as supplemental protection for non inductive control loads and lighting circuits

9) Class Midget fuses (500V, 0.25To 30A)

- **Description:**
- Provides supplemental protection to high inrush loads. has a 10,000A interruption rating, 500VAC. Fiber tube construction.
- **Application:**
- Recommended to use as supplemental protection for inductive control loads such as transformers and solenoids.

10) Class Midget fuses (250V, 0.5To 30A)

- **Description:**
- Provides supplemental protection to high inrush loads. has a 10,000A interruption rating, fiber tube construction. Dual element allows harmless inductive surges to pass without opening
- **Application:**
- Recommended to use as supplemental protection for inductive control loads such as transformers and solenoids

11) Class 1 1/4" x 1/4" Ceramic (250,125V, 0.5To 30A)

- **Description:**
- Fast acting 1/4" x 1-1/4" ceramic tube construction.
- **Application:**
- Recommended to use as supplemental protection for inductive control loads such as transformers and solenoids.

12) Class 1 1/4" x 1/4" Glass (250,32V, 0.5To 30A)

- **Description:**
- Fast acting 1/4" x 1-1/4" glass tube construction.
- **Application:**
- Recommended as supplemental protection for electronic applications.

13) Class 5mmx20mm Glass (250,125V, 0.063To 15A)

- **Description:**
- Fast acting 5mmx20mm glass tube construction.
- **Application:**
- Recommended as supplemental protection for electronic applications.

14) Class 5mmx20mm Glass (250,125V, 0.5To 10A)

- **Description:**
- Medium Time Delay 5mm x 20mm glass tube construction.
- **Application:**
- Recommended as supplemental protection for electronic applications.

15) Class 1 1/4" x 1/4" Ceramic (250V, 0.5To 20A)

- **Description:**
- Time Delay 1/4" x 1-1/4" ceramic tube construction.
- **Application:**
- Recommended as supplemental protection for electronic applications.

16) Class 1 1/4" x 1/4" Glass (250,32V, 0.0625To 20A)

- **Description:**
- Time Delay 1/4" x 1-1/4" glass tube construction.
- **Application:** Recommended as supplemental protection for electronic applications

17) Class 5mmx20mm Glass (250V, 0.5To 10A)

- **Description:**
- Fast acting 5mm x 20mm glass tube construction
- **Application:**
- Recommended as supplemental protection for electronic applications.

18) Class 5mmx20mm Glass (250V, 0.25To 6.3A)

- **Description:**
- Time Delay 5mm x 20mm glass tube construction.
- **Application:**
- Recommended as supplemental protection for electronic applications.

Selection of Fuse for Main and Branch Circuits:

1) Transformer Circuit Fuses (NEC 450.3b, 240.3, 240.21, 430.72 (c) as required):

- (a) PRIMARY FUSES: Size fuses not over 125%. As exceptions exist, refer to the NEC
- Recommended fuses Time Delay- Class RK1, Class RK5, Class L, Class J)
- (b) SECONDARY FUSES (Sum of following): **125% of the continuous load + 100% of non-continuous load.** Fuse size not to exceed 125% of transformer secondary rated amps.

2) Branch Circuit Fuse Size, No Motor Load (NEC 240.3, 210.20):

- **100% of non-continuous load, +125% of continuous load.**
- Do not exceed conductor ampacity. Recommended fuses: LENRK, ECNR, NCLR, JDL, LCU.

3) Branch Circuit Fuse Size, No Motor Load (NEC240.3, 210.20):

- 100% of non-continuous load, + 125% of continuous load. Fuse may be sized 100% when used with a continuous rated switch. Recommended fuses same as 4.

4) Feeder Circuit Fuse Size, Mixed Load (NEC 240.3, 430.63, 430.24):

- (a) **100% of non-continuous, non-motor load + 125% of continuous, non-motor load.**
- (b) Determine non-continuous motor load (NEC430.22 (e).1.) Add to "a" above.
- (c) Determine A/C or refrigeration load. (NEC 440.6). Add to "a" above.
- (d) Feeder protective device shall have a rating or setting not greater than the rating of the largest branch device and sum of the FLCs of the other motors.(NEC 430.62)

5) Feeder Circuit Fuse Size, 100% Motor Load (NEC 240.3, 430.62 (a).

- (a)Determine non-continuous motor load (NEC430.22 (e).
- (b)Determine load of A/C or refrigeration equipment (NEC 440.6). Add to "a" above.
- (c) Feeder protective device shall have a rating or setting not greater than the rating of the largest branch device and sum of the FLCs of the other motors.(NEC 430.62)

6) Branch Circuit Fuse Size, Individual Motor Load, With Fuse Overload Protection (No Starter Overload Relays): (NEC 430.32, 430.36):

- (a) Motors with 1.15 Service Factor or temperature rise not over 40 Degrees C., size fuses at not more than 125% of the motor nameplate current rating.
- (b) For all other A-C motors, size fuses at not more than 115 %.
- (c) Best protection is obtained by measuring motor running current and sizing fuses at 125% of measured current for normal motor operation. Reference to "Average Time/Current Curves" is recommended.

7) .Branch Circuit Fuse Size, Individual Motor Load, With Starter Overload Relays: (NEC 430.32, 430.52):

- (a) For "back-up" NEC® overload, ground fault and short circuit protection size the fuses the same as (8 a, b) above, or the next standard size larger.

- (b) The fuse sizes in a) above may be increased as allowed by NEC® references. Generally, dual element fuses should not exceed 175% of motor nameplate F.L.A. and non-UL defined time-delay fuses not more than 300 %.

8) Fuse Sizing for Individual Large Motors With F.L.A. Above 480 Amps or Otherwise Require Class L Fuses - (NEC 430.52):

- **Application Tips:**
- Size fuses as closely as practical to the ampacity of the protected circuit components without the probability of unnecessary fuse opening from harmless, transient current surges. This usually requires a choice between time-delay and non-time-delay fuses.
- Use Class R fuse clips with Class R fuses to prevent installation of fuses with less interrupting rating or current limitation. Class H fuse reducers cannot be used with Class R fuse clips.
- When a conductor is oversized to prevent excess voltage drop, size the fuses for the ampacity of protected circuit components instead of over sizing fuses for the larger conductor.

Selection of Fuse for Motor Protection:

- Group installation is an approach to building multi-motor control systems in accordance with Section 430-53 of the National Electrical Code. The selection of components used in group installations is a simple process which consists of several steps.
- First is the selection of the appropriate fuse as Branch Circuit Protective Device (BCPD).
- Second is the selection of the appropriate motor starter and protector.
- Third, the selected MMP must be checked for UL listing with the selected BCPD and the available short circuit current at the application location.

1) Fused disconnect

- Calculate maximum fuse size according to NEC 430-53 (c).
- Imax (fuse size) =175% x FLC (full load current for largest motor) + the sum of FLC (full load current for largest motor) + the sum of FLC values for other motors on that branch using NEC Table 430-150 on the right.
- Select fuse from NEC Table 240-6 below. Where Imax falls between two fuse ampere ratings NEC 430-53 (c) permits going to the next high ampere rating.

2) Motor protector selection

- Select the proper MMP catalog number for each motor load from the based on the actual motor full load current (FLA) using the "Thermal setting range" column for reference.

3) MMP Interruption ratings

- Using the interruption ratings table on the next page, identify the system application voltage and interrupting capacity for the type of fuse selected in step1 above.
- **NEC 240-6 Standard fuse amperes 15, 20, 25, 30, 40, 45, 50, 60, 70, 80, 90, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600**
- Examples: Select components for protecting the following 3-phase, 460VAC, squirrel cage induction motors. The nameplate data are: 1/2 HP, 1.0 FLA; 3 HP, 4.8 FLA; 5 HP, 7.6 FLA; 7.5 HP, 11 FLA; 10 HP, 14 FLA.
- Example: using fused disconnect
- Imax = 175% x 14 + (11 + 7.6 + 4.8 + 1) = 48.9A
- Fuse rating using Table NEC 240-6 = 50A
- Minimum disconnect size = 115% x Total FLA
- NEC 430-150 table = 115% x (14+ 11 + 7.6 + 4.8 + 1) = 44.16
- Disconnect for 50A fuses is ok
- **NEC Table 430-150 full load current, 3ph AC motor**

H.P	Induction Type Motor (Squirrel Cage, Wound Type)		
	230V Amp	460V Amp	575V Amp
½	2	1	0.8
¾	2.8	1.4	1.1
1	3.6	1.8	1.4
1.5	5.2	2.6	2.1
2	6.8	3.4	2.7
3	9.6	4.8	3.9
5	15.2	7.6	6.1

7.5	22	11	9
10	28	14	11
15	42	21	17
20	54	27	22
25	68	34	27

Fuse Ratings

- Fuses with an A-C voltage rating may be applied at system voltages below the fuse voltage rating, but not at voltages above the fuse voltage rating.
- The other A-C fuse ratings remain the same at applied voltages below the fuse voltage rating.
- A-C rated fuses should not be applied in D-C voltage circuits unless D-C application ratings are provided by the fuse manufacturer.
- Except for some special purpose fuses, D-C ratings are not usually shown on fuse labels.
- The operating frequency (Hertz) will affect fuse characteristics in various ways.
- Time/Current Curves will not shift and fuse ratings will not change from 1-100 Hertz in normal applications. If ferrous hardware is used to mount the fuses, eddy current heating could alter the ratings.
- Above 100 Hertz, "skin effect" could alter the fuses' rating characteristics. This effect must be analyzed on an individual application basis.

Technical Specification for Rewire able Porcelain Cut out Fuse Unit

Electrical Characteristics & Performance:

- The rated currents of fuse carriers & fuse bases are 16A, 32A, 63A, 100A, 200A, 300A, 400A & 500A.
- The re- wire able fuses shall comply with IS : 2086 as amended from time to time up to date unless otherwise stated elsewhere in this specification.
- The rated breaking capacity of the fuses up to 16A rating is 2 KA and for above 16A rating the same shall be 4 KA, at a p.f. not exceeding 0.4 (lag).
- The fuses wire shall conform to IS: 9962:1981 or latest amendment thereof, if any.
- The fuses wire shall be surrounded by an asbestos/porcelain tube for tending distribution of temperature symmetrically. However, it may not be necessary for rating up to 100Amps.
- The ends of the tubes shall be baffled by the construction of the body & holder so that flame cannot emit.
- The length of the fuse wire & mass of the terminals shall be so designed to give desired current- time characteristics of the fuse wire.
- The continuous rating of tinned-copper fuse wire in semi-enclosed fuses shall not be greater than 60% of their minimum fusing current.
- The fuse shall glow within 30 minutes when carrying 1.9 times its rated current.
- The fuse shall carry 1.6 times rated current for at least 30 minutes.
- The fuses unit shall be capable of withstanding the let through fault current corresponding to prospective fault current.
- The fuse carrier shall be capable to carry following size of fuse wires(tinned Copper Wire):

Rated Current	Size of Fuse (mm)	Fusing Current
16Amps	0.5 mm	25 Amp
32Amps	0.9 mm	50 Amp
63Amps	1.6 mm	100 Amp
100Amps	2.0 mm	160 Amp
200Amps	2X2.3 mm	300 Amp
300Amps	2X3.2 mm	480 Amp
400Amps	2X3.66 mm	600 Amp
500Amps	2X4.0mm	800 Amp

Technical Specification for L.T Rewire able Porcelain Fuse Unit

1) Mounting-of Fuse Unit:

- The Fuse Unit can be mounted in an enclosed or open state at any angle on a vertical plain without impairing their performance.

2) Contacts:

- The contacts of Fuse Unit shall be robust construction and securely fixed on porcelain fuse base/ carrier and shall conform to the ; provision of IE Rule,1956 with latest amendments.
- Fixed and Moving Contact materials & other requirements: Annealed Electrolytic Copper duly electroplated with tin or silver to avoid oxidization above 500 C . For fuse up to 100A tin plating shall be used with 8-10 micron thickness of plating.
- Fixed contacts shall be of spring loaded reversible loop type for base & that for Moving contact (carrier) is knife contact type of 'U'SHAPE.
- The current density of contact material shall not exceed limit as per IS;2086;1993 or other applicable standard .
- The resistivity of contact material shall be less than0.017 micro ohm/meter.
- The melting point and specific heat of contact shall be 10800C & 375 J/KGK respectively.
- The magnitude of temperature rise of contacts at maximum ambient temperature of 400C for fixed & for carrier is 550C.
- The voltage drop cross contacts with carrier fully engaged with contacts shall not exceed the limit as stated in IS; 2086; 1993 or other applicable standards.
- The spring material of reversible loop base shall be of phosphor bronze.

3) Terminal Blocks:

- The terminal blocks shall be made of solid brass/solid copper alloy block of adequate mass to keep down the temperature of the fuse unit. The temperature rise of fuse contacts and terminals need be limited to lower values as far as possible up to 100% rated current for continuous operation to keep down the rate of contacts.
- Terminal blocks shall be of following sectional area and lengths to take cable connections by means of standard terminal screws up to 100A only. Above termination of Incoming/outgoing cables will be made extended copper strips of thickness not below the size specified as follows and also as stated in Annexure.

Rating	Min Acceptable Section Area (Including area of Hole)	Length (Min)	Dia of hole in Terminal Block and in extended Plate	Size of Extended Terminal Plate
16 Amps	60 mm2	9 mm.	4.5 mm	Nil
32 Amps	80 mm2	9 mm.	5.5 mm	Nil
63 Amps	200 mm2	9 mm.	9.5 mm	Nil
100Amps	300 mm2	9 mm.	12.6 mm	Nil
200 Amps	700 mm2	9 mm.	10 mm (In Ex.Plate)	5 x31 mm2
300 Amps	1000 mm2	9 mm.	12 mm (In Ex.Plate)	6 x41 mm2
400 Amps	1100 mm2	9 mm.	12 mm (In Ex.Plate)	6 x46 mm2
500 Amps	1200 mm2	9 mm.	16 mm (In Ex.Plate)	7 x50 mm2

- The hole in the Terminal Block shall be of appropriate diameter to receive Aluminum Conductor of rated current carrying capacity.
- The brass socket of alum cable should have identical curre4nt carrying capacity of that of the cable. The extended plates should be adequately electro-tinned and provided with hole/brass bolts and nuts/washer for termination of Incoming/outgoing cable.
- To eliminate hazards of accidentally touching live parts, the extended terminals may be either provided with protective enclosure (for extended pert only)or duly insulated with heat shrinkage PVC Tube.
- The heat shrinkage PVC covering should be of 1.1 KV Grade.
- The following are the recommended cable size for different current rating of fuse.

Fuse Rating	Size of Aluminum	Overall Dia of Conductor
16Amp	1X6 mm2	2.80 mm
16Amp	1X6 mm2	5.10 mm
32Amp	1X35 mm2	7.50 mm
100Amp	1X70 mm2	11.2 mm
200Amp	1X95 mm2	12.50 mm
300Amp	1X120 mm2 (2 No Parallel)	14.5 mm
400Amp	1X185 mm2 (2 No Parallel)	17.5 mm
500Amp	1X300 mm2 (2 No Parallel)	22.5 mm

4) Withdrawal Force:

Fuse Rating	Withdrawal Force
16Amp	0.5 To 2.5 Kg
32Amp	1.5 To 5.5 Kg
63Amp	3 To 10 Kg
100Amp	4 To 10 Kg
200Amp	15 To 70 Kg
300Amp	15 To 70 Kg
400Amp	20 To 80 Kg
500Amp	20 To 80 Kg

5) Insulation Resistance:

- The insulation resistance of the fuse carrier & base contacts measured at a voltage of 500V D.C. between the following parts shall be as under;
- Between live terminals and exposed metal parts-10 Meg.Ohm.
- Between live terminals and outgoing terminals-10 Meg.Ohm
- The power frequency withstand value shall be 2 KV r. m. s. for 1 minute for 1-phase 240V, 16A & for all rating of 500A, 3- Ph. ,4- Wire shall be 2.5 KV r. m. s. for 1 minute.

6) Constructional Features of the Fuse Unit:

- The Fuse unit can be mounted in enclosed or open state at any angle on a vertical plain without comparing their performance.
- The fuse unit shall be manufactured from the best quality of materials available indigenous.
- The constructional features of the fuse unit shall be in accordance with the following stipulations in general.
- One Fuse base made of porcelain containing fixed contact which shall be connected to fixed terminal and shall be so constructed to engage suitably with the carrier contact.
- The fixed contacts shall be of reverse loop type to prevent any tendency to throughout the fuse carrier under service conditions specified in IS; 2086;1993.
- The phosphor bronze leaf shall be used to achieve the desired pressure of contacts.
- One Fuse base made of porcelain containing contacts with fuse element. The carrier contacts shall be suitable for engaging with fixed contact and capable of having a fuse element attached to it. The fuse holder shall be of grip type. The carrier contacts shall be 'U' shaped and of knife contact design.

7) Porcelain:

- The fuse and carrier shall be made from good quality porcelain which is made from felspar (It serves as the fluxing or melting constituents), Quarts and chins clay.
- The thickness of porcelain shall be 15 mm. minimum at fuse base and 20 mm. minimum for the grip of the handle for the fuse carrier.

8) Thickness of Porcelain:

- The fuse base and carrier shall be of robust design so as to impart sufficient mechanical endurance strength and withdrawal force to sustain impact from blown fuse and handling throughout its life.
- The thickness of porcelain shall be 15 mm. minimum at fuse base and 20 mm. minimum for the grip of the handle for the fuse carrier.

9) Marking On Ceramics:

- Every fuse carrier shall have marking clearly and indelibly cast, attached or permanently marked in the intended manner outside surface visible to operator.
- Rated Current. / Rated voltage / Size of Fuse Wire / Nature of Supply.
- Manufacturers Trade/ Brand Name Mark.

10) Sealing:

- The holes in fuse carriers for fixing contacts shall be filled up with insulating grad ligur/epoxy based compounds to avoid accidental contact with the live parts.
- Live parts on the underside of the fuse base shall be either covered by a shield or barrier 3mm. below the surface of the base and covered with a water-proof insulating sealing compound which will not deteriorated or flow at a temperature lower than 1000C.

Chapter:45 How to select MCB / MCCB

Introduction:

- MCB or MCCB are widely used in electrical distribution system for ON/OFF Electrical supply and it also gives over current and short circuit protection. Selection of MCB or MCCB involved technical, Mechanical parameters. Some parameters are important but some parameters are confusing and mislead to wrong selection of MCCB. Some parameters are directly affected on cost of MCCB.

Specification / Name Plate Details of MCB/MCCB:

- Following specifications are required to select appropriate MCB or MCCB.

(A) Current Related:

- Frame Size (Inm): Amp
- Rated current (In/ Ie): Amp
- Ultimate short circuit breaking capacity (Icu): KA
- Rated short-circuit breaking capacity (Ics): % of Icu

(B) Voltage Related:

- Rated voltage (Ue): Volt
- Rated Insulation voltage (Ui): Volt
- Rated impulse withstand voltage(Uimp): KV
- No's of Pole : SP,DP,TP,TPN,FP

(C) Application Type:

- Utilization Category/ Characteristic : B,C or D curve

(D) Accessories:

- Rotary Handle: Extended/ Direct
- Alarm Contact:
- Shunt Trip:
- Under voltage Trip:
- Mechanical interlocking:
- Manual /Auto operation
- Motorized Operation:

(E) Protection Type:

- Protection : Over current / Short circuit
- Trip Mechanism: Thermal / Magnetic / Solid / Microprocessor
- Trip Mechanism adjustment : Fixed / Adjustable

(F) Others:

- Frequency;
- Reference temperature: (if different from 30°C)
- Pollution degree:
- Suitability for isolation:
- Type of Mounting arrangement
- Electrical Life Cycles:
- Mechanical Life Cycles:
- Dimension: mm
- Weight: Kg
- Reference Standard: IEC: 60947-1/2, IS: 13947-1/2

(A) Current Related:

(a) Frame Size (Inm):

- Breaker Frame Size indicates the basic framework of the Plastic shell of MCCB that can hold the biggest rated current.
- It is the maximum current value for which the MCCB is designed (upper limit of the adjustable trip current range) and it also determines the physical dimensions of the device.
- **There are varieties current ratings MCCB for the same series frame Size.**

- For example, DX100 Frame Size MCCB for rated current of 16A, 20A, 25A, 32A, 40A, 50A, 63A, 80A, 100A.
- Same DX225 Frame Size MCCB for rated current of 100A, 125A, 160A, 180A, 200A, 225A.
- In above DX100 and DX225 has two Type of frame Size for rated current of 100A, but the shape and size of breaking capacity of circuit breakers is not the same.

(b) Rated Current (In /Ie):

- It is the current value above which overload protection is tripped.
- For MCB it is fixed while in MCCB the rated current is an adjustable range instead of a fixed value.
- Standard rating of MCB is 1A, 2A, 3A, 4A, 6A, 10A, 13A, 16A, 20A, 25A, 32A, 40A, 50A, 63A, 100A for MCB.

(B) Voltage Related:

(a) Ultimate short-circuits breaking capacity (Icu):

- Breaking capacity can be defined as the maximum level of fault current which can be safely cleared.
- **It is the highest fault current that the MCCB can trip without being damaged permanently.**
- The MCCB will be reusable after interrupting a fault, as long as it doesn't exceed this value.
- It is indicate operation reliability of MCCB
- This parameter may increase or decrease the cost, so it should be properly decided. Breaking capacity should be higher than the possible fault level. For domestic application fault level may be 10kA.

(b) Operating short-circuits breaking capacity (Ics):

- It is expressed as a percentage ratio of Icu and tells you the maximum short-circuit current if a circuit breaker can break three times and still resume normal service.
- **The higher the Ics, the more reliable the circuit breaker**
- It is the maximum possible fault current that the MCCB can clear. If the fault current exceeds this value, the MCCB will be unable to trip and another protection mechanism must operate.
- If a fault above the Ics but below the Icu occurs, the MCCB can interrupt it successfully but will need a replacement due to the damage suffered.
- The Main difference between Ultimate Short Circuit (Icu) and Service Breaking Capacity (Ics) that Icu (Ultimate Braking Capacity) means Circuit breaker can remove the fault and remain usable but Ics (Service Braking Capacity) means Circuit breaker can remove the fault, but it may not be usable afterwards.
- For example, if a circuit breaker has an Ics of 25,000 Amperes and an Icu of 40,000 Amperes:
- Any fault below 25kA will be cleared with no problem.
- A fault between 25kA and 40kA will cause permanent damage when cleared.
- Any current exceeding 40 kA can't be cleared by this breaker.

(c) Rated working voltage (Ue):

- It is the continuous operation voltage for which the MCCB is designed.
- This value is typically equivalent or close to a standard system voltage.
- In three phase it is usually 400V or 415 V. For single phase it is 230V or 240V.

(d) Rated Insulation voltage (Ui):

- It is the maximum voltage that the MCCB can resist according to laboratory tests.
- It is higher than the rated working voltage, in order to provide a margin of safety during field operation.

(e) Rated impulse withstands voltage (Uimp):

- It is the value of transient peak voltage the circuit-breaker can withstand from switching surges or lighting strikes imposed on the supply.
- This value characterizes the ability of the device to withstand transient over voltages such as lightning (standard impulse 1.2/50 µs).
- Uimp = 8kV means Tested at 8 kV peak with 1.2/50µs impulse wave.

(f) Number of Poles:

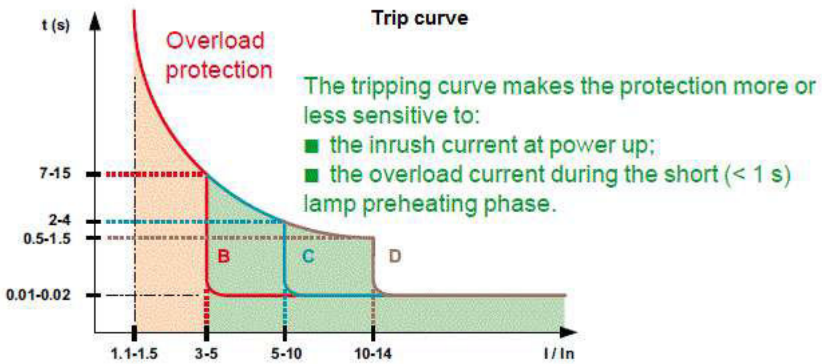
- No of Pole for MCCB depends on Single Phase & Three Phase Power Controlling /Protection
- **Single Pole (SP) MCB:**
- A single pole MCB provides switching and protection for one single phase of a circuit.
- Used: for Single Phase circuit
- **Double Pole (DP) MCB:**
- A two Pole MCB provides switching and protection both for a phase and the neutral.
- **Used:** for Single Phase circuit

- **Triple Pole (TP) MCB:**
- A triple/three phase MCB provides switching and protection only to three phases of the circuit and not to the neutral.
- Used: for Three Phase circuit
- **3 Pole with Neutral (TPN (3P+N) MCB):**
- A TPN MCB, has switching and protection to all three phases of circuit and additionally Neutral is also part of the MCB as a separate pole. However, Neutral pole is without any protection and can only be switched.
- Used: for Three Phase circuit with Neutral
- **4 Pole (4P) MCB:**
- A 4 pole MCB is similar to TPN but additionally it also has protective release for the neutral pole. This MCB should be used in cases where there is possibility of high neutral current flow through the circuit as in cases of an unbalanced circuit.
- **Used:** for Three Phase circuit with Neutral

(C) Application Type:

(a) Utilization category / Characteristic (B, C, D, K, Z curve):

- Characteristic of Trip curves of MCCB tell about the trip current rating of MCCB.
- MCB will trip instantaneously according to their Tripping Characteristic at 0.1 sec.
- There are various type of MCCB
- Type B MCCB
- Type C MCCB
- Type D MCCB
- Type K MCCB
- Type Z MCCB



Type B MCCB:

- **Operating Current:** This type of MCB trips between 3 and 5 times rated current (In).
- **Operating Time:** 0.04 To 13 Sec
- For example a 10A device will trip at 30-50A.
- **Application:** Domestic applications or light commercial applications where connected loads are primarily lighting fixtures, domestic appliances with mainly resistive elements.
- **Suitable for:** Resistive Load application (Lighting , Small Motor)
- **Surge Current:** The surge current level is relatively low.
- **Installation at:** At Sub feeder of Distribution Board.

Type C MCCB:

- **Operating Current:** This type of MCB trips between 5 and 10 times full load current.
- **Operating Time:** 0.04 To 5 Sec
- **Application:** commercial or industrial type of applications, fluorescent lighting, motors etc where there could be chances of higher values of short circuit currents in the circuit.
- **Suitable for:** Inductive Load application (Pumps, Motor, fluorescent lighting.)
- **Surge Current:** The surge current level is relatively moderate level.
- **Installation at:** At incoming / Outgoing of Distribution Board.

Type D MCCB:

- **Operating Current:** This type of MCB trips between 10 and 20 times full load current.

- **Operating Time:** 0.04 To 3 Sec
- **Application:** specialty industrial / commercial uses (Transformers or X-ray machines, large winding motors, discharge lighting, large battery charging). Where current inrush can be very high.
- **Suitable for:** Inductive-Capacitive Load application (Pumps, Motor)
- **Surge Current:** The surge current level is relatively High
- **Installation at:** At incoming of Distribution Board / Panels.

Type K MCCB:

- **Operating Current:** This type of MCB trips between 8 and 12 times full load current.
- **Operating Time:** 0.04 To 5 Sec
- **Application:** Suitable for inductive and motor loads with high inrush currents.
- **Surge Current:** The surge current level is relatively High
- **Installation at:** At incoming of Distribution Board / Panels.

Type Z MCCB:

- **Operating Current:** This type of MCB trips between 2 and 3 times full load current.
- **Operating Time:** 0.04 To 5 Sec
- **Application:** These types of MCBs are highly sensitive to short circuit and are used for protection of highly sensitive devices such as semiconductor devices.
- **Surge Current:** The surge current level is relatively too low
- **Installation at:** At Sub feeder of Distribution Board for IT equipments.

(D) Accessories:

(a) Rotary Handle:

- It is used to extend ON/OFF handle of MCCB when Panel Door is closed.
- It is also used to indicate ON/OFF or Trip Position

(b) Shunt Trip:

- Used for Remote Tripping

(c) Alarm contact:

- It gives Tripping Indication when MCCB Trip.
- It does not give when MCCB is in normal condition (either ON or OFF)

(d) Auxiliary contact:

- It used for remote signaling and control purpose.
- It is also give ON/OFF indication of MCCB at remote location.

(e) Under Voltage Tripping:

- It used to trip MCCB in under voltage condition (70 to 35% of rated Voltage).

(f) Mechanical Interlocking:

- It used to mechanical interlock of two MCCB on the same Panel.

(g) Manual / Auto:

- MCCB may have provision for Auto /Manual operation.
- An "auto/manual" switch in front of Panel.
- When set to the "Manual" position, lock out electrical control and when set to "auto", lock out the manual control; remote indication

(h) Motorized operation:

- MCCB may have option for manual operation or with a motor mechanism for electrically controlled operation.

(E) Others:

(I) Frequency:

- MCB is designed and used in AC power system of 50 to 60Hz.
- Electromagnetic force of magnetic release is related with power supply frequency so If Frequency is changed than electromagnetic fore of Magnetic element is changed hence MCCB tripping current will be different.
- If we used MCCB for protection in DC circuits than specially design DC circuit MCCB should be used rather than normal type of MCCB.

(II) Isolation:

- MCCB is suitability for visible isolation. It is particularly important.
- If a circuit breaker is turned off, it should indicate so visibly.
- It should not be able to indicate otherwise if the contacts are not open. In other words, it offers proof of isolation.

(III) Type of Mounting Arrangement:

- According to mounting arrangement, MCBs can be divided into two categories.
- DIN rail mount MCCB
- Plug-in MCCB
- **DIN Rail Mount MCB**
- The main advantage of this type of MCB is versatility
- DIN rails are used by many different types of electrical and communications equipment, and they are mainstream in industrial settings.
- They can be easily integrated into nearly any control or protection system.
- A disadvantage of this type of MCB is that more work is required for installation, and plug-in MCBs may be a better choice for simple installations.
- **Plug-In MCB**
- These MCBs are easy for installation. As name indicates, they just have to be plugged into a compatible electric panel.
- Plug-in MCBs are suitable for applications that use circuit breakers exclusively- typically residential and commercial electrical distribution systems.
- When using plug-in MCBs it is important that the breakers and the panel must match. It is not an issue when both are of the same brand

(IV) Pollution degrees:

- It determines in what kind of environment circuit breakers can be installed.
- In a Domestic purpose where there is no dust no humidity, the circuit breaker is comfortable.
- For Domestic purpose pollution degree 2 is suitable.
- But in an outdoor public installation where there may be dust which cause leakage currents and lead to dangerous arcs.

- For dusty pollution, humidity environment or outdoor type heavy-duty applications (incoming switchboards) pollution degree 3 is suitable.

(V) Energy Class:

- MCB need some time for tripping, In this time, fault current will create some energy which will exist in system.
- This energy is termed as release energy. For efficient MCB operation it should be in within limited. On basis of amount of release energy it is classified in class 1, class 2 and class 3.
- Class 3 is best which allows maximum 1.5L joule/second.

Example of MCB / MCCB specification / Name Plate:

Frame:	F750
Rated Operational Voltage (Ue):	415V
Rated Insulation Voltage (Ui) :	690V
Rated Impulse withstand Voltage (Uimp):	6KV
Rated Current (Ie) :	80A
Ultimate Breaking Capacity (Icu):	10KA
Service Breaking Capacity (Ics) :	75 % of Icu
Utilization Category :	A Type
No. of Poles:	3
Suitability for Isolation:	Yes
Electrical Life Cycles :	5000
Mechanical Life Cycles:	25000
Release Type :	Thermal – Magnetic
Thermal:	Fixed
Magnetic:	Fixed
Terminal Capacity Cable:	50 mm2
Dimensions (mm) WXHXD :	75X130X60
Weight:	0.84Kg
Operating Temp Range:	-5 to +50°C
Reference Temperature:	50°C

Main factors affected on cost for same rating of MCCB

- Short circuit Capacity
- No of Poles
- Type of Application (Characteristic Type)
- Type of Trip Mechanism (Thermal-Thermal-Magnetic, Solid, Microprocessor)
- Accessories

What should I select MCB or MCCB

- The selection of MCB or MCCB depends upon your application. Main difference between MCB and MCCB

Characteristics	MCB	MCCB
Standard	IEC60898-1	IEC60947-2
Rated current	6A to 100A	10A to 2500A.
Interrupting rating	Up to 18KA	10KA to 200KA
Trip Mechanism	Thermal / Magnetic	Thermal / Magnetic / Static
Trip characteristics Settings	Not adjusted	Fixed /Adjustable Thermal operated for overload and Magnetic operation for instant trip in Short circuit conditions
Application	Indoor Type	Indoor / Outdoor Type
Pollution Degree	0 to 2	3
Suitable for	Low current circuits (homes, shops, school and offices).	High power rating i.e. commercial and industrial use

User	This is designed for unskilled user / uninstructed user and not being maintained consequently	This is designed for skilled user and supposed to be maintained properly
Type of Protection	over current protection	over current / Short Circuit / Earth Fault protection
Mounting	Rail Mounted	Rail / Fixed / Draw out Mounted
Operating Mechanism	Electrical /Mechanical Operating	Electrical /Mechanical / Motorized Operating
		

- **Example:** what should we select MCB or MCCB for current carrying capacity 100A and breaking capacity 15KA and cost is a not main criteria.
- For this rating both MCB and MCCB are available so we should consider application and other facilities to choose MCB or MCCB.
- If we want to use it at indoor purpose, having less Space and if we do not need tripping adjustment and other function or accessories than MCB is best option.
- If we want to use it at indoor / Outdoor purpose, having Space and need tripping adjustment for coordination with other MCCB, We need Interlocking for safety and other function or accessories than MCCB is best option.

Characteristics	**IEC 60898-1 (MCB)**	**IEC 60947-2 (MCCB)**
Rated Current: In	6 – 125A	0.5 – 160A
SC Breaking Capacity	<25kA	<50kA
Rated Voltage: Ue	400V	440V, 500V, 690V
Impulse Voltage: Uimp	4kV	6kV – 8kV
Pollution Degree	2	3
Curves	B,C,D	B,C,D,K,Z,MA
Application Current	AC	AC or DC
Application	Residential	Residential / Commercial / Industrial

Chapter:46 Type of Tripping Mechanism of MCB / MCCB

Introduction:

- Moulded Case Circuit Breakers are electromechanical devices which manually / automatically protect / Open a circuit from Over current and Short Circuit. There is various type of Tripping mechanism to trip MCB/MCCB.

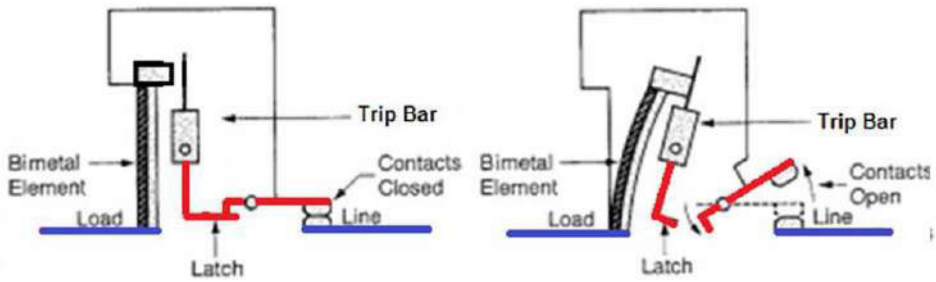
MCCB Tripping Mechanism:

- MCCBs have following various Operating Mechanisms these are given below

1) Thermal Trip
2) Magnetic Trip
3) Thermal- Magnetic Trip
4) Electronic Trip
5) Microprocessor Trip

(1) Thermal Trip Mechanism (Inverse-time)

- The thermal trip mechanism of MCCB works as a delay fuse.
- It will protect a circuit against a small overload that continues for a long time.
- In Thermal trip MCCB a bimetal strip is connected in series with the circuit load.



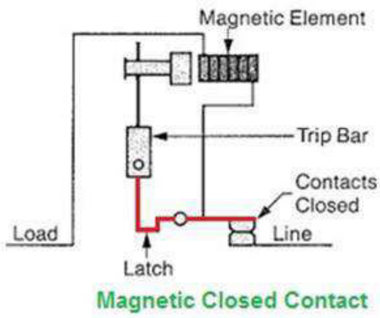
- When normal current pass through bimetallic strip and rise temperature of bimetallic strip and it increase length of bimetallic strip but this expansion rate is not enough for bending movement of strip and the contacts will remain closed.
- As current of MCCB increase beyond over load current. It heats enough bimetal and thus bimetallic strip bend as per current level and Close contact will be open.
- **The amount of current needed to trip the MCCB depends on the size of bimetallic Strip.**
- **The time the bimetal needs to bend and trip the circuit varies inversely with the current.**
- It has Inverse time characteristics, they allow a long-time delay on light overloads and they have a fast response on heavier overloads.
- The thermal element will also protect the circuit against temperature increases.
- It is Sensitive to ambient temperature
- MCCB must carry 100% of rated current continuously at 40 deg C.
- At 200% rated current, maximum trip times are

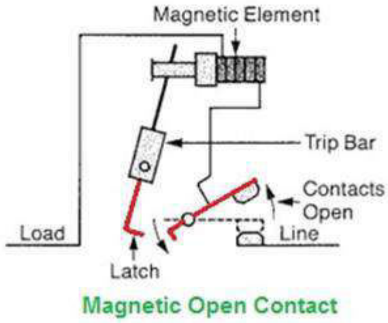
Trip Time of Thermal Element @200% current	
Amp Rating	**Max Time @ 200%**
0-30	2 min
31-50	4 min
51-100	6 min
101-150	8 min
151-225	10 min
1601-2000	28 min

- **Tripping Action:** Tripping Time will depend upon Current. The larger the overload, the faster the circuit breaker will trip
- **Used For:** Over Load Protection

(2) Magnetic Trip Mechanism (Instantaneous-trip)

- In magnetic trip MCCB an electromagnet (an iron core with a wire coil around it, forming an electromagnet) is in series with the circuit load.

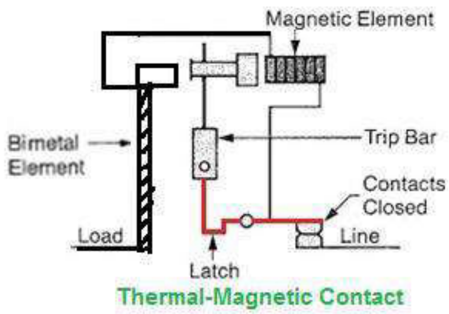




- With normal current, the electromagnet will not have enough electromagnetic field to attraction the trip bar for movement and the contacts will remain closed.
- As High current (Short Circuit) current through the coil increases the strength of the magnetic field of the electromagnet. As soon as the current in the circuit becomes large enough, the trip bar is pulled toward the magnetic element (electromagnet), the contacts are opened and the current stops.
- **The amount of current needed to trip the MCCB depends on the size of the gap between the trip bar and the magnetic element.**
- **On some MCCB this gap (trip current) are fixed and some MCCB are adjustable.**
- **Tripping Action:** A magnetic circuit breaker will trip instantly when the preset current is present.
- **Used For:** Short Circuit Protection

(3) Thermal-Magnetic Trip mechanism (inverse-time & instantaneous-trip)

- Thermal-magnetic circuit breaker (TMD) is most common use for over current and short circuit protection.
- It is a combination of Thermal Circuit breaker and Magnetic Circuit Breaker.
- It contain two different switching mechanisms, a bimetal switch and an electromagnet
- The thermal Property (Bimetal Strip gets elongated when heating) is used to sense the overload and Magnetic Property (Magnetic Flux / induction) is used to sense the short circuit.



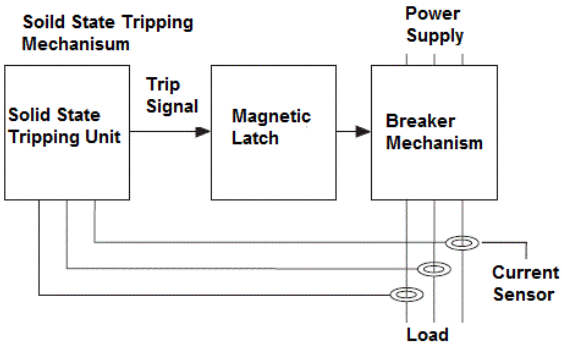
Characteristic:

- In Thermal-Magnetic Circuit Breaker both Thermal element (Bimetallic Strip) and Magnetic element (Electromagnet) are connected in series with load.
- In normal Load a bimetallic element is heated by the normal load current, the bimetallic element does not bend, and the magnetic element does not attract the trip bar.
- If the temperature or current increases over a sustained period of time, the bimetallic element will bend, push the trip bar and release the latch. The circuit breaker will trip.
- If the current suddenly or rapidly increases enough, the magnetic element will attract the trip bar, release the latch, and the circuit breaker will trip.
- Thermal Trip gives inverse time characteristic and Magnetic Circuit Breaker (instantaneous-trip circuit breakers) gives instantaneous-tripping.
- **MCCB Rating:** 10 A to 1600A
- **Operating Time:** 4mili sec.

- **Application:**
- For residential Load
- For to heavy industrial loads.
- For higher level (short circuit) over currents,
- For motor-circuit protection.
- AC/DC power distribution.
- Electrical machines
- Protection for transformers, motors, generators.
- For Protection of capacitor.
- **Protection Range:**
- The adjustable overload protection is from 70% to 100% of the nominal current (0.7 to 1xIn)
- Short circuit setting from 5 to 10 times of the rated current is possible.
- For example: A 100 A thermal-magnetic circuit breaker will trip within a short time if it is subjected to a current of 400 A, but a 100 A instantaneous-trip circuit breaker will carry that overload indefinitely, if the adjustable trip is set above that level.
- Instantaneous-trip circuit breakers are circuit breakers that have a magnetic trip function but not a thermal trip function. They are designed for one very specific purpose, that being to provide branch-circuit short-circuits protection for motor circuits.
- **Advantage:**
- economical, tried and tested technology
- **Disadvantage:**
- The operating characteristics of the breaker may vary depending on the ambient temperature.
- It needs particular time to trip (heat up the metallic strip > open circuit the holding coil > opens the contacts
- Provide less flexibility of adjustment than electronic releases.

(4) Electronic (Static) Trip Mechanism:

- A coil, placed on each conductor, continuously measures the current in each of them.
- This information is processed by an electronic module which controls the tripping of the circuit breaker when the values of the settings are exceeded.
- Both the overload trip action and the short-circuit trip action of breakers with electronic trip units are achieved by the use of current transformers and solid-state circuitry that monitors the current and initiates tripping through a flux shunt trip when an overload or a short circuit is present.
- **MCCB Rating:** 20 A to 2500A
- **Operating Time:** 4mili sec.
- **Protection Range:**
- The adjustable overload protection is from 60% to 100% of the nominal current (0.6 to 1xIn)
- Short circuit setting from 2 to 10 times of the rated current is possible.

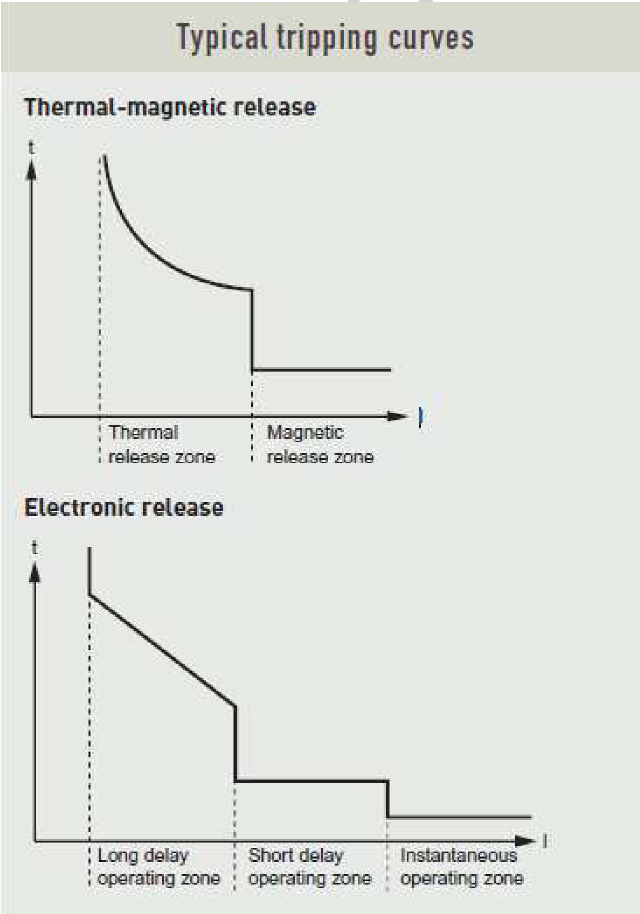


- **Advantage:**
- The operating characteristic of the breaker is independent of the ambient temperature.
- More accurate and more flexible settings
- Becoming standard for larger size breakers
- Ground fault easy to provide
- It has wide flexibility to takes care of future increases in load capacity of an installation and ensures better planning at an optimum cost

- **Disadvantage:**
- It is costly compare to TMD Type MCCB.
- **Application:**
- Electronic trip breakers are generally applied for applications where high levels of system coordination.
- Electronic trip breakers can provide superior protection and coordination as well as system alarms and diagnostics, monitoring and communications.

(5) Microprocessor Trip Mechanism:

- In Microprocessor type tripping mechanism release, sensing and tripping executed by Microprocessor by use of CT or current sensing resistor
- It gives the very faster response than TMD Release.
- **MCCB Rating:** 20 A to 2500A
- **Operating Time:** 4mili sec.
- **Protection Range:**
- The adjustable overload protection is from 60% to 100% of the nominal current (0.6 to 1xIn)
- Short circuit setting from 2 to 10 times of the rated current is possible.
- **Advantage:**
- System Diagnosis is possible as it stores the Trip history within the internal memory.
- Trip current indication is also available for understanding of type of fault and set-up programming at site.
- High repeat accuracy and High reliability.
- Provide coordination, Interlocking to other MCCB.
- High Flexibility
- **Disadvantage:**
- It is costly compare to TMD Type MCCB.



Chapter: 47 Setting of overload, short circuit & Ground Fault Protection of MCCB

Introduction:

- There are various types of protections setting in MCCB, which define various protection of Electrical Network.
- In MCCB we can set most of protection are adjustable according to Electrical Load profile.
- The main adjustable Setting in MCCB are
- Over current Setting
- Short Circuit Setting
- Ground Fault Setting

Meaning of each selector switches of MCCB

- As Per Standard IEC 60947-2 defines the names of the selector switches.

Setting	Adjustment	Protection For
Ir	Long time Pick up Current Setting (or thermal Setting). This is a multiplication coefficient of the rating of the device. **(Ir=xIn)**	Protection against overloads
tr	Long time delay Setting in seconds, enabling in particular the starting current of a motor to be tolerated. **(tr=Sec)**	Protection against overloads
Im / Isd	Short time (Magnetic Setting). This is a multiplier of the Ir setting, often 1.5 to 10 times the Ir current **(im=xIr)**	Protection against short circuits.
tm / tsd	Short time delay Setting, enabling in particular the discrimination (time) to be increased with downstream feeders and the magnetization peaks of a transformer or a motor to be tolerated. It is recommended that the I^2t selector switch is set to the ON position. **(tm=Sec)**	Protection against short circuits.
Ii	Instantaneous current Setting. Protecting the installation against strong short circuits (dead short circuits) by instantaneous tripping without Time Delay and self-protection of the circuit breaker. The **Ii > Isd.**	Protection against Dead Short circuits.
Ig	for monitoring the earth fault current circulating in the Phase and Earth conductor in TNS systems	Earth protection
tg	Earth protection time delay	Earth protection
I delta n	Adjustment of the sensitivity of the earth leakage protection	Earth leakage protection
delta t	Earth leakage protection delay.	Earth leakage protection

Setting of each Protection switch of MCCB

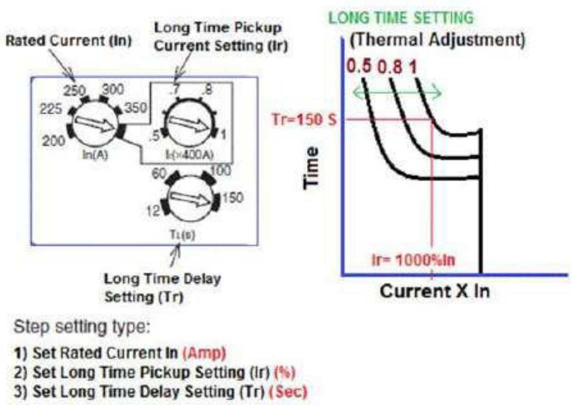
(1) For Low level Fault / Over Current Protection (Thermal Setting):

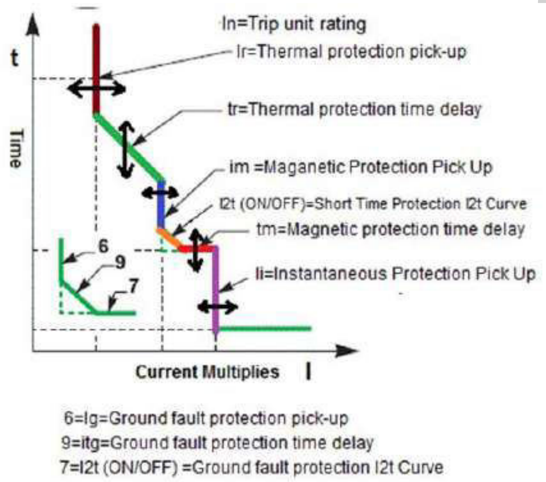
(a) Long-Pickup Current Setting (Ir):

- It is determines the continuous ampere rating of the breaker.
- Long time protection is time-dependent.
- Long Pickup (Ir) value (multiplied by the ampere rating (In) of MCCB) sets the maximum current level which the circuit breaker will carry continuously.
- If MCB is 1000A Rating but Full Load current is 800A than MCCB Rating can be changed from 1000A to 800A by setting it 0.8, Now Ir=0.8XIn =0.8x1000=800Amp
- If the current exceeds this value for longer than the circuit breaker will trip at the set delay time.
- Long time protection is inverse time type (with I2t constant)
- The long-time pickup (Ir) is adjustable from **0.4 to 1.0 times the sensor plug rating (In)**
- **Standard Practice for Setting:**
- No trip for a current below 105% of Ir
- Trip in less than two hours for a current equal to for
  a) 120% of Ir for an electronic trip unit and for
  b) 130% of Ir for a thermal-magnetic trip unit
- For a higher fault current, the trip time is inversely proportional to the fault current value.

(b) Long-Time delay Setting (tr):

- Long time delay (tr) sets length of time that the circuit breaker will carry a sustained overload before tripping.
- The delay bands are labeled in seconds of over current at six times the ampere rating.
- Long-time delay is an inverse time characteristic in that the tripping time decreases as the current increases.
- The long-time delay (tr) sets the length of the time that the circuit breaker will carry an over current (below the short-time or instantaneous pickup current level) before tripping.
- The Long time delay can be set to I2t On and I2t OFF settings.
- (A) I2t Response:I2t Out ,For coordination with other circuit breakers with electronic trip devices and for coordination with thermal-magnetic circuit breakers.
- (B) I2t Response: I2t In ,For coordination with fuses and upstream transformer





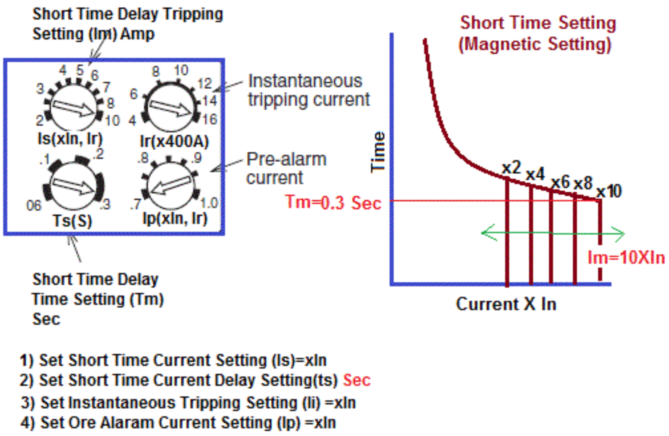
(2) For Short Circuit Protection (Magnetic Setting):

(a) Short Time pickup Current Setting (Im):

- Short time protection is time-independent.
- It is determines or sets the level of fault current at which the short-time trip delay countdown is actuated.
- Short Time Pick up Value (Im) (multiplied by the ampere rating) sets the short circuit current level at which the circuit breaker will trip after the set time delay.
- The short-time pickup (Isd) sets current level (below instantaneous trip level) at which circuit breaker will trip after the preset time delay.
- **Standard Practice for Setting:**
- No trip for a current below 80% of the short time setting
- Trip for a current equal to 120% of the short time setting
- The trip time is Less than 0.2 s for a short time protection with no time delay and equal to the value of the time delay tsd for a protection with time delay

(b) Short time delay Setting (tm):

- Short Time delay sets the amount of time the breaker will carry both a low level and high fault currents before tripping.
- tm sets length of time the circuit breaker will carry a short circuit within the short-time pickup range.
- Delays bands are labeled in seconds of short-circuit current at 10 times the ampere rating.
- The short time delay can be set to I2t On and I2t OFF settings (Inverse Time Delay).
- (A) **I2t OFF: Gives Constant time delay** usually in multiplication of 0.5 sec. It has not inverse-time delay Characteristic. It is used for coordination with other circuit breakers with electronic trip devices and for coordination with thermal-magnetic circuit breakers.
- (B) **I2t ON :Gives an inverse-time delay** that resembles the time/current characteristics of fuse It is used for coordination with fuses and upstream transformer



(3) For Instantaneous Trip (Short Circuit Protection):

(a) Instantaneous Pickup Setting (Ii):

- Instantaneous protection is time-independent.
- It is determines the level of fault current that will actuate a trip with no time delay.
- Ii value (multiplied by the ampere rating (In)) sets the short-circuit current level at which the circuit breaker will trip with no intentional time delay.
- This protection trips to eliminate quickly high value currents and its trip times cannot be set
- The instantaneous function will override the short-time function if the instantaneous Pickup is adjusted at the same or lower setting than the Short Time Pickup.
- **Standard Practice for Setting:**
- No trip for a current below 80% of the instantaneous setting
- Trip for a current equal to 120% of the instantaneous setting
- The trip time is less than 0.2 second.

(4) For Ground Fault Protection:

Ground Fault (G)

- **Ground Fault Pickup Setting (Ig):**
- It is determining the level of fault current at which the ground fault trip delay countdown is actuated.
- **Ground Fault Delay Setting (Itg) :**
- It is determines the amount of time the breaker will carry a ground fault before tripping.
- It can be set to I2t On and I2t OFF settings.
- (A) I2t Response:I2t Out ,For coordination with other circuit breakers with electronic trip devices and for coordination with thermal-magnetic circuit breakers.
- (B) I2t Response: I2t In ,For coordination with fuses and upstream transformer

Example for Settings of MCCB for Protections

- **Example1:** We have Sub feeder MCCB Size of 2000A, Short Circuit Current is 4000A. Maximum Load Current is 1000A .What is Over current (Long Time) and Short Circuit (Short Time) and Instantaneous setting of MCCB.
- Here In=2000A

Over current Setting:

- Dial Setting=(Load current / MCB Rating) =1000/2000=0.5 , set Dial at 0.5
- Over current Setting Ir=0.5xIn =0.5X2000=1000A
- For Set Over Current Time Delay: It is necessary to overview Over current Time delay of downstream MCCB and Upper stream MCCB for better coordination otherwise for downstream fault upper stream MCCB gives tripping.
- **Downstream Over current Time Delay< Over current Time Delay< Upper stream Over current Time Delay.**
- In Our example it is last MCCB in circuit and upper stream MCCB Over current delay setting is 2 Sec so Select tr=1 Sec.

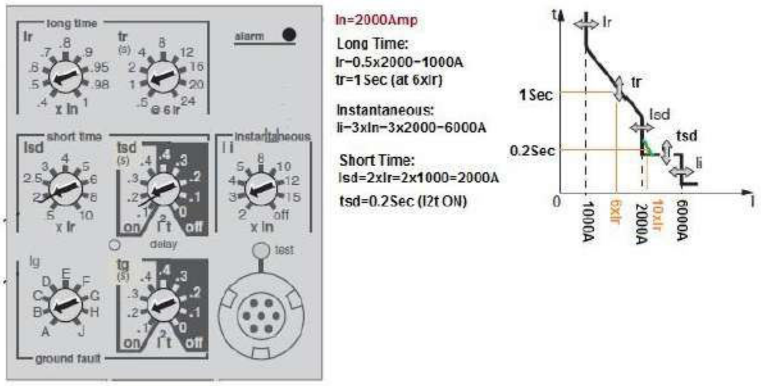
Short Circuit Current Setting:

- Dial Setting=(Short Circuit Current/ MCB Rating) =4000/2000=2

- Short Circuit Setting Isd=2xIn=2x2000=4000A
- **Downstream Short current Time Delay< Short current Time Delay < Upper stream Over current Time Delay Short current Time Delay**
- Our example it is last MCCB in circuit and upper stream MCCB Short Circuit current delay setting is 0.4 Sec so Select Isd=0.2Sec.
- For coordination of other MCCB we need I2t ON with 0.2 Sec delay.

Instantaneous Tripping Setting:

- Instantaneous Tripping gives instant tripping without any delay for switching or short Circuit current.
- **Instantaneous Tripping >= Short Circuit Tripping Setting**
- If We can set Ii=3xIn =3x2000=6000A , It will full fill our requirement
- Here Ii>Isd=6000A>4000A.

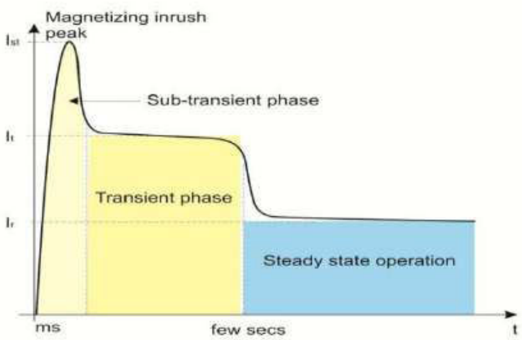


Example for Setting of MCCB for Motor Circuit

- When we select an MCCB for motor application, it is necessary that the instantaneous release setting in the MCCB is set to a value higher than the highest anticipated Motor magnetizing inrush current during switching-on the motor.
- The values for magnetizing inrush current (sub transient current) are higher in case of high efficiency motors as compared to standard efficiency motors.
- By theoretical and empirical means it is established that the maximum ratio between peak and LRC can go up to 2.5 for high efficiency motors.

Motor Starting Current:

- Motor starting current is one of the most important electrical parameter of motor to understand its electrical characteristics.
- It is important to note the distinction between inrush current and starting current
- The current drawn by the motor in different phases are.
  1. Inrush Current (Sub transient phase)
  2. Starting or Lock Rotor Current (Transient phase)
  3. Steady state operation.



Inrush Current (Sub transient phase)

- During the initial phase of motor starting Current drawn by motor is known as inrush current or peak current.

- Inrush current is the current drawn between switch on and when the magnetic fields are established in the motor this current is due to magnetizing inrush component of the motor starting current.
- **Inrush Current:** It is generally 13 to 17 x FLA for older motors to New Motor.
- **The duration of inrush current:** It is in milliseconds.
- Motor circuits are highly inductive. Motor can be started at any point on voltage wave of the circuit. Depending on the initiation of the circuit i.e. point on the voltage wave.
- The magnitude of the asymmetry is directly related to X/R ratio of the circuit.

Starting Current (Transient phase)

- Motor starting current or Lock Rotor Current is the current drawn while Motor is accelerating to full speed.
- **Starting Current:** It is depend upon Starting method of Motor
- For DOL Starter : 6 to 8 x FLA
- Star- Delta: 2 to 3 x FLA
- Auto Transformer: 2 to 3 x FLA
- Soft Starter: 3 to 5 x FLA
- VFD: 1.5 x FLA
- The duration of Starting current: Depend upon Load and Application (10 To 40 Sec)

The Magnetic Settings for Motor should be as follows:

- **Motor Starting Current < Magnetic Setting of MCCB < Short Circuit Current**
- The MCCB should not trip during starting of the motor. Therefore setting should be 1.3 times the starting current. Normally the starting current will be 6 times the full load current of the motor. Therefore it will be 7.8 times the full load current.
- However you have to calculate the short circuit current at the motor terminal. This depends on source fault level at the bus feeding the motor and cable impedance between the MCCB and motor. The setting on the MCCB should be less than the calculated short circuit current.
- **Motor Acceleration Time < Magnetic Time Setting of MCCB**
- Another important consideration is the acceleration time should be less than the time set on the MCCB for the magnetic setting.

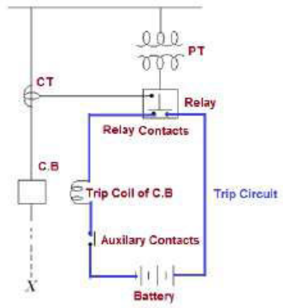
Chapter:48 Type and Revolution of Electrical Relay

Introduction:

- Protective relays work in concert with sensing and control devices to accomplish their function. Under normal power system operation, a protective relay remains idle and serves no active function. But when fault or undesirable condition arrives Relay must be operated and function correctly.
- A Power System consists of various electrical components like Generator, transformers, transmission lines, isolators, circuit breakers, bus bars, cables, relays, instrument transformers, distribution feeders, and various types of loads. Faults may occur in any part of power system as a short circuit & earth fault. Fault may be Single Line to Ground, Double Line to Ground, Line to Line, three phase short circuit etc. This results in flow of heavy fault current through the system. Fault level also depends on the fault impedance which depends on the location of fault referred from the source side. To calculate fault level at various points in the power system, fault analysis is necessary.
- The protection system operates and isolates the faulty section. The operation of the protection system should be fast and selective i.e. it should isolate only the faulty section in the shortest possible time causing minimum disturbance to the system. Also, if main protection fails to operate, there should be a backup protection for which proper relay co-ordination is necessary. Failure of a protective relay can result in devastating equipment damage and prolonged downtime.

Working of Protective Scheme:

- Protective relaying senses the abnormal condition in a part of power system and gives an alarm or isolates that part from healthy system. Protective relaying is a team work of CT, PT, protective relays, time delay relays, trip circuits, circuit breakers etc.
- Protective relaying plays an important role in minimizing the faults and also in minimizing the damage in the event of faults.



- Figure shows basic connections of circuit breaker control for the opening operation. The protected circuit X is shown by dashed line. When a fault occurs in the protected circuit the relay connected to CT and PT actuates and closes its contacts.
- Current flows from battery in the trip circuit. As the trip coil of circuit breaker is energized, the circuit breaker operating mechanism is actuated and it operates for the opening operation. Thus the fault is sensed and the trip circuit is actuated by the relay and the faulty part is isolated.

What is Relay:

- A relay is automatic device which senses an abnormal condition of electrical circuit and closes its contacts. These contacts in turns close and complete the circuit breaker trip coil circuit hence make the circuit breaker tripped for disconnecting the faulty portion of the electrical circuit from rest of the healthy circuit.

Functions of protective relaying:

- To sound an alarm or to close the trip circuit of a circuit breaker so as to disconnect Faulty Section.
- To disconnect the abnormally operating part so as to prevent subsequent faults. For e.g. Overload protection of a machine not only protects the machine but also prevents Insulation failure.
- To isolate or disconnect faulted circuits or equipment quickly from the remainder of the system so the system can continue to function and to minimize the damage to the faulty part. For example - If machine is disconnected immediately after a winding fault, only a few coils may need replacement. But if the fault is sustained, the entire winding may get damaged and machine may be beyond repairs.

- To localize the effect of fault by disconnecting the faulty part from healthy part, causing least disturbance to the healthy system.
- To disconnect the faulty part quickly so as to improve system stability, service continuity and system performance. Transient stability can be improved by means of improved protective relaying.
- To minimize hazards to personnel

Desirable qualities of protective relaying:

- Selectivity,
- Discrimination
- Stability
- Sensitivity,
- Power consumption
- System Security
- Reliability
- Adequateness
- Speed & Time

Terminology of protective relay:

- **Pickup level of actuating signal:** The value of actuating quantity (voltage or current) which is on threshold above which the relay initiates to be operated. If the value of actuating quantity is increased, the electromagnetic effect of the relay coil is increased and above a certain level of actuating quantity the moving mechanism of the relay just starts to move.
- **Reset level:** The value of current or voltage below which a relay opens its contacts and comes in original position.
- **Operating Time of Relay:** Just after exceeding pickup level of actuating quantity the moving mechanism (for example rotating disc) of relay starts moving and it ultimately close the relay contacts at the end of its journey. The time which elapses between the instant when actuating quantity exceeds the pickup value to the instant when the relay contacts close.
- **Reset time of Relay:** The time which elapses between the instant when the actuating quantity becomes less than the reset value to the instant when the relay contacts returns to its normal position.
- **Reach of Relay:** A distance relay operates whenever the distance seen by the relay is less than the pre-specified impedance. The actuating impedance in the relay is the function of distance in a distance protection relay. This impedance or corresponding distance is called reach of the relay.

History and Revolution of Protective Relay:

- The evolution of protective relays begins with the electromechanical relays. Over the past decade it upgraded from electromechanical to solid state technologies to predominate use of microprocessors and microcontrollers.
- The timeline of the development of protective relays is shown below

1900 to 1963	1963 to 1972	1972 to 1980	1980 to 1990
Electromechanical Relay.	**Static Relay**	**Digital Relay**	**Numerical Relay**
1925=Single Disc Type Relay (Single Input)	1963=Static Relay (All Purpose)	1980=Digital Type Relay (All Purpose)	1990=Numerical Type Relay (All Purpose)
1961=Single Cup Type Relay (Impedance Relay)	1972=Static Relay with self checking (All Purpose)		

Types of Relays:

- Types of protection relays are mainly

(A) Based on Characteristic:

1. Definite time Relays.
2. Inverse definite minimum time Relays (IDMT)
3. Instantaneous Relays
4. IDMT with Instantaneous.
5. Stepped Characteristic
6. Programmed Switches

7. Voltage restraint over current relay

(B) Based on logic:

1. Differential
2. Unbalance
3. Neutral Displacement
4. Directional
5. Restricted Earth Fault
6. Over Fluxing
7. Distance Schemes
8. Bus bar Protection
9. Reverse Power Relays
10. Loss of excitation
11. Negative Phase Sequence Relays etc.

(C) Based on Actuating parameter:

1. Current Relays
2. Voltage Relays
3. Frequency Relays
4. Power Relays etc.

(D) Based on Operation Mechanism:

1. Electro Magnetic Relay
2. Static Relay
   - i. Analog Relay
   - ii. Digital Relay
   - iii. Numerical /Microprocessor Relay
3. Mechanical relay.
   - i. Thermal
     (a) OT Trip (Oil Temperature Trip)
     (b) WT Trip (Winding Temperature Trip)
     (C) Bearing Temp Trip etc.
   - ii. Float Type
     (a) Buchholz
     (b) OSR
     (c) PRV
     (d) Water level Controls etc.
   - iii. Pressure Switches.
   - iv. Mechanical Interlocks.
   - v. Pole discrepancy Relay.

(E) Based on Applications:

1. Primary Relays.
2. Backup Relays.

Type of Relay based on Relay Operation Mechanism:

(1) Electromagnetic Relay:

- Electromagnetic relays are further categorized under two following categories.

(A) Electromagnetic Attraction Relay:

- This Relay works on Electromagnetic Attraction Principle

(B) Electromagnetic Induction Relay:

- This Relay works on Electromagnetic Induction Principle

(2) Solid State (Static) Relay:

- Solid-state (and static) relays are further categorized under following designations.

(A) Analog Relay:

- In Analog relays are measured quantities are converted into lower voltage but similar signals, which are then combined or compared directly to reference values in level detectors to produce the desired output.

(B) Digital Relay:

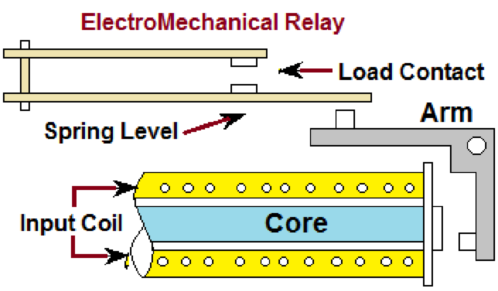
- In Digital relays measured ac quantities are manipulated in analogue form and subsequently converted into square-wave (binary) voltages. Logic circuits or microprocessors compare the phase relationships of the square waves to make a trip decision.

(C) Numerical Relay:

- In Numerical relays measured ac quantities are sequentially sampled and converted into numeric data form. A microprocessor performs mathematical and/or logical operations on the data to make trip decisions.

(1) Electromechanical Relay:

- **History of Relay:**
- This is the first generation oldest relaying system and they have been in use for many years. They have earned a well-deserved reputation for accuracy, dependability, and reliability. There are two basic types of operating mechanisms: the electromagnetic-attraction relay and electromagnetic-induction relay.
- **Measuring Principles:**
- The electromechanical protective relayconverts the voltages and currents to magnetic and electric forces and torques that press against spring tensions in the relay. The tension of the spring and taps on the electromagnetic coils in the relay are the main processes by which a user sets in a relay.
- **Function of Relay:**
- These relays are usually instantaneous in action, with no intentional time delay, closing as soon after pickup as the mechanical motion permits. We can add time delay by means of a bellows, dashpot, or a clockwork escapement mechanism. However, the timing accuracy is considerably less precise than that of induction type relays. As such, users seldom choose these relays with time delay in switchgear applications.
- Electromechanical Relays can operate with either AC or DC on the coils. Therefore, the DC component of an asymmetrical fault definitely affects these relays using this principle.
- Most relays come enclosed in a semi flush-mounting draw out case. Installers typically install relays usually on the door of the switchgear cubicle. They bring sensor and control wiring to connections on the case. The relay inserts into the case and connects by means of small switches or a bridging plug, depending on the manufacturer.
- As such, we can disconnect and withdraw it from the case without disturbing the wiring. When the relay is disconnected, the current transformer (CT) connections in the case are automatically shorted to short circuit the CT secondary winding and protect the CT from overvoltage and damage.
- **Operation of Electromagnetic-attraction Relay:**
- Figure shows a typical electro-mechanical relay. An input voltage is applied to the coil mechanism. The input voltage magnetizes the core which pulls the arm towards it. This action causes the output contacts to touch, closing the load circuit. When the input voltage is removed, the spring lever will push the contacts away from each other, breaking the load circuit connection.



- **Operation of Electromagnetic-Induction Relay:**
- Induction relays are available in many variations to provide accurate pickup and time-current responses for a wide range of simple or complex system.
- They are actually like induction motors. On the relay, the moving element (rotor) is usually a metal disk, although sometimes it's a metal cylinder or cup. The stationary part (stator) is one or more integral electromagnets, with current or potential coils inducing currents in the disk, causing it to rotate. Until the rotational forces are great enough to turn the disk and bring its moving contact against the stationary contact, a spring restrains the disk motion.

Electromechanical Relay

- This closes the circuit the relay is controlling. The greater the sensed fault, the greater the current in the coils, and the faster the disk rotates.
- A calibrated adjustment called the time dial sets the spacing between the moving and stationary contacts; this varies the operating time of the relay from fast (contacts only slightly open) to slow (contacts nearly a full disk revolution apart). Reset action begins upon removing the rotational force, either by closing the relay contact that trips a breaker or by otherwise removing the malfunction the relay is sensing. The restraining spring resets the disk to its original position. The time required to reset depends on the type of relay and the time-dial setting (contact spacing).
- Most electromechanical Relays are typically rated for minimum input to output isolation voltages of 1500 to 2000 VAC.

Limitations of Electromagnetic relays:

- Low speed of operation.
- Change in characteristics over a period due to ageing effect.
- Component failure leading to relay failure.
- Relay is Bulky: Because there are internal mechanical components with physical dimension restraints, the package size of an electromechanical Relay can limit the size of a PCB design Excessive power consumption.
- Imposes high burden on CT
- No fault data available except phase indication.
- Inherent in its design, the Electromechanical Relay must make mechanical contacts in order to switch a load. At the point of these contacts, oxidation breakdown occurs over extended life cycling (typically 106 operations), and the relay will need to be replaced.
- When an electromechanical Relay is activated, bounce occurs at the contact site. Bounce creates a window of time where the load circuit is flickering between open and closed, a condition which may need to be considered in load design.
- Isolation voltage is another area where Electromechanical Relays are limited.

(2) The Solid-State Relay (Static Relay):

- **History of Relay:**
- The static relay are next generation relays .The Solid Static relays was first introduced in 1960's. The term 'static' implies that the relay has no moving mechanical parts in it. Compared to the Electromechanical Relay, the Solid Static relay has longer life-span, decreased noise when operates and faster respond speed. However, it is not as robust as the Electromechanical Relay.
- Static relays were manufactured as semi conductor devices which incorporate transistors, ICs, capacitors, small micro processors etc.
- The static relays have been designed to replace almost all the functions which were being achieved earlier by electromechanical relays.
- **Measuring principles:**
- The working principle of the Solid Static relays is similar to that of the Electromechanical Relay which means the Solid Static relays can perform tasks that the Electromechanical Relay can perform.
- The Solid Static relays use analogue electronic devices instead of magnetic coils and mechanical components to create the relay characteristics. the measurement is carried out by static circuits consisting of comparators, level detectors, filter etc while in a conventional electro-magnetic relay it is done by comparing operating torque (or force) with restraining torque (or force). The relaying quantity such as voltage/current is rectified and measured.

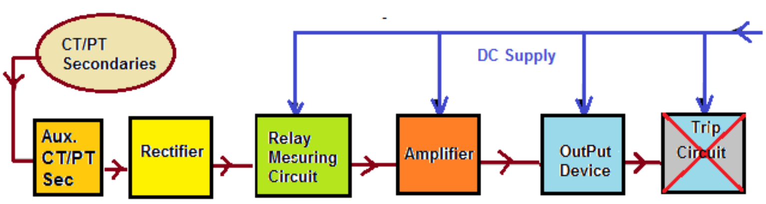
When the quantity under measurement attains certain well-defined value, the output device is triggered and thereby the circuit breaker trip circuit is energized.

- In a solid state relay, the incoming voltage and current waveforms are monitored by analog circuits, not recorded or digitized. The analog values are compared to settings made by the user via potentiometersin the relay, and in some case, taps on transformers.
- In some solid state relays, a simple microprocessor does some of the relay logic, but the logic is fixed and simple. For instance, in some time over current solid state relays, the incoming AC current is first converted into a small signal AC value, and then the AC is fed into a rectifierand filter that converts the AC to a DC value proportionate to the AC waveform. An op-amp and comparator is used to create a DC that rises when a trip point is reached. Then a relatively simple microprocessor does a slow speed A/D conversion of the DC signal, integrates the results to create the time-over current curve response, and trips when the integration rises above a set point. Though this relay has a microprocessor, it lacks the attributes of a digital/numeric relay, and hence the term "microprocessor relay" is not a clear term.
- **Function of Relay:**
- Early versions used discrete devices such as transistors and diodes in conjunction with resistors, capacitors, inductors, etc., but advances in electronics enabled the use of linear and digital integrated circuits in later versions for signal processing and implementation of logic functions. While basic circuits may be common to a number of relays, the packaging was still essentially restricted to a single protection function per case, while complex functions required several cases of hardware suitably interconnected.

Static Relay

- User programming was restricted to the basic functions of adjustment of relay characteristic curves. Therefore it can be viewed in simple terms as an analogue electronic replacement for electromechanical relays, with some additional flexibility in settings and some saving in space requirements.
- In some cases, relay burden is reduced, making for reduced CT/VT output requirements. in a static relay there is no armature or other moving element and response is developed by electronic, magnetic or other components without mechanical motion.
- A relay using combination of both static and electro-magnetic units is also called a static relay provided that static units accomplish the response.
- Additional electro-mechanical relay units may be employed in output stage as auxiliary relays. A protective system is formed by static relays and electro-mechanical auxiliary relays.
- The performance of static relay is better than electromagnetic relays as they are fast acting and accuracy of measurement is better than electromagnetic relay.
- The constraint in static relay is limited function/features. In the last decade, some micro processors were introduced in this relay to achieve the functions like (i) Fuse failure features (ii) Self check feature (iii) Dead Pole detection and iv) Carrier aided protection features.
- **Operation of Relay:**
- The essential components of static relays are shown in fig. The output of CT and PT are not suitable for static components so they are brought down to suitable level by auxiliary CT and PT. Then auxiliary CT output is given to rectifier. Rectifier rectifies the relaying quantity i.e., the output from a CT or PT or a transducer.

Static Relay



- The rectified output is supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits. The output is actuated when the dynamic input (i.e., the relaying quantity) attains the threshold value. This output of the measuring unit is amplified by amplifier and fed to the output unit device, which is usually an electro-magnetic one. The output unit energizes the trip coil only when relay operates.

Advantages of Solid State Relay:

- Static Relay burden is less than Electromagnetic type of relays. Hence error is less.
- Low Weight
- Required Less Space which results in panel space saving.
- Arc less switching
- No acoustical noise.
- Multi-function integration.
- Fast response.
- Long life (High Reliability): more than 109 operations
- High Range of Setting compared to electromechanical Relay
- More Accurate compared to electromechanical Relay
- Low Electromagnetic Interference.
- Less power consumption.
- Shock and vibration resistant
- No contact bounce
- Microprocessor compatible.
- Isolation of Voltage
- No moving parts: There are no moving parts to wear out or arcing contacts to deteriorate that are often the primary cause of failure with an Electro Mechanical Relay.
- No mechanical contact bounce or arcing: A solid-state relay doesn't depend on mechanical forces or moving contacts for its operation but performs electronically. Thus, timing is very accurate even for currents as low as the pickup value. There is no mechanical contact bounce or arcing, and reset times are extremely short.
- Low input signal levels: Ideal for Telecommunication or microprocessor control industries. Solid state relays are fast becoming the better choice in many applications, especially throughout the telecommunication and microprocessor control industries.
- Cost Issues: In the past, there has been a rather large gap between the price of an electromechanical relay and the price of a solid state relay. With continual advancement in manufacturing technology, this gap has been reduced dramatically making the advantages of solid state technology accessible to a growing number of design engineers.

Limitations of static relays:

- Auxiliary voltage requirement for Relay Operation.
- Static relays are sensitive to voltage transients which are caused by operation of breaker and isolator in the primary circuit of CTs and PTs.
- Serious overvoltage is also caused by breaking of control circuit, relay contacts etc. Such voltage spikes of small duration can damage the semiconductor components and also cause mal operation of relays.
- Temperature dependence of static relays: The characteristics of semiconductor devices are affected by ambient temperature.
- Highly sophisticated isolation and filter circuits are required to be built into the relay design to take care of electromagnetic interference and transient switching disturbances in the power system.
- Highly reliable power supply circuits are required.
- Effect of environmental conditions like humidity, high ambient temperature, dust accumulation on PCB leading to tracking.
- The component failure.
- Non availability of fault data.
- Characteristic variations with passage of time.

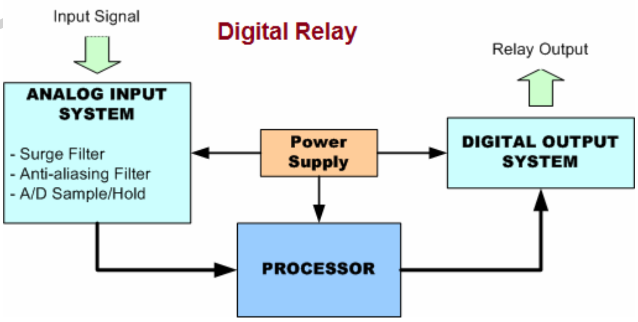
(3) Digital Relay:

- **History of Relay:**
- Around 1980s the digital relay entered the market. Compared to the Solid State Relay, the digital relay takes the advantages of the development of microprocessors and microcontrollers. Instead of using analog signals, the digital relay converts all measured analog quantities into digital signals.

- Digital protection relays is a revolution step in changing Relay technology. In Digital Relay Microprocessors and microcontrollers are used in replacement of analogue circuits used in static relays to implement relay functions. Digital protection relays introduced in 1980. However, such technology will be completely superseded within the next five years by numerical relays.
- By the mid-1990s the solid state and electromechanical relay had been mostly replaced by digital relay in new construction. In distribution applications, the replacement by the digital relay proceeded a bit more slowly. While the great majority of feeder relays in new applications today are digital, the solid state relay still sees some use where simplicity of the application allows for simpler relays, and which allows one to avoid the complexity of digital relays
- **Measuring principles:**
- Compared to static relays, digital relays introduce Analogue to Digital Convertor (A/D conversion) of all measured analogue quantities and use a microprocessor to implement the protection algorithm. The microprocessor may use some kind of counting technique, or use the Discrete Fourier Transform (DFT) to implement the algorithm.
- The Microprocessors used in Digital Relay have limited processing capacity and memory compared to that provided in numerical relays.
- **Function of Relay:**
- The functionality tends therefore to be limited and restricted largely to the protection function itself. Additional functionality compared to that provided by an electromechanical or static relay is usually available, typically taking the form of a wider range of settings, and greater accuracy. A communications link to a remote computer may also be provided.

Digital Relay

- The limited power of the microprocessors used in digital relays restricts the number of samples of the waveform that can be measured per cycle. This, in turn, limits the speed of operation of the relay in certain applications. Therefore, a digital relay for a particular protection function may have a longer operation time than the static relay equivalent. However, the extra time is not significant in terms of overall tripping time and possible effects of power system stability.
- **Operation of Relay:**
- Digital relay consists of: (1) Analogue input subsystem, (2) Digital input subsystem, (3) Digital output subsystem, (4) A processor along with RAM (data scratch pad), main memory (historical data file) and power supply



- Digital relaying involves digital processing of one or more analog signals in three steps: Conversion of analogue signal to digital form Processing of digital form Boolean decision to trip or not to trip

Advantages of Digital Relay:

- High level of functionality integration.
- Additional monitoring functions.
- Functional flexibility.
- Capable of working under a wide range of temperatures.
- They can implement more complex function and are generally more accurate

- Self-checking and self-adaptability.
- Able to communicate with other digital equipment (pear to pear).
- Less sensitive to temperature, aging
- Economical because can be produced in volumes
- More Accurate.
- plane for distance relaying is possible
- Signal storage is possible

Limitations of Digital Relay:

- Short lifetime due to the continuous development of new technologies.
- The devices become obsolete rapidly.
- Susceptibility to power system transients.
- As digital systems become increasingly more complex they require specially trained staff for Operation.
- Proper maintenance of the settings and monitoring data.

(4) Numerical Relay:

History of Relay:

- The first protection devices based on microprocessors were employed in 1985. The widespread acceptance of numerical technology by the customer and the experiences of the user helped in developing the second generation numerical relays in 1990.
- Conventional electromechanical and static relays are hard wired relays. Their wiring is fixed, only their setting can be manually changed. Numeric relays are programmable relays. The characteristics and behaviour of the relay are can be programmed.
- First generation numerical relays were mainly designed to meet the static relay protection characteristic, whereas modern numeric protection devices are capable of providing complete protection with added functions like control and monitoring. Numerical protection devices offer several advantages in terms of protection, reliability, and trouble shooting and fault information.
- **The distinction between digital and numerical relay rests on points of fine technical detail, and is rarely found in areas other than Protection.** They can be viewed as natural developments of digital relays as a result of advances in technology. Typically, they use a specialized digital signal processor (DSP) as the computational hardware, together with the associated software tools.

Measuring principles:

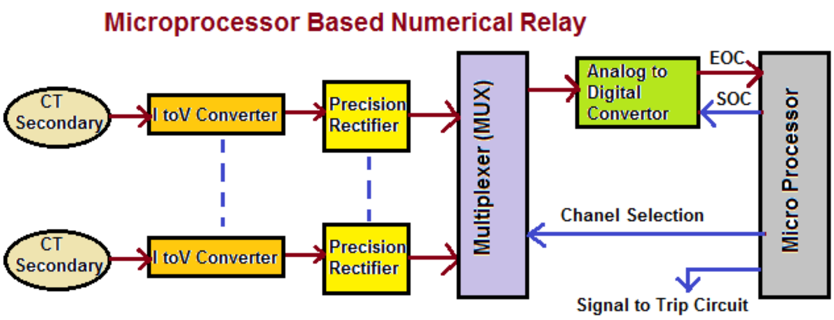
- The input analogue signals are converted into a digital representation and processed according to the appropriate mathematical algorithm. Processing is carried out using a specialized microprocessor that is optimized for signal processing applications, known as a digital signal processor or DSP for short. Digital processing of signals in real time requires a very high power microprocessor.
- The measuring principles and techniques of conventional relays (electromechanical and static) are fewer than those of the numerical technique, which can differ in many aspects like the type of protection algorithm used, sampling, signal processing, hardware selection, software discipline, etc. These are microprocessor-based relays in contrast to other relays that are electromechanically controlled.

Function of Relay:

- Modern power system protection devices are built with integrated functions. Multi-functions like protection, control, monitoring and measuring are available today in numeric power system protection devices. Also, the communication capability of these devices facilitates remote control, monitoring and data transfer.
- Traditionally, electromechanical and static protection relays offered single-function, single characteristics, whereas modern numeric protection offers multi-function and multiple characteristics.
- The measuring principles and techniques of conventional relays (electromechanical and static) are fewer than those of the numerical technique, which can differ in many aspects like the type of protection algorithm used, sampling, signal processing, hardware selection, software discipline, etc.
- First generation numerical relays were mainly designed to meet the static relay protection characteristic, whereas modern numeric protection devices are capable of providing complete protection with added functions like control and monitoring. Numerical protection devices offer several advantages in terms of protection, reliability, and trouble shooting and fault information. Numerical protection devices are available for generation, transmission and distribution systems.

Numerical Relay

- Numerical relays are micro processor based relays and having the features of recording of parameter used as disturbance recorder flexibility of setting & alarms & can be used one relay for all type of protections of one equipment hence less area is required. Wide Range of setting, more accurate, Low burden hence low VA of CT is required which minimize the cost.
- Numeric relays take the input analog quantities and convert them to numeric values. All of the relaying functions are performed on these numeric values.
- The following sections cover relay hardware, relay software, multiple protection characteristics, adaptive protection characteristics, data storage, instrumentation feature, self-check feature, communication capability, additional functions, size and cost-effectiveness.
- Numerical protection devices are available for generation, transmission and distribution systems. Modern power system protection devices are built with integrated functions. Multi-functions like protection, control, monitoring and measuring are available today in numeric power system protection devices. Also, the communication capability of these devices facilitates remote control, monitoring and data transfer.
- These relays provide great precision and convenience in application in the sophisticated electronic products. By combining several functions in one case, numerical relays also save capital cost and maintenance cost over electromechanical relays. The disadvantages of a conventional electromechanical relay are overcome by using microcontroller for realizing the operation of the relays. Microcontroller based relays perform very well and their cost is relatively low
- Also, the communication capability of these devices facilitates remote control, monitoring and data transfer. Traditionally, electromechanical and static protection relays offered single-function, single characteristics, whereas modern numeric protection offers multi-function and multiple characteristics. Some protections also offer adaptable characteristics, which dynamically change the protection characteristic under different system conditions by monitoring the input parameters.
- Operation of Relay: A current signal from CT is converted into proportional voltage signal using I to V converter.
- The ac voltage proportional to load current is converted into dc using precision rectifier and is given to multiplexer (MUX) which accepts more than one input and gives one output.
- Microprocessor sends command signal to the multiplexer to switch on desired channel to accept rectified voltage proportional to current in a desired circuit.



- Output of Multiplexer is fed to analog to digital converter (ADC) to obtain signal in digital form. Microprocessor then sends a signal ADC for start of conversion (SOC), examines whether the conversion is completed and on receipt of end of conversion (EOC) from ADC, receives the data in digital form. The microprocessor then compares the data with pick-up value. If the input is greater than pick-up value the microprocessor send a trip signal to circuit breaker of the desired circuit.
- Incase of instantaneous over current relay there is no intentional time delay and circuit breaker trips instantly. In case of normal inverse, very inverse, extremely inverse and long inverse over current relay the inverse current-time characteristics are stored in the memory of microprocessor in tabular form called as look-up table.

Advantages of Numerical relays:

- **Compact Size:** Electromechanical Relay makes use of mechanical comparison devices, which cause the main reason for the bulky size of relays. It uses a flag system for the indication purpose whether the relay has been activated or not. While Numerical Relay is in Compact Size and use Indication on LCD for Relay activation.
- Digital protection can be physically smaller, and almost always requires less panel wiring than equivalent functions implemented using analog technology.
- **Flexibility:** A variety of protection functions can be accomplished with suitable modifications in the software only either with the same hardware or with slight modifications in the hardware.
- **Reliability:** A significant improvement in the relay reliability is obtained because the use of fewer components results in less interconnections and reduced component failures.
- **Multi Function Capability:** Traditional electromechanical and static protection relays offers single-function and single characteristics. Range of operation of electromechanical relays is narrow as compared to numerical relay.
- **Different types of relay characteristics:** It is possible to provide better matching of protection characteristics since these characteristics are stored in the memory of the microprocessor.
- **Digital communication capabilities:** The microprocessor based relay furnishes easy interface with digital communication equipments. Fibre optical communication with substation LAN
- **Modular frame:** The relay hardware consists of standard modules resulting in ease of service.
- **Low burden:** The microprocessor based relays have minimum burden on the instrument transformers.
- **Sensitivity:** Greater sensitivity and high pickup ratio.
- **Speed:** With static relays, tripping time of ½ cycle or even less can be obtained.
- **Fast Resetting:** Resetting is less.
- **Data History:** Availability of fault data and disturbance record. Helps analysis of faults by recording details of (1) Nature of fault, (2) Magnitude of fault level, (3) Breaker problem, (4) C.T. saturation, (5) Duration of fault.
- **Auto Resetting & Self Diagnosis:** Electromechanical relay do not have the ability to detect whether the normal condition has been attained once it is activated thus auto resetting is not possible and it has to be done by the operating personnel. while in Numerical Relay auto Resetting is Possible
- By combining several functions in one case, numerical relays also save capital cost and maintenance cost over electromechanical relays
- Separate connection is not required, zero sequence voltages and currents can be derived inside the processor
- Basic hardware is shared between multiple functions, the cost of individual protection functions can be reduced significantly.
- Loss of voltage feature helps block the relay in case of momentary/permanent loss of voltage.

Limitations of Numerical Relay:

- Numerical Relay offers more functionality, and greater precision. Unfortunately, that does not necessarily translate into better protection.
- Numerical Relay can make faster decisions. However, in the real world, faster protection itself is of no value because circuit breakers are still required to interrupt at the direction of the protective equipment, and the ability to make circuit breakers interrupt faster is very limited.
- Numerical Relay protection often relies on non-proprietary software, exposing the system to potential risk of hacking.
- Numerical Relay protection sometimes has exposure to externally-sourced transient interference that would not affect conventional technology.
- Numerical Relay protection shares common functions. This means that there are common failure modes that can affect multiple elements of protection. For example, failure of a power supply or an input signal processor may disable an entire protective device that provides many different protection functions. This problem has receive a lot of design attention, and experience generally has supported the notion that the equipment has a very high reliability once it is past the infant mortality stage. But it remains something to be aware of.
- A multifunction numeric relay can provide three phase, ground, and negative sequence directional or non-directional over current protection with four shot recloser, forward or reverse power protection, breaker failure, over/under frequency, and over/under voltage protection, sync check, breaker monitoring and control, It would take 10 - 11 single function Solid State or Electromechanical relays at least 5 to 6 times the cost. Additionally Numeric relays have Communications capabilities, sequence-of-events recording, fault reporting, rate-of-change frequency, and metering functions, all in an integrated system.

Comparison of Different Type Relay:

Characteristic	Electro Mechanical Relay	Static Relay	Digital Relay	Numerical Relay
Technology Standard	1st generation Relays.	2nd generation Relays.	Present generation Relays.	Present generation Relays.
Operating Principle	They use principle of electromagnetic principle.	In this relays transistors and IC's r been used	They use Microprocessor. Within built software with predefined values	They use Microprocessor. Within built software with predefined values
Measuring elements/ Hardware	Induction disc, Electromagnets, Induction cup, Balance Beam	R, L, C, Transistors, Analogue ICs comparators	Microprocessors, Digital ICs, Digital Signal Processors	Microprocessor s, Digital ICs, Digital Signal processors
Measuring method	Electrical Qtys converted into mechanical force,torque	Level detectors, comparison with reference value in analogue comparator	A/D conversion, Numerical algorithm techniques evaluate tripcriteria	A/D conversion, Numerical algorithm techniques evaluate tripcriteria
Surrounding Environment	Depend upon gravitation and the value changes to the surrounding magnetic fields also.	There value may vary with respect to temperature also.		
Relay Size	Bulky	Small	Small	Compact
Speed of Response	Slow	Fast	Fast	Very Fast
Timing function	Mechanical clock works, dashpot	Static timers	Counter	Counter
Time of Accuracy	Temp .Dependant	Temp. Dependant	Stable	Stable
Reliability	High	Low	High	High
Vibration Proof	No	Yes	Yes	Yes
Characteristics	Limited	Wide	Wide	Wide
Requirement of Draw Out	Required	Required	Not Required	Not Required
CT Burden	High	Low	Low	Low
CT Burden	8 to 10 VA	1 VA	<0.5 VA	<0.5 VA
Reset Time	Very High	Less	Less	Less
Auxiliary supply	Required	Required	Required	Required
Range of settings	Limited	Wide	Wide	Wide
Isolation Voltage	Low	High	High	High
Function	Single Function	Single Function	Multi Function	Single Function
Maintenance	Frequent	Frequent	Low	Very Low
Resistance	100 milleohms	10 Ohms	10 Ohms	10 Ohms
Output Capacitance	< 1 Pico Farad	> 20 Pico Farads	> 20 Pico Farads	> 20 Pico Farads
Deterioration due to Operation	Yes	No	No	No
Relay Programming	No	Partially	Programmable	Programmable
SCADA Compatibility	No	No	Possible	Yes
Operational value indication	Not Possible	Possible	Possible	Possible
Visual indication	Flags, targets	LEDs	LEDs, LCD	LEDs, LCD
Self monitoring	No	Yes	Yes	Yes

Parameter setting	Plug setting, dial setting	Thumb wheel, dual in line switches	Keypad for numeric values, through computer	Keypad for numeric values, through computer
Fault Disturbance Recording	Not possible	Not possible	possible	possible

Relay's Nomenclature as per ANSI:

RELAY CODE (ANSI)	
Code	**Type of Relay**
1	Master Element
2	Time-delay Starting or Closing Relay
3	Checking or Interlocking Relay
4	Master Contactor
5	Stopping Device
6	Starting Circuit Breaker
7	Rate of Change Relay
8	Control Power Disconnecting Device
9	Reversing Device
10	Unit Sequence Switch
11	Multifunction Device
12	Over speed protection
13	Synchronous-Speed Device
14	Under speed Device
15	Speed or Frequency Matching Device
16	Data Communications Device
17	Shunting or Discharge Switch
18	Accelerating or Decelerating Device
19	Starting-to-Running Transition Contactor
20	Electrically-Operated Valve
21	Distance protection Relay
21G	Ground Distance
21P	Phase Distance
22	Equalizer circuit breaker
23	Temperature control device
24	Volts per hertz relay
25	Synchronizing or synchronism-check device
26	Apparatus thermal device
27	Under voltage relay
27P	Phase Under voltage
27S	DC under voltage relay
27TN	Third Harmonic Neutral Undervoltage
27TN/59N	100% Stator Earth Fault
27X	Auxiliary Under voltage
27 AUX	Under voltage Auxiliary Input
27/27X	Bus/Line Under voltage
27/50	Accidental Generator Energization
28	Flame Detector
29	Isolating Contactor
30	Annunciator Relay

31	Separate Excitation Device
32	Directional Power Relay
32L	Low Forward Power
32N	Watt metric Zero-Sequence Directional
32P	Directional Power
32R	Reverse Power
33	Position Switch
34	Master Sequence Device
35	Brush-Operating or Slip-ring Short Circuiting Device
36	Polarity or Polarizing Voltage Device
37	Undercurrent or Under power Relay
37P	Under power
38	Bearing Protective Device / Bearing Rtd
39	Mechanical Condition Monitor
40	Field Relay / Loss of Excitation
41	Field Circuit Breaker
42	Running Circuit Breaker
43	Manual Transfer or Selector Device
44	Unit Sequence Starting Relay
45	Atmospheric Condition Monitor
46	Reverse-Phase or Phase Balance Current Relay or Stator Current Unbalance
47	Phase-Sequence or Phase Balance Voltage Relay
48	Incomplete Sequence Relay / Blocked Rotor
49	Machine or Transformer Thermal Relay / Thermal Overload
49RTD	RTD Biased Thermal Overload
50	Instantaneous Overcurrent Relay
50BF	Breaker Failure
50DD	Current Disturbance Detector
50EF	End Fault Protection
50G	Ground Instantaneous Overcurrent
50IG	Isolated Ground Instantaneous Overcurrent
50LR	Acceleration Time
50N	Neutral Instantaneous Overcurrent
50NBF	Neutral Instantaneous Breaker Failure
50P	Phase Instantaneous Overcurrent
50SG	Sensitive Ground Instantaneous Overcurrent
50SP	Split Phase Instantaneous Current
50Q	Negative Sequence Instantaneous Overcurrent
50/27	Accidental Energization
50/51	Instantaneous / Time-delay Overcurrent relay
50Ns/51Ns	Sensitive earth-fault protection
50/74	Ct Trouble
50/87	Instantaneous Differential
51	Phase Inverse Time Overcurrent IDMT (Time delay phase overcurrent)
51G	Ground Inverse Time Overcurrent
51LR	AC inverse time overcurrent (locked rotor) protection relay
51N	Neutral Inverse Time Overcurrent
51P	Phase Time Overcurrent

51R	Locked / Stalled Rotor
51V	Voltage Restrained Time Overcurrent
51Q	Negative Sequence Time Overcurrent
52	AC circuit breaker
52a	AC circuit breaker position (contact open when circuit breaker open)
52b	AC circuit breaker position (contact closed when circuit breaker open)
53	Exciter or Dc Generator Relay
54	Turning Gear Engaging Device
55	Power Factor Relay
56	Field Application Relay
57	Short-Circuiting or Grounding Device
58	Rectification Failure Relay
59	Overvoltage Relay
59B	Bank Phase Overvoltage
59P	Phase Overvoltage
59N	Neutral Overvoltage
59NU	Neutral Voltage Unbalance
59P	Phase Overvoltage
59X	Auxiliary Overvoltage
59Q	Negative Sequence Overvoltage
60	Voltage or current balance relay
60	Voltage or Current Balance Relay
60N	Neutral Current Unbalance
60P	Phase Current Unbalance
61	Density Switch or Sensor
62	Time-Delay Stopping or Opening Relay
63	Pressure Switch Detector
64	Ground Protective Relay
64F	Field Ground Protection
64R	Rotor earth fault
64REF	Restricted earth fault differential
64S	Stator earth fault
64S	Sub-harmonic Stator Ground Protection
64TN	100% Stator Ground
65	Governor
66	Notching or Jogging Device/Maximum Starting Rate/Starts Per Hour/Time Between Starts
67	AC Directional Overcurrent Relay
67G	Ground Directional Overcurrent
67N	Neutral Directional Overcurrent
67Ns	Earth fault directional
67P	Phase Directional Overcurrent
67SG	Sensitive Ground Directional Overcurrent
67Q	Negative Sequence Directional Overcurrent
68	Blocking Relay / Power Swing Blocking
69	Permissive Control Device
70	Rheostat
71	Liquid Switch
72	DC Circuit Breaker

73	Load-Resistor Contactor
74	Alarm Relay
75	Position Changing Mechanism
76	DC Overcurrent Relay
77	Telemetering Device
78	Phase Angle Measuring or Out-of-Step Protective Relay
78V	Loss of Mains
79	AC Reclosing Relay / Auto Reclose
80	Liquid or Gas Flow Relay
81	Frequency Relay
81O	Over Frequency
81R	Rate-of-Change Frequency
81U	Under Frequency
82	DC Reclosing Relay
83	Automatic Selective Control or Transfer Relay
84	Operating Mechanism
85	Pilot Communications, Carrier or Pilot-Wire Relay
86	Lock-Out Relay, Master Trip Relay
87	Differential Protective Relay
87B	Bus Differential
87G	Generator Differential
87GT	Generator/Transformer Differential
87L	Segregated Line Current Differential
87LG	Ground Line Current Differential
87M	Motor Differential
87O	Overall Differential
87PC	Phase Comparison
87RGF	Restricted Ground Fault
87S	Stator Differential
87S	Percent Differential
87T	Transformer Differential
87V	Voltage Differential
88	Auxiliary Motor or Motor Generator
89	Line Switch
90	Regulating Device
91	Voltage Directional Relay
92	Voltage And Power Directional Relay
93	Field-Changing Contactor
94	Tripping or Trip-Free Relay

Abbreviation Code	
AFD	Arc Flash Detector
CLK	Clock or Timing Source
CLP	Cold Load Pickup
DDR	Dynamic Disturbance Recorder
DFR	Digital Fault Recorder
DME	Disturbance Monitor Equipment
ENV	Environmental data

HIZ	High Impedance Fault Detector
HMI	Human Machine Interface
HST	Historian
LGC	Scheme Logic
MET	Substation Metering
PDC	Phasor Data Concentrator
PMU	Phasor Measurement Unit
PQM	Power Quality Monitor
RIO	Remote Input/output Device
RTD	Resistance Temperature Detector
RTU	Remote Terminal Unit/Data Concentrator
SER	Sequence of Events Recorder
TCM	Trip Circuit Monitor
LRSS	Local/Remote selector switch
VTFF	Vt Fuse Fail
	Suffixes Description
_1	Positive-Sequence
_2	Negative-Sequence
A	Alarm, Auxiliary Power
AC	Alternating Current
AN	Anode
B	Bus, Battery, or Blower
BF	Breaker Failure
BK	Brake
BL	Block (Valve)
BP	Bypass
BT	Bus Tie
BU	Backup
C	Capacitor, Condenser, Compensator, Carrier Current, Case or Compressor
CA	Cathode
CH	Check (Valve)
D	Discharge (Valve)
DC	Direct Current
DCB	Directional Comparison Blocking
DCUB	Directional Comparison Unblocking
DD	Disturbance Detector
DUTT	Direct Under reaching Transfer Trip
E	Exciter
F	Feeder, Field, Filament, Filter, or Fan
G	Ground or Generator
GC	Ground Check
H	Heater or Housing
L	Line or Logic
M	Motor or Metering
MOC	Mechanism Operated Contact
N	Neutral or Network
O	Over
P	Phase or Pump

PC	Phase Comparison
POTT	Pott: Permissive Overreaching Transfer Trip
PUTT	Putt: Permissive Under reaching Transfer Trip
R	Reactor, Rectifier, or Room
S	Synchronizing, Secondary, Strainer, Sump, or Suction (Valve)
SOTF	Switch On To Fault
T	Transformer or Thyratron
TD	Time Delay
TDC	Time-Delay Closing Contact
TDDO	Time Delayed Relay Coil Drop-Out
TDO	Time-Delay Opening Contact
TDPU	Time Delayed Relay Coil Pickup
THD	Total Harmonic Distortion
TH	Transformer (High-Voltage Side)
TL	Transformer (Low-Voltage Side)
TM	Telemeter
TT	Transformer (Tertiary-Voltage Side)
U	Under or Unit
X	Auxiliary
Z	Impedance

Relays for Transmission & Distribution Lines protection:

No	Line	Protection
1	400 KV Transmission Line	Main-I: Non switched or Numerical Distance Scheme
		Main-II: Non switched or Numerical Distance Scheme
2	220 KV Transmission Line	Main-I : Non switched distance scheme (Fed from Bus PTs)
		Main-II: Switched distance scheme (Fed from line CVTs) With a changeover facility from bus PT to line CVT and vice-versa
3	132 KV Transmission Line	Main Protection: Switched distance scheme (fed from bus PT).
		Backup Protection: 3 Nos. directional IDMT O/L Relays and 1 No. Directional IDMT E/L relay.
4	33 KV Lines	Non-directional IDMT 3 Over Current and 1 Earth Fault relays
5	11KV Line	Non-directional IDMT 2 Over Current and 1 Earth Fault relays

Reference:

- Handbook of Switchgear –Bhel
- Digital/Numerical Relays -T.S.M. Rao

Chapter: 49 Method for Installation of DB or Panel

Purpose:

- This method of statement describe the procedure for safely installation and testing of DB and LV Panel as per contract specification and as per the standard Practice and Code.

General Equipment & Tools:

- The equipment that will be engaged for Installation of Panel ,D.B will be
- Tool Box with Screwdriver, Pliers, Spanner , Hammer
- Drilling Machine with various Bits , Grinding & Cutting Machine
- Electrical Tester , Continuity Tester ,Multi Meter , Earth Tester , IR Tester
- Wire Cutter , Blower ,Crimping Tools
- Knockout punch and Flat File
- Marker, Measuring tape, Level gauge / Spirit level.
- Ladder / Scaffolding / Mobile scaffold
- Chain Block and Pipe Wrench
- Portable Lights
- Removable Barricades

Storage & Material Handling:

- Suitable lockable storage shall be made on Site.
- The storage area must be free from dust and Water leakages / seepages.
- The DB, Panel and Accessories shall be unloaded with care in designated area of the Store to avoid any damages and against the effects of weather or any construction activities of Site.
- The Material will be stacked / unload in the site store on a proper stand on wooden loft on a flat surface at a sufficient height from Ground.
- Materials shall be stored in a place free of water and adequately covered to avoid any kind of damages.
- Proper protection should be given to the material by means of covering the material with Tarpaulin sheet etc.
- If they are dispatch in packs or pallets, each pack of pallet shall be lifted individually with suitable lifting equipment.
- The material shall be transported / Shifted in their original packing to Site location.

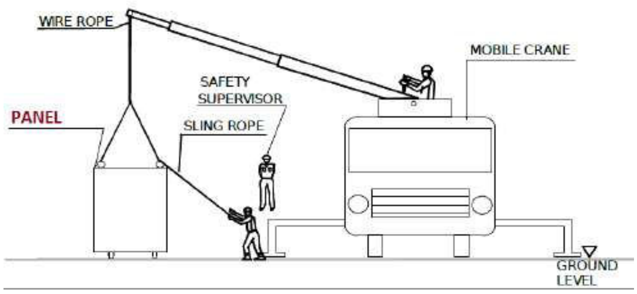
Inspection of Materials:

- **Inspection of Materials:**
- Check the reference of delivered material against approved submittal and purchase order.
- Check The Material according to its Type, Size, Make
- **Physical Damages Inspection:**
- In case of any damages observed during inspection, the concern report will be issued and Material shall be returned to the supplier for replacement.

Sequence of Installation Works:

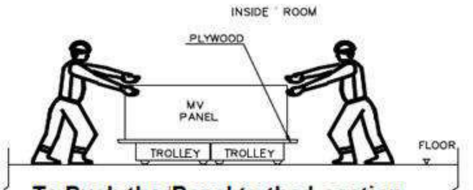
(1) Shifting of Panel on Site

- Prior to commencement of Panel installation works, areas and access shall be checked and confirmed by safety officer, that they are in a suitable Condition for installation works.
- Decide appropriate Size of Crain / Hydra according to weight of Panel.
- Panel shall be carefully unloaded or shifted to the site by using Crane/Hydra or by sufficient manpower and moved to a defined installation location.
- Remove the packing and ensure that the panel is free from transportation damages
- Check The shop drawings, Material submittals, Method statement, ITP & HIRA are approved,
- Ensure all contents are available inside the panel.
- Ensure control wiring identification shall be correctly done.
- Megger shall be used having a valid calibration certificate.

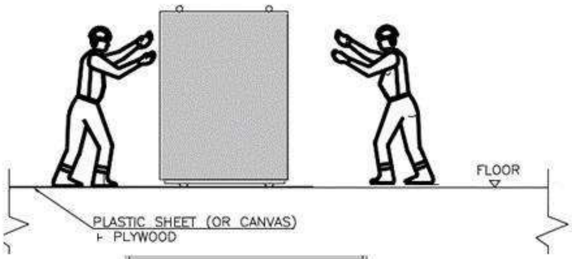


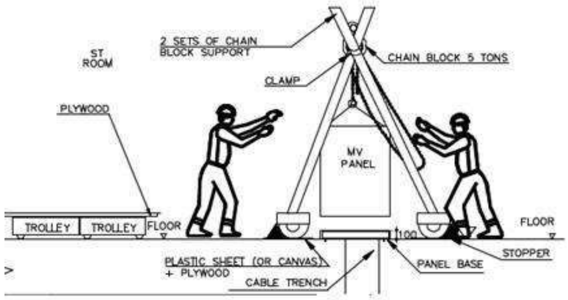
(2) Installation of Panel:

- **Marking of Panel Position:**
- For floor mounted panel, the exact location of the panel and fixing holes to be marked on the concrete plinth for the installation.

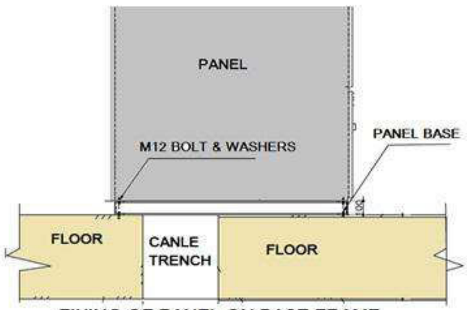


To Push the Panel to the Location





To Lift Up & Position the Panel in Substation Room



FIXING OF PANEL ON BASE FRAME

- Remove the Factory packing and ensure that the LT panel is free from transportation damages
- Install the panel in proper alignment and fix properly.
- To secure panel base to the floor using M12 anchor bolts.
- Access around the panel to be checked for future maintenance as per regulations.
- Ensure the services contains water is away from the panel or properly protected against any accidental leakages.
- Incoming and outgoing cables shall be marked/identified as per approved shop drawing.
- Mark the fixing position of the DB's support as per approved shop drawing and coordinate with other equipment and services.
- After marking are then drilled according to the selected sizes of anchor bolts to appropriate depth as per approved shop drawing.
- Locknuts on the anchor bolts will ensure a permanent fixing of the DB support to the wall/slab.
- After installation of DB supports, installing position of the DB as per approved shop drawing.
- Ensure that painting of the wall is completed prior to marking and mounting of DB.
- All DBs wall mounting and floor mounted arrangement will be in accordance with approved shop drawings and the approved material submittal.
- If there is more than one DB to be installed at the same location, they shall be installed side by side and clearance shall be maintained as per approved shop drawing.
- The height of Distribution Board shall be maintained as per approved shop drawing so that easy access for termination of cables and other maintenance work can be carried out.
- Check the position according to the approved shop drawings.
- Check & ensure adequate space is available for maintenance
- After installation, the panel shall be properly cleaned and protected to prevent dust & contamination.

- Before beginning installation in any area, examine all adjoining works in that area should be completed. Installation shall not proceed in that area until such conditions are corrected by the contractor.
- Fix all equipment independently of wiring system. Use cadmium of zinc electroplated bolts, nuts, washers and screw.
- Mount single DB at 1800mm from finish floor level to top of equipment, unless shown otherwise on drawing / schedules.
- Ensures that clearance in front of switchgear is not less than 1m, or as indicated.
- For flush installation, DB's all conductors shall terminate behind the board in an adaptable box.
- For surface mounting, trunking shall be fixed between the board and ceiling or floor level, or conduit run directly into Trunking which prevent correct installation of the Trunking lid.
- The panel with plywood will be pushed towards the trolleys inside substation Room
- When the panel reaches on the trolleys inside the substation room. Push the panel to the location where need to install (Detail – 6).
- To set up the chain block support to fix the chain block.
- When the panel reaches the actual installed location, lifting-up of panel by using of chain block. Lift the panel on the panel base
- **If Panel is in section wise**
- Position the first section panel on the fixing channel & check the leveling by using the level bar & adjusting with liners.
- To secure panel to the panel base using M12 anchor bolts.
- To rack in the correct breaker & PT to the correct panel.
- Proceed in the same manner for the second sections.
- Position the second section next to the first panel.
- Secure the second section to the panel base using two M12 anchor bolts
- Interconnect & fasten the two section units together.
- Proceed in the same manner for the other sections.

(3) Non-Electrical checks before Charging Panel:

a) General Checking of Panel:

- Confirm label/marking to ensure that is the Panel is correct according to the approved shop drawings.
- All components (Circuit Breakers, Relays, Voltmeter and Ammeter) of the panel shall be verified against the approved panel / Technical drawing as per correct in Numbers, rating & size.
- Ensure all contents are available inside DB.
- Check that it is not possible to come into contact with energized equipment when working on the system.
- If there are any Correction or modification than Check All internal connections/modification will be carried out by the Manufacturer.
- Check the main bus bar and auxiliary circuits (control, monitoring, alarm, and fault) for continuity.
- All breakers (incoming/outgoing) shall be in "OFF" position and to be locked to prevent mishandling

b) Visual Checking of Panel:

- Ensure the absence of all foreign bodies inside the switchboard.
- Identifications labels of approved engraved type nameplate shall be fixed on DB.
- Check the compliance with the protection index (leak tightness of the functional units, various sealing points, etc.).
- Check the Continuity of grounding bus bar to the main earthing system.
- Check that the panel hinged doors are connected to the frame by earthing braids.
- Adequate earth continuity shall be made between the various components.
- Check the door locks for correct operation
- Check the connections for conformity with the reference drawings.
- Check Continuity of Main, Auxiliary, Eathing and Neutral Busbar with respect to incomer and outgoing Circuits.
- Check the connections for conformity with the reference drawings and their tightness.
- Number terminals, cables and component parts to correspond with manufacturer have certified drawings.
- Ensure that vents are clear and filters are in place. Screens covering ventilation openings should be in place to prevent entry of rodents or small animals.
- Check the outer appearance (absence of any traces of shocks, peeling paint) -carry out any touch-ups if needed.

c) Mechanical Checking of C.B:

- Check for correct racking in and Out for circuit breaker and check :
- That it is impossible to rack in a circuit breaker in the closed position.
- That it is impossible to close a circuit breaker not correctly racked in.
- That it is impossible to rack out a circuit breaker is in ON condition.

d) Tightness of all Connection of Switchgear.

- Fully tight all Bolted electrical connections of Electrical Switch gear of Panel.
- Loose bolted electrical connections can lead to higher energy consumption and eventual equipment failure if not properly addressed.
- Loose control, Power wires can lead to spark, over heat which turns in to catastrophic failure.
- Check that all wiring connections are tight and that wiring is secure to prevent damage during routine operation of moving parts, especially when removing draw-out circuit breakers or opening and closing cubicle doors.
- Gently tug on control wires to ensure a tight connection or use a screwdriver to gently verify torque on the connection. Infrared scans are also very effective for finding loose wires in control circuits.
- Tighten all the connections as required

e) General Wiring Checks for Switchgear

- Wire inserted in the Panel will be cross-checked for existing circuit number done and final ferruling shall be done as approved shop drawing.
- Wire in Panel shall be used cable tie and dress with bunching of the phase-neutral and earth and lugged to the respective MCBs and Bus bar as per approved shop drawing.
- Bunching shall be done as per phase separation respectively R, Y and B.

f) Moving Parts and Interlock Checks for Switchgear

- Confirm the correct operation and sequencing of electrical and mechanical interlock systems. Attempt closure on locked-open devices and attempt to open locked-closed devices.

g) Lubrication of Switchgear and Switchboards

- Check for appropriate lubrication on moving current-carrying parts and moving/sliding surfaces to keep everything operating smoothly. This includes hinges, locks, and latches.

h) Insulators and Barrier Checks for Switchgear

- Tracking is an electrical discharge phenomenon caused by electrical stress on insulation. This stress can occur phase-to-phase or phase-to-ground. Although tracking can occur internally in certain insulating materials, these materials as a rule are not used in medium- or high-voltage switchgear insulation. Tracking, when it occurs in switchgear assemblies, normally is found on insulation surfaces.
- Electrical insulators should be inspected for evidence of physical damage or contaminated surfaces. Damage caused by electrical distress is normally evident on the surface of insulating members in the form of corona erosion or markings or tracking paths.
- Inspect barrier and shutter assemblies for proper installation and operation. All active components should be exercised, mechanical indicating devices should be inspected for correct operation.

i) Moisture and Corona Inspections for Switchgear and Switchboards

- If corona occurs in switchgear assemblies, it is usually localized in thin air gaps that exist between a high-voltage bus bar and its adjacent insulation or between two adjacent insulating members. Corona might also form around bolt heads or other sharp projections that are not properly insulated or shielded. Corona in low-voltage switchgear is practically nonexistent.
- Inspect for evidence of moisture or corona when performing maintenance inspections. On outdoor assemblies, roof or wall seams should be checked for evidence of leakage, and any leaking seams should be sealed with weatherproof caulk.

(4) ELECTRICAL CHECKS BEFORE CHARGING THE PANEL

- **TESTING CONTINUITY BETWEEN ALL METAL PARTS AND GROUND**
- For performing this test, it is generally recommended to use a milliohm meter for continuity measurement.
- **INSULATION RESISTANCE TESTS For SWITCHGEAR**
- It is recommended to perform these tests before connection starting so all isolating devices will be closed.
- If cables are already connected, open the isolating devices before any test.
- Disconnect the ground sensing device and the control cables.
- Using a 1000 V DC megohmmeter, measure the insulation resistance after a one minute Electrification time between :
- 1) Phase to Phase

- 2) Phase to Neutral
- 3) Phase to Ground
- 4) Ground to Earth
- Using a 500 V DC megohmmeter, measure the insulation resistance after a one minute electrification time between:
- 1) Auxiliary circuit and ground.
- Reconnect the cables after testing.
- **Control Wiring Electrical Tests for Switchgear and Switchboards**
- Perform insulation-resistance tests on control wiring with respect to ground. Apply 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable for one minute each.
- Important: Units with solid-state components could be damaged if not properly isolated (via removal of plugs and/or fuses) before applying test voltage. Be sure to follow all manufacturers' recommendations when performing dielectric tests on solid state components
- Minimum insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.

Charging & Testing of Panel:

- **Cable Terminations:**
- Identify cable to be laid and Cut the cable to required length.
- Put temporary marker onto the cable.
- Carefully pull (using suitable method) and lay the cable to its route
- Make appropriate opening (Cut-out) in DB /PANEL for inserting the cable with a rubber gasket so that there will be no sharp edges and secure the wire insulation from damage.
- Gland the cables using appropriate cable glands size.
- Terminate cables inside enclosure by securing cables to switchboards with gland bracket; and enclosure with glanding plates or fabricated steel extension boxes.
- Slice the cable and identify cores to be used. Installed the ferrule number and cable lug
- Dressing the cable inside the panel and Secure the cables (if necessary) with cable ties or other suitable method
- Install cable marker / tag as specified
- Terminate the cable properly & as per termination schedule
- Earth the glands to the equipment earth grid
- After complete termination of wire/cable same DB compartment shall be cleaned and fixed door.
- **Earthing Connections:**
- The Panel Main earthing bar is to connected to earth electrode or earthing Grid by Suitable size of 2 No's of Eathing Strip or Earthing Wire via testing joints.
- **Energize the Panel**
- Switch off All Switchgear of Panel.
- Connect the incoming cables of Panel to the Power Supply Source.
- Check healthy ness of Power Supply at incoming of Panel.
- **NO LOAD:**
- Measure input Voltage of Power Supply between Phase to Phase, between Phase and Neutral and between Neutral and Ground.
- If measured incoming Voltage is within limit than Switch ON the Main Breaker of Panel.
- Measure Voltage on Bus bar between Phase to Phase, between Phase and Neutral and between Neutral and Ground.
- If measured Bus bar Voltage is within limit than Panel should operate on NO LOAD Condition for 5 minutes to observe any heating, sparking and performance of accessories of Panel.
- After 5 minute, one by one Switch ON the all Circuit Breaker of Panel.
- **ON LOAD:**
- Measure Voltage on each outgoing feeder of panel between Phase to Phase, between Phase and Neutral and between Neutral and Ground.
- If measured Voltage of outgoing feeders are in within limit than Panel should Energize for 2 hours and verify complete performance. Check for any unusual temperature rise in cables, terminals and protective devices.
- **Correct Phasing:**

- Check Phase Sequence of Power Supply at Outgoing Circuit of Panel.
- If there is not correct phase sequence for three phase power supply, reverse one phase at incoming side of Panel.
- **Indicators**
- Check all Power Supply ON /OFF / TRIP indicator works properly.
- If any associated converters check the indications to the corresponding output terminal block.
- **Under/Overvoltage Protection**
- Check the relay operation and adjust to the desired rating.
- The protection information reports shall be checked up to the distribution board output terminal block.
- **Automatic Transfer Switches**
- Check mechanical and / or electrical interlocks.
- With the both available supplies (Main Power & D.G Power) confirm the functional checks by presence of voltage, loss of supply, restoration of supply in manual and in automatic mode.
- The both incoming supplies are readiness in the distribution board
- **Record The Test Data:**

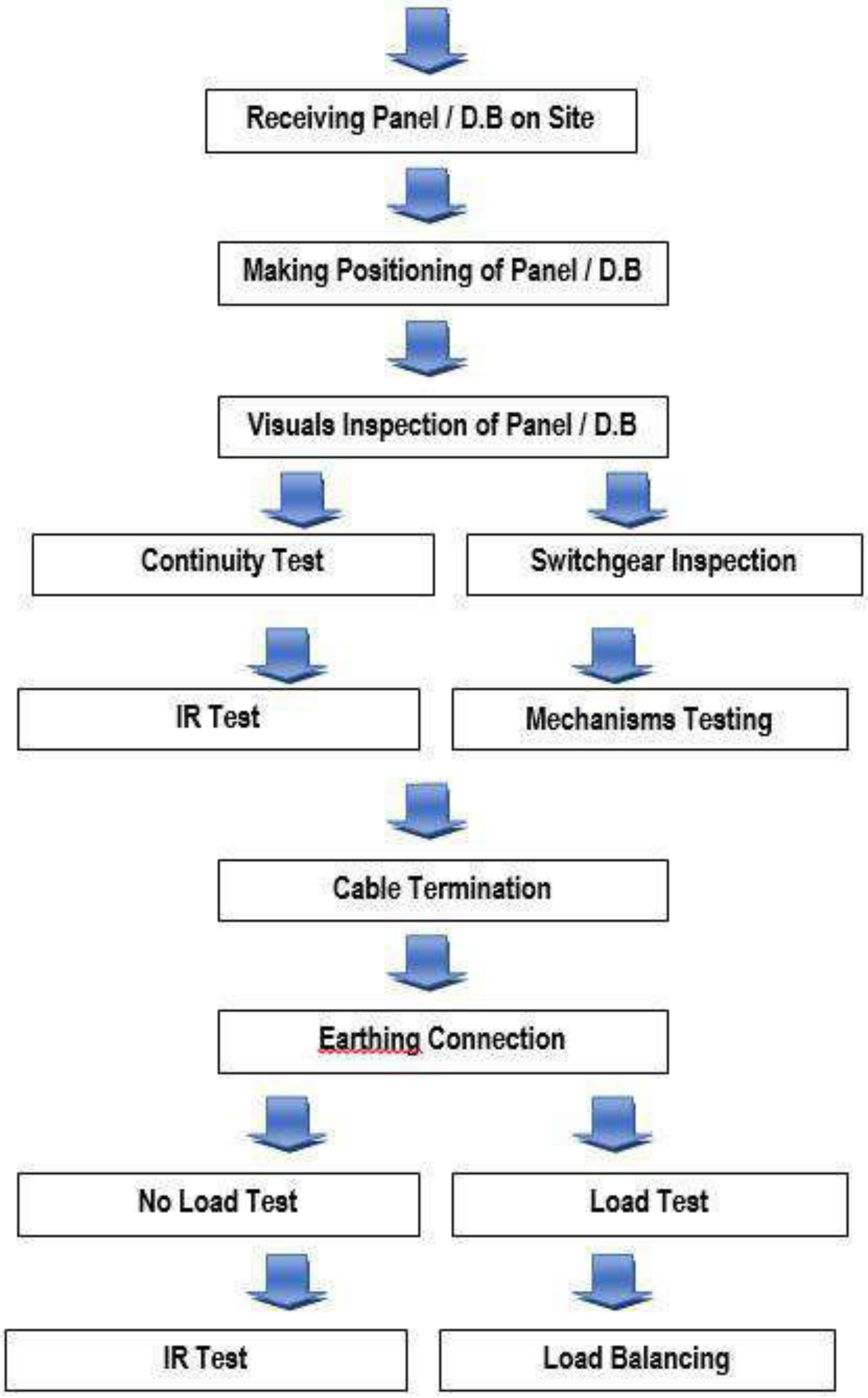
Floor Marking Near Electrical Panels:

- Keep Space in Front of Electrical Panels Clear
- The area in front of electrical panels must be kept clear and marking with effective floor marking taps.
- While specific colors of floor marking tape are not required, it's often recommended that employers select colors that indicate a hazard is present. Striped black and yellow floor marking tape often serves this purpose, as black and yellow are regularly used for hazard markings.
- When the nominal voltage to ground for a piece of electrical equipment is 600 volts or less, the minimum depth of clear working space in front of the equipment must be 3 feet (in some circumstances, it must be larger). This distance applies to some situations involving voltages up to 2500 volts as well.

Codes and Standards:

- Panel shall comply with the latest Relevant Indian Standards and Electricity Rule and Regulations and shall be as per IS-13947-1993.
- The general construction shall confirm to IS-8623-1977 (Part-1) for factory built assembled switchgear & control gear for voltage up to and including 1100 V AC.

Flow Chart of Panel / D.B Installation:



Chapter: 50 Working Space for Electrical Equipments – Panels.

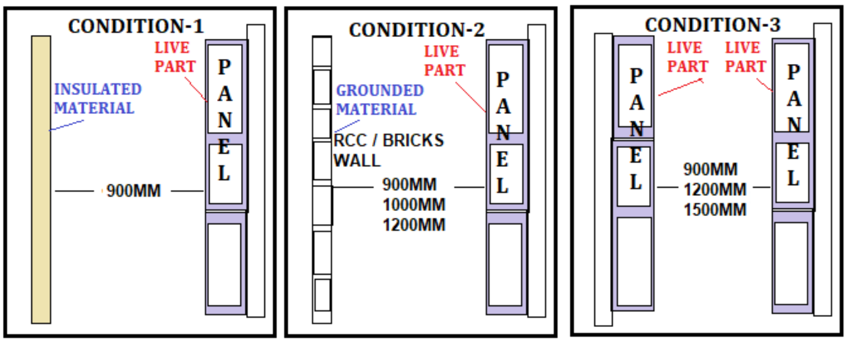
Electrical Equipment Space (As per NEC 110.26)

(A) Working Space:

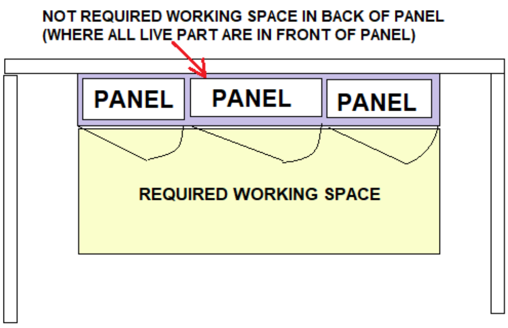
- Equipment that may need examination, adjustment, servicing, or maintenance while energized must have working space which is measured from the enclosure front, must not be less than the distances contained in Table 110.26(A)(1).

(1) Depth of Working Space.

Table 110.26(A)(1) Working Space			
Voltage-to-Ground	**One side of working Space having Panel Exposed live parts and other side of Working Space having no live or grounded parts (including concrete, brick, or tile walls)**	**One side of working Space having Panel Exposed live parts and other side of Working Space having live or grounded parts (including concrete, brick, or tile walls)**	**Exposed live parts on both sides of the working space.**
0 To 150V	3 Foot (900MM)	3 Foot (900MM)	3 Foot (900MM)
151V To 600V	3 Foot (900MM)	3.5 Foot (1000MM)	4 Foot (1200MM)
601V TO 1000V	3 Foot (900MM)	4 Foot (1200MM)	5 Foot (1500MM)

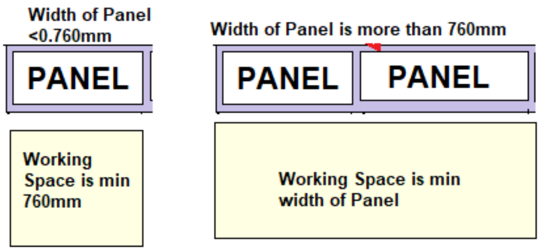


- **Rear and Sides.** Working space isn't required for the back or sides of assemblies where all connections and all renewable or adjustable parts are accessible from the front.



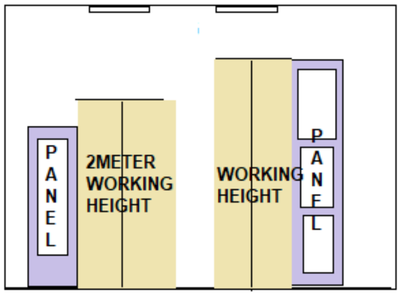
(2) Width of Working Space.

- **The width of the working space must be a minimum of 760MM (30 in) but in no case less than the width of the equipment.**
- The width of the working space can be measured from left-to-right, from right-to-left, or simply centred on the equipment, and the working space can overlap the working space for other electrical equipment.
- In all cases, the working space must be of sufficient width, depth, and height to permit all equipment doors to open 90 degrees.



(3) Height of Working Space (Headroom).

- **The height of the working space in front of equipment must not be less than 2 Meter (6½ ft) measured from the grade, floor, platform, or the equipment height, whichever is greater.**
- Equipment such as raceways, cables, wireways, cabinets, panels, and so on, can be located above or below electrical equipment, but must not extend more than 6 in. into the equipment's working space.

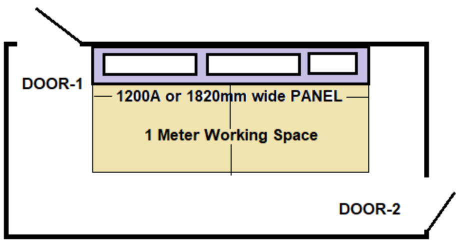


(B) Limited Access

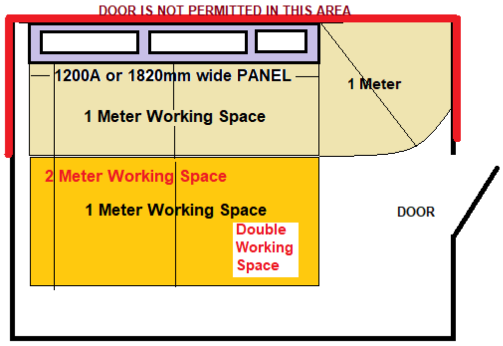
- Where equipment is installed above a lay-in ceiling, there shall be an opening not smaller than 559 mm × 559 mm (22 in. × 22 in.), or in a crawl space, there shall be an accessible opening not smaller than 559 mm × 762 mm (22 in. × 30 in.).
- The width of the working space shall be the width of the equipment enclosure or a minimum of 762 mm (30 in.) whichever is greater.
- All enclosure doors or hinged panels shall be capable of opening a minimum of 90 degrees.
- The space in front of the enclosure shall comply with the depth requirements of Table 110.26(A)(1).
- The maximum height of the working space shall be the height necessary to install the equipment in the limited space. A horizontal ceiling structural member or access panel shall be permitted in this space.

(C) Entrance to and Egress from Working Space.

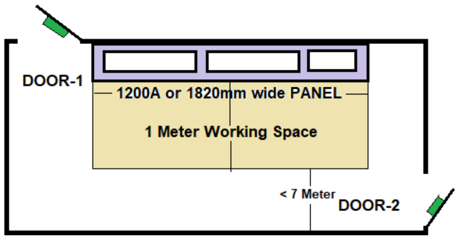
- **(1) Minimum Required:** At least one entrance of sufficient area must provide access to and egress from the working space.
- **(2) Large Equipment:** An entrance to and egress from each end of the working space of for electrical equipment rated 1,200A or more and over 6 ft wide is required an entrance of Not Less than 600MM Wide and 1800MM Height at each end of Working Place.



- A single entrance to and egress from the required working space is permitted where either of the following conditions is met:
- **(a) Unobstructed Egress.** Only one entrance is required where the location permits a continuous and unobstructed way of egress travel.
- **(b) Double Workspace.** Only one entrance is required where the required working space depth is doubled, and the equipment is located so the edge of the entrance is no closer than the required working space distance.



- **(3) Personnel Doors:** If equipment with overcurrent or switching devices rated 1,200A or more is installed, personnel door(s) for entrance to and egress from the working space located less than **25** ft from the nearest edge of the working space must have the door(s) open in the direction of egress and be equipped with panic hardware or other devices that open under simple pressure



(D) Illumination:

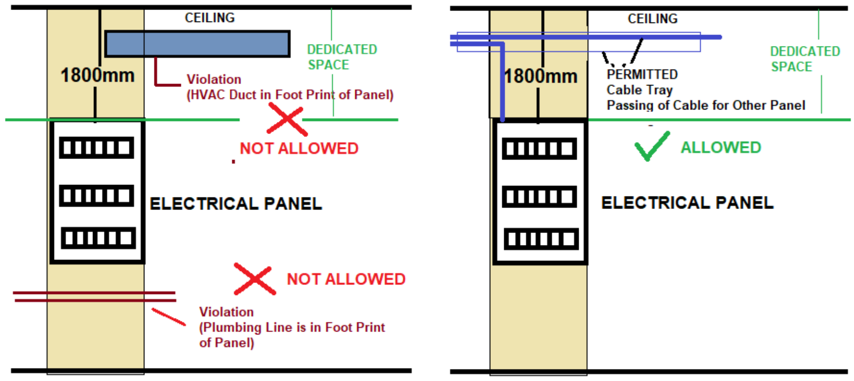
- Service equipment, switchboards, panel boards, as well as motor control centres located in indoors must have illumination and controlled by automatic means only.

(E) Dedicated Equipment Space:

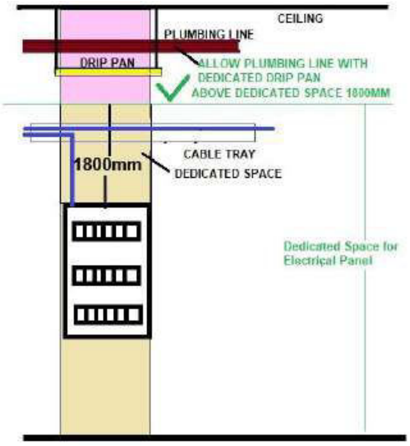
- Switchboards, panel boards, and motor control centres must have dedicated equipment space as follows:

(i) Indoors Panel (110.26 (E))

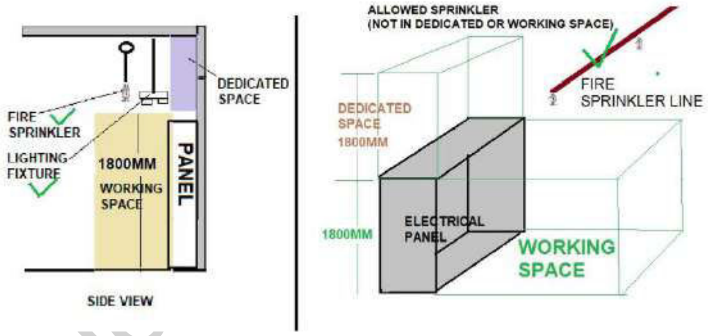
- **(a) Dedicated Electrical Space:**
- a dedicated electrical space is defined as the space equal to the width and the depth of the equipment extending from the floor to a **height of 1.8 m above the equipment or the structural ceiling, whichever is lower.**
- No piping, ducts, or other foreign equipment can be installed in this dedicated Electrical footprint space.
- Busways, conduits, raceways, and cables are permitted to enter through this Dedicated Electrical Space / zone.



- **(b) Foreign Systems:**
- Foreign systems can be located above the dedicated space if proper protection is installed to prevent damage to the electrical equipment from condensation, leaks, or breaks in the foreign systems,
- This can be achieved by installation of simple as a drip-pan.



- **(c) Sprinkler Protection (110.26(E)):**
- Sprinkler protection shall be permitted in the area above the dedicated electrical space if the electrical equipment is properly protected against Water leaks or breaks in the Sprinkler system.
- Sprinkler System shall not be permitted in Working Space of Electrical Equipment.
- **Hence the sprinkler piping can run above the dedicated electrical space 1.8 m above equipment** as long as the Electrical equipment below is protected from leaks, condensation, and even breaks by using dedicated Drip Pan.
- But drip pans which may create an obstruction to sprinkler system discharge. **So, it is always advisable to avoid locating sprinklers and sprinkler piping directly above electrical equipment and sprinklers and sprinkler piping are not permitted to be located directly within the working space for the equipment as shown in the figure**.



- Where all of the following conditions are met, sprinklers shall not be required in electrical rooms
- (1) The room is dedicated to electrical equipment only.
- (2) Only dry-type or liquid-type with listed K-class fluid electrical equipment is used.
- (3) Equipment is installed in a 2-hour fire-rated enclosure including protection for penetrations.
- (4) Storage is not permitted in the room.
- **(d) Suspended Ceilings:**
  - A dropped, Suspended or other similar hanging ceiling that does not add strength to the building structure is permitted to be located directly in the dedicated space, because they are not considered structural ceilings. Building structural members are also permitted in this space.

(ii) Outdoor Panels.

- Outdoor Electrical installations must comply with the following:

(a) Installation Requirements:

- Switchboards, switchgear, panel boards installed outdoors must be Installed in identified enclosures
- Protected from accidental contact by unauthorized personnel, or by vehicular traffic.
- Protected by accidental spillage or leakage from piping systems

(b) Work Space.

- The working clearance space shall include the zone described in 110.26(A). No architectural appurtenance or other equipment shall be located in this zone.
- Exception: Structural overhangs or roof extensions shall be permitted in this zone.

(c) Dedicated Equipment Space Outdoor.

- The footprint space (width and depth of the equipment) extending from grade to a height of 6 ft above the equipment must be dedicated for the electrical installation.
- No piping, ducts, or other equipment foreign to the electrical installation can be installed in this dedicated footprint space.

(F) Locked Electrical Equipment Rooms or Enclosures.

- Electrical equipment rooms and enclosures housing electrical equipment can be controlled by locks because they are still considered to be accessible to qualified persons who require access.

Enclosure for Electrical Installations (110.31).

- Electrical installations in an Electrical Room, or closed area surrounded by a wall, screen, or fence shall be access or controlled by a lock(s) or other approved manners.
- Electrical Installation Area (Indoor and Outdoor) shall be accessible to qualified persons only.
- The type of enclosure used shall be designed and constructed according to the nature and degree of the hazard(s) associated with the installation.
- For Outdoor Type Electrical installations shall be covered by Fence.
- **Fence:** A fence shall not be less than 2.1 m (7 ft) in height or a combination of 1.8 m (6 ft) or more of fence fabric and a 300 mm (1 ft) or more extension utilizing three or more strands of barbed wire or equivalent.
- The distance from the fence to live parts shall be not less than given in Table 110.31.

Min. Distance from Fence to Live Part Table 110.31	
Nominal Voltage	Min. Distance from Live Part (Meter)
601 V To 13799 V	3.05 Meter
13800 V To 230000 V	4.57 Meter
Above 230000 V	5.49 Meter

1) Electrical Room.

- Where an electrical vault is required or specified for conductors and equipment 110.31(A)(1) to (A)(5) shall apply.
- **(1) Walls and Roof.** The walls and roof shall be constructed of a minimum fire rating of 3 hours. For the purpose of this section, studs and wallboard construction shall not be permitted.
- **(2) Floors.** The floors of vaults in contact with the earth shall be of concrete that is not less than 102 mm (4 in.) thick, but where the vault is constructed with a vacant space or other stories below it, the floor shall have adequate structural strength for the load imposed on it and a minimum fire resistance of 3 hours.
- **(3) Doors.** Each doorway leading into a vault from the building interior shall be provided with a tight-fitting door that has a minimum fire rating of 3 hours.
- **(4) Locks.** Doors shall be equipped with locks, and doors shall be kept locked, with access allowed only to qualified persons. Personnel doors shall swing out and be equipped with panic bars, pressure plates, or other devices that are normally latched but that open under simple pressure.

2) Enclosed Equipment Accessible to Unqualified Persons.

- Ventilating or similar openings in equipment shall be designed such that foreign objects inserted through these openings are deflected from energized parts.
- Where exposed to physical damage from vehicular traffic, suitable guards shall be provided.
- Non-metallic or metal-enclosed equipment located outdoors and accessible to the general public shall be designed such that exposed nuts or bolts cannot be readily removed, permitting access to live parts.
- Where non-metallic or metal-enclosed equipment is accessible to the general public and **the bottom of the enclosure is less than 2.5 m (8 ft) above the floor or grade level, the enclosure door or hinged cover shall be kept locked.** Doors and covers of enclosures used solely as pull boxes, splice boxes, or junction boxes shall be locked, bolted, or screwed on. Underground box covers that weigh over 45.4 kg (100 lb) shall be considered as meeting this requirement.

Introduction:

- Forms of segregation have great importance in electrical Panel designs.
- Form of segregation is the rule for provide separation from a one energizes function part to other energize function pant and access to a part of the assembly while other parts may remain energized. This can be achieved by using metallic or non-metallic physical barriers or insulation.
- The form of segregation provides protection against four objectives.

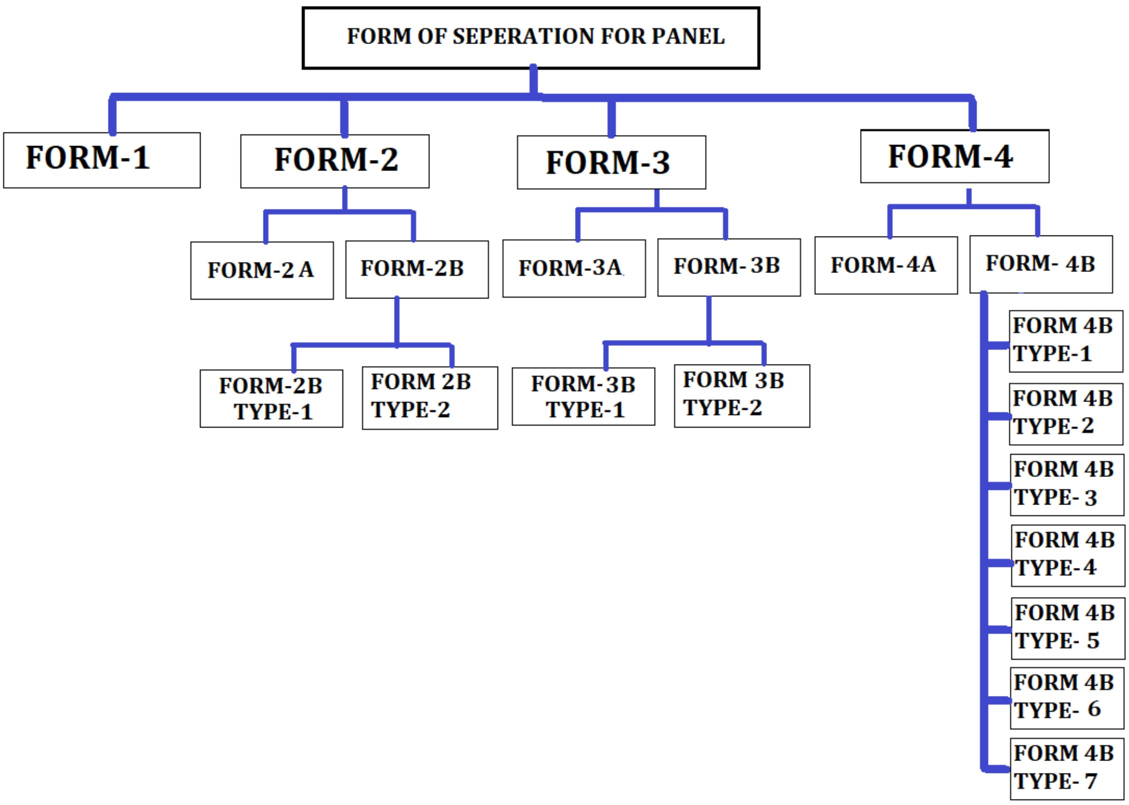
1. Protection against direct contact with live dangerous parts of adjacent functional units.
2. Protection against the entry of solid objects from one unit of an assembly to an adjacent unit.
3. Limitation of the effects of the spread of electric arcs.
4. Facilitation of panel maintenance operations.

Type of Seperation:

- As specified by AS / NZS / IEC 61439, There are four main categories outlined by the standard for internally separating the switchgear units and busbars of a Panel are

a) Form 1 (No segregation between busbar, terminals and Switchgear units)
b) Form 2 (Separation between switchgear units and the busbar)
c) Form 3 (Separation are between switchgear units and the busbar and Separation between Switchgear unit to Switchgear Unit)
d) Form 4 (Segregation between busbar, terminals and Switchgear units)

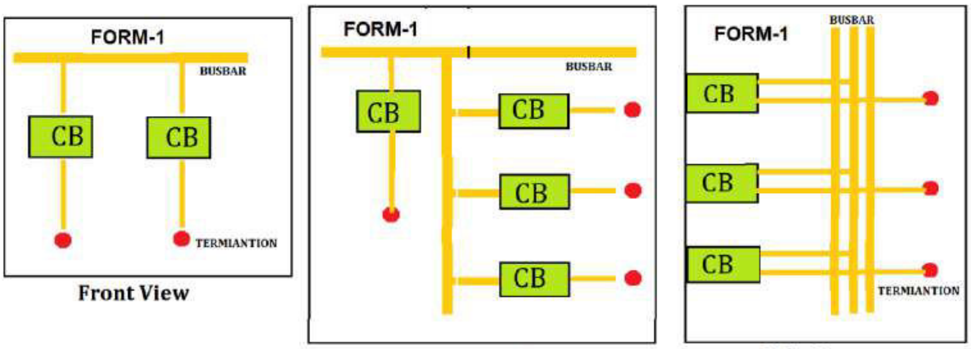
- The complexity of the forms increases with the numbers.



(1) Form 1:

- A Form 1 Panel has no internal separation among busbar, switchgear and outgoing Cable Terminations.
- All functional units are installed in one central section to provide protection against contact with any internal live parts.
- **Busbar and Switchgear:** Bus bars are not separated from the Switchgear units,
- **Busbar and Termination:** Bus bars are not separated from any incoming or outgoing terminations.

- **Switchgear and Switchgear units:** Switchgear units are not separated from each other.
- **Switchgear and Termination:** Switchgear units are not separated from any incoming or outgoing termination.
- **Termination and Termination:** Incoming and outgoing terminals are not separated from each other



Front View　Front View　Side View

Advantage:
- Simple Design and Less Space Required.

Electrical Safety:
- Less due to No separation between live parts.
- This form construction is rarely used.

Cost:
- Less Cost

Application:
- For small, low power switchboards.

(2) Form 2

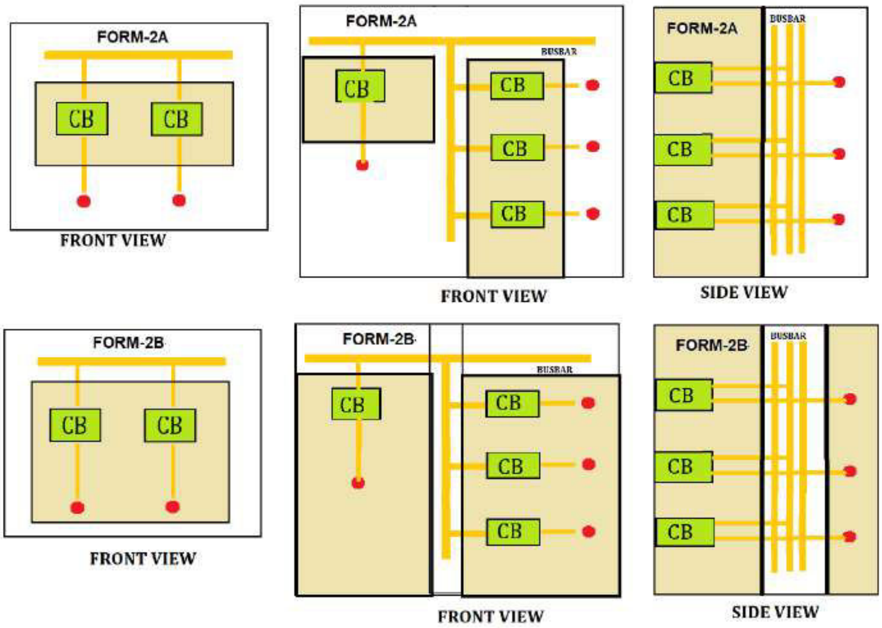
- Form 2a is the simplest for protecting against accidental contact with any internal live parts or components like the busbars, which are considered to be the most dangerous components.
- In FORM-2, Busbar is Separate from the Switchgear units but may or may not be separate from Cable terminal.
- **Busbar and Switchgear:** Bus bars are separated from the Switchgear units,
- **Busbar and Termination:** Bus bars may or may not separate from any incoming or outgoing terminations.
- **Switchgear and Switchgear units:** Switchgear units are not separated from each other.
- **Switchgear and Termination:** Switchgear units are not separated from any incoming or outgoing termination.
- **Termination and Termination:** Incoming and outgoing terminals are not separated from each other
- This is further classified into 2 categories.

FORM 2A
- Terminals are not separated from the busbars or each other.

FORM 2B
- Terminals are separated from the busbars

FORM 2B TYPE 1
- As form 2 but Busbar separation is achieved by insulated coverings, e.g. PVC sleeving, wrapping or coating.
- Terminals are the therefore separated from the busbars, but not from functional units or each other.

FORM 2B TYPE 2
- As from 2 but Busbar separation is achieved by metallic or non-metallic rigid barriers or partitions
- Terminals are therefore separated from the busbars, but not from functional units or each other



Advantages:

- There are several advantages to segregating functional units and busbars.
- This model allows circuit breakers to be reset when the switchboard is live because the operator is not exposed to a live busbar.

Electrical Safety:

- More than Form-1 due to separation between live parts (Busbar and Switchgear).

Cost:

- More Costly than Form-1

Application:

- For small, low power switchboards.

(3) Form 3

- This is more complicated but safer than Form 2.
- In form 3a, each device is isolated in a compartment that protects it from the effects of any incidents that may occur on another Part / Switchgear.
- Busbars and functional units are segregated. Functional units are also separated from each other in cubicles, and terminals are then separated from functional units, but they are not segregated from other functional units' terminals.
- **Busbar and Switchgear:** Bus bars are separated from the Switchgear units,
- **Busbar and Termination:** Bus bars are not separated from any incoming or outgoing terminations.
- **Switchgear and Switchgear units:** Switchgear units are separated from each other.
- **Switchgear and Termination:** Switchgear units are separated from any incoming or outgoing termination.
- **Termination and Termination:** Incoming and outgoing terminals are not separated from each other
- This is further classified into 2 categories.

FORM 3A

- External cabling terminals are not segregated from busbars.

FORM 3B

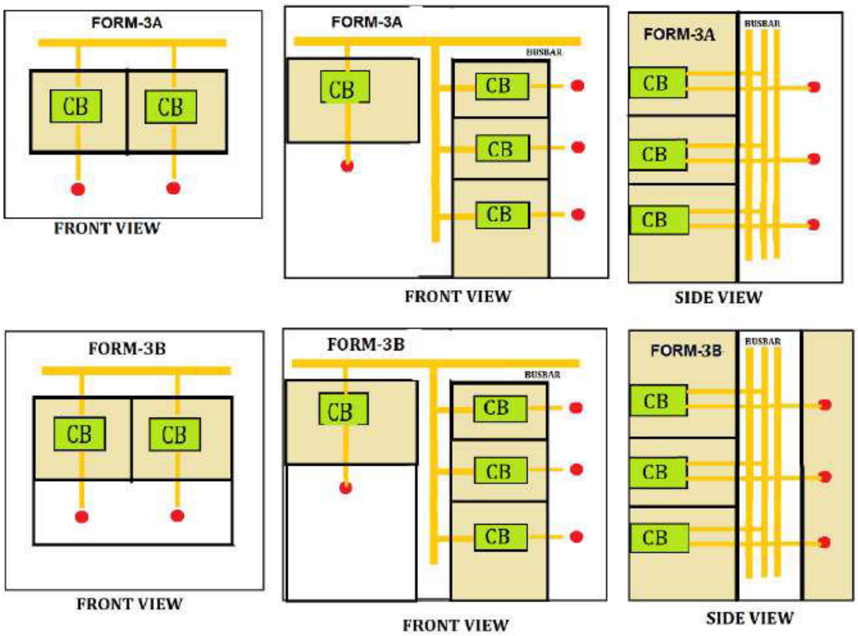
- External cabling terminals are separated from busbars

FORM 3B TYPE 1

- As from 3 but: Busbar separation is achieved by insulated coverings, e.g. PVC sleeving, wrapping or coating.
- Terminals are therefore separated from the busbars, but not from each other.

FORM 3B TYPE 2

- As form 3 but: Busbar separations is achieved by metallic or non-metallic rigid barriers or partitions.
- Terminals are therefore separated from the busbars, but not from each other.



Advantages:

- The advantages include safety, ease of maintenance and reliability because it's possible to isolate and perform maintenance on each starter without having to power down the whole switchboard.
- Serious faults within a starter are also more likely to be contained within a cubicle meaning adjacent starters are unaffected and can operate normally.

Electrical Safety:

- More reliable and safer than Form-2 due to separation between live parts (Busbar and Switchgear, Switchgear and Switchgear).

Cost:

- All these advantages come at a cost as a Form 3 board is significantly bigger and more expensive than a Form 1 or 2 board.

Application:

- Form 3 segregation is typically used for Big projects and larger operations that have a greater number of loads, motors and critical processes.
- They are utilised when safety, reliability and limited downtime are crucial.

(4) Form 4

- This is the highest form rating, as specified by AS/NZS / IEC 61439.1.
- Busbars are separated from functional units
- Functional units are separated from each other
- Terminations to functional units are separated from each other
- **Busbar and Switchgear:** Bus bars are separated from the Switchgear units,
- **Busbar and Termination:** Bus bars are separated from any incoming or outgoing terminations.
- **Switchgear and Switchgear units:** Switchgear units are separated from each other.
- **Switchgear and Termination:** Switchgear units are separated from any incoming or outgoing termination.
- **Termination and Termination:** Incoming and outgoing terminals are separated from each other
- This is further classified into 2 categories.

FORM 4A

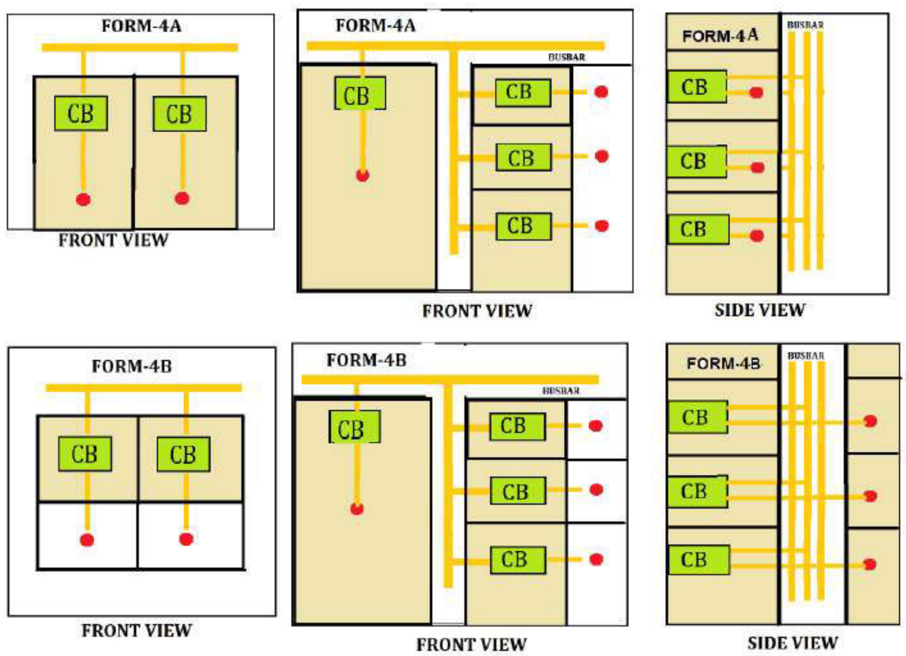
- External cabling terminals are within the same cubicle as the corresponding functional unit.

FORM 4B

- The external cabling terminals are not in the same cubicle as the corresponding functional unit, and they are separated from the terminals of other functional units.

CLASSIFICATION OF FORM 4B

TYPE	Busbar Separation	Termination Location	Cable Gland
FORM 4B TYPE-1	PVC sleeving, wrapping or coating.	Termination is within the same compartment as the functional unit.	Common Gland Plate
FORM 4B TYPE-2	Rigid Barriers	Termination is within the same compartment as the functional unit.	Common Gland Plate
FORM 4B TYPE-3	Rigid Barriers	Termination is within the same compartment as the functional unit.	Individual Gland Plate
FORM 4B TYPE-4	PVC sleeving, wrapping or coating.	Terminals are external to the functional unit and separated by insulated coverings, e.g. PVC Boots	Common Gland Plate
FORM 4B TYPE-5	Rigid Barriers	Terminals are external to the functional unit and separated by insulated coverings, e.g. PVC Boots	Common Gland Plate
FORM 4B TYPE-6	Rigid Barriers	Terminals are external to the functional unit compartment and enclosed in their own compartment by means of rigid barriers or partitions	Common Gland Plate
FORM 4B TYPE-7	Rigid Barriers	Terminals are external to the functional unit compartment and enclosed in their own compartment by means of rigid barriers or partitions complete with integral glanding facility	Individual Gland Plate



- The major difference between Forms 3 and 4 is the separation of the terminals of each functional unit the terminals of other units.

Advantages:

- The main advantage of this model is the ability to safely connect and disconnect outgoing cables while the rest of the switchboard remains in operation.
- In Large Panel access is required for inspection, to reset an auxiliary function. If the point of isolation and termination are each in their own individual box this can be deemed safer than if all the devices and connections are behind a single door

Electrical Safety:

- More reliable and safer than Form-4 due to separation between live parts (Busbar and Switchgear, Switchgear and Switchgear, Termination and Termination).
- Due to internal segregation is to limit the effects on adjacent circuits if something goes wrong. An external fault should cause a device to trip but this must not have any effect on any other circuits.

Cost:

- Form 4 board is significantly bigger and more expensive than a Form 3 board.

Applications:

- used in hospitals or for critical industrial processes.

SUMAMRY OF FORM OF SEPERATION OF PANEL				
SEPERATION BETWEEN	**FORM-1**	**FORM-2**	**FORM-3**	**FORM-4**
BUSBAR--SWITCHGEAR	**NO**	**YES**	**YES**	**YES**
BUSBAR--TERMIATION	**NO**	**NO / YES**	**YES**	**YES**
SWITCHGEAR—SWITCHGEAR.	**NO**	**NO**	**YES**	**YES**
SWITCHGEAR--TERMIANTION	**NO**	**NO**	**NO**	**YES**
TERMIANATION--TERMIANTION	**NO**	**NO**	**NO**	**YES**

Chapter: 52 Electrical Questions & Answers

1) Why ELCB cannot work if Neutral input of ELCB does not connect to ground?

- ELCB is used to detect earth leakage fault. Once the phase and neutral are connected in an ELCB, the current will flow through phase and that same current will have to return neutral so resultant current is zero.
- Once there is a ground fault in the load side, current from phase will directly pass through earth and it will not return through neutral through ELCB. That means once side current is going and not returning and hence because of this difference in current ELCB will trip and it will safe guard the other circuits from faulty loads. If the neutral is not groundedfault current will definitely high and that full fault current will come back through ELCB, and there will be no difference in current.

2) What is the difference between MCB & MCCB, Where it can be used?

- MCB is miniature circuit breaker which is thermal operated and use for short circuit protection in small current rating circuit.
- Normally it is used where normal current is less than 100A.
- MCCB moulded case circuit breaker and is thermal operated for over load current and magnetic operation for instant trip in short circuit condition. Under voltage and under frequency may be inbuilt.
- Normally it is used where normal current is more than 100A.

3) Why in a three pin plug the earth pin is thicker and longer than the other pins?

- It depends upon R=ρL/A where area(A) is inversely proportional to resistance (R), so if area (A) increases, R decreases & if R is less the leakage current will take low resistance path so the earth pin should be thicker.It is longer because The First to make the connection and last to disconnect should be earth Pin. This assures Safety for the person who uses the electrical instrument.

4) Why Delta Star Transformers are used for Lighting Loads?

- For lighting loads, neutral conductor is must and hence the secondary must be star winding and this lighting load is always unbalanced in all three phases.
- To minimize the current unbalance in the primary we use delta winding in the primarySo delta / star transformer is used for lighting loads.

5) What are the advantages of star-delta starter with induction motor?

- The main advantage of using the star delta starter is reduction of current during the starting of the motor. Starting current is reduced to 3-4 times of current of Direct online starting Hence the starting current is reduced , the voltage drops during the starting of motor in systems are reduced.

6) What is meant by regenerative braking?

- When the supply is cut off for a running motor, it still continue running due to inertia. In order to stop it quickly we place a load (resistor) across the armature winding and the motor should have maintained continuous field supplyso that back e.m.f voltage is made to apply across the resistor and due to load the motor stops quickly. This type of breaking is called as “Regenerative Breaking”.

7) When voltage increases then current also increases then why we need of over voltage relay and over current relay? Can we measure over voltage and over current by measuring current only?

- No. We cannot sense the over voltage by just measuring the current only because the current increases not only for over voltages but also for under voltage (As most of the loads are non-linear in nature).So, the over voltage protection & over current protection are completely different.
- Over voltage relay meant for sensing over voltages & protect the system from insulation break down and firing. Over current relay meant for sensing any internal short circuit, over load condition, earth fault thereby reducing the system failure & risk of fire. So, for a better protection of the system. It should have both over voltage & over current relay.

8) If one lamp connects between two phases it will glow or not?

- If the voltage between the two phases is equal to the lamp voltage then the lamp will glow.
- When the voltage difference is big it will damage the lamp and when the difference is smaller the lamp will glow depending on the type of lamp.

9) What are HRC fuses and where it is used?

- HRC stand for “high rupturing capacity” fuse and it is used in distribution system for electrical transformers

10) Mention the methods for starting an induction motor?

- The different methods of starting an induction motor

- DOL:direct online starter
- Star delta starter
- Auto transformer starter
- Resistance starter
- Series reactor starter

11) What is the difference between earth resistance and earth electrode resistance?

- Only one of the terminals is evident in the earth resistance. In order to find the second terminal we should recourse to its definition:
- Earth Resistance is the resistance existing between the electrically accessible part of a buried electrode and another point of the earth, which is far away.
- The resistance of the electrode has the following components:
  (A) the resistance of the metal and that of the connection to it.
  (B) The contact resistance of the surrounding earth to the electrode.

12) Why most of analog o/p devices having o/p range 4 to 20 mA and not 0 to 20 mA?

- 4-20 mA is a standard range used to indicate measured values for any process. The reason that 4ma is chosen instead of 0 mA is for fail safe operation.
- For example: A pressure instrument gives output 4mA to indicate 0 psi up to 20 mA to indicate 100 psior full scale. Due to any problem in instrument (i.e) broken wire, its output reduces to 0 mA. So if range is 0-20 mA then we can differentiate whether it is due to broken wire or due to 0 psi.

13) Two bulbs of 100w and 40w respectively connected in series across a 230v supply which bulb will glow bright and why?

- Since two bulbs are in series they will get equal amount of electrical current but as the supply voltage is constant across the Bulb (P=V^2/R).So the resistance of 40W bulb is greater and voltage across 40W is more (V=IR) so 40W bulb will glow brighter.

14) What happen if we give 220 volts dc supply to bulb or tube light?

- Bulbs or devices for AC are designed to operate such that it offers high impedance to AC supply. Normally they have low resistance. When DC supply is applied, due to low resistance, the current through lamp would be so high that it may damage the bulb element

15) What is meant by knee point voltage?

- Knee point voltage is calculated for electrical Current transformers and is very important factor to choose a CT. It is the voltage at which a CT gets saturated.

16) What is reverse power relay?

- Reverse Power flow relay are used in generating stations' protection.
- A generating station is supposed to feed power to the grid and in case generating units are off, there is no generation in the plant then plant may take power from grid. To stop the flow of power from grid to generator we use reverse power relay.

17) What will happen if DC supply is given on the primary of a transformer?

- Mainly transformer has high inductance and low resistance. In case of DC supply there is no inductance, only resistance will act in the electrical circuit. So high electrical current will flow through primary side of the transformer. So for this reason coil and insulation will burn out
- When AC current flow to primary winding it induced alternating flux which also link to secondary winding so secondary current flow in secondary winding according to primary current.Secondary current also induced emf (Back emf) in secondary winding which oppose induced emf of primary winding and thus control primary current also.
- If DC current apply to Primary winding than alternating flux is not produced so no secondary emf induced in secondary winding so primary current may goes high and burn transformer winding.

18) Different between megger and contact resistance meter?

- Megger used to measure cable resistance, conductor continuity, phase identification where as contact resistance meter used to measure low resistance like relays, contactors.

19) When we connect the capacitor bank in series?

- We connect capacitor bank in series to improve the voltage profile at the load end in transmission line there is considerable voltage drop along the transmission line due to impedance of the line. so in order to bring the voltage at the load terminals within its limits i.e (+ or – %6)of the rated terminal voltage the capacitor bank is used in series

20) What is Diversity factor in electrical installations?

- Diversity factor is the ratio of the sum of the individual maximum demands of the various subdivisions of a system, or part of a system, to the maximum demand of the whole system, or part of the system, under consideration. Diversity factor is usually more than one.

21) Why humming sound occurred in HT transmission line?

- This sound is coming due to ionization (breakdown of air into charged particles) of air around transmission conductor. This effect is called as Corona effect, and it is considered as power loss.

22) Why frequency is 50 hz only & why should we maintain the frequency constant?

- We can have the frequency at any frequency we like, but then we must also make our own motors, transformers or any other equipment we want to use.
- We maintain the frequency at 50 Hz or 60hzbecause the world maintains a standard at 50 /60hz and the equipments are made to operate at these frequency.

23) If we give 2334 A, 540V on Primary side of 1.125 MVA step up transformer, then what will be the Secondary Current, If Secondary Voltage=11 KV?

- As we know the Voltage & current relation for transformer-V1/V2 = I2/I1
  We Know, VI= 540 V; V2=11KV or 11000 V; I1= 2334 Amps.
  By putting these value on Relation-
  540/11000= I2/2334
  So,I2 = 114.5 Amps

24) What are the points to be considered for MCB (miniature circuit breaker selection)?

- I(L)x1.25=I(MAX) maximum current. Mcb specification is done on maximum current flow in circuit.

25) How can we start-up the 40w tube light with 230v AC/DC without using any choke/Coil?

- It is possible by means of Electronic choke. Otherwise it's not possible to ionize the particles in tube. Light, with normal voltage.

26) What is "pu" in electrical engineering?

- Pu stands for per unit and this will be used in power system single line diagram there it is like a huge electrical circuit with no of components (generators, transformers, loads) with different ratings (in MVA and KV). To bring all the ratings into common platform we use pu concept in which, in general largest MVA and KV ratings of the component is considered as base values, then all other component ratings will get back into this basis. Those values are called as pu values. (p.u=actual value/base value).

27) Why link is provided in neutral of an ac circuit and fuse in phase of ac circuit?

- Link is provided at a Neutral common point in the circuit from which various connections are taken for the individual control circuit and so it is given in a link form to withstand high Amps.
- But in the case of Fuse in the Phase of AC circuit it is designed such that the fuse rating is calculated for the particular circuit (i.e load) only. So if any malfunction happens the fuse connected in the particular control circuit alone will blow off.
- If Fuse is provided in Neutral and if it is blowout and at the same time Supply is on than due to open or break Neutral Voltage is increase and equipment may be damage.

28) If 200w, 100 w and 60 w lamps connected in series with 230V AC , which lamp glow brighter? Each lamp voltage rating is 230V.

- Each bulb when independently working will have currents (W/V= I)
- For 200 Watt Bulb current (I200) =200/230=0.8696 A
- For 100 Watt Bulb current (I100) =100/230=0.4348 A
- For 60 Watt Bulb current (I60) =60/230=0.2609 A
- Resistance of each bulb filament is (V/I = R)
- For 200 Watt Bulb R200= 230/0.8696= 264.5 ohms
- For 100 Watt Bulb R100= 230/0.4348 = 528.98 ohms and
- For 60 Watt Bulb R60= 230/0.2609=881.6 ohms respectively
- Now, when in series, current flowing in all bulbs will be same. The energy released will be I2R
- Thus, light output will be highest where resistance is highest. Thus, 60 watt bulb will be brightest.
- The 60W lamp as it has highest resistance & minimum current requirement.
- Highest voltage drop across it X I [which is common for all lamps] =s highest power.
- Note to remember:

- Lowest power-lamp has highest element resistance.
- And highest resistance will drop highest voltage drop across it in a Series circuit
- And highest resistance in a parallel circuit will pass minimum current through it. So minimum power dissipated across it as min current X equal Voltage across =s min power dissipation

29) How to check Capacitor with use of Multi meter.

- Most troubles with Capacitorseither open or short.
- An ohmmeter (multi meter) is good enough. A shorted Capacitor will clearly show very low resistance. A open Capacitor will not show any movement on ohmmeter.
- A good capacitor will show low resistance initially, and resistance gradually increases. This shows that Capacitor is not bad. By shorting the two ends of Capacitor (charged by ohmmeter) momentarily can give a weak spark.To know the value and other parameters, you need better instruments

30) What is the difference between Electronic regulator and ordinary rheostat regulator for fans?

- The difference between the electronic and ordinary regulator is that in electronic regulator power losses are less because as we decrease the speed the electronic regulator give the power needed for that particular speed .But in case of ordinary rheostat type regulator the power wastage is same for every speed and no power is saved. In electronic regulator triac is employed for speed control. by varying the firing angle speed is controlled but in rheostat control resistance is decreased by steps to achieve speed control.

31) What will happen when power factor is leading in distribution of power?

- If there is high power factor, i.e if the power factor is close to one:
- Losses in form of heat will be reduced,
- Cable becomes less bulky and easy to carry, and very cheap to afford.
- It also reduces over heating of transformers.

32) What the main difference between UPS & inverter?

- Uninterrupted power supply is mainly use for short time. Means according to ups VA it gives backup. Ups is also two types: on line and offline. Online ups having high volt and amp for long time backup with high dc voltage. But ups start with 12v dc with 7 amps. but inverter is start with 12v,24,dc to 36v dc and 120amp to 180amp battery with long time backup

33) Which type of A.C motor is used in the fan?

- It is Single Phase induction motor which mostly squirrel cage rotor and are capacitor start capacitor run.

34) What is the difference between synchronous generator and asynchronous generator?

- In simple, synchronous generator supplies' both active and reactive power but asynchronous generator (induction generator) supply's only active power and observe reactive power for magnetizing. This type of generators is used in windmills.

35) What is the Polarization index value?

- Its ratio between insulation resistance (IR)i.e meager value for 10min to insulation resistance for 1 min. It ranges from 5-7 for new motors & normally for motor to be in good condition it should be Greater than 2.5

36) What is Automatic Voltage regulator (AVR)?

- AVR is an abbreviation for Automatic Voltage Regulator.
- It is important part in Synchronous Generators; it controls the output voltage of the generator by controlling its excitation current. Thus it can control the output Reactive Power of the Generator.

37) Difference between a four point starter and three point starters?

- The shunt connection in four point starter is provided separately from the line where as in three point starter it is connected with line which is the drawback in three point starter

38) What happens if we connect a capacitor to a generator load?

- Connecting a capacitor across a generator always improves power factor, but it will help depends up on the engine capacity of the alternator, otherwise the alternator will be over loaded due to the extra watts consumed due to the improvement on pf.
- Don't connect a capacitor across an alternator while it is picking up or without any other load

39) Why the capacitors work on ac only?

- Generally capacitor gives infinite resistance to dc components (i.e., block the dc components). It allows the ac components to pass through.

40) Why the up to dia 70mm^2 live conductor, the earth cable must be same size but above dia 70mm^2 live conductor the earth conductor need to be only dia 70mm^2?

- The current carrying capacity of a cable refers to it carrying a continuous load.
- An earth cable normally carries no load, and under fault conditions will carry a significant instantaneous current but only for a short time most Regulations define 0.1 to 5 sec before the fuse or breaker trips. Its size therefore is defined by different calculating parameters.
- The magnitude of earth fault current depends on:
- (a) the external earth loop impedance of the installation (i.e. beyond the supply terminals)
- (b) the impedance of the active conductor in fault
- (c) the impedance of the earth cable.
- i.e. Fault current = voltage / a + b + c
- Now when the active conductor (b) is small, its impedance is much more than (a), so the earth (c) cable is sized to match. As the active conductor gets bigger, its impedance drops significantly below that of the external earth loop impedance (a); when It is quite large its impedance can be ignored. At this point there is no merit in increasing the earth cable size
- i.e. Fault current = voltage / a + c
- (c) is also very small so the fault current peaks out.
- The neutral conductor is a separate issue. It is defined as an active conductor and therefore must be sized for continuous full load. In a 3-phase system,
- If balanced, no neutral current flows. It used to be common practice to install reduced neutral supplies, and cables are available with say half-size neutrals (remember a neutral is always necessary to provide single phase voltages). However the increasing use of non-linear loads which produce harmonics has made this practice dangerous, so for example the current in some standard require full size neutrals. Indeed, in big UPS installations I install double neutrals and earths for this reason.

41) Why We use of Stones/Gravel in electrical Switch Yard

- Reducing Step and Touch potentials during Short Circuit Faults
- Eliminates the growth of weeds and small plants in the yard
- Improves yard working condition
- Protects from fire which cause due to oil spillage from transformer and also protects from wild habitat.

42) What is service factor?

- Service factor is the load that may be applied to a motor without exceeding allowed ratings.
- For example, if a 10-hp motor has a 1.25 service factor, it will successfully deliver 12.5 hp (10 x 1.25) without exceeding specified temperature rise. Note that when being driven above its rated load in this manner, the motor must be supplied with rated voltage and frequency.
- However a 10-hp motor with a 1.25 service factor is not a 12.5-hp motor. If the 10-hp motor is operated continuously at 12.5 hp, its insulation life could be decreased by as much as two-thirds of normal. If you need a 12.5-hp motor, buy one; service factor should only be used for short-term overload conditions

43) Why transmission line 11KV OR 33KV, 66KV not in 10KV 20KV?

- The miss concept is Line voltage is in multiple of 11 due to Form Factor. The form factor of an alternating current waveform (signal)is the ratio of the RMS (Root Mean Square) value to the average value (mathematical mean of absolute values of all points on the waveform). In case of a sinusoidal wave, the form factor is 1.11.
- The Main reason is something historical. In olden days when the electricity becomes popular, the people had a misconception that in the transmission line there would be a voltage loss of around 10%. So in order to get 100 at the load point they started sending 110 from supply side. This is the reason. It has nothing to do with form factor (1.11).
- Nowadays that thought has changed and we are using 400 V instead of 440 V, or 230 V instead of 220 V.
- Also alternators are now available with terminal voltages from 10.5 kV to 15.5 kV so generation in multiples of 11 does not arise. Now a days when, we have voltage correction systems, power factor improving capacitors, which can boost/correct voltage to desired level, we are using the exact voltages like 400KV in spite of 444KV

44) What is electrical corona?

- Corona is the ionization of the nitrogen in the air, caused by an intense electrical field.
- Electrical corona can be distinguished from arcing in that corona starts and stops at essentially the same voltage and is invisible during the day and requires darkness to see at night.
- Arcing starts at a voltage and stops at a voltage about 50% lower and is visible to the naked eye day or night if the gap is large enough (about 5/8″ at 3500 volts).

45) What are the indications of electrical corona?

- A sizzling audible sound, ozone, nitric acid (in the presence of moisture in the air) that accumulates as a white or dirty powder, light (strongest emission in ultraviolet and weaker into visible and near infrared) that can be seen with the naked eye in darkness, ultraviolet cameras, and daylight corona cameras using the solar-blind wavelengths on earth created by the shielding ozone layer surrounding the earth.

46) What damage does corona do?

- The accumulation of the nitric acid and micro-arcing within it create carbon tracks across insulating materials. Corona can also contribute to the chemical soup destruction of insulating cements on insulators resulting in internal flash-over.
- The corona is the only indication. Defects in insulating materials that create an intense electrical field can over time result in corona that creates punctures, carbon tracks and obvious discoloration of NCI insulators.

47) How long does corona require creating visible damage?

- In a specific substation the corona ring was mistakenly installed backwards on a temporary 500kV NCI insulator, at the end of two years the NCI insulator was replaced because 1/3 of the insulator was white and the remaining 2/3 was grey.

48) What voltage are corona rings typically installed at?

- It varies depending upon the configuration of the insulators and the type of insulator, NCI normally start at 160kV, pin and cap can vary starting at 220kV or 345kV depending upon your engineering tolerances and insulators in the strings.

49) How do we select transformers?

- Determine primary voltage and frequency.
- Determine secondary voltage required.
- Determine the capacity required in volt-amperes. This is done by multiplying the load current (amperes) by the load voltage (volts) for single phase.
- For example: if the load is 40 amperes, such as a motor, and the secondary voltage is 240 volts, then 240 x 40 equals 9600 VA. A 10 KVA (10,000 volt-amperes) transformer is required.
- Always select Transformer Larger than Actual Load.This is done for safety purposes and allows for expansion, in case more loads is added at a later date. For 3 phase KVA, multiply rated volts x load amps x 1.73 (square root of 3) then divide by 1000.
- Determine whether taps are required. Taps are usually specified on larger transformers.

50) Why Small Distribution Transformers not used for Industrial Applications?

- Industrial control equipment demands a momentary overload capacity of three to eight times' normal capacity. This is most prevalent in solenoid or magnetic contactor applications where inrush currents can be three to eight times as high as normal sealed or holding currents but still maintain normal voltage at this momentary overloaded condition.
- Distribution transformers are designed for good regulation up to 100 percent loading, but their output voltage will drop rapidly on momentary overloads of this type making them unsuitable for high inrush applications.
- Industrial control transformers are designed especially for maintaining a high degree of regulation even at eight time's normal load. This results in a larger and generally more expensive transformer.

51) Can 60 Hz transformers be used at higher frequencies?

- Transformers can be used at frequencies above 60 Hz up through 400 Hz with no limitations provided nameplate voltages are not exceeded.
- However, 60 Hz transformers will have less voltage regulation at 400 Hz than 60 Hz.

52) What is meant by regulation in a transformer?

- Voltage regulation in transformers is the difference between the no load voltage and the full load voltage. This is usually expressed in terms of percentage.
- For example: A transformer delivers 100 volts at no load and the voltage drops to 95 volts at full load, the regulation would be 5%.Distribution transformers generally have regulation from 2% to 4%, depending on the size and the application for which they are used.

53) Why is impedance important?

- It is used for determining the interrupting capacity of a circuit breaker or fuse employed to protect the primary of a transformer.
- Example: Determine a minimum circuit breaker trip rating and interrupting capacity for a 10 KVA single phase transformer with 4% impedance, to be operated from a 480 volt 60 Hz source.
- Calculate:

- Normal Full Load Current = Nameplate Volt Amps / Line Volts = 10,000 VA / 480 V = 20.8 Amperes
- Maximum Short Circuit Amps = Full Load Amps / 4% =20.8 Amps / 4%= 520 Amp
- The breaker or fuse would have a minimum interrupting rating of 520 amps at 480 volts.
- Example: Determine the interrupting capacity, in amperes, of a circuit breaker or fuse required for a 75 KVA, three phase transformer, with a primary of 480 volts delta and secondary of 208Y/120 volts. The transformer impedance (Z) = 5%. If the secondary is short circuited (faulted), the following capacities are required:
- Normal Full Load Current =Volt Amps / √ 3 x Line Volts= 75,000 VA / √ 3 x Line Volts √ 3 x 480 V =90 Amps
- Maximum Short Circuit Line Current = Full Load Amps / 5%= 90 Amps / 5% =1,800 Amps
- The breaker or fuse would have a minimum interrupting rating of 1,800 amps at 480 volts.
- Note:The secondary voltage is not used in the calculation. The reason is the primary circuit of the transformer is the only winding being interrupted.

54) What causes flash-over?

- Flash-over causes are not always easily explained, can be cumulative or stepping stone like, and usually result in an outage and destruction. The first flash-over components are available voltage and the configuration of the energized parts, corona may be present in many areas where the flash-over occurs, and flash-over can be excited by stepping stone defects in the insulating path.

55) What are taps and when are they used?

- Taps are provided on some transformers on the high voltage winding to correct for high or low voltage conditions, and still deliver full rated output voltages at the secondary terminals. Taps are generally set at two and a half and five percent above and below the rated primary voltage.

56) Can Transformers be reverse connected?

- Drytype distribution transformers can be reverse connected without a loss of KVA rating, but there are certain limitations. Transformers rated 1 KVA and larger single phase, 3 KVA and larger three phases can be reverse connected without any adverse effects or loss in KVA capacity.
- The reason for this limitation in KVA size is, the turns ratio is the same as the voltage ratio.
- Example: A transformer with a 480 volt input, 240 volt output— can have the output connected to a 240 volt source and thereby become the primary or input to the transformer, then the original 480 volt primary winding will become the output or 480 volt secondary.
- On transformers rated below 1 KVA single phase, there is a turn's ratio compensation on the low voltage winding. This means the low voltage winding has a greater voltage than the nameplate voltage indicates at no load.
- For example, a small single phase transformer having a nameplate voltage of 480 volts primary and 240 volts secondary, would actually have a no load voltage of approximately 250 volts, and a full load voltage of 240 volts. If the 240 volt winding were connected to a 240 volt source, then the output voltage would consequently be approximately 460 volts at no load and approximately 442 volts at full load. As the KVA becomes smaller, the compensation is greater—resulting in lower output voltages.
- When one attempts to use these transformers in reverse, the transformer will not be harmed; however, the output voltage will be lower than is indicated by the nameplate.

57) What is the difference between "Insulating", "Isolating", and "Shielded Winding" transformers?

- Insulating and isolating transformers are identical. These terms are used to describe the separation of the primary and secondary windings. A shielded transformer includes a metallic shield between the primary and secondary windings to attenuate (lessen) transient noise.

58) How many BTU's of heat does a transformer generate?

- The heat a transformer generates is dependent upon the transformer losses. To determine air conditioning requirements multiply the sum of the full load losses (obtained from factory or test report) of all transformers in the room by 3.41 to obtain the BTUs/hour.
For example: A transformer with losses of 2000 watts will generate 6820 BTUs/hour.

59) What is a transformer and how does it work?

- A transformer is an electrical apparatus designed to convert alternating current from one voltage to another. It can be designed to "step up" or "step down" voltages and works on the magnetic induction principle.
- A transformer has no moving parts and is a completely static solid state device, which insures, under normal operating conditions, a long and trouble-free life. It consists, in its simplest form, of two or more coils of insulated wire wound on a laminated steel core.

- When voltage is introduced to one coil, called the primary, it magnetizes the iron core. A voltage is then induced in the other coil, called the secondary or output coil. The change of voltage (or voltage ratio) between the primary and secondary depends on the turns ratio of the two coils.

60) Factors Affecting Corona Discharge Effect:

- Corona Discharge Effect occurs because of ionization if the atmospheric air surrounding the voltage conductors, so Corona Discharge Effect is affected by the physical state of the atmosphere as well as by the condition of the lines.
- (1)Conductor: Corona Discharge Effect is considerably affected by the shape, size and surface conditions of the conductor .Corona Discharge Effect decreases with increases in the size (diameter) of the conductor, this effect is less for the conductors having round conductors compared to flat conductors and Corona Discharge Effect is concentrated on that places more where the conductor surface is not smooth.
- (2) Line Voltage: Corona Discharge effect is not present when the applied line voltages are less. When the Voltage of the system increases (In EHV system) corona Effect will be more.
- (3) Atmosphere: Breakdown voltage directly proportional to the density of the atmosphere present in between the power conductors. In a stormy weather the ions present around the conductor is higher than normal weather conditionSo Corona Breakdown voltage occurs at low voltages in the stormy weather condition compared to normal conditions
- (4)Spacing between the Conductors:Electro static stresses are reduced with increase in the spacing between the conductors. Corona Discharge Effect takes place at much higher voltage when the distance between the power conductors increases.

61) Will a transformer change Three Phases to Single Phase?

- A transformer will not act as a phase changing device when attempting to change three phase to single phase.
- There is no way that a transformer will take three phase in and deliver single phase out while at the same time presenting a balanced load to the three phase supply system.
- There are, however, circuits available to change three phase to two phase or vice versa using standard dual wound transformers. Please contact the factory for two phase applications.

62) Can 60 Hz transformers be operated at 50 Hz?

- Transformers rated below 1 KVA can be used on 50 Hz service.
- Transformers 1 KVA and larger, rated at 60 Hz, should not be used on 50 Hz service, due to the higher losses and resultant heat rise. Special designs are required for this service. However, any 50 Hz transformer will operate on a 60 Hz service.

63) Can transformers be used in parallel?

- Single phase transformers can be used in parallel only when their impedances and voltages are equal. If unequal voltages are used, a circulating current exists in the closed network between the two transformers, which will cause excess heating and result in a shorter life of the transformer. In addition, impedance values of each transformer must be within 7.5% of each other.
- For example: Transformer A has an impedance of 4%, transformer B which is to be parallel to A must have impedance between the limits of 3.7% and 4.3%. When paralleling three phase transformers, the same precautions must be observed as listed above, plus the angular displacement and phasing between the two transformers must be identical.

64) What are causes of insulator failure?

- Electrical field intensity producing corona on contaminated areas, water droplets, icicles, corona rings, … This corona activity then contributes nitric acid to form a chemical soup to change the bonding cements and to create carbon tracks, along with ozone and ultraviolet light to change the properties of NCI insulator coverings. Other detrimental effects include water on the surface or sub-surface freezing and expanding when thawing, as a liquid penetrating into a material and then a sudden temperature change causes change of state to a gas and rapid expansion causing fracture or rupture of the material.

65) Causes of Corona

- Corona is causes by the following reasons:
- The natural electric field caused by the flow of electrons in the conductor. Interaction with surrounding air. Poor or no insulation is not a major cause but increases corona.
- The use of D.C (Direct Current) for transmission.(Reason why most transmission is done in form of AC)

66) Effects of Corona

- Line Loss – Loss of energy because some energy is used up to cause vibration of the air particles.

- Long term exposure to these radiations may not be good to health (yet to be proven).
- Audible Noise
- Electromagnetic Interference to telecommunication systems
- Ozone Gas production
- Damage to insulation of conductor.

67) What is polarity, when associated with a transformer?

- Polarity is the instantaneous voltage obtained from the primary winding in relation to the secondary winding.
- Transformers 600 volts and below are normally connected in additive polarity — that is, when tested the terminals of the high voltage and low voltage windings on the left hand side are connected together, refer to diagram below. This leaves one high voltage and one low voltage terminal unconnected.
- When the transformer is excited, the resultant voltage appearing across a voltmeter will be the sum of the high and low voltage windings.
- This is useful when connecting single phase transformers in parallel for three phase operations. Polarity is a term used only with single phase transformers.

68) What is exciting current?

- Exciting current, when used in connection with transformers, is the current or amperes required for excitation. The exciting current on most lighting and power transformers varies from approximately 10% on small sizes of about 1 KVA and smaller to approximately .5% to 4% on larger sizes of 750 KVA. The exciting current is made up of two components, one of which is a real component and is in the form of losses or referred to as no load watts; the other is in the form of reactive power and is referred to as KVAR.

69) What is Boucholz relay and the significance of it in to the transformer?

- Boucholz relay is a device which is used for the protection of transformer from its internal faults,
- it is a gas based relay. whenever any internal fault occurs in a transformer, the boucholz relay at once gives a horn for some time, if the transformer is isolated from the circuit then it stop its sound itself otherwise it trips the circuit by its own tripping mechanism.

70) Why we do two types of earthing on transformer (Body earthing & neutral earthing)

- The two types of earthing are Familiar as Equipment earthing and system earthing.
- In Equipment earthing: body (non conducting part) of the equipment should be earthed to safeguard the human beings.
- The System Earthing : In this neutral of the supply source (Transformer or Generator) should be grounded. With this, in case of unbalanced loading neutral will not be shifted. So that unbalanced voltages will not arise.We can protect the equipment also. With size of the equipment (transformer or alternator)and selection of relying system earthing will be further classified into directly earthed, Impedance earthing, resistive (NGRs) earthing.

71) Conductor corona is caused by?

- Corona on a conductor can be due to conductor configuration (design) such as diameter too small for the applied voltage will have corona year-around and extreme losses during wet weather, the opposite occurs during dry weather as the corona produces nitric acid which accumulates and destroys the steel reinforcing cable (ACSR) resulting in the line dropping. Road salts and contaminants can also contribute to starting this deterioration.

72) What is flash-over and arcing?

- Flash-over is an instantaneous event where the voltage exceeds the breakdown potential of the air but does not have the current available to sustain an arc, an arc can have the grid fault current behind it and sustain until the voltage decreases below 50% or until a protective device opens.
- Flash-over can also occur due to induced voltages in unbounded (loose bolts, washers, etc) power pole or substation hardware, this can create RFI/TVI or radio/TV interference. Arcing can begin at 5 volts on a printed circuit board or as the insulation increases it may require 80kVAC to create flash-over on a good cap and pin insulator.

73) How to Minimizing Corona Effects

- Installing corona rings at the end of transmission lines.
- A corona ring, also called anti-corona ring, is a toroid of (typically) conductive material located in the vicinity of a terminal of a high voltage device. It is electrically insulated.
- Stacks of more spaced rings are often used. The role of the corona ring is to distribute the electric field gradient and lower its maximum values below the corona threshold, preventing the corona discharge.

74) What is BIL and how does it apply to transformers?

- BIL is an abbreviation for Basic Impulse Level. Impulse tests are dielectric tests that consist of the application of a high frequency steep wave front voltage between windings, and between windings and ground. The Basic Impulse Level of a transformer is a method of expressing the voltage surge (lightning, switching surges, etc.) that a transformer will tolerate without breakdown.
- All transformers manufactured in this catalog, 600 volts and below, will withstand the NEMA standard BIL rating, which is 10 KV.
- This assures the user that he will not experience breakdowns when his system is properly protected with lightning arrestors or similar surge protection devices.

75) The difference between Ground and Neutral?

- NEUTRAL is the origin of all current flow. In a poly-phase system, as its phase relationship with all the three phases is the same, (i.e.) as it is not biased towards any one phase, thus remaining neutral, that's why it is called neutral.
- Whereas, GROUND is the EARTH on which we stand. It was perceived to utilize this vast, omnipresent conductor of electricity, in case of fault, so that the fault current returns to the source neutral through this conductor given by nature which is available free of cost. If earth is not used for this purpose, then one has to lay a long. long metallic conductor for the purpose, thus increasing the cost.
- Ground should never be used as neutral. The protection devices (eg ELCB, RCD etc) work basically on principle that the phase currects are balanced with neutral current. In case you use ground wire as the neutral, these are bound to trip if they are there – and they must be there. at least at substations. And these are kept very sensitive i.e. even minute currents are supposed to trip these.
- One aspect is safety – when someone touches a neutral, you don't want him to be electrocuted – do you? Usually if you see the switches at home are on the phase and not neutral (except at the MCB stage). Any one assumes the once the switch is off, it is safe (the safety is taken care of in 3 wire system, but again most of the fixtures are on 2 wire) – he will be shocked at the accidental touching of wire in case the floating neutral is floating too much.

76) What is impedance of a transformer?

- If you mean the percentage impedance of the transformed it means the ratio of the voltage(that if you applied it to one side of the transformer while the other side of the transformer is short cuitcuted, a full load current shall flow in the short circuits side), to the full load current.
- More the %Z of transformer, more Copper used for winding, increasing cost of the unit. But short circuit levels will reduce, mechanical damages to windings during short circuit shall also reduce. However, cost increases significantly with increase in %Z.
- Lower %Z means economical designs. But short circuit fault levels shall increase tremendously, damaging the winding & core.
- The high value of %Z helps to reduce short circuit current but it causes more voltage dip for motor starting and more voltage regulation (% change of voltage variation) from no load to full load.

77) How are transformers sized to operate Three Phase induction type squirrel cage motors?

- The minimum transformer KVA rating required to operate a motor is calculated as follows:
- Minimum Transformer KVA =Running Load Amperes x 1.73x Motor Operating Voltage / 1000
- NOTE: If motor is to be started more than once per hour add 20% additional KVA. Care should be exercised in sizing a transformer for an induction type squirrel cage motor as when it is started, the lock rotor amperage is approximately 5 to 7 times the running load amperage. This severe starting overload will result in a drop of the transformer output voltage.
- When the voltage is low the torque and the horsepower of the motor will drop proportionately to the square of the voltage.
- For example: If the voltage were to drop to 70% of nominal, then motor horsepower and torque would drop to 70 % squared or 49% of the motor nameplate rating.
- If the motor is used for starting a high torque load, the motor may stay at approximately 50% of normal running speed The underlying problem is low voltage at the motor terminals. If the ampere rating of the motor and transformer over current device falls within the motor's 50% RPM draw requirements, a problem is likely to develop. The over current device may not open under intermediate motor ampere loading conditions.
- Overheating of the motor and/or transformer would occur, possibly causing failure of either component.
- This condition is more pronounced when one transformer is used to power one motor and the running amperes of the motor is in the vicinity of the full load ampere rating of the transformer. The following precautions should be followed:

- (1)When one transformer is used to operate one motor, the running amperes of the motor should not exceed 65% of the transformer's full load ampere rating.
- (2) If several motors are being operated from one transformer, avoid having all motors start at the same time. If this is impractical, then size the transformer so that the total running current does not exceed 65% of the transformer's full load ampere rating.

78) Which Point need to be consider while Neutral Earthing of Transformer?

- The following points need to check before going for Neutral Grounding Resistance.
- Fault current passing through ground, step and touch potential.
- Capacity of transformer to sustain ground fault current, w.r.t winding, core burning.
- Relay co-ordination and fault clearing time.
- Standard practice of limiting earth fault current. In case no data or calculation is possible, go for limiting E/F current to 300A or 500A, depending on sensivity of relay.

79) Why a neutral grounding contactor is needed in diesel generator?

- There would not be any current flow in neutral if DG is loaded equally in 3 phases , if there any fault(earth fault or over load) in any one of the phase ,then there will be un balanced load in DG . at that time heavy current flow through the neutral ,it is sensed by CT and trips the DG. so neutral in grounded to give low resistance path to fault current.
- An electrical system consisting of more than two low voltage Diesel Generator sets intended for parallel operation shall meet the following conditions:
- (i) Neutral of only one generator needs to be earthed to avoid the flow of zero sequence current.
- (ii) During independent operation, neutrals of both generators are required in low voltage switchboard to obtain three phases, 4 wire system including phase to neutral voltage.
- (iii) required to achieve restricted earth fault protection (REF) for both the generators whilst in operation.
- Solution:
- Considering the requirement of earthing neutral of only one generator, a contactor of suitable rating shall be provided in neutral to earth circuit of each generator. This contactor can be termed as "neutral contactor".
- Neutral contactors shall be interlocked in such a way that only one contactor shall remain closed during parallel operation of generators. During independent operation of any generator its neutral contactor shall be closed.
- Operation of neutral contactors shall be preferably made automatic using breaker auxiliary contacts.

80) Neutral grounded system vs solidly grounded system

- In India, at low voltage level (433V) weMUST do only Solid Earthing of the system neutral.
- This is by IE Rules 1956, Rule No. 61 (1) (a). Because, if we option for impedance earthing, during an earth fault, there will be appreciable voltage present between the faulted body & the neutral, the magnitude of this voltage being determined by the fault current magnitude and the impedance value.
- This voltage might circulate enough current in a person accidentally coming in contact with the faulted equipment, as to harm his even causing death. Note that, LV systems can be handled by non-technical persons too. In solid earthing, you do not have this problem, as at the instant of an earth fault, the faulted phase goes to neutral potential and the high fault current would invariably cause the Over current or short circuit protection device to operate in sufficiently quick time before any harm could be done

81) What is the reason of grounding or earthing of equipment?

- with a ground path, in case of short circuit the short circuit current goes to the body of the equipment & then to the ground through the ground wire. Hence if at the moment of fault if a person touches the equipment body he will not get a shock cause his body resistance (in thousands of ohms) will offer a high resistance path in comparison to the ground wire. Hence the fault current will flow thru the ground wire & not thru human body.
- Providing a ground path helps in clearing the fault. A CT in the ground connection detects the high value fault current hence the relay connected to the CT gives breaker a trip command.
- Grounding helps in avoiding arcing faults. IF there would have been no ground then a fault with the outer body can cause a arcing to the ground by breaking the air. This is dangerous both for the equipment & the human beings.

82) A type-C MCB has thermo magnetic capability 5In to 10In that means a short circuit current will be interrupted as the value will reach between 5In to 10In but the MCB breaking capacity is (for example) define as 10kA.

- 5In to 10In is the pickup threshold for the magnetic trip element. The MCB will trip instantaneously when the current is between these limits. 10kA is the short circuit withstands capacity of the MCB.

- Under normal condition, a current limiting type MCB will trip on short circuit (magnetic trip) and the current during circuit interruption will be much less than the prospective current. However, the MCBs have to have a short circuit capacity more than or equal to the fault level at the location where it is installed.

83) What is Ferrari Effect?

- Ferranti Effect is due to the rise in voltage at the receiving end than that of the sending end. This occurs when the load on the system reduces suddenly.
- Transmission line usually consists of line inductance, line to earth capacitance and resistance. Resistance can be neglected with respect to the line inductance .When the load on the system falls the energy stored in the capacitance gets discharged. The charging current causes inductive reactance voltage drop. This gets added vector ally to the sending end voltage and hence causes the voltage at the receiving end to raise
- A Long transmission line draws significant amount of charging current. If such line is open circuited or very lightly loaded at the receiving end, the voltage at the receiving end may become greater than sending end voltage. This effect is known Ferranti effect and is due to the voltage drop across the line inductance (due to charging current) being in phase with the sending end voltages. Therefore both capacitance and inductance is responsible to produce this phenomenon.
- The capacitance (charging current) is negligible in short lines, but significant in medium and long transmission line. Hence, this phenomenon is applicable for medium and long transmission line. The main impact of this phenomenon is on over voltage protection system, surge protection system, insulation level etc.

84) Can single phase transformers be used for three phase applications?

- Yes. Three phase transformers are sometimes not readily available whereas single phase transformers can generally be found in stock. Three single phase transformers can be used in delta connected primary and wye or delta connected secondary. They should never be connected wye primary to wye secondary, since this will result in unstable secondary voltage. The equivalent three phase capacity when properly connected of three single phase transformers is three times the nameplate rating of each single phase transformer.

85) What is BIL and how does it apply to transformers?

- BIL is an abbreviation for Basic Impulse Level. Impulse tests are dielectric tests that consist of the application of a high frequency steep wave front voltage between windings, and between windings and ground. The BIL of a transformer is a method of expressing the voltage surge that a transformer will tolerate without breakdown.

86) Where Auto-recloser is used?

- For Generator protection / Transformer Protection / Transmission Line / Bus bar protection.
- Many faults on overhead transmission lines are transient in nature 90% of faults are used by birds, tree branches. These condition results in arching faults and the arc in the fault can be extinguished by de-energizing the lines by opening of CB on the both ends of the lines.
- Open-0.3 second-Close-3minute-Close this is the sequence of AR. i.e.-OPEN,C-CLOSED
- whenever faults occurs CB opens, then after 0.3 sec it closes automatically, if faults persists then it will open after 3 min it closes and if still fault persists. It remains in open condition.
- Auto reclosure is generally used for Transmission lines where the general types of faults are transient in nature.
- It can be three phase auto-reclosure or single pole auto-reclosure.
- The single pole auto reclosures are generally for 400kV line below this three pole auto- reclosures are used.
- The reason for a line the single pole reclosures provides a better stability of the system since some part of power is still transferred through the healthy phases.
- Also 400kV breaker till date has a independent drive/ trip/ close coils for the three poles, below that all breakers have common drive/ trip / closing coils for the three poles.

87) What is difference between power transformers & distribution transformers?

- Distribution Transformers are designed for a maximum efficiency at 50% of load. Whereas power transformers are designed to deliver max efficiency ay 90% and above loads.
- The distributions transformers have low impedance so as to have a better regulation power transformers have higher so as to limit the SC current.
- Power transformers are used to step up voltages from 11 KV which is the generating voltage to 132 or whatever will be the transmission voltage levels. Power transformers are having Star-Delta connection. It will be located at power generating stations.
- Distribution transformers are used to step down voltages from transformer levels to 11 KV/415 V. Will be having Delta-Star. It will be located in substations near load centers.

- The main basic difference lies in the Design stage itself as power transformer are to operate at near full load so there sensing is such that they achieve equal. of copper losses & iron losses at full loads whereas this is achieved in the design itself at about 50% loading in dist transformer but friends there is a dilemma as our dist. transformer are almost fully loaded & beyond so they never go operate at their full eff. & also poor voltage regulation.
- The difference between power and distribution transformers refers to size & input voltage. Distribution transformers vary between 25 kVA and 10 MVA, with input voltage between 1 and 36 kV. Power transformers are typically units from 5 to 500 MVA, with input voltage above 36 kV. Distribution transformer design to have a max efficiency at a load lower than full load. Power transformer design to have a max efficiency at full load

88) What will be happen if the neutral isolator will be open or close during the running condition of power?

- During normal condition the neutral isolating switch should be kept close. In case it is kept open, under balanced load conditions the current through neutral will not flow & nothing harmful will take place but in case an earth fault takes place then there will be no earth fault current flowing through the system & the generator will run as a ungrounded generator. Thus the earth fault will not be cleared.
- If more number of generators are connected parallel. We will have a close loop and hence negative sequence current will flow. This will increase the rotor temperature. Hence if more number of generators are connected then only one is earthed and others are open.
- In case of Two or more generators connected to a common bus without a transformer in between, basically in hydro stations, one of the Neutral Isolation Switch(NIS) is kept closed & rest are opened to prevent circulating currents to flow between generators. Hence the above explanation will not be valid for such systems.
- Sometime we may want to test generator and may want to isolate the neutral from ground. like for example meggaring etc. In such case we would like to open ground connection cable in case we want to remove the NIS? we will certainly not like to open all the bolted connections for just a small test like checking insulation with a meggar etc. for such things we need a NIS.
- Neutral isolator is required if we have delta transmission system and at the time to connection with the Grid Neutral isolation is required.
- If we ungrounded the neutral then the generator is connected to the ground via Phase to earth capacitances. Hence during faults arcing grounds can take place. Which are dangerous both to human &equipment.
- When we provide earthed neutral, for a fault, earth fault current will start flowing through the neutral, which we can sense thru a CT & relay & hence can immediately identify & clear the fault in about 100 ms by opening the associated breaker/prime mover/excitation. Quicker the fault clearance less is the damage.

89) Why shorting type terminal required for CT?

- During maintenance or secondary injection you will need to bypass the CT & for the same you need shorting link. During sec. injection you will short circuit the main CT & bypass it. Open circuiting the CT will saturate it & damage it.

90) Why fuse is given for only PT and not CT?

- Fuse if given for CT blows off due to a fault then rather than protecting the CT it will make it open circuited hence it will be saturated & damaged. For PT it gives overload & SC protection.

91) Why is insulating base required for LA?

- The LA is provided with a dedicated Prper earthing which may be in the form of a buried treated electrode next to it.LA connection is securely made with the electrode via a surge counter. If we directly earth the LA through structure then the surge counter will not be able to measure the no of surges. For lesser rating the counter is not provided, hence we can bypass the insulated base. But then proper earthing has to be assured.

92) Can 60 Hz transformers be operated at 50 Hz?

- Transformers 1 KVA and larger, rated at 60 Hz, should not be used on 50 Hz service due to higher losses and resultant heat rise. However, any 50 Hz transformer will operate on 60 Hz service.

93) Can transformers be used in parallel?

- Single phase transformers can be used in parallel only when their voltages are equal. If unequal voltages are used, a circulating current exists in the closed network between the two transformers which will cause excess heating and result in a shorter life of the transformer. In addition impedance values of each transformer must be within 7.5% of each other.

94) Can Transformers be reverse connected?

- Dry type distribution transformers can be reverse connected without a loss of KVA rating, but there are certain limitations. Transformers rated 1 KVA and larger single phase, 3 KVA and larger three phases can be reverse connected without any adverse effects or loss in KVA capacity.

95) Why short circuit do not take place when electrode is touched to ground.

- Basically during welding we force a short-circuit at the electrode tip. The fault condition produces large magnitude currents. Greater the Current value have greater I2R heat produced. The arcing energy elevates the temperature & hence melts the electrode material over the joint.
- The transformer is designed to withstand such high currents. But welding is a very complex & detailed phenomenon. Besides there are many principles on which welding operates. Some may be a welding, dc welding, arc, constant voltage, constant current etc

96) What's the difference between generator breaker and simple breaker?

- Breaker is one which disconnects the circuit in fault condition and It is similar for all equipment. Based on the equipment voltage and maximum short circuit current the ratings will be decided. For better understanding we call generator or transformer or line etc breakers.

97) What is accuracy Class of the instrument?

- Generally the class indicates the accuracy with which the meter will indicate or equipment will measure with respect to its input.
- The accuracy of different equipment will depend on number of factors.
- For example for a PT accuracy will depend on its leakage reactance & winding resistance. For a PT accuracy gives the voltage & phase error & it varies with the VA burden of secondary. Also better core material will give better heat dissipation & reduce error. class of accuracy will give the voltage error for a PT
- different type of PTs available are:0.1, 0.2, 0.5, 1, 5 & error values will be: class% voltage error(+/_) phase displacement
  Similarly indicating instruments shall have accuracies & accordingly application as depicted below for testing the following values are generally used:
- for routine tests : accuracy class 1
- for type tests : accuracy class 0.5 or better.
- indicating meters generally will have accuracy of 1.

98) First pole to clear factor-Circuit breakers

- The first pole to clear factor (kpp) is depending on the earthing system of the network. The first pole to clear factor is used to calculating the transient recovery voltage for three phase faults. In general following cases apply:-
  1. kpp = 1.3 corresponds to three phase faults in system with an earthed neutral.
  2. kpp = 1.5 corresponds to three phase faults in isolated or resonant earthed system.
  3. kpp = 1.0 corresponds to special cases e.g. railway systems.
- A special case is when there is a three phase fault without involving earth in a system with earthed neutral. This case responds to kpp = 1.5 . This special case is however not normally considered in the standards.

99) Why we use a resistance to ground the neutral when we need always low resistivity for the grounding?

- If we ground the generator directly then whenever a fault will take place at any phase with ground the fault current flowing throw the faulted phase-to ground-to neutral will be very high cause there will be no resistance to limit the value of fault current. Hence we insert a resistance in the neutral circuit to limit this fault current. Also we need to reduce the fault current to such a value that the protection CTs are able to identify the fault current without saturating the CTs. Communicate it to the protection relays & hence the relays can then isolate the system from the fault; so that the system is isolated from the fault before the harm is done by the fault current. That is the reason that all the equipment will be designed for fault KA values for 1 sec so that the total operation(CT sensing-relay functioning-circuit breaker operation) time will be less than 1 sec. hence the Breakers will isolate the fault before 1 sec i.e. within the time period the equipment are designed to carry the fault current. Thus all your objectives of:
- Preventing the arcing.
- Limiting the fault current.
- isolating the faulted system are achieved

100) Why are NGR's rated for 10sec?

- NGR are placed in the neutral circuit & hence will be energized only in the fault conditions thus their continuous loading is not expected. Hence they are selected for intermittent rating. Similarly when we place a transformer in the neutral grounding circuit the KVA rating obtained after the calculation is multiplied by a diversity factor to obtain smaller rating cause the therefore It will not be continuously rated.
- NIS is also provided to cut the circulating negative sequence current in 2 more generators connected in parallel. in some grid conditions they ask to keep neutral isolated after being connected to grid.

101) How to calculate knee point voltage and significance of knee point voltage?

- Knee point voltage: That point on the magnetizing curve (BH curve) where an increase of 10% in the flux density (voltage) causes an increase of 50% in the magnetizing force (current). Its significance lies mainly in PS class core of CTs used for diff protection

102) Design method for neutral grounding resistor?

- NGR design basics:
- Capacitive coupling of generator, equipment and the ground
- Generator to ground capacitance.
- Generator cable to ground capacitance (or bus duct as the case may be)
- Low voltage winding of trafo & ground capacitance.
- Surge arrestor capacitance.
- The total capacitance is then obtained from the above values & then we calculate from that the capacitive reactance. The capacitive current then produced is calculated from the generator voltage & the capacitive reactance obtained above. Once the current is obtained we can then calculate the electrostatic KVA from the current multiplied with voltage.

103) Criterion is there for selection of Insulation Disc in Transmission and Distribution Line.

- 11kV is the phase to earth voltage for 220kV =220/ (sqrt(3)*11)=12 No's of disc are suitable.The number can be increased to increase the creep age distance.
- While selecting the disc insulators one has to keep in mind the following things:
  1. EM-strength of the string. All the forces coming on to the string & the ability of the string to withstand them.
  2. Sufficient Cree page distance so as not to cause a flashover.
  3. Interface with the type of conductor used (moose, tarantula, zebra etc)
- So we will get the value of no of discs by dividing the phase to earth voltage with 1.732. Once that is done then we need to see its suitability with respect to EM strength.
- After this we need to consider the force that the stack has to bear. If we have a strain type of fitting i.e. the stack has to bear horizontal conductor tension, weight load of the conductor, wind load, ice load etc then the number of insulator discs required may be more.
- But for a suspension type system which has to bear only the weight then number of discs required may be less than what we get by dividing by 11. That is the reason we have seen only 23/24 discs in 400 kv line cause in that case the creep age obtained must have been enough & also the strain requirement.
- 33kv insulators are generally used in a vertical installation & are not stacked together because that will make the suspension very rigid

104) Do taps work the same when a transformer is reverse fed?

- Taps are normally in the primary winding to adjust for varying incoming voltage. If the transformer is reverse fed, the taps are on the output side and can be used to adjust the output voltage.

105) Why may we get the wrong output voltage when installing a step up transformer?

- Transformer terminals are marked according to high and low voltage connections. An H terminal signifies a high voltage connection while an X terminal signifies a lower voltage connection. A common misconception is that H terminals are primary and X terminals secondary. This is true for step down transformers, but in a step up transformer the connections should be reversed. Low voltage primary would connect to X terminals while high voltage secondary would connect on the H terminals.

106) Can a single phase transformer be used on a three phase source?

- Yes. Any single phase transformer can be used on a three phase source by connecting the primary leads to any two wires of a three phase system, regardless of whether the source is three phase 3-wire or three phase 4-wire. The transformer output will be single phase.

107) Why in Double circuit wire are transposed (R – B, Y – Y, B – R)

- This is done to avoid
  1. Proximity effect

2. Skin effect
3. Radio interference
4. Reduction in noise in communication Signals

108) Selection of LA

- The voltage rating of LA is selected as: Line voltage x sqrt(2)/ sqrt(3) so for 11kV line its 9kV
- In that case also the values would not differ much if We takes the TOV factor as 1.4. However, we can take the value of 1.56 as TOV to be more precise.

109) Which is more dangerous AC or DC

- Low frequency (50 – 60 Hz) AC currents can be more dangerous than similar levels of DC current since the alternating fluctuations can cause the heart to lose coordination, inducing ventricular fibrillation, which then rapidly leads to death.
- However any practical distribution system will use voltage levels quite sufficient to ensure a dangerous amount of current will flow, whether it uses alternating or direct current. Since the precautions against electrocution are similar, ultimately, the advantages of AC power transmission outweighed this theoretical risk, and it was eventually adopted as the standard.

110) What all are the applications where high speed grounding switches are used.

- Generator neutral is earthed directly or through distribution transformer. This neutral earthing is through done through a switch. This is general practice for only one generator.
- For two generators in parallel to a bus the neutral earthing is different. If both the neutral earthing is closed the negative sequence current will be flowing though both the generator taking earth as path. This leads to increase in loss and increase in temperature (This may leads to false tripping also). Hence once the second generator is synchronized with the bus or grid the neutral is isolated.
- Neutral grounding switch we do not need a high speed grounding switch. A normal switch with the correct rating capacity would also work.

111) What is Skin Effect and how does it happen??

- According to faradays law of electromagnetic induction, a conductor placed in a changing magnetic field induces an emf. The effect of back emf is maximum at the centre because of maximum lines of field there. Hence the maximum opposition of current at inner side of conductor and minimum opposition at the surface. Hence the current tries to follow at the surface. It is due to this reason that we take hollow tube conductors in bus duct.
- Taking into account the inductance effect, its simple consider the DC current. Since its constant & not varying hence no back emf but if we gradually start increasing the frequency then the flux cutting the conductor goes on increasing, hence greater the frequency greater the alternating flux cutting the conductor & hence greater the back emf & therefore greater the skin effect.

112) Why we ground the sheath of single core power cables and to avoid grounded at both the ends?

- A single core cable with a sheath is nothing but a conductor carrying current surrounded by another conductor (sheath). Hence the Alternative current in the conductor induces voltages in the sheath or the armour. Hence grounding these cables at both ends will cause the potential of the armour to be same as ground potential & hence shall become safe for the personnel.
- But grounding the cables at both the end will cause a problem. In that case the circulating currents will start flowing with the armor, the ground & with the two ends of the grounding completing the circuit. This will also provide path for the fault currents to flow. Hence this whole thing will cause the cable to produce some I2R losses, hence heating & hence the current carrying capacity will be de rated. This system of cable earthing is called both-end bonding. This system is suggested only when one wants to avoid the voltage development because can either go with the de rated cable or if one updates the cable in advance.
- When only one end of the cable sheath is grounded then there is no path for the circulating current to flow. Hence the current carrying capacity of the cable will be good. But in this case potential will be induced between sheath & ground. This potential is proportional to the length of the cable & hence this will limit the length of the cable used. This method is called single point bonding. This is thus used only for short lengths.
- There is another system called the cross bonding system in which the sheath are sectionaliosed & cross connected so that the circulating currents are minimized. Although some potential will also exist between sheath & ground, the same being maximum at the link boxes where bonding is done. This method provides maximum possible current carrying capacity with the maximum possible lengths.

113) What is EDO & MDO type breaker?

- In the Breakers for the operation spring charging is must.

- In EDO breaker the spring charging is done with a motor and draw out manually by hand. so EDO means Electrically spring charged Draw Out breaker
- In MDO breaker the spring charging is also done by hand manually and draw out about also by hand only. so MDO means Manual spring charge Draw Out breaker

114) Why transformer rating is in KVA or KW?

- Because power factor of the load is not defined in case of transformer that's why it is not possible to rate transformer in KW.
- The losses (cu loss and iron loss) of the transformer depends on current and voltage purely, not on load i.e, phase angle between the current and voltage i.e. why transformer rated in kVA
- Transformer is not a load and having no effect on P.F (that's why no change in its power factor) and it only transfer the constant power from one voltage level to another voltage level without changing frequency. since both the losses viz copper loss(depends on current) and iron loss(depends on voltage) are independent of power factor, that is why a Transformers rating is not on kW, but on KVA

115) Why the secondary of CT never open when burden is connected on the CT.?

- secondary of CT is never opened as because CT is always connected to the line so opening the secondary will mean there will be no counter mmf to balance the primary current as a result of which a very high induced emf may appear in the secondary as flux is very high and no counter mmf and this will be dangerous for the personnel in the secondary side and for pt if it is shorted then with full voltage applied to the primary.
- If we short the secondary then much high current will circulate in the secondary due to high induced emf much higher than the actual full load current as a result of which the transformer's secondary winding may burn out.

116) Distance relay setting

- Step1:
  Get the conductor Details (i.e Positive Sequence Impedance (Z), Zero Sequence Impedance(Z0)) which is in Primary value. Convert in terms of secondary values.
- Step 2 :
  Based upon the calculated value divide into various zones
- Zone 1 (Forward) means 80% of your protected line length.
- Zone 2 (Forward) means 100% of protected line length + 20% Adjacent Shortest line
- Zone 3 (Forward) means 100% of protected line length + 50% Adjacent Longest line.
- Zone 4 (Reverse) means 10% of protected line.

117) Difference between CT class 0.2 and 0.2S?

- **0.2S & 0.5S:**Special type of measurement CTs they guarantee the declared accuracy, even with 20% loading. And some definite error can be defined even with a load as low as 1%. Thus they are suitable for industries where loads are commissioned in steps or stages. Also for tariff metering purposes.
- **0.2S:** Special class for metering. It is more accurate than 0.2 classes. Generally if we use 0.2s class CT than VA burden of core is also come down.
- In 0.2 classes CT, ratio & phase angle errors must be within the specified limits at 5%, 20%, 100% & 120% of rated secondary current. Whereas in 0.2s class CT, ratio & phase angle errors must be within the specified limits at 1%, 5%, 20%, 100% & 120% of rated secondary current. Also in 0.2s class, Ratio & Phase angle errors limits are lower than 0.2 classes.

118) Why we use inductors

- Inductors have the property to oppose sudden changes in Current. When connected to the primary side of transformer, if any sudden short circuit (very high) current flows due to some fault in the system, the inductor will oppose the flow of that current saving the transformer.
- Secondly, for the problem of lagging current. Capacitors are connected across the inductor to improve the lagging current. So Mainly Inductor is used to (i) protected the transformer, (ii) solved the problem of lagging current.

119) Why do we need a bigger breaker when reverse feeding a transformer?

- Typically the output winding is wound first and is therefore closest to the core. When used as exciting winding a higher inrush current results. In most cases the inrush current is 10 to 12 times the full load current for 1/10 of a second. When the transformer is reverse fed the inrush current can be up to 16 times greater. In this case a bigger breaker with a higher AIC rating must be used to keep the transformer online.

120) How many types of Neutral grounding system?

- There are primarily three types of grounding system which are:

- (1)Solid grounding – The neutral point of the system is grounded without any resistance. If the ground fault occurs, high ground current passes through the fault. Its use is very common in low voltage system, where line to neutral voltage is used for single phase loads.
- (2) Low Resistance grounding (LRG) – This is used for limiting the ground fault current to minimize the impact of the fault current to the system. In this case, the system trips for the ground fault. In this system, the use of line to neutral (single phase) is prohibited. The ground fault current is limited to in the rage from 25A to 600A.
- (3) High Resistance Grounding (HRG) – It is used where service continuity is vital, such as process plant motors. With HRG, the neutral is grounded through a high resistance so that very small current flows to the ground if ground fault occurs. In the case of ground fault of one phase, the faulty phase goes to the ground potential but the system doesn't trip. This system must have a ground fault monitoring system. The use of line to neutral (single phase) is prohibited (NEC, 250.36(3)) in HRG system, however, phase to neutral is used with using the additional transformer having its neutral grounded. When ground fault occurs in HRG system, the monitoring systems gives alarm and the plant operators start the standby motor and stop the faulty one for the maintenance. This way, the process plant is not interrupted. The ground fault current is limited to 10A or less.
- There are other two types such as Corner Grounding (for Delta system) and ungrounded system but they are not commonly used.

121) What value AC meters show, is it the RMS or peak voltage?

- AC voltmeters and ammeters show the RMS value of the voltage or current. DC meters also show the RMS value when connected to varying DC providing the DC is varying quickly, if the frequency is less than about 10Hz you will see the meter reading fluctuating instead.

122) Why in the transmission tower construction Middle arm is longer than the upper and lower Arm.

- Conductor of Upper Arm and Lower Arm will stay apart.
- To prevent big birds (Ostriches etc) from bumping their heads against the conductor above when they sit on the wire below.
- Designed to maintain the mechanical requirement to prevent arching between conductors while maintaining a tower height that is manageable, and of course preventing head injuries to birds
- The arms are of different links to prevent a broken upper line from falling on one or more of the phase lines below.
- The clearance from other phase.
- Mutual inductance minimization.
- Preventing droplet of water/ice to fall on bottom conductor.

123) What is the difference between Surge Arrester & Lightning Arrestor

- LA is installed outside and the effect of lightning is grounded, where as surge arrestor installed inside panels comprising of resistors which consumes the energy and nullify the effect of surge.
- Transmission Line Lightning Protection:
- The transmission line towers would normally be higher than a substation structure, unless you have a multi-storey structure at your substation.
- Earth Mats are essential in all substation areas, along with driven earth electrodes (unless in a dry sandy desert site).
- It is likewise normal to run catenaries' (aerial earth conductors) for at least 1kM out from all substation structures. Those earth wires to be properly electrically to each supporting transmission tower, and bonded back to the substation earth system.
- It is important to have the catenaries' earth conductors above the power conductor lines, at a sufficient distance and position that a lightning strike will not hit the power conductors.
- In some cases it is thus an advantage to have two catenary earth conductors, one each side of the transmission tower as they protect the power lines below in a better manner.
- In lightning-prone areas it is often necessary to have catenary earthing along the full distance of the transmission line.
- Without specifics, (and you could not presently give tower pictures in a Post because of a CR4 Server graphics upload problem), specifics would include:
- Structure Lightning Protection:
- At the Substation, it is normal to have vertical electrodes bonded to the structure, and projecting up from the highest points of the structure, with the location and number of those electrodes to be sufficient that if a lightning

strike arrived, it would always be a vertical earthed electrode which would be struck, rather than any electrical equipment.

- In some older outdoor substation structures, air-break isolator switches are often at a very high point in the structure, and in those cases small structure extension towers are installed, with electrodes at the tapered peak of those extension towers.
- The extension towers are normally 600mm square approximately until the extension tower changes shape at the tapered peak, and in some cases project upwards from the general structure 2 to 6 metres, with the electrode some 2 to 3 metres projecting upwards from the top of the extension tower.
- The substation normally has a Lightning Counter – which registers a strike on the structure or connected to earth conductors, and the gathering of that information (Lightning Days, number per Day/Month/Year, Amperage of each strike)

124) How Corona Discharge Effect Occur in Transmission Line?

- In a power system transmission lines are used to carry the power. These transmission lines are separated by certain spacing which is large in comparison to their diameters.
- In Extra High Voltage system (EHV system) when potential difference is applied across the power conductors in transmission lines then air medium present between the phases of the power conductors acts as insulator medium however the air surrounding the conductor subjects to electro static stresses. When the potential increases still further then the atoms present around the conductor starts ionize. Then the ions produced in this process repel with each other and attracts towards the conductor at high velocity which intern produces other ions by collision.
- The ionized air surrounding the conductor acts as a virtual conductor and increases the effective diameter of the power conductor. Further increase in the potential difference in the transmission lines then a faint luminous glow of violet color appears together along with hissing noise. This phenomenon is called virtual corona and followed by production of ozone gas which can be detected by the odor. Still further increase in the potential between the power conductors makes the insulating medium present between the power conductors to start conducting and reaches a voltage (Critical Breakdown Voltage) where the insulating air medium acts as conducting medium results in breakdown of the insulating medium and flash over is observed. All this above said phenomenon constitutes CORONA DISCHARGE EFFECT in electrical Transmission lines.

125) Methods to reduce Corona Discharge Effect:

- Critical Breakdown voltage can be increased by following factors
- By increasing the spacing between the conductors:
- Corona Discharge Effect can be reduced by increasing the clearance spacing between the phases of the transmission lines. However increase in the phases results in heavier metal supports. Cost and Space requirement increases.
- By increasing the diameter of the conductor:
- Diameter of the conductor can be increased to reduce the corona discharge effect. By using hollow conductors corona discharge effect can be improved.
- By using Bundled Conductors:
- By using Bundled Conductors also corona effect can be reduced this is because bundled conductors will have much higher effective diameter compared to the normal conductors.
- By Using Corona Rings or Grading Rings:
- This is of having no greater significance but i presented here to understand the Corona Ring in the Power system. Corona Rings or Grading Rings are present on the surge arresters to equally distribute the potential along the Surge Arresters or Lightning Arresters which are present near the Substation and in the Transmission lines.

126) How to test insulators?

- Always remember to practice safety procedures for the flash-over voltage distance and use a sturdy enclosure to contain an insulator that may shatter, due to steam build-up from moisture in a cavity, arcing produces intense heat, an AM radio is a good RFI/arcing detection device, a bucket truck AC dielectric test set (130KV) is a good test set for most pin and cap type insulators. A recent article said the DC voltage required to "search out defects can be 1.9 times the AC voltage.
- Insulators have a normal operating voltage and a flash-over voltage. Insulators can have internal flash-over that are/are not present at normal operating voltage. If the RFI is present, de-energize the insulator (line) and if the RFI goes away, suspect the insulator (line). Then there can be insulators that have arcing start when capacitor or other transients happen, stop when the line is de-energized or dropped below 50% of arc ignition voltage. Using a

meg-ohm-meter can eliminate defective insulators that will immediately arc-over tripping the test set current overload.

127) How to identify the starting and ending leads of winding in a motor which is having 6 leads in the terminal box

- If it is a single speed motor then we have to identify 6 leads.
- Use IR tester to identify 3 windings and their 6 leads. Then connect any two leads of two winding and apply small voltage across it and measure the current.
- Then again connect alternate windings of same two windings and apply small amount of voltage (same as before) and measure current.
- Check in which mode you get the max current and then mark it as a1-a2 & b1-b2. You get max current when a2-b1 will be connected and voltage applied between a1-b2.
- Follow the same process to identify a1-a2, b1-b2, c1-c2.now we will be able to connect it in delta or star.

128) How to measure Transformer Impedance?

- Follow the steps below:
- (1) Short the secondary side of the transformer with current measuring devices (Ammeter)
- (2) Apply low voltage in primary side and increase the voltage so that the secondary current is the rated secondary current of the transformer. Measure the primary voltage (V1).
- (3) Divide the V1 by the rated primary voltage of the transformer and multiply by 100. This value is the percentage impedance of the transformer.
- When we divide the primary voltage V1 with the full load voltage we will get the short circuit impedance of the transformer with refereed to primary or Z01. For getting the percentage impedance we need to use the formula = Z01*Transformer MVA /(Square of Primary line voltage).

129) Why Bus Couplers are normally 4-Pole. Or When Neutral Isolation is required?

- Neutral Isolation is mandatory when you have a Mains Supply Source and a Stand-by Power Supply Source. This is necessary because if you do not have neutral isolation and the neutrals of both the sources are linked, then when only one source is feeding and the other source is OFF, during an earth fault, the potential of the OFF Source's Neutral with respect to earth will increase, which might harm any maintenance personnel working on the OFF source. It is for this reason that PCC Incomers & Bus Couplers are normally 4-Pole. (Note that only either the incomer or the bus coupler needs to be 4-pole and not both).
- 3pole or 4pole switches are used in changing over two independant sources ,where the neutral of one source and the neutral of another source should not mix the examples are electricity board power supply and standalone generator supply etc. the neutral return current from one source should not mix with or return to another source. as a mandatory point the neutral of any transformer etc are to be earthed, similarly the neutral of a generator also has to be earthed. While paralling (under uncontrolled condition) the neutral current between the 2 sources will crises cross and create tripping of anyone source breakers.
- also as per IEC standard the neutral of a distribution system shall not be earthed more than once. means earthing the neutral further downstream is not correct,

130) Why Three No's of Current transformer in 3 phase Star point is grounded.

- For CT's either you use for 3 phase or 2 phase or even if you use only 1 CT's for the Over current Protection or for the Earth Faults Protection, their neutral point is always shorted to earth. This is NOT as what you explain as above but actually it is for the safety of the CT's when the current is passing thru the CT's.
- In generally, tripping of Earth faults and Over current Protection has nothing to do with the earthing the neutral of the CT's. Even these CT's are not Grounded or Earthed, these Over current and the Earth Faults Protection Relay still can operated.
- Operating of the Over current Protection and the Earth Faults Relays are by the Kirchhoff Law Principle where the total current flowing into the points is equal to the total of current flowing out from the point.
- Therefore, for the earth faults protection relays operating, it is that, if the total current flowing in to the CT's is NOT equal total current flowing back out of the CT's then with the differences of the leakage current, the Earth Faults Relays will operated.

131) What is tertiary winding of Transformer?

- Providing a tertiary winding for a transformer may be a costly affair. However, there are certain constraints in a system which calls for a tertiary transformer winding especially in the case of considerable harmonic levels in the distribution system. Following is an excerpt from the book "The J&P Transformer Book".
- Tertiary winding is may be used for any of the following purposes:

- (A)To limit the fault level on the LV system by subdividing the infeed that is, double secondary transformers.
- (B)The interconnection of several power systems operating at different supply voltages.
- (C) The regulation of system voltage and of reactive power by means of a synchronous capacitor connected to the terminals of one winding.
- It is desirable that a three-phase transformer should have one set of three-phase windings connected in delta thus providing a low-impedance path for third-harmonic currents. The presence of a delta connected winding also allows current to circulate around the delta in the event of unbalance in the loading between phases, so that this unbalance is reduced and not so greatly fed back through the system.
- Since the third-order harmonic components in each phase of a three-phase system are in phase, there can be no third-order harmonic voltages between lines. The third-order harmonic component of the magnetising current must thus flow through the neutral of a star-connected winding, where the neutral of the supply and the star-connected winding are both earthed, or around any delta-connected winding. If there is no delta winding on a star/star transformer, or the neutral of the transformer and the supply are not both connected to earth, then line to earth capacitance currents in the supply system lines can supply the necessary harmonic component. If the harmonics cannot flow in any of these paths then the output voltage will contain the harmonic distortion.
- Even if the neutral of the supply and the star-connected winding are both earthed, then although the transformer output waveform will be undistorted, the circulating third-order harmonic currents flowing in the neutral can cause interference with telecommunications circuits and other electronic equipment as well as unacceptable heating in any liquid neutral earthing resistors, so this provides an added reason for the use of a delta connected tertiary winding.
- If the neutral of the star-connected winding is unearthed then, without the use of a delta tertiary, this neutral point can oscillate above and below earth at a voltage equal in magnitude to the third-order harmonic component. Because the use of a delta tertiary prevents this it is sometimes referred to as a stabilizing winding.
- When specifying a transformer which is to have a tertiary the intending purchaser should ideally provide sufficient information to enable the transformer designer to determine the worst possible external fault currents that may flow in service. This information (which should include the system characteristics and details of the earthing arrangements) together with a knowledge of the impedance values between the various windings, will permit an accurate assessment to be made of the fault currents and of the magnitude of currents that will flow in the tertiary winding. This is far preferable to the purchaser arbitrarily specifying a rating of, say, 33.3%, of that of the main windings.

132) Why do transformers hum?

- Transformer noise is caused by a phenomenon which causes a piece of magnetic sheet steel to extend itself when magnetized. When the magnetization is taken away, it goes back to its original condition. This phenomenon is scientifically referred to as magnetostriction.
- A transformer is magnetically excited by an alternating voltage and current so that it becomes extended and contracted twice during a full cycle of magnetization. The magnetization of any given point on the sheet varies, so the extension and contraction is not uniform. A transformer core is made from many sheets of special steel to reduce losses and moderate the ensuing heating effect.
- The extensions and contractions are taking place erratically all over a sheet and each sheet is behaving erratically with respect to its neighbour, so you can see what a moving, writhing construction it is when excited. These extensions are miniscule proportionally and therefore not normally visible to the naked eye. However, they are sufficient to cause a vibration, and consequently noise. Applying voltage to a transformer produces a magnetic flux, or magnetic lines of force in the core. The degree of flux determines the amount of magnetostriction and hence, the noise level Why not reduce the noise in the core by reducing the amount of flux? Transformer voltages are fixed by system requirements. The ratio of these voltages to the number of turns in the winding determines the amount of magnetization. This ratio of voltage to turns is determined mainly for economical soundness. Therefore the amount of flux at the normal voltage is fixed. This also fixes the level of noise and vibration. Also, increasing (or decreasing) magnetization does not affect the magnetostriction equivalently. In technical terms the relationship is not linear.

133) How can we reduce airborne noise?

- Put the transformer in a room in which the walls and floor are massive enough to reduce the noise to a person listening on the other side. Noise is usually reduced (attenuated) as it tries to pass through a massive wall. Walls can be of brick, steel, concrete, lead, or most other dense building materials.

- Put the object inside an enclosure which uses a limp wall technique. This is a method which uses two thin plates separated by viscous (rubbery) material. As the noise hits the inner sheet some of its energy is used up inside the viscous material. The outer sheet should not vibrate.
- Build a screen wall around the unit. This is cheaper than a full room. It will reduce the noise to those near the wall, but the noise will get over the screen and fall elsewhere (at a lower level). Screens have been made from wood, concrete, brick and with dense bushes (although the latter becomes psychological)
- Do not make any reflecting surface coincident with half the wave length of the frequency. What does this mean? Well, every frequency has a wave length. To find the wave length in air, for instance, you divide the speed of sound, in air (generally understood as 1130 feet per second) by the frequency. If a noise hits a reflecting surface at these dimensions it will produce what is called a standing wave. Standing waves will cause reverberations (echoes) and an increase in the sound level. If you hit these dimensions and get echoes you should apply absorbent materials to the offending walls (fibreglass, wool, etc.)

134) What is polarity, when associated with a transformer?

- Polarity is the instantaneous voltage obtained from the primary winding in relation to the secondary winding. Transformers 600 volts and below are normally connected in additive polarity. This leaves one high voltage and one low voltage terminal unconnected. When the transformer is excited, the resultant voltage appearing across a voltmeter will be the sum of the high and low voltage windings. This is useful when connecting single phase transformers in parallel for three phase operations. Polarity is a term used only with single phase transformers.

135) What is exciting current?

- Exciting current is the current or amperes required for excitation. The exciting current on most lighting and power transformers varies from approximately 10% on small sizes of about 1 KVA and less to approximately 2% on larger sizes of 750 KVA.

136) Can a three phase transformer be loaded as a single phase transformer?

- Yes, but the load cannot exceed the rating per phase and the load must be balanced. (KVA/3 per phase)
- For example: A 75 kVA 3 phase transformer can be loaded up to 25 kVA on each secondary. If you need a 30 kVA load, 10 kVA of load should be supplied from each secondary.

137) What are taps and when are they used?

- Taps are provided on some transformers on the high voltage winding to correct for high or low voltage conditions, and still deliver full rated output voltages at the secondary terminals.
- Standard tap arrangements are at two-and-one-half and five percent of the rated primary voltage for both high and low voltage conditions.
- For example, if the transformer has a 480 volt primary and the available line voltage is running at 504 volts, the primary should be connected to the 5% tap above normal in order that the secondary voltage be maintained at the proper rating.

138) What is the difference between "Insulating," "Isolating,"and"Shielded Winding" transformers?

- Insulating and isolating transformers are identical. These terms are used to describe the isolation of the primary and secondary windings, or insulation between the two.
- A shielded transformer is designed with a metallic shield between the primary and secondary windings to attenuate transient noise.
- This is especially important in critical applications such as computers, process controllers and many other microprocessor controlled devices.
- All two, three and four winding transformers are of the insulating or isolating types. Only autotransformers, whose primary and secondary are connected to each other electrically, are not of the insulating or isolating variety.

139) Can transformers be operated at voltages other than nameplate voltages?

- In some cases, transformers can be operated at voltages below the nameplate rated voltage.
- In NO case should a transformer be operated at a voltage in excess of its nameplate rating, unless taps are provided for this purpose. When operating below the rated voltage, the KVA capacity is reduced correspondingly.
- For example, if a 480 volt primary transformer with a 240 volt secondary is operated at 240 volts, the secondary voltage is reduced to 120 volts. If the transformer was originally rated 10 KVA, the reduced rating would be 5 KVA, or in direct proportion to the applied voltage.

140) Can a Single Phase Transformer be used on a Three Phase source?

- Yes. Any single phase transformer can be used on a three phase source by connecting the primary leads to any two wires of a three phase system, regardless of whether the source is three phase 3-wire or three phase 4-wire. The transformer output will be single phase.

141) Can Transformers develop Three Phase power from a Single Phase source?

- No. Phase converters or phase shifting devices such as reactors and capacitors are required to convert single phase power to three phases.

142) Can Single Phase Transformers be used for Three Phase applications?

- Yes. Three phase transformers are sometimes not readily available whereas single phase transformers can generally be found in stock.
- Three single phase transformers can be used in delta connected primary and wye or delta connected secondary. They should never be connected wye primary to wye secondary, since this will result in unstable secondary voltage. The equivalent three phase capacity when properly connected of three single phase transformers is three times the nameplate rating of each single phase transformer. For example: Three 10 KVA single phase transformers will accommodate a 30 KVA three phase load

143) Difference between Restricted Earth Fault & Unrestricted Earth Fault protections?

- Restricted earth fault is normally given to on star connected end of power equipment like generators, transformers etc. mostly on low voltage side. For REF protection 4 no's CTs are using one each on phase and one in neutral. It is working on the principle of balanced currents between phases and neutral. Unrestricted E/F protection working on the principle of comparing the unbalance on the phases only. For REF protection PX class CT are using but for UREF 5P20 Cts using.
- For Differential Protection CTs using on both side HT & LV side each phase, and comparing the unbalance current for this protection also PX class CTs are using.

144) Can transformers be operated at voltages other than nameplate voltages?

- In some cases, transformers can be operated at voltages below the nameplate rated voltage. In NO case should a transformer be operated in excess of its nameplate rating unless taps are provided for this purpose. When operating below the rated voltage the KVA capacity is reduced correspondingly.

145) How many types of cooling system it transformers?

- ONAN (oil natural,air natural)
- ONAF (oil natural,air forced)
- OFAF (oil forced,air forced)
- ODWF (oil direct,water forced)
- OFAN (oil forced,air natural)

146) What is the function of anti-pumping in circuit breaker?

- when breaker is close at one time by close push button, the anti pumping contactor prevent re close the breaker by close push button after if it already close.

147) There are a Transformer and an induction machine. Those two have the same supply. For which device the load current will be maximum?

- The motor has max load current compare to that of transformer because the motor consumes real power..and the transformer is only producing the working flux and it's not consuming. Hence the load current in the transformer is because of core loss so it is minimum.

148) Where the lighting arrestor should be placed in distribution lines?

- Near distribution transformers and out going feeders of 11kv and incoming feeder of 33kv and near power transformers in sub-stations.

149) Why Delta Star Transformers are used for Lighting Loads?

- For lighting loads, neutral conductor is must and hence the secondary must be star winding. and this lighting load is always unbalanced in all three phases.
- To minimize the current unbalance in the primary we use delta winding in the primary. So delta / star transformer is used for lighting loads.

150) NGR grounded system vs. solidly grounded system

- In India, at low voltage level (433V) we must do only Solid Earthing of the system neutral. This is by IE Rules 1956, Rule No. 61 (1) (a).Because, if we have opt for impedance earthing, during an earth fault, there will be appreciable voltage present between the faulted body & the neutral, the magnitude of this voltage being determined by the fault current magnitude and the impedance value.

- This voltage might circulate enough current in a person accidentally coming in contact with the faulted equipment, as to harm his even causing death. Note that, LV systems can be handled by non-technical persons too.
- In solid earthing, you do not have this problem, as at the instant of an earth fault, the faulted phase goes to neutral potential and the high fault current would invariably cause the Over current or short circuit protection device to operate in sufficiently quick time before any harm could be done.

151) Why Do not We Break Neutral in AC Circuits?

- Neutral is connected to earth at some point, thus it has some value as a return path in the event of say and equipment earth being faulty. It's a bit like asking 'why don't we break the Earth connection'
- It was stupid and dangerous, as it was possible for the neutral fuse to blow; giving the appearance of 'no power' when in fact the equipment was still live.

152) What is Minimum Value of Insulation Resistance / Polarization Index?

- Motor Insulation Resistance:
- The acceptable meg-ohm value = motor KV rating value + 1 (For LV and MV Motor).
- Example, for a 5 KV motor, the minimum phase to ground (motor body) insulation is 5 + 1 = 6 meg-ohm.
- Panel Bus Insulation Resistance:
- The acceptable meg-ohm value = 2 x KV rating of the panel.
- Example, for a 5 KV panel, the minimum insulation is 2 x 5 = 10 meg-ohm
- IEEE 43 – INSULATION RESISTANCE AND POLARIZATION INDEX (min IR at 400C in MΩ)

Minimum Insulation Resistance	TEST SPECIMEN
R1 min = kV+1 R1 min = 100	For most windings made before about 1970, all field windings, and others not described below For most dc armature and ac windings built after about 1970 (form wound coils)
R1 min = 5	For most machines with random -wound stator coils and form-wound coils rated below 1kV

153) What is service factor?

- Service factor is the load that may be applied to a motor without exceeding allowed ratings. For example, if a 10-hp motor has a 1.25 service factor; it will successfully deliver 12.5 hp (10 x 1.25) without exceeding specified temperature rise. Note that when being driven above its rated load in this manner, the motor must be supplied with rated voltage and frequency.
- Keep in mind, however, that a 10-hp motor with a 1.25 service factor is not a 12.5-hp motor. If the 10-hp motor is operated continuously at 12.5 hp, its insulation life could be decreased by as much as two-thirds of normal. If you need a 12.5-hp motor, buy one; service factor should only be used for short-term overload conditions.

154) Calculate the size the CT on the neutral point of the secondary side of 11/0.415 kV Transformer

- For high impedance relays (differential or restricted earth fault relays), 'Class X' current transformers are recommended to be used.
- Please note that both CTs (neutral & phase) shall have the same characteristics. The following is an example to size the CT:
- Input data: 11/0.415 kV ,2500 KVA Power transformer ,Transformer impedance is 6% ,Length of cable from neutral CT to the relay is 200 m ,Cross section of CT cable to be used is 6 mm^2 -copper and resistance is 0.0032 Ω/m
- Step 1: Calculation of CT Rated Primary Current
- I = kVA/ (0.415×1.732) = 2500/ (0.415×1.732) = 3478.11 A, CT with primary current of 4000 A to be selected.
- Select the secondary current of the CT 1 or 5 A. selecting 1 A secondary current, as the cross section and length of pilot wires can have a significant effect on the required knee voltage of the CT and therefore the size and cost of the CT. When the relay is located some distance from the CT, the burden is increased by the resistance of the pilot wires.
- Step 2: Calculation of maximum Fault Current
- Ift = kVA/ (0.415×1.732x Z)
- Ift = 2500/ (0.415×1.732×0.06) = 57968.59 A (say 58000 A)
- Step 3: Calculation of the Knee Voltage of the CT (Vkp)

- Vkp = (2x Iftx (Rct+Rw)/CT transformation ratio)
- Where: Rct is the CT resistance (to be given by the manufacturer), Here Rct is1.02 Ω.
- Rw: total CT cable resistance= 2x cable length (200 m) x wire resistance= 2x200x0.0032= 1.28 Ω
- CT transformation ratio = CT Primary Current/CT Secondary Current
- CT transformation ratio = 4000/5= 800 A, for CT with 5 A secondary current; or,
- CT transformation ratio = 4000/1= 4000 A, for CT with 1 A secondary current. We will use 1 A in this example.
- Vkp = (2x58000x (1.02+1.28)/4000)= 66.7 V.
- The Vkp of the CT should be higher than the setting of relay stability voltage (Vs), to ensure stability of the protection during maximum through fault current.
- To calculate the stability voltage, we should follow the related formula given by the relay manufacturer, as each relay manufacturer has its own formula.
- we may calculate the Vkp as above using a CT with secondary current of 5 A, and you will notice the difference in the Vkp.

155) When should we use Molded Case Circuit Breakers and Mini Circuit Breakers?

- MCB is Miniature Circuit Breaker, since it is miniature it has limitation for Short Circuit Current and Amp Rating MCB:
- MCB are available as Singe module and used for :-
- Number of Pole :- 1,2,3,4 – 1+ N , & 3 + N
- Usually Current range for A.C. 50-60 HZ, is from 0.5 Amp – 63 Amp. Also available 80A, 100A, and 125 Amp.
- SC are limited 10 KA
- Applications are as: – Industrial, Commercial and Residential application.
- Tripping Curve:
- (1) B Resistive and lighting load,
- (2) C Motor Load,
- (3) D Highly inductive load.
- MCCB:
- MCCB: – Moulded Case Circuit Breaker.
- MCCB are available as Singe module and used for:
- Number of Pole :- 3 pole , & 4 Pole
- Current range for A.C:
- For 3.2 /6.3/12.5/25/50/100/125/160 Amp and Short Circuit Capacity 25/35/65 KA.
- For 200 250 Amp and Short Circuit Capacity 25/35/65 KA
- For 400 630/800 Amp and Short Circuit Capacity 50 KA
- Protection release :
- Static Trip :- Continuous adjustable overload protection range 50 to 100 % of the rated current Earth fault protection can be add on with adjustable earth fault pick up setting 15 to 80 % of the current.
- Micro processor Based release:
- Over load rated current 0.4 to1.0 in steps of o.1 of in trip time at 600 % Ir (sec) 0.2.0.5,1, 1.5 , 2 ,3
- Short Circuit :-2 to10 in steps of 1 lr , short time delay (sec) 0.02.0.05,0.1, 0.2 ,0.3
- Instantaneous pick up :2 to10 in steps of 1 in Ground fault pick up Disable: 0.2 to 0.8 in steps of 0.1 of in Ground fault delay (sec): 0.1 to 0.4 in steps of 0.1
- MCB (Miniature Circuit Breaker) Trip characteristics normally not adjustable, factory set but in case of MCCB (Moulded Case Circuit Breaker) Trip current field adjustable.

Chapter: 53 Type of Electrical Power Distribution System

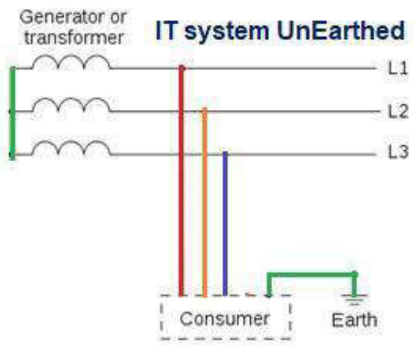
Introduction:

- Electrical power is distribution either three wires or Four wires (3 wire for phases and 1 wire for Neutral). Voltage between Phase to Phase Called Line Voltage and Voltage between Phase and Neutral is Called Phase Voltage.
- This Forth wire may or may not be distributed in Distribution System and Same way this neutral may or may not be earthed
- Depending of this neutral condition (Earthed-not Earthed-access-not access) there are various type of earthing System.
- The neutral may be directly connected to earth or connected through a resistor or a reactor. This system is called directly earthed or Earthed System.
- When a connection has not been made between the neutral point and earth, we say that the neutral is unearthed.
- In a network, the earthing system plays a very important role. When an insulation fault occurs or a phase is accidentally earthed, the values taken by the fault currents, the touch voltages and over voltages are closely linked to the type of neutral earthing connection.
- A directly earthed neutral strongly limits over voltages but it causes very high fault currents, here as an unearthed neutral limits fault currents to very low values but encourages the occurrence of high over voltages.
- In any installation, service continuity in the event of an insulation fault is also directly related to the earthing system. An unearthed neutral permits service continuity during an insulation fault. Contrary to this, a directly earthed neutral, or low impedance-earthed neutral, causes tripping as soon as the first insulation fault occurs.
- The choice of earthing system in both low voltage and medium voltage networks depends on the type of installation as well as the type of network. It is also influenced by the type of loads and service continuity required.
- The Main objectives of an earthing system are Provide an alternative path for the fault current to flow so that it will not endanger the user, Ensure that all exposed conductive parts do not reach a dangerous potential, Maintain the voltage at any part of an electrical system at a known value and prevent over current or excessive voltage on the appliances or equipment.
- Different earthing systems are capable of carrying different amounts of over current. Since the amount of over current produced in different types of installation differs from each other, required type of earthing will also differ according to the type of installation. so in order to ensure that the installation goes with the existing earthing system or else to do any modification accordingly, we need to have a proper idea of the present earthing system. It would enhance the safety as well as the reliability
- As per IEC 60364-3 There are three types of systems:
  (1) Unearthed System:
    - IT System.
  (2) Earthed System:
    - TT
    - TN (TN-S, TN-C, TN-C-S).
- The first letter defines the neutral point in relation to earth:
  1. **T = directly earthed neutral (from the French word Terre)**
  2. **I =unearthed or high impedance-earthed neutral (e.g. 2,000 Ω)**
- The second letter defines the exposed conductive parts of the electrical installation in relation to earth:
  1. **T =directly earthed exposed conductive parts**
  2. **N =exposed conductive parts directly connected to the neutral conductor**

Unearthed System:

1) IT system unearthed (High Impedance earthed neutral)

- First Letter I= the neutral is unearthed at Transformer or Generator side.
- Second Letter T= Frame parts of the loads are interconnected and earthed at Load Side



- It is compulsory to install an overvoltage limiter between the MV/LV transformer neutral point and earth.
- If the neutral is not accessible, the overvoltage limiter is installed between a phase and earth.
- It runs off external over voltages, transmitted by the transformer, to the earth and protects the low voltage network from a voltage increase due to flashover between the transformer's medium voltage and low voltage windings.

Advantages:

- System providing the best service continuity during use.
- When an insulation fault occurs, the short-circuit current is very low.
- Higher operational safety only a capacitive current flows, which is caused by the system leakage capacitance if an earth fault occurs.
- Better accident prevention the fault current is limited by the body impedance, earthing resistance and the high impedance of the earth fault loop.

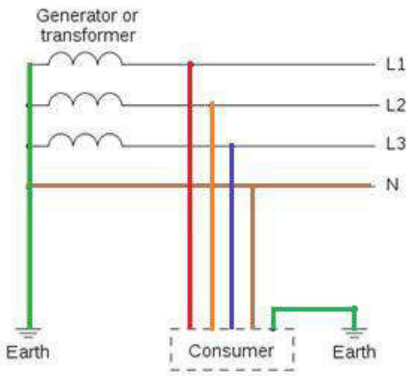
Disadvantages:

- Requires presence of maintenance personnel to monitor and locate the first fault during use.
- Requires a good level of network insulation (High leakage current must be supplied by insulating transformers).
- Overvoltage limiters must be installed.
- Requires all the installation's exposed conductive parts to be Same Voltage level. If this is not possible RCDs must be installed.
- Locating faults is difficult in widespread networks.
- When an insulation fault with reference to the earth occurs, the voltage of the two healthy phases in relation to the earth take on the value of the phase-to-phase voltage So when Select Size of equipments it is need to higher insulation level of the Equipments.
- The risk of high internal over voltages making it advisable to reinforce the equipment insulation.
- The compulsory insulation monitoring, with visual and audible indication of the first fault if tripping is not triggered until the second fault occurs.
- Protection against direct and indirect contact is not guaranteed.
- Short-circuit and earth fault currents may cause fires and destroy parts of the plant.

Earthed System:

(i) TT system directly earthed neutral

- First letter T=the neutral is directly earthed.
- Second letter T= the exposed conductive parts of the loads are interconnected and earthed.
- The transformer neutral is earthed;
- The frames of the electrical loads are also connected to an earth connection



System characteristics:

- High earth fault loop impedance
- Low earth fault current
- Utility company need not to provide earth for consumer

Advantages:

- save earth wires
- The big advantage of the TT earthing system is the fact that it is clear of high and low frequency noises that come through the neutral wire from various electrical equipment connected to it.
- TT has always been preferable for special applications like telecommunication sites that benefit from the interference-free earthing
- Does not have the risk of a broken neutral.
- The simplest system to design, implement, monitor and use.
- Easily find location of faults.
- Upon occurrence of an insulation fault, the short-circuit current is small.
- Reduces the risk of over voltages occurring.
- Authorizes the use of equipment with a normal phase to earth insulating level.

Disadvantages:

- High demand of E/F relays.
- Individual earth system needs higher investment.
- Higher touch voltage.
- Induce Potential gradient.
- Switching upon occurrence of the first insulation fault.
- Use of an RCD on each outgoing feeder to obtain total selectivity.
- Special measures must be taken for the loads or parts of the installation causing high leakage currents during normal operation in order to avoid spurious tripping (feed the loads by insulating transformers or use high threshold RCDs, compatible with the exposed conductive part earth resistance).
- Very high fault currents leading to maximum damage and disturbance in telecommunication networks.
- The risk for personnel is high while the fault lasts; the touch voltages which develop being high.
- Requires the use of differential protection devices so that the fault clearance time is not long. These systems are costly.

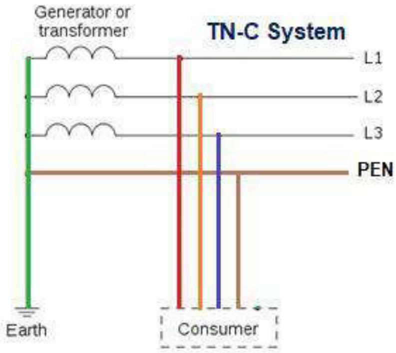
(ii) TN System: Neutral-connected exposed conductive part

- First Letter T = the neutral is directly earthed at Transformer.
- Second Letter N=the Frames of Electrical loads are connected to the neutral Conductor.
- There are two types of TN systems, depending on whether the neutral conductor and Earth conductor are combined or not:

(a) TN-C:

- In TNC System (the third letter C=combined Neutral and Earth Conductor), the neutral and Earth conductors are combined in a single conductor and earthed at source end.
- This Combined Neutral-Earth wire is than distributed to Load side.

- In This System Earthing connections must be evenly placed along the length of the Neutral-(Earth) conductor to avoid potential rises in the exposed conductive parts at Load Side if a fault occurs.
- This system must not be used for copper cross-sections of less than 10 mm^2 and aluminum cross-sections of less than 16 mm^2, as well as downstream of a TNS system (As per IEC 60364-5).



System Characteristics:

- Low earth fault loop impedance.
- High earth fault current.
- More than one earth fault loops.

Advantages:

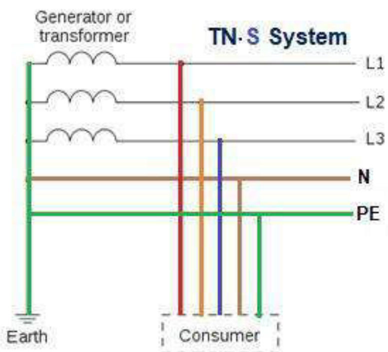
- No earth wire required; allow of multi-point earth,
- Better earthing continuity.
- Neutral never have float voltage.
- Impedance of earth fault loop could be predicted.
- The TNC system may be less costly upon installation (elimination of one switchgear pole and one conductor).

Disadvantages:

- If not multi-point earthed, and the neutral earth broken, the exposed metallic part may have float voltage.
- High earth fault level,
- Intervene the operation of earth fault protective device.
- Current operated type device is not appropriated, voltage detected type could be employed.
- Third and multiples of third harmonics circulate in the protective conductor (TNC system).
- The fire risk is higher and, moreover, it cannot be used in places presenting a fire risk (TNC system).

(b) TN-S:

- In TN-S system (the third letter S=Separate Neutral and Earth Conductor) neutral of the source of energy is connected with earth at one point only, generally near to the Source. The neutral and Earth conductors are separately distributed to load.
- In This System Earthing connections must be evenly placed along the length of the Neutral-(Earth) conductor to avoid potential rises in the exposed conductive parts at Load Side if a fault occurs.
- This system must not be used upstream of a TNC system.



System characteristic:

- Low earth fault loop impedance
- High earth fault current

Advantages:

- Use of over current protective devices to ensure protection against indirect contact.

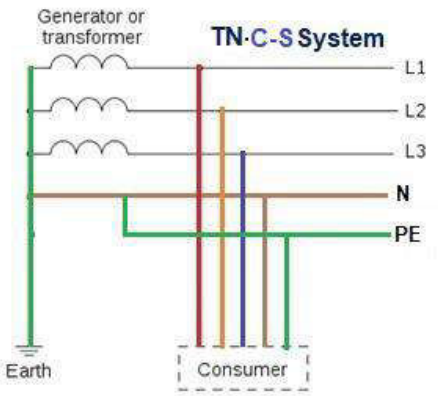
- Earth fault protection device operates faster.
- Allow multi point earth, better earthing continuity; minimize the use of earth fault relay because of low earth fault loop impedance

Disadvantages:

- Switching on occurrence of the first insulation fault.
- The TNC system involves the use of fixed and rigid trunkings
- Requires earthing connections to be evenly placed in the installation so that the protective conductor remains at the same potential as the earth.
- A tripping check on occurrence of the insulation fault should be carried out, if possible, when the network is being designed using calculations, and must be performed during commissioning using measurements; this check is the only guarantee that the system operates both on commissioning and during operation, as well as after any kind of work on the network (modification, extension).
- Passage of the protective conductor in the same trunkings as the live conductors of the corresponding circuits.
- high earth fault level under earth fault condition,
- low power factor (high inductance of long cable)
- Requires extra equal potential bonding.
- On occurrence of an insulation fault, the short-circuit current is high and may cause damage to equipment or electromagnetic disturbance.

(c) TN-C-S System:

- The Neutral and Earth wires are combined within the supply cable.
- Typically this will be a concentric cable, with the live as the central core, and a ring of wires around this for the combined neutral and earth.
- At the property, the Neutral and Earth are separated, with the earth terminal usually being on the side of the cutout. Inside the cutout, the live and neutral are linked.
- Throughout the supply network, the combined earth/neutral conductor is connected to the ground in multiple places, either buried underground or at the poles for overhead supplies.
- This multiple earthing is why a TNCS supply is often called PME (Protective Multiple Earthing).



Advantages:

- Cost for core cable is cheaper than a 3 core
- As the outer sheath is usually plastic, there are no problems with corrosion.

Disadvantage:

- When the combined earth/neutral conductor is broken. This results in a voltage appearing on the exposed metalwork in the customer's property, which can be a shock risk.
- This happens as the earth and neutral are connected in the cutout, and there is no direct connection to the ground other than in the supply network.
- In the event of a fault, the current flowing in the customer's earthing conductors can be much greater that for a TNS system.
- It is also possible to get unusual circulating earth currents between properties, particularly where some properties have metal water pipes and others have plastic

Reference:

- Protection of Electrical Network-Christophe Prévé

Chapter:54 Impact of Floating Neutral in Distribution System

Introduction:

- If The Neutral Conductor opens, Break or Loose at either its source side (Distribution Transformer, Generator or at Load side (Distribution Panel of Consumer), the distribution system's neutral conductor will "float" or lose its reference ground Point. The floating neutral condition can cause voltages to float to a maximum of its Phase volts RMS relative to ground, subjecting to its unbalancing load Condition.
- Floating Neutral conditions in the power network have different impact depending on the type of Supply, Type of installation and Load balancing in the Distribution. Broken Neutral or Loose Neutral would damage to the connected Load or Create hazardous Touch Voltage at equipment body. **Here we are trying to understand the Floating Neutral Condition in T-T distribution System.**

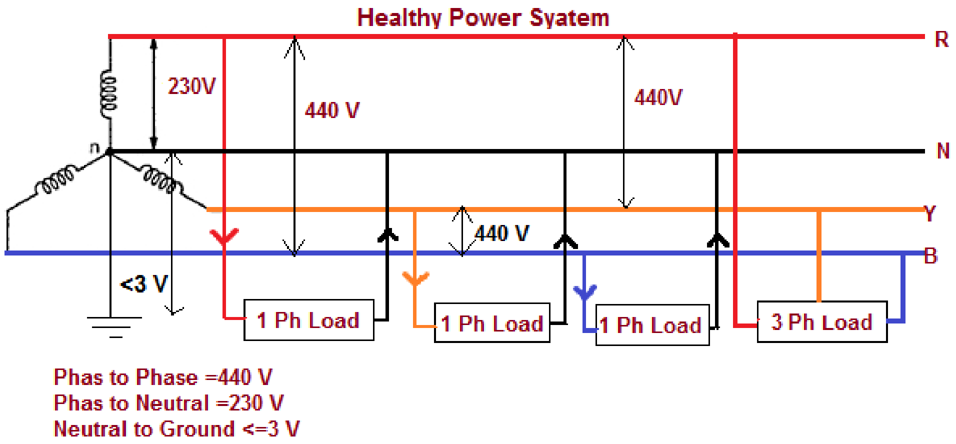
What is Floating Neutral?

- If the Star Point of Unbalanced Load is not joined to the Star Point of its Power Source (Distribution Transformer or Generator) then Phase voltage do not remain same across each phase but its vary according to the Unbalanced of the load.
- As the Potential of such an isolated Star Point or Neutral Point is always changing and not fixed so it's called Floating Neutral.

Normal Power Condition &Floating Neutral Condition

Normal Power Condition:

- On 3-phase systems there is a tendency for the star-point and Phases to want to 'balance out' based on the ratio of leakage on each Phase to Earth. The star-point will remain close to 0V depending on the distribution of the load and subsequent leakage (higher load on a phase usually means higher leakage).
- Three phase systems may or may not have a neutral wire. A neutral wire allows the three phase system to use a higher voltage while still supporting lower voltage single phase appliances. In high voltage distribution situations it is common not to have a neutral wire as the loads can simply be connected between phases (phase-phase connection).

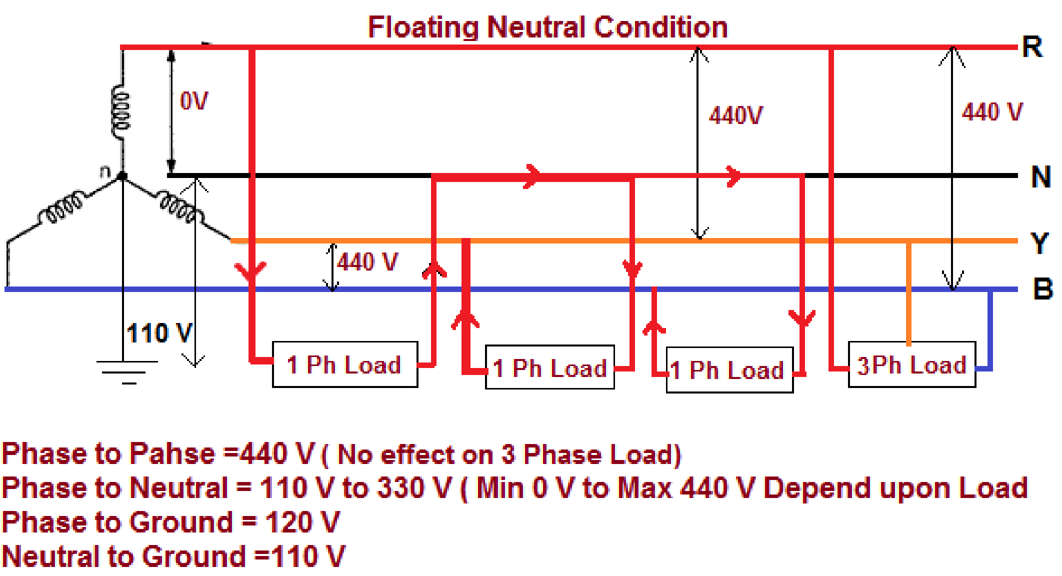


- **3 Phase 3 Wire System:**
- Three phases has properties that make it very desirable in electric power systems. Firstly the phase currents tend to cancel one another (summing to zero in the case of a linear balanced load). This makes it possible to eliminate the neutral conductor on some lines. Secondly power transfer into a linear balanced load is constant.
- **3 Phase 4 Wire System for Mix Load:**
- Most domestic loads are single phase. Generally three phase power either does not enter domestic houses or it is split out at the main distribution board.
- Kirchhoff's Current Law states that the signed sum of the currents entering a node is zero. If the neutral point is the node, then, in a balanced system, one phase matches the other two phases, resulting in no current through neutral. Any imbalance of Load will result in a current flow on neutral, so that the sum of zero is maintained.

- For instance, in a balanced system, current entering the neutral node from one Phase side is considered positive, and the current entering (actually leaving) the neutral node from the other side is considered negative.
- This gets more complicated in three phase power, because now we have to consider phase angle, but the concept is exactly the same. If we are connected in Star connection with a neutral, then the neutral conductor will have zero current on it only if the three phases have the same current on each. If we do vector analysis on this, adding up sin(x), sin(x+120), and sin(x+240), we get zero.
- The same thing happens when we are delta connected, without a neutral, but then the imbalance occurs out in the distribution system, beyond the service transformers, because the distribution system is generally a Star Connected.
- The neutral should never be connected to a ground except at the point at the service where the neutral is initially grounded (At Distribution Transformer). This can set up the ground as a path for current to travel back to the service. Any break in the ground path would then expose a voltage potential. Grounding the neutral in a 3 phase system helps stabilize phase voltages. A non-grounded neutral is sometimes referred to as a "floating neutral" and has a few limited applications.

Floating Neutral Condition:

- Power flows in and out of customers' premises from the distribution network, entering via the Phase and leaving via the neutral. If there is a break in the neutral return path electricity may then travel by a different path. Power flow entering in one Phase returns through remanning two phases. Neutral Point is not at ground Level but it Float up to Line Voltage. This situation can be very dangerous and customers may suffer serious electric shocks if they touch something where electricity is present.



- Broken neutrals can be difficult to detect and in some instances may not be easily identified. Sometimes broken neutrals can be indicated by flickering lights or tingling taps. If you have flickering lights or tingly taps in your home, you may be at risk of serious injury or even death.

Voltage Measurement between Neutral to Ground:

- A rule-of-thumb used by many in the industry is that Neutral to ground voltage of 2V or less at the receptacle is okay, while a few volts or more indicates overloading; 5V is seen as the upper limit.
- **Low Reading**:
- If Neutral to ground voltage is low at the receptacle than system is healthy, If It is high, then you still have to determine if the problem is mainly at the branch circuit level, or mainly at the panel level.
- Neutral to ground voltage exists because of the IR drop of the current travelling through the neutral back to the Neutral to ground bond. If the system is correctly wired, there should be no Neutral to Ground bond except at the source transformer (at what the NEC calls the source of the Separately Derived System, or SDS, which is usually a transformer). Under this situation, the ground conductor should have virtually no current and therefore no IR drop on it. In effect, the ground wire is available as a long test lead back to the Neutral to ground bond.
- **High Reading:**

- A high reading could indicate a shared branch neutral, i.e., a neutral shared between more than one branch circuits. This shared neutral simply increases the opportunities for overloading as well as for one circuit to affect another.
- **Zero Reading:**
- A certain amount of Neutral to ground voltage is normal in a loaded circuit. If the reading is stable at close to 0V. There is a suspect an illegal Neutral to ground bond in the receptacle (often due to lose strands of the neutral touching some ground point) or at the subpanel. Any Neutral to ground bonds other than those at the transformer source (and/or main panel) should be removed to prevent return currents flowing through the ground conductors.

Various Factors which cause Neutral Floating:

- There are several factors which are identifying as the cause of neutral floating. The impact of Floating Neutral is depend on the position where Neutral is broken

(1) At The Three Phase Distribution Transformer:

- Neutral failure at transformer is mostly failure of Neutral bushing.
- The use of Line Tap on transformer bushing is identified as the main cause of Neutral conductor failure at transformer bushing. The Nut on Line Tap gets loose with time due to vibration and temperature difference resulting in hot connection. The conductor start melting and resulting broke off Neutral.
- Poor workmanship of Installation and technical staff also one of the reasons of Neutral Failure.
- A broken Neutral on Three phases Transformer will cause the voltage float up to line voltage depending upon the load balancing of the system. This type of Neutral Floating may damage the customer equipment connected to the Supply.
- Under normal condition current flow from Phase to Load to Load to back to the source (Distribution Transformer).When Neutral is broken current from Red Phase will go back to Blue or Yellow phase resulting Line to Line voltage between Loads.
- **Some customer will experience over voltage while some will experience Low voltage.**

(2) Broken Overhead Neutral conductor in LV Line:

- The impact of broken overhead Neutral conductor at LV overhead distribution will be similar to the broken at transformer.
- Supply voltage floating up to Line voltage instead of phase Voltage. This type of fault condition may damage customer equipment connected to the supply.

(3) Broken of Service Neutral Conductor:

- A broken Neutral of service conductor will only result of loss of supply at the customer point. No any damages to customer equipments.

(4) High Earthing Resistance of Neutral at Distribution Transformer:

- Good Earthing Resistance of Earth Pit of Neutral provide low resistance path for neutral current to drain in earth. High Earthing Resistance may provide high resistance Path for grounding of Neutral at Distribution Transformer.
- Limit earth resistance sufficiently low to permit adequate fault current for theoperation of protective devices in time and to reduce neutral shifting.

(5) Over Loading & Load Unbalancing:

- Distribution Network Overloading combined with poor load distribution is one of the most reason of Neutral failure.
- Neutral should be properly designed so that minimum current will be flow in to neutral conductor. Theoretically the current flow in the Neutral is supposed to be zero because of cancellation due to 120 degree phase displacement of phase current.
- **IN= IR<0 + IY<120 + IB<-120.**
- In Overloaded Unbalancing Network lot of current will flow in Neutral which break Neutral at its weakest Point.

(6) Shared neutrals

- Some buildings are wired so that two or three phases share a single neutral. The original idea was to duplicate on the branch circuit level the four wire (three phases and a neutral) wiring of panel boards. Theoretically, only the unbalanced current will return on the neutral. This allows one neutral to do the work for three phases. This wiring shortcut quickly became a dead-end with the growth of single-phase non-linear loads. The problem is that zero sequence current

- From nonlinear loads, primarily third harmonic, will add up arithmetically and return on the neutral. In addition to being a potential safety problem because of overheating of an undersized neutral, the extra neutral current creates a higher Neutral to ground voltage. This Neutral to ground voltage subtracts from the Line to Neutral voltage available to the load. If you're starting to feel that shared neutrals are one of the worst ideas that ever got translated to copper.

(7) Poor workmanship & Maintenance :

- Normally LV network is mostly not given attention by the Maintenance Staff. Loose or inadequate tightening of Neutral conductor will affect on continuity of Neutral which may cause floating of Neutral.

How to detect Floating Neutral Condition in Panel:

- Transformer Secondary is star connected, Phase to neutral = 240V and Phase to phase = 440V.

Condition (1): Neutral is not Floating

- Whether the Neutral is grounded the voltages remain the same 240V between phase & Neutral and 440V between phases. The Neutral is not Floating.

Condition (2): Neutral is floating

- **All Appliances are connected:** If the Neutral wire for a circuit becomes disconnected from the household's main power supply panel while the Phase wire for the circuit still remains connected to the panel and the circuit has appliances plugged into the socket outlets. In that situation, if you put a voltage Tester with a neon lamp onto the Neutral wire it will glow just as if it was Live, because it is being fed with a very small current coming from the Phase supply via the plugged-in appliance(s) to the Neutral wire.
- **All Appliances are Disconnected:**If you unplug all appliances, lights and whatever else may be connected to the circuit, the Neutral will no longer seem to be Live because there is no longer any path from it to the Phase supply.
- **Phase to Phase Voltage:**The meter indicates 440VAC.
- **Phase to Neutral Voltage:** The meter indicates 110V AC to 330VAC.
- **Neutral to Ground Voltage:** The meter indicates110V.
- **Phase to Ground Voltage:** The meter indicates120V.
- This is because the neutral is "floats" above ground potential (110V + 120V = 230VAC). As a result the output is isolated from system ground and the full output of 230V is referenced between line and neutral with noground connection.
- If suddenly disconnect the Neutral from the transformer Neutral but kept the loading circuits as they are, Then Load side Neutral becomes Floating since the equipment that are connected between Phase to Neutral will become between Phase to Phase (R to Y,Y to B), and since they are not of the same ratings, the artificial resulting neutral will be floating, such that the voltages present at the different equipments will no longer be 240V but somewhere between 0 (not exactly) and the 440 V (also not exactly). Meaning that on one line Phase to Phase, some will have less than 240V and some will have higher up to near 415. All depends on the impedance of each connected item.
- In an unbalance system, if the neutral is disconnected from the source, the neutral becomes floating neutral and it is shifted to a position so that it is closer to the phase with higher loads and away from the phase with smaller load. Let us assume an unbalance 3 phase system has 3 KW load in R-phase, 2 KW load in Y-phase and 1 KW load in B-phase. If the neutral of this system is disconnected from the main, the floating neutral will be closer to R-phase and away from B-phase. So, the loads with B-phase will experience more voltage than usual, while the loads in R-phase will experience less voltage. Loads in Y-phase will experience almost same voltage. The neutral disconnect for an unbalanced system is dangerous to the loads. Because of the higher or lower voltages, the equipment is most likely to be damaged.
- **Here we observe that Neutral Floating condition does not impact on 3 Phase Load but It impacts only 1 Phase Load only**

How to Eliminate Neutral Floating:

- There are Some Point needs to be consider to prevent of Neutral Floating.

a) Use 4 Pole Breaker/ELCB/RCBO in Distribution Panel:

- A floating neutral can be a serious problem. Suppose we have a breaker panel with 3 Pole Breaker for Three Phase and Bus bar for Neutral for 3 Phase inputs and a neutral (Here we have not used 4 Pole Breaker). The voltage between each Phase is 440 and the voltage between each Phase and the neutral is 230. We have single breakers feeding loads that require 230Volts. These 230Volt loads have one line fed by the breaker and a neutral.

- Now suppose the Neutral gets loose or oxidized or somehow disconnected in the panel or maybe even out where the power comes from. The 440Volt loads will be unaffected however the 230V loads can be in serious trouble. With this Floating neutral condition you will discover that one of the two lines will go from 230Volts up to 340 or 350 and the other line will go down to 110 or 120 volts. Half of your 230Volt equipment will go up in high due to overvoltage and the other half will not function due to a low voltage condition. So, be careful with floating neutrals.
- Simply use ELCB, RCBO or 4 Pole Circuit Breaker as income in the 3ph supply system since if neutral opens it will trip the complete supply without damaging to the system.

b) Using Voltage Stabilizer:

- Whenever neutral fails in three phase system, the connected loads will get connected between phases owing to floating neutral. Hence depending on load resistance across these phases, the voltage keeps varying between 230V to 400V.A suitable servo stabilizer with wide input voltage range with high & low cutoff may help in protecting the equipments.

c) Good workmanship & Maintenance:

- Give higher Priority on Maintenance of LV network . Tight or apply adequate Torque for tightening of Neutral conductor in LV system

Conclusion:

- A Floating Neutral (Disconnected Neutral) fault condition is **VERY UNSAFE** because If Appliance is not working and someone who does not know about the Neutral Floating could easily touch the Neutral wire to find out why appliances does not work when they are plugged into a circuit and get a bad shock. Single phase Appliances are design to work its normal Phase Voltage when they get Line Voltage Appliances may Damage .Disconnected Neutral fault is a very unsafe condition and should be corrected at the earliest possible by troubleshooting of the exact wires to check and then connect properly.

Chapter:55 Total Losses in Distribution & Transmission Lines

Introduction:

- Power generated in power stations pass through large & complex networks like transformers, overhead lines, cables & other equipments and reaches at the end users.It is fact that the Unit of electric energy generated by Power Station does not match with the units distributed to the consumers. Some percentage of the units is lost in the Distribution network. This difference in the generated & distributed units is known as Transmission and Distribution loss.
- Transmission and Distribution loss are the amounts that arenot paid for by users.
- T&D Losses= (Energy Input to feeder(Kwh)-Billed Energy to Consumer(Kwh)) / Energy Input kwh x100
- Distribution Sector considered as the weakest link in the entire power sector.Transmission Losses is approximate 17% while Distribution Losses is approximate 50%.
- There are two types of Transmission and Distribution Losses
    1. Technical Losses
    2. Non Technical Losses (Commercial Losses)

Technical Losses:

- The technical losses are due to energy dissipated in the conductors, equipment used for transmission Line, Transformer, sub- transmission Line and distribution Line and magnetic losses in transformers.
- Technical losses are normally 22.5%, and directly depend on the network characteristics and the mode of operation.
- The major amount of losses in a power system is in primary and secondary distribution lines. While transmission and sub-transmission lines account for only about 30% of the total losses. Therefore the primary and secondary distribution systems must be properly planned to ensure within limits.
- The unexpected load increase was reflected in the increase of technical losses above the normal level
- Losses are inherent to the distribution of electricity and cannot be eliminated.
- There are two Type of Technical Losses.

(a) Permanent / Fixed Technical losses:

- Fixed losses do not vary according to current. These losses take the form of heat and noise and occur as long as a transformer is energized.
- Between 1/4 and 1/3 of technical losses on distribution networks are fixed losses. Fixed losses on a network can be influenced in the ways set out below.
- Corona Losses.
- Leakage Current Losses.
- Dielectric Losses.
- Open-circuit Losses.
- Losses caused by continuous load of measuring elements
- Losses caused by continuous load of control elements.

(b) Variable Technical losses

- Variable losses vary with the amount of electricity distributed and are, more precisely, proportional to the square of the current. Consequently, a 1% increase in current leads to an increase in losses of more than 1%.
- Between 2/3 and 3/4 of technical (or physical) losses on distribution networks are variable Losses.
- By increasing the cross sectional area of lines and cables for a given load, losses will fall. This leads to a direct trade-off between cost of losses and cost of capital expenditure. It has been suggested that optimal average utilization rate on a distribution network that considers the cost of losses in its design could be as low as 30 per cent.
- joule losses in lines in each voltage level
- impedance losses
- Losses caused by contact resistance.

Main Reasons for Technical Losses:

(1) Lengthy Distribution lines:

- In practically 11 KV and 415 volts lines, in rural areas are extended over long distances to feed loads scattered over large areas. Thus the primary and secondary distributions lines in rural areas are largelyradial laid usually extend over long distances. This results in high line resistance and therefore high I2R losses in the line.
- Haphazard growths of sub-transmission and distribution system in to new areas.
- Large scale rural electrification through long 11kV and LT lines.

(2) Inadequate Size of Conductors of Distribution lines:

- The size of the conductors should be selected on the basis of KVA x KM capacity of standard conductor for a required voltage regulation but rural loads are usually scattered and generally fed by radial feeders. The conductor size of these feeders should be adequate.

(3) Installation of Distribution transformers away from load centers:

- Distribution Transformers are not located at Load center on the Secondary Distribution System.
- In most of case Distribution Transformers are not located centrally with respect to consumers. Consequently, the farthest consumers obtain an extremity low voltage even though a good voltage levels maintained at the transformers secondary. This again leads to higher line losses. (The reason for the line losses increasing as a result of decreased voltage at the consumers end Therefore in order to reduce the voltage drop in the line to the farthest consumers, the distribution transformer should be located at the loadcenter to keep voltage drop within permissible limits.

(4) Low Power Factorof Primary and secondary distribution system:

- In most LT distribution circuits normally the Power Factor ranges from 0.65 to 0.75. A low Power Factor contributes towards high distribution losses.
- For a given load, if the Power Factor is low, the current drawn in highAnd the losses proportional to square of the current will be more. Thus, line losses owing to the poor PF can be reduced byimproving the Power Factor. This can be done by application of shunt capacitors.
- Shunt capacitors can be connected eitherin secondary side (11 KV side) of the 33/11 KV power transformers or at various point of Distribution Line.
- The optimum rating of capacitor banks for a distribution system is 2/3rd of the average KVAR requirement of that distribution system.
- The vantage point is at 2/3rd thelength of the main distributor from the transformer.
- A more appropriate manner of improving this PF of the distribution system and thereby reduce the line losses is to connect capacitors across the terminals of theconsumers having inductive loads.
- By connecting the capacitors across individual loads, the line loss is reduced from 4 to 9% depending upon the extent of PF improvement.

(5) Bad Workmanship:

- Bad Workmanship contributes significantly role towards increasing distribution losses.
- Joints are a source of power loss. Therefore the number of joints should be kept to a minimum. Proper jointing techniques should be used to ensure firm connections.
- Connections to the transformer bushing-stem, drop out fuse, isolator, and LT switch etc. should be periodically inspected and proper pressure maintained to avoid sparking and heating of contacts.
- Replacement of deteriorated wires and services should also be made timely to avoid any cause of leaking and loss of power.

(6) Feeder Phase Current and Load Balancing:

- One of the easiest loss savings of the distribution system is balancing current along three-phase circuits.
- Feeder phase balancing also tends to balance voltage drop among phases giving three-phase customers less voltage unbalance. Amperage magnitude at the substation doesn’t guarantee load is balanced throughout the feeder length. Feeder phase unbalance may vary during the day and with different seasons. Feeders are usually considered “balanced” when phase current magnitudes are within 10.Similarly, balancing load among distribution feeders will also lower losses assuming similar conductor resistance. This may require installing additional switches between feeders to allow for appropriate load transfer.
- Bifurcation of feeders according to Voltage regulation and Load.

(7) Load Factor Effect on Losses:

- Power consumption of Customer varies throughout the day and over seasons. Residential customers generally draw their highest power demand in the evening hours. Same commercial customer load generally peak in the early afternoon. Because current level (hence, load) is the primary driver in distribution power losses, keeping power consumption more level throughout the day will lower peak power loss and overall energy losses. Load variation is Called load factor and It varies from 0 to 1.

- Load Factor=Average load in a specified time period / peak load during that time period.
- For example, for 30days month (720 hours) peak Load of the feeder is 10 MW. If the feeder supplied a total energy of 5,000 MWH, the load factor for that month is(5,000 MWh)/ (10MW x 720) =0.69.
- Lower power and energy losses are reduced by raising the load factor, which, evens out feeder demand variation throughout the feeder.
- The load factor has been increase by offering customers "time-of-use" rates. Companies use pricing power to influence consumers to shift electric-intensive activities during off-peak times (such as, electric water and space heating, air conditioning, irrigating, and pool filter pumping).
- With financial incentives, some electric customers are also allowing utilities to interrupt large electric loads remotely through radio frequency or power line carrier during periods of peak use.Utilities can try to design in higher load factors by running the same feeders through residential and commercial areas

(8) Transformer Sizing and Selection:

- Distribution transformers use copper conductor windings to induce a magnetic field into a grain-oriented silicon steel core. Therefore, transformers have both load losses and no-load core losses.
- Transformer copper losses vary with load based on the resistive power loss equation (Ploss = I2R).
- For some utilities, economic transformer loading means loading distribution transformers to capacity-or slightly above capacity for a short time-in an effort to minimize capital costs and still maintain long transformer life.
- However, since peak generation is usually the most expensive, total cost of ownership (TCO) studies should take into account the cost of peak transformer losses. Increasing distribution transformer capacity during peak by one size will often result in lower total peak power dissipation-more so if it is over Loaded.
- Transformer no-load excitation loss(iron loss) occurs from a changing magnetic field in the transformer core whenever it is energized. Core loss varies slightly with voltage but is essentially considered constant. Fixed iron loss depends on transformer core design and steel lamination molecular structure.Improved manufacturing of steel cores and introducing amorphous metals (such as metallic glass) have reduced core losses.

(9) Balancing 3 phase loads

- Balancing 3-phase loads periodically throughout a network can reduce losses significantly. It can be done relatively easily on overhead networks and consequently offers considerable scope for Cost effective loss reduction, given suitable incentives.

(10) Switching off transformers

- One method of reducing fixed losses is to switch off transformers in periods of low demand. If two transformers of a certain size are required at a substation during peak periods, only one might be required during times of low demand so that the other transformer might be switched off in order to reduce fixed losses.
- This will produce some offsetting increase in variable losses and might affect security and quality of supply as well as the operational condition of the transformer itself. However, these trade-offs will not be explored and optimized unless the cost of losses are taken into account.

(11) Other Reasons for Technical Losses:

- Unequal load distribution among three phases in L.T system causing high neutral currents.
- leaking and loss of power
- Over loading of lines.
- Abnormal operating conditions at which power and distribution transformers are operated
- Low voltages at consumer terminals causing higher drawl of currents by inductive loads.
- Poor quality of equipment used in agricultural pumping in rural areas,cooler air-conditioners and industrial loads in urban areas.

Non-Technical / Commercial Losses:

- Non-technical losses are at **16.6%,** and related to meter reading, defective meter and error in meter reading, billing of customer energy consumption, lack of administration, financial constraints,and estimating unmetered supply of energy as well as energy thefts.

Main Reasons for Non-Technical Losses:

(1) Power Theft :

- Theft of power is energy delivered to customers that is not measured by the energy meter for the customer. Customer tempers the meter by mechanical jerks, placement of powerful magnets or disturbing the disc rotation with foreign matters, stopping the meters by remote control.

(2) Metering Inaccuracies:

- Losses due to metering inaccuracies are defined as the difference between the amount of energy actually delivered through the meters and the amount registered by the meters.
- All energy meters have some level of error which requires that standards be established. Measurement Canada, formerly Industry Canada, is responsible for regulating energy meter accuracy.
- Statutory requirements5 are for meters to be within an accuracy range of +2.5% and – 3.5%. Old technology meters normally started life with negligible errors, but as their mechanisms aged they slowed down resulting
- in under-recording. Modern electronic meters do not under-record with age in this way.
- Consequently, with the introduction of electronic meters, there should have been a progressive reduction in meter errors. Increasing the rate of replacement of mechanical meters should accelerate this process

(3) Unmetered Losses for very small Load:

- Unmetered losses are situations where the energy usage is estimated instead of measured with an energy meter. This happens when the loads are very small and energy meter installation is economically impractical. Examples of this are street lights and cable television amplifiers.

(4) Unmetered supply:

- Unmetered supply to agricultural pumps is one of the major reasons for commercial losses. In most states, the agricultural tariff is based on the unit horsepower (H.P.) of the motors. Such power loads get sanctioned at thelow load declarations.
- Once the connections are released, the consumers increasing their connected loads, without obtaining necessarysanction, for increased loading, from the utility.
- Further estimation of the energy consumed in unmetered supply has a great bearing on the estimation of T&D losses on account of inherent errors in estimation.
- Most of the utilities deliberately overestimate the unmetered agricultural consumption to get higher subsidy from the State Govt.and also project. reduction in losses. In other words higher the estimates of the unmetered consumption, lesser the T&D loss figure and vice versa.
- Moreover the correct estimation of unmetered consumption by the agricultural sector greatly depends upon the cropping pattern, ground water level, seasonal variation, hours of operation etc.

(5) Error in Meter Reading:

- Proper Calibrated Meter should be used to measure Electrical Energy. Defective Energy Meter should be replaced immediately.
- The reason for defective meter are Burning of meters, Burn out Terminal Box of Meter due to heavy load, improper C.T.ratio and reducing the recording,Improper testing and calibration of meters.

(6) Billing Problems:

- Faulty and untimely serving Bill should be main part of non-Technical Losses.
- Normal Complain regarding Billing are Not Receipt of Bill, Late Receipt of Bill, Receiving wrong Bill , Wrong Meter Reading, Wrong Tariff, wrong Calculations.

How to reduce Technical Losses:

(1) Converting LV Line to HV Line:

- Many Distribution pockets of Low Voltage (430V) in Town are surrounded by higher voltage feeders. At this lower voltage, more conductor current flows for the same power delivered, resulting in higher I2R losses.
- Converting old LV (430V) feeders to higher voltage the Investment Cost is high and often not economically justifiable but If parts of the LV (430V) Primary feeders are in relatively good condition, installing multiple step-down power transformers at the periphery of the 430 volt area will reduce copper losses by injecting load current at more points (i.e., reducing overall conductor current and the distance traveled by the current to serve the load).

(2) Large Commercial / Industrial Consumer get direct Line from Feeder:

- Design the distribution network system in such a way that if it is Possible than large consumer gets direct Power Line from feeder.

(3) Adopting High Voltage Distribution Service (HVDS) for Agricultural Customer:

- In High Voltage direct service (HVDS) ,11KV line direct given to cluster of 2 to 3 Agricultural Customer for Agricultural Pump set and employed small distribution Transformer (15KVA) for given these 2 to 3 customer through smallest (almost negligible) LT distribution Lines.
- In HVDS there is less distribution losses due to minimum length of Distribution Line, High quality of Power Supply with no Voltage drop, Less Burn out of motor due to less voltage fluctuation and Good quality of Power, to avoid overloading of Transformer.

(4) Adopting Arial Bundle Conductor (ABC):

- Where LT Line are not totally avoidable use Arial Bundle Conductor to minimize faults in Lines, to avoid direct theft from Line (Tampering of Line).

(5) Reduce Number of Transformer:

- Reduce the number of transformation steps.
- Transformers are responsible for almost half of network losses.
- High efficiency distribution transformers can make a large impact on reduction of Distribution Losses

(6) Utilize Feeder on its Average Capacity:

- By overloading of Distribution Feeder Distribution Losses will be increase.
- The higher the load on a power line, the higher its variable losses. It has been suggested that the optimal average utilizations rate of distribution network cables should be as low as 30% if the cost of losses is taken into account.

(7) Replacements of Old Conductor/Cables:

- By using the higher the cross-section area of Conductor / cables the losses will be lower but the same time cost will be high so by forecasting the future Load an optimum balance between investment cost and network losses should be maintained.

(8) Feeder Renovation / Improvement Program:

- Reconductoring of Transmission and Distribution Line according to Load.
- Identification of the weakest areas in the distribution system and strengthening /improving them.
- Reducing the length of LT lines by relocation of distribution sub stations or installations of additional new distribution transformers.
- Installation of lower capacity distribution transformers at each consumer premises instead of cluster formation and substitution of distribution transformers with those having lower no load losses such as amorphous core transformers.
- Installation of shunt capacitors for improvement of power factor.
- Installation of single-phase transformers to feed domestic and nondomestic load in rural areas.
- Providing of small 25kVA distribution transformers with a distribution box attached to its body, having provision for installation of meters,MCCB and capacitor.
- Lying of direct insulated service line to each agriculture consumer from distribution transformers
- Due to Feeder Renovation Program T&D loss may be reduced from 60-70 % to 15-20 %.

(9) Industrial / Urban Focus Program:

- Separations of Rural Feeders from Industrial Feeders.
- Instantly release of New Industrial or HT connections.
- Identify and Replacement of slow and sluggish meters by Electronics type meters.
- In Industrial and agricultural Consumer adopt One Consumer, one Transformer scheme with meter should be Introduced.
- Change of old Service Line by armored cable.
- Due to Feeder Renovation Program T&D loss may be reduced from 60-70 % to 15-20 %.

(10) Strictly Follow Preventive Maintenance Program:

- Required to adopt Preventive Maintenance Program of Line to reduce Losses due to Faulty / Leakage Line Parts.
- Required to tights of Joints, Wire to reduce leakage current.

How to reduce Non-Technical Losses:

(1) Making mapping / Data of Distribution Line:

- Mapping of complete primary and secondary distribution system with all parameters such as conductor size, line lengths etc.
- Compilation of data regarding existing loads, operating conditions, forecast of expected loads etc.
- Preparation of long-term plans for phased strengthening and improvement of the distribution systems along with transmission system.

(2) Implementation of energy audits schemes:

- It should be obligatory for all big industries and utilities to carry out Energy Audits of their system.
- Further time bound action for initiating studies for realistic assessment of the total T&D Losses into technical and non-technical losses has also to be drawn by utilities for identifying high loss areas to initiate remedial measures to reduce the same.
- The realistic assessment of T&D Loss of a utility greatly depends on the chosen sample size which in turn has a bearing on the level of confidence desired and the tolerance limit of variation in results.
- In view of this it is very essential to fix a limit of the sample size for realistic quick estimates of losses.

(3) Mitigating power theft by Power theft checking Drives:

- Theft of electric power is a major problem faced by all electric utilities. It is necessary to make strict rule by State Government regarding Power theft. Indian Electricity Act has been amended to make theft of energy and its abetment as a cognizable offence with deterrent punishment of up to 3 years imprisonment.
- The impact of theft is not limited to loss of revenue, it also affects power quality resulting in low voltage and voltage dips.
- Required to install proper seal management at Meter terminal Box, at CT/PT terminal to prevent power theft. Identify Power theft area and required to expedite power theft checking drives.
- Installation of medium voltage distribution (MVD) networks in theft-prone areas, with direct connection of each consumer to the low voltage terminal of the supply transformer.
- All existing unmetered services should be immediately stopped.

(4) Replacement of Faulty/Sluggish Energy Meter:

- It is necessary to replacement of Faulty or sluggish Meter by Distribution Agency to reduce unmetered Electrical energy.
- Required to test Meter periodically for testing of accuracy of meter. Replacement of old erroneous electromechanical meters with accurate Electro static Meter (Micro presser base) for accurate measurement of energy consumption.
- Use of Meter boxes and seals them properly to ensure that the meters are properly sealed and cannot betampered.

(5) Bill Collection facility:

- Increase Bill's Payment Cells, Increasing drop Box facility in all Area for Payment Collection.
- E-Payment facility gives more relief to Customer for bill Payment and Supply agency will get Payment regularly and speedily from Customer.
- Effectively disconnect the connection of defaulter Customer who does not pay the Bill rather than give them chance to pay the bill.

(6) Reduce Debit areas of Sub Division:

- Recovery of old debts in selected cases through legal, communication andjudicial actions.
- Ensuring police action when required to disconnect connection of defaulter Consumer.

(7) Watchdog effect on users.

- Users must aware that the distribution Agency can monitor consumption at its convenience. This allows the company fast detection of any abnormal consumption due to tampering or by-passing of a meter and enables the company to take corrective action.
- The result is consumer discipline. This has been shown to be extremely effective with all categories of large and medium consumers having a history of stealing electricity. They stop stealing once they become aware that the utility has the means to detect and record it.
- These measures can significantly increase the revenues of utilities with high non-technical losses.

(8) Loss Reduction Programmed:

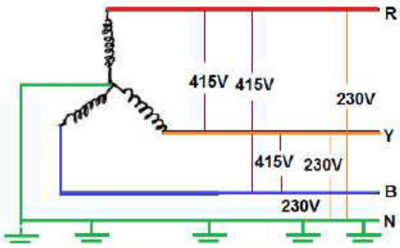
- The increased hours of supply to Agriculture and Rural domestic consumers have resulted in higher loss levels.

Chapter:56 Single Earthed & Multi Earthed Neutral

Introduction:

- In Distribution System Three Phase load is unbalance and non linear so The Neutral plays an important role in Distribution system.
- MULTI-GROUNDED three-phase four-wire service is widely adopted in modern power distribution systems due to having lower installation costs and higher sensitivity of fault protection than three-phase three-wire service. The neutrals play an important role in power quality and safety problems.
- The multi grounded neutral system is the predominant electrical distribution system used in the United States. It allow an uncontrolled amount of electric current to flow over the earth unrestrained, posing the potential of harm to the public and to animals causing electric shocks and is presumed responsible for undetected electrocutions.
- The protective grounding used in low voltage,600-volt and below, applications will be described and used to explain the hazards involved with the present day multi grounded neutral distribution System, used in the United States. This will allow the reader to see the parallels between the safe low voltage distribution system and the dangerous medium voltage multi grounded neutral distribution system.
- The reasons for the development of the three phase, four-wire, multi-grounded systems involve a combination of safety and economic considerations. The three-phase, four-wire multi-grounded design has been successfully used for many years and is well documented in the standards including the National Electrical Code (NEC).It is Crucial decisions to adopt Multi Grounded Neutral System "save money" by the adoption of the multi grounded neutral electrical distribution system in the cost of the public's safety.

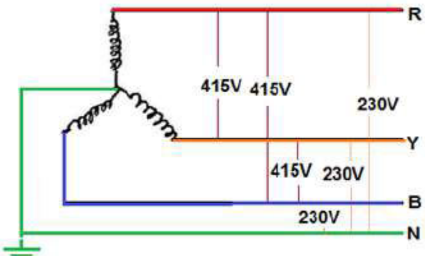
Multi Earthed Neutral System (MEN):



Three Phase Four Wire Multi Grounded Neutral

- Fig shows the multi-grounded neutral systems commonly used by the electric utilities in North America. The neutral grounding reactor is used by some utilities to reduce the available ground fault current while at the same time still maintaining an effectively grounded system.
- The multiple earthed neutral (MEN) system of earthing is one in which the low voltage neutral conductor is used as the low resistance return path for fault currents and where its potential rise is kept low by having it connected to earth at a number of locations along its length. The neutral conductor is connected to earth at the distribution transformer, at each consumer's installation and at specified poles or underground pillars. The resistance between the neutral conductor of the distribution system and the earth must not exceed 10 ohms at any location.
- **NEC Article 250 Part X Grounding of Systems and Circuits 1 kV and Over (High Voltage)**
- (A) Multiple Grounding: The neutral of a solidly grounded neutral system shall be permitted to be grounded at more than one point.
- (B) Multi-grounded Neutral Conductor:Ground each transformer, Ground at 400 m intervals or less Ground shielded cables where exposed to personnel contact.

Single Earthed Neutral:



Three Phase Four Wire Single Grounded Neutral

- Fig Show Single Grounded Neutral Which is different from Multi Grounded System .Figure shows the neutral also connected to earth, but the neutral conductor is extended along with the phase conductors. The configuration shown in figure allows electrical loads, transformers to be placed between any of the three phase conductors, phase-to-phase and/or phase-to-neutral.
- This connection, phase to neutral will force electric current to flow over the neutral back to the transformer. So far, this electrical connection is acceptable, as long as the neutral is insulated or treated as being potentially energized, but modifications will be made in the future that will negate safety for the public and animals.
- The ground connection would typically be located in the distribution substation. This may appear insignificant, but the differences are significant

Advantages of Multiple Grounded Neutral Systems:

(1) Optimize the Size of Surge Arrestor:

- Surge arresters are applied to a power system based on the line-to-ground voltage under normal condition and abnormal conditions. Under ground-fault conditions, the line-to-ground voltage can increase up to 1.73 per unit on the two, un faulted.
- Application of surge arresters on a power system is dependent on the effectiveness of the system grounding. The over voltage condition that can occur during a ground fault can be minimized by keeping the zero sequence impedance low. Therefore, optimization in sizing the surge arresters on the system is dependent on the system grounding.
- An effectively grounded power system allows the use of a lower rated surge arrester. The lower rated surge arrester provides better surge protection at a lower cost. An effectively grounded system can only be accomplished using a properly sized, multi-grounded system neutral.
- With Single Grounded Neutral System require the use of full line-to-line voltage rated arresters. This increases the cost of the surge arresters while at the same time reduces the protection provided by the surge arrester. In addition, if the fourth wire neutral is not multi grounded, it would be good practice to place surge arresters at appropriate locations on that conductor.

(2) The zero sequence impedance is lower for a multi grounded system than the single point grounded neutral system.

(3) Freezing and arctic conditions have an adverse impact on the zero sequence impedance. A multi-grounded system neutral will still lower the zero sequence impedance over a single point ground. In fact, without the multi-grounded system, it is more probable that insufficient fault current will flow to properly operate the ground fault protection.

(4) Cost of Equipment for the multi-grounded system is lower.

(5) Safety Concerns on Cable Shields.

- Medium voltage and high voltage cables typically have cable shields (NEC requirement above 5 kV) that need to be grounded. There are several reasons for this shield:
    - To confine electric fields within the cable
    - To obtain uniform radial distribution of the electric field
    - To protect against induced voltages
    - To reduce the hazard of shock
- If the shield is not grounded, the shock hazard can be increased. With the shield grounded at one point, induced voltage on the shield can be significant and create a shock hazard. Therefore, it is common practice to apply multiple grounds on the shield to keep the voltage limited to 25 volts.
- This practice of multi-grounding cable shields includes the grounding of concentric neutrals on power cables thereby extending the need for multi-grounding of neutrals on the power system.

Disadvantages of Multiple Neutral Grounding:

(1) Less Electrical Safety in Public and Private Property.

- With a multi grounded neutral distribution system it is necessary to have an electrical connection to earth at least 4 times per mile to keep the voltage on the multi grounded neutral from exceeding approximately 25 volts making it safe for the linemen should they come into contact with the neutral and the earth.
- As per NESC Rule 096 C in the section with the multi grounded neutral conductor connected to earth at least 4 times per mile and at each transformer and lightning arrester there are now multiple paths over and through the earth that the hazardous electric current can flow over continuously, uncontrolled.

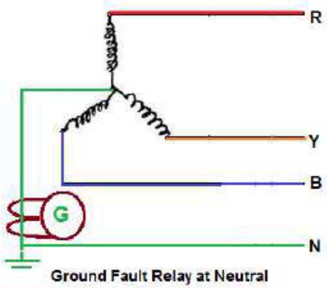
- The path that this current flow takes through the earth cannot be determined. We cannot put an isotope on each electron and trace its path as it flows uncontrolled through the earth. It is irresponsible to permit stray uncontrolled electric current to flow into and over private property.
- The National Electrical Code (NEC) requires the neutral in the service disconnect and over current panel board to be connected to the earth also. Now the secondary neutral is connected to earth a second time. A parallel connection of the neutral to earth now exists permitting hazardous electric current to flow continuously uncontrolled over the earth.

(2) Earth Fault Protection Relay setting is complicated.

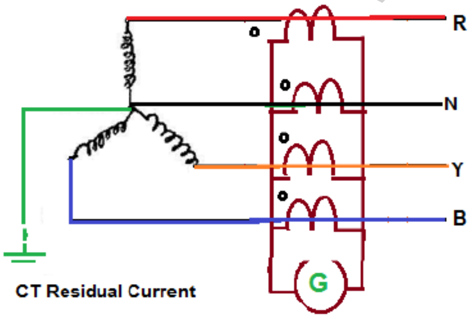
Advantages of Single Grounded Neutral System:

(1) Protection Relay Setting is more easy in Single Grounded Neutral:

- Protective relays need to sense abnormal conditions, especially those involving a ground fault. The single point grounded system, with or without a neutral conductor, current flowing into the ground should be considered abnormal (excluding normal charging current). For sensing of ground faults are:



- A current transformer in the location where the neutral is grounded can be used to sense the ground fault (zero sequence) current.
- A zero sequence CT enclosing the three phase and neutral conductors.



- Four CT residue circuit (Three CT residual with neutral CT cancellation).
- Protecting against ground faults on a multi-grounded neutral system is more difficult than the single point grounded system since both neutral and ground fault currents must be considered.
- Neutral current and likewise ground fault current can flow in both the neutral and the ground. So, We have must calculate both current as the amount of neutral current which may flow in the circuit, and the ground fault setting must be above this neutral current. This is self explanatory from Fig.

(2) Sensing of Ground Fault current :

- While the sensing of the ground fault current in the single point grounded system is less complex than the multi grounded system, the amount of ground fault current on the single-point grounded system may be greatly limited due to the fact that all ground fault current must return through the earth. This is especially true where the earth resistivity is high, the soil is frozen or the soil is extremely dry.

Reference:

- John P. Nelson Fellow, IEEE ANSI/IEEE Std 142-1991.
- Westinghouse Electric Corporation, Electrical Transmission and Distribution Reference Book NFPA 70, National Electrical Code 2002.
- Jeffery Leib, Train-Car Crashes on the Rise,Denver Post Newspaper, November 7, 2002.
- R.T. Beck and Luke Yu, Design Considerations for Grounding Systems

Chapter:57 Type of Neutral Earthing in Distribution System

Introduction:

- In the early power systems were mainly Neutral ungrounded due to the fact that the first ground fault did not require the tripping of the system. An unscheduled shutdown on the first ground fault was particularly undesirable for continuous process industries. These power systems required ground detection systems, but locating the fault often proved difficult. Although achieving the initial goal, the ungrounded system provided no control of transient over-voltages.
- A capacitive coupling exists between the system conductors and ground in a typical distribution system. As a result, this series resonant L-C circuit can create over-voltages well in excess of line-to-line voltage when subjected to repetitive re-strikes of one phase to ground. This in turn, reduces insulation life resulting in possible equipment failure.
- Neutral grounding systems are similar to fuses in that they do nothing until something in the system goes wrong. Then, like fuses, they protect personnel and equipment from damage. Damage comes from two factors, how long the fault lasts and how large the fault current is. Ground relays trip breakers and limit how long a fault lasts and Neutral grounding resistors limit how large the fault current is.

Importance of Neutral Grounding:

- There are many neutral grounding options available for both Low and Medium voltage power systems. The neutral points of transformers, generators and rotating machinery to the earth ground network provides a reference point of zero volts. This protective measure offers many advantages over an ungrounded system, like,

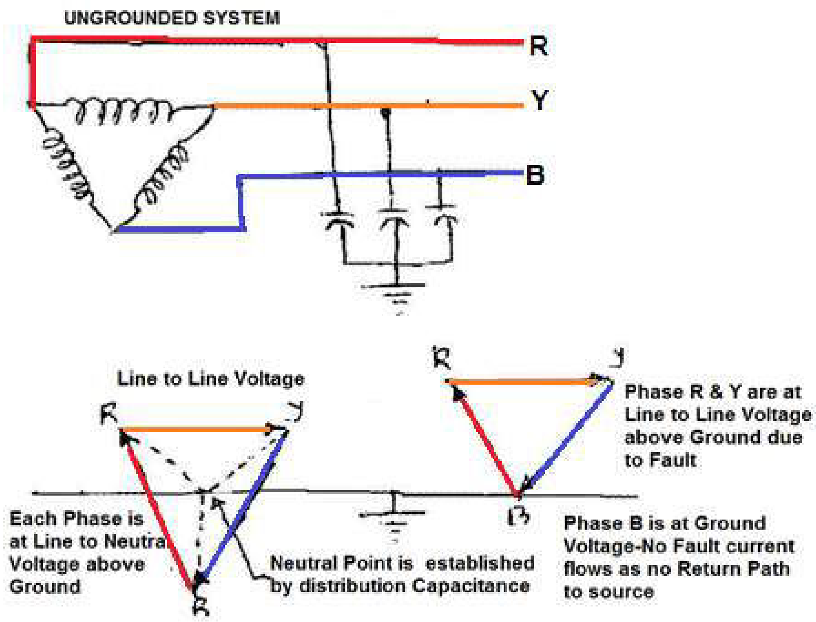
1. Reduced magnitude of transient over voltages
2. Simplified ground fault location
3. Improved system and equipment fault protection
4. Reduced maintenance time and expense
5. Greater safety for personnel
6. Improved lightning protection
7. Reduction in frequency of faults.

Method of Neutral Earthing:

- There are five methods for Neutral earthing.
    1. Unearthed Neutral System
    2. Solid Neutral Earthed System.
    3. Resistance Neutral Earthing System.
        a. Low Resistance Earthing.
        b. High Resistance Earthing.
    4. Resonant Neutral Earthing System.
    5. Earthing Transformer Earthing.

(1) Ungrounded Neutral Systems:

- In ungrounded system there is no internal connection between the conductors and earth. However, as system, a capacitive coupling exists between the system conductors and the adjacent grounded surfaces. Consequently, the "ungrounded system" is, in reality, a "capacitive grounded system" by virtue of the distributed capacitance.
- Under normal operating conditions, this distributed capacitance causes no problems. In fact, it is beneficial because it establishes, in effect, a neutral point for the system; As a result, the phase conductors are stressed at only line-to-neutral voltage above ground.
- But problems can rise in ground fault conditions. A ground fault on one line results in full line-to-line voltage appearing throughout the system. Thus, a voltage 1.73 times the normal voltage is present on all insulation in the system. This situation can often cause failures in older motors and transformers, due to insulation breakdown.



Advantage:

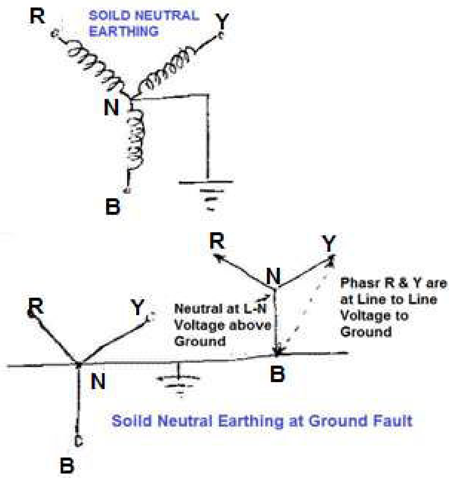
- After the first ground fault, assuming it remains as a single fault, the circuit may continue in operation, permitting continued production until a convenient shut down for maintenance can be scheduled.

Disadvantages:

- The interaction between the faulted system and its distributed capacitance may cause transient over-voltages (several times normal) to appear from line to ground during normal switching of a circuit having a line-to ground fault (short). These over voltages may cause insulation failures at points other than the original fault.
- A second fault on another phase may occur before the first fault can be cleared. This can result in very high line-to-line fault currents, equipment damage and disruption of both circuits.
- The cost of equipment damage.
- Complicate for locating fault(s), involving a tedious process of trial and error: first isolating the correct feeder, then the branch, and finally, the equipment at fault. The result is unnecessarily lengthy and expensive down downtime.

(2) Solidly Neutral Grounded Systems:

- Solidly grounded systems are usually used in low voltage applications at 600 volts or less.
- In solidly grounded system, the neutral point is connected to earth.
- Solidly Neutral Grounding slightly reduces the problem of transient over voltages found on the ungrounded system and provided path for the ground fault current is in the range of ***25 to 100% of the system three phase fault current.*** However, if the reactance of the generator or transformer is too great, the problem of transient over voltages will not be solved.
- While solidly grounded systems are an improvement over ungrounded systems, and speed up the location of faults, they lack the current limiting ability of resistance grounding and the extra protection this provides.
- To maintain systems health and safe, Transformer neutral is grounded and grounding conductor must be extend from the source to the furthest point of the system within the same raceway or conduit. Its purpose is to maintain very low impedance to ground faults so that a relatively high fault current will flow thus insuring that circuit breakers or fuses will clear the fault quickly and therefore minimize damage. It also greatly reduces the shock hazard to personnel.



- If the system is not solidly grounded, the neutral point of the system would "float" with respect to ground as a function of load subjecting the line-to-neutral loads to voltage unbalances and instability.
- The single-phase earth fault current in a solidly earthed system may exceed the three phase fault current. The magnitude of the current depends on the fault location and the fault resistance. One way to reduce the earth fault current is to leave some of the transformer neutrals unearthed.

Advantage:

- The main advantage of solidly earthed systems is low over voltages, which makes the earthing design common at high voltage levels (HV).

Disadvantage:

- This system involves all the drawbacks and hazards of high earth fault current: maximum damage and disturbances.
- There is no service continuity on the faulty feeder.
- The danger for personnel is high during the fault since the touch voltages created are high.

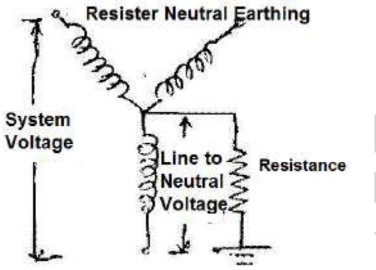
Applications:

- Distributed neutral conductor.
- 3-phase + neutral distribution.
- Use of the neutral conductor as a protective conductor with systematic earthing at each transmission pole.
- Used when the short-circuit power of the source is low.

(3) Resistance earthed systems:

- Resistance grounding has been used in three-phase industrial applications for many years and it resolves many of the problems associated with solidly grounded and ungrounded systems.
- Resistance Grounding Systems limits the phase-to-ground fault currents. The reasons for limiting the Phase to ground Fault current by resistance grounding are:
    1. To reduce burning and melting effects in faulted electrical equipment like switchgear, transformers, cables, and rotating machines.
    2. To reduce mechanical stresses in circuits/Equipments carrying fault currents.
    3. To reduce electrical-shock hazards to personnel caused by stray ground fault.
    4. To reduce the arc blast or flash hazard.
    5. To reduce the momentary line-voltage dip.
    6. To secure control of the transient over-voltages while at the same time.
    7. To improve the detection of the earth fault in a power system.
- Grounding Resistors are generally connected between ground and neutral of transformers, generators and grounding transformers ***to limit maximum fault current as per Ohms Law to a value which will not damage the equipment*** in the power system and allow sufficient flow of fault current to detect and operate Earth protective relays to clear the fault. Although it is possible to limit fault currents with high resistance Neutral grounding Resistors, earth short circuit currents can be extremely reduced. As a result of this fact, protection devices may not sense the fault.
- Therefore, it is the most common application to limit single phase fault currents with low resistance Neutral Grounding Resistors to approximately rated current of transformer and / or generator.

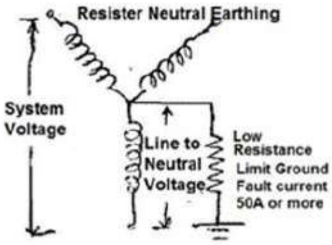
- In addition, limiting fault currents to predetermined maximum values permits the designer to selectively coordinate the operation of protective devices, which minimizes system disruption and allows for quick location of the fault.
- There are two categories of resistance grounding:
  - (1) Low resistance Grounding.
  - (2) High resistance Grounding.
- Ground fault current flowing through either type of resistor when a single phase faults to ground will increase the phase-to-ground voltage of the remaining two phases. As a result, **conductor insulation and surge arrestor ratings must be based on line-to-line voltage**. This temporary increase in phase-to-ground voltage should also be considered when selecting two and three pole breakers installed on resistance grounded low voltage systems.
- The increase in phase-to-ground voltage associated with ground fault currents also precludes the connection of line-to-neutral loads directly to the system. If line-to neutral loads (such as 277V lighting) are present, they must be served by a solidly grounded system. This can be achieved with an isolation transformer that has a three-phase delta primary and a three-phase, four-wire, wye secondary.

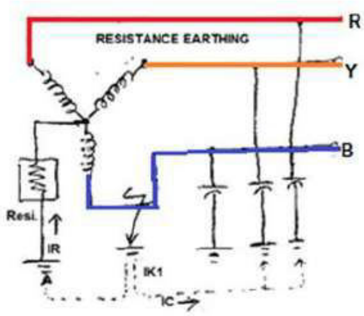


- Neither of these grounding systems (low or high resistance) reduces arc-flash hazards associated with phase-to-phase faults, but both systems significantly reduce or essentially eliminate the arc-flash hazards associated with phase-to-ground faults. Both types of grounding systems limit mechanical stresses and reduce thermal damage to electrical equipment, circuits, and apparatus carrying faulted current.
- The difference between Low Resistance Grounding and High Resistance Grounding is a matter of perception and, therefore, is not well defined. Generally speaking high-resistance grounding refers to a system in which the NGR let-through current is less **than 50 to 100 A.** Low resistance grounding indicates that NGR current would be **above 100 A.**
- A better distinction between the two levels might be alarm only and tripping. An alarm-only system continues to operate with a single ground fault on the system for an unspecified amount of time. In a tripping system a ground fault is automatically removed by protective relaying and circuit interrupting devices. Alarm-only systems usually limit NGR current to 10 A or less.
- **Rating of The Neutral grounding resistor:**
  1. **Voltage**: Line-to-neutral voltage of the system to which it is connected.
  2. **Initial Current:** The initial current which will flow through the resistor with rated voltage applied.
  3. **Time:** The "on time" for which the resistor can operate without exceeding the allowable temperature rise.

(A) Low Resistance Grounded:

- Low Resistance Grounding is used for large electrical systems where there is a high investment in capital equipment or prolonged loss of service of equipment has a significant economic impact and it is not commonly used in low voltage systems because the limited ground fault current is too low to reliably operate breaker trip units or fuses. This makes system selectivity hard to achieve. Moreover, low resistance grounded systems are not suitable for 4-wire loads and hence have not been used in commercial market applications
- A resistor is connected from the system neutral point to ground and generally sized to permit only **200A to 1200 amps** of ground fault current to flow. Enough current must flow such that protective devices can detect the faulted circuit and trip it off-line but not so much current as to create major damage at the fault point.





- Since the grounding impedance is in the form of resistance, any transient over voltages are quickly damped out and the whole transient overvoltage phenomena is no longer applicable. Although theoretically possible to be applied in low voltage systems (e.g. 480V),significant amount of the system voltage dropped across the grounding resistor, there is not enough voltage across the arc forcing current to flow, for the fault to be reliably detected. For this reason**, low resistance grounding is not used for low voltage systems** (under 1000 volts line to-line).

Advantages:

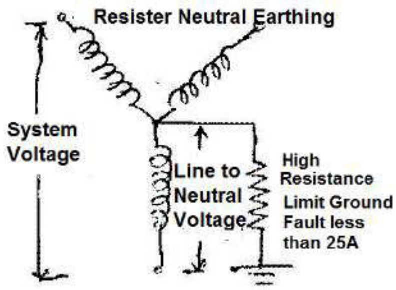
- Limits phase-to-ground currents to 200-400A.
- Reduces arcing current and, to some extent, limits arc-flash hazards associated with phase-to-ground arcing current conditions only.
- May limit the mechanical damage and thermal damage to shorted transformer and rotating machinery windings.

Disadvantages:

- Does not prevent operation of over current devices.
- Does not require a ground fault detection system.
- May be utilized on medium or high voltage systems.
- Conductor insulation and surge arrestors must be rated based on the line to-line voltage. Phase-to-neutral loads must be served through an isolation transformer.
- **Used:** Up to 400 amps for 10 sec are commonly found on medium voltage systems.

(B) High Resistance Grounded:

- High resistance grounding is almost identical to low resistance groundingexcept that the ground fault current magnitude is typically limited to **10 amperes or less**. High resistance grounding accomplishes two things.
- The first is that the **ground fault current magnitude is sufficiently low enough such** that no appreciable damage is done at the fault point. This means that the faulted circuit need not be tripped off-line when the fault first occurs. Means that once a fault does occur, we do not know where the fault is located. In this respect, it performs just like an ungrounded system.
- The second point is it can **controlthe transient overvoltage phenomenon** present on ungrounded systems if engineered properly.
- Under earth fault conditions, the resistance must dominate over the system charging capacitance but not to the point of permitting excessive current to flow and thereby excluding continuous operation.



- High Resistance Grounding (HRG) systems limit the fault current when one phase of the system shorts or arcs to ground, but at lower levels than low resistance systems.
- In the event that a ground fault condition exists, the HRG typically limits the current to 5-10A.
- HRG's are continuous current rated, so the description of a particular unit does not include a time rating. Unlike NGR's, ground fault current flowing through a HRG is usually not of significant magnitude to result in the operation of an over current device. Since the ground fault current is not interrupted, a ground fault detection system must be installed.

- These systems include a bypass contactor tapped across a portion of the resistor that pulses (periodically opens and closes). When the contactor is open, ground fault current flows through the entire resistor. When the contactor is closed a portion of the resistor is bypassed resulting in slightly lower resistance and slightly higher ground fault current.
- **To avoid transient over-voltages, an HRG resistor must be sized so that the amount of ground fault current** the unit will allow to flow exceeds the electrical system's charging current. As a rule of thumb, charging current is estimated at 1A per 2000KVA of system capacity for low voltage systems and 2A per 2000KVA of system capacity at 4.16kV.
- These estimated charging currents increase if surge suppressors are present. Each set of suppressors installed on a low voltage system results in approximately 0.5A of additional charging current and each set of suppressors installed on a 4.16kV system adds 1.5A of additional charging current.
- A system with 3000KVA of capacity at 480 volts would have an estimated charging current of 1.5A.Add one set of surge suppressors and the total charging current increases by 0.5A to 2.0A. A standard 5A resistor could be used on this system. Most resistor manufacturers publish detailed estimation tables that can be used to more closely estimate an electrical system's charging current.

Advantages:

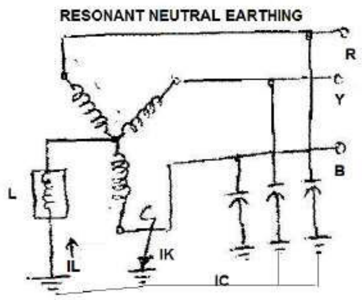
- Enables high impedance fault detection in systems with weak capacitive connection to earth
- Some phase-to-earth faults are self-cleared.
- The neutral point resistance can be chosen to limit the possible over voltage transients to 2.5 times the fundamental frequency maximum voltage.
- Limits phase-to-ground currents to 5-10A.
- Reduces arcing current and essentially eliminates arc-flash hazards associated with phase-to-ground arcing current conditions only.
- Will eliminate the mechanical damage and may limit thermal damage to shorted transformer and rotating machinery windings.
- Prevents operation of over current devices until the fault can be located (when only one phase faults to ground).
- May be utilized on low voltage systems or medium voltage systems up to 5kV. IEEE Standard 141-1993 states that "high resistance grounding should be restricted to 5kV class or lower systems with charging currents of about 5.5A or less and should not be attempted on 15kV systems, unless proper grounding relaying is employed".
- Conductor insulation and surge arrestors must be rated based on the line to-line voltage. Phase-to-neutral loads must be served through an isolation transformer.

Disadvantages:

- Generates extensive earth fault currents when combined with strong or moderate capacitive connection to earth Cost involved.
- Requires a ground fault detection system to notify the facility engineer that a ground fault condition has occurred.

(4) Resonant earthed system:

- Adding inductive reactance from the system neutral point to ground is an easy method of limiting the available ground fault from something near the maximum 3 phase short circuit capacity (thousands of amperes) to a relatively low value (200 to 800 amperes).
- To limit the reactive part of the earth fault current in a power system a neutral point reactor can be connected between the transformer neutral and the station earthing system.
- A system in which at least one of the neutrals is connected to earth through an
    1. Inductive reactance.
    2. Petersen coil / Arc Suppression Coil / Earth Fault Neutralizer.
- The current generated by the reactance during an earth fault approximately compensates the capacitive component of the single phase earth fault current, is called a resonant earthed system.
- The system is hardly ever exactly tuned, i.e. the reactive current does not exactly equal the capacitive earth fault current of the system.
- A system in which the inductive current is slightly larger than the capacitive earth fault current is over compensated. A system in which the induced earth fault current is slightly smaller than the capacitive earth fault current is under compensated.



- However, experience indicated that this inductive reactance to ground resonates with the system shunt capacitance to ground under arcing ground fault conditions and creates very high transient over voltages on the system.
- To control the transient over voltages, the design must permit at least 60% of the 3 phase short circuit current to flow underground fault conditions.
- Example. A 6000 amp grounding reactor for a system having 10,000 amps 3 phase short circuit capacity available. Due to the high magnitude of ground fault current required to control transient over voltages, inductance grounding is rarely used within industry.
- **Petersen Coils:**
- A Petersen Coil is connected between the neutral point of the system and earth, and is rated so that the capacitive current in the ***earth fault is compensated by an inductive current passed by the Petersen Coil***. A small residual current will remain, but this is so small that any arc between the faulted phase and earth will not be maintained and the fault will extinguish. Minor earth faults such as a broken pin insulator, could be held on the system without the supply being interrupted. Transient faults would not result in supply interruptions.
- Although the standard 'Peterson coil' does not compensate the entire earth fault current in a network due to the presence of resistive losses in the lines and coil, it is now possible to apply 'residual current compensation' by injecting an additional 180° out of phase current into the neutral via the Peterson coil. The fault current is thereby reduced to practically zero. Such systems are known as 'Resonant earthing with residual compensation', and can be considered as a special case of reactive earthing.
- Resonant earthing can reduce EPR to a safe level. This is because the Petersen coil can often effectively act as a high impedance NER, which will substantially reduce any earth fault currents, and hence also any corresponding EPR hazards (e.g. touch voltages, step voltages and transferred voltages, including any EPR hazards impressed onto nearby telecommunication networks).

Advantages:

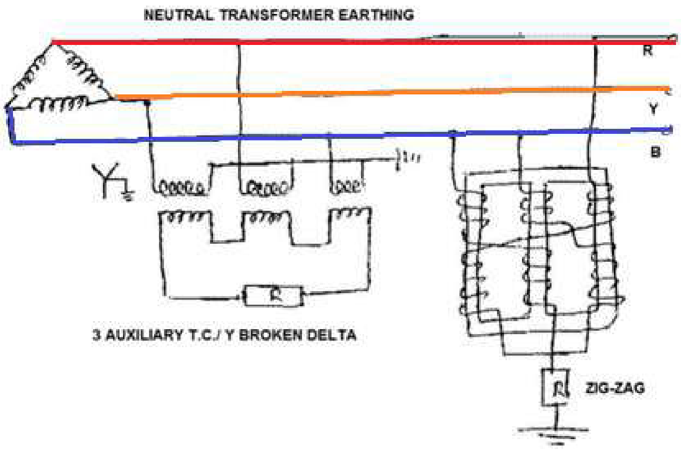
- Small reactive earth fault current independent of the phase to earth capacitance of the system.
- Enables high impedance fault detection.

Disadvantages:

- Risk of extensive active earth fault losses.
- High costs associated.

(5) Earthing Transformers:

- For cases where there is no neutral point available for Neutral Earthing (e.g. for a delta winding), an earthing transformer may be used to provide a return path for single phase fault currents.



- In such cases the impedance of the earthing transformer may be sufficient to act as effective earthing impedance. Additional impedance can be added in series if required. A special 'zig-zag' transformer is sometimes used for earthing delta windings to provide a low zero-sequence impedance and high positive and negative sequence impedance to fault currents.

Conclusion:

- Resistance Grounding Systems have many advantages over solidly grounded systems including arc-flash hazard reduction, limiting mechanical and thermal damage associated with faults, and controlling transient over voltages.
- High resistance grounding systems may also be employed to maintain service continuity and assist with locating the source of a fault.
- When designing a system with resistors, the design/consulting engineer must consider the specific requirements for conductor insulation ratings, surge arrestor ratings, breaker single-pole duty ratings, and method of serving phase-to-neutral loads.

Comparison of Neutral Earthing System:

Condition	Ungrounded	Solid Grounded	Low Resistance Grounded	High Resistance Grounded	Reactance Grounding
Immunity to Transient Over voltages	Worse	Good	Good	Best	Best
73% Increase in Voltage Stress Under Line-to-Ground Fault Condition	Poor	Best	Good	Poor	
Equipment Protected	Worse	Poor	Better	Best	Best
Safety to Personnel	Worse	Better	Good	Best	Best
Service Reliability	Worse	Good	Better	Best	Best
Maintenance Cost	Worse	Good	Better	Best	Best
Ease of Locating First Ground Fault	Worse	Good	Better	Best	Best
Permits Designer to Coordinate Protective Devices	Not Possible	Good	Better	Best	Best
Reduction in Frequency of Faults	Worse	Better	Good	Best	Best
Lighting Arrestor	Ungrounded neutral type	Grounded-neutral type	Ungrounded neutral type	Ungrounded neutral type	Ungrounded neutral type
Current forphase-to groundfaultin percent of three-phasefault current	Less than 1%	Varies, may be100% or greater	5 to 20%	Less than1%	5 to 25%

Reference:

- By Michael D. Seal, P.E., GE Senior Specification Engineer.
- IEEE Standard 141-1993, “Recommended Practice for Electrical Power Distribution for Industrial Plants”
- Don Selkirk, P.Eng, Saskatoon, Saskatchewan Canada

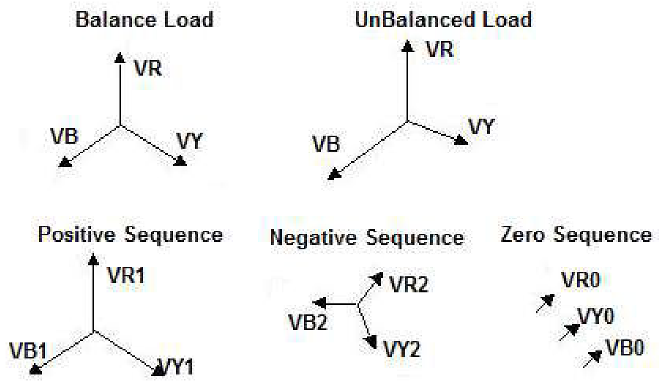
Chapter: 58   Effects of Unbalanced Electrical Load on System

Introduction:

- Generally, three phase balance is the ideal situation for a power system and quality of delivered Electrical Power. However Voltage unbalance may makes worse effect on Power quality of Electrical Power at distribution level.
- The voltages are quite well balanced at the generator and transmission levels. But the voltages at the utilization level can become unbalanced due to the unequal system impedances, the unequal distribution of single phase loads, asymmetrical three-phase equipment and devices (such as three-phase transformers with open star-open delta connections), unbalanced faults, bad connections to electrical connectors.
- An excessive level of voltage unbalance can have serious impacts on power quality. In the system the level of current unbalance is several times the level of voltage unbalance. Such an unbalance in the line currents can lead to excessive line losses, losses in the stator and rotor of Motor Malfunctioning of Relay, unsymmetrical measuring of Meters. Voltage unbalance also has an impact on ac variable speed drive systems where the front end converter consists of three-phase rectifier systems
- Phase balancing is very important and usable to reduce distribution feeder losses and Improve system stability and security

What is unbalance Voltage

- Any deviation in voltage and current waveform from perfect sinusoidal, in terms of magnitude or phase shift is termed as unbalance
- In ideal conditions the phases of power supply are 120 degree apart in terms of phase angle and magnitude of their peaks should be same. On distribution level, the load imperfections cause current unbalance which travel to transformer and cause unbalance in the three phase voltage. Even minor unbalance in the voltage at transformer level disturbs the current waveform significantly on all the loads connected to it



- If three phase voltages have the same magnitude and are in exactly 120deg phase displacement, then the Three-phase voltage is called balanced, otherwise, it is unbalanced.
- There are no negative- and zero-sequence voltages in a balanced system, only positive-sequence components of balanced three-phase voltage exist. On the contrary, if the system is unbalanced, negative-sequence components or zero-sequence components or both may exist in the system.

Causes of unbalance Voltage

- Switching of three phase heavy loads results in current and voltage surges which cause unbalance in the system.
- Unequal impedances in the power transmission or distribution system cause differentiating current in three phases.
- Any large single phase load, or a number of small loads connected to only one phase cause more current to flow from that particular phase causing voltage drop on line
- With continuous operation of motor's in various environment cause degradation of rotor and stator windings. This degradation is usually different in different phases, affecting both the magnitude and phase angel of current waveform

- A three phase equipment such as induction motor and Transformer with unbalance in its windings. If the reactance of three phases is not same, it will result in varying current flowing in three phases and give out system unbalance.
- A current leakage from any phase through bearings or motor body provides floating earth at times, causing fluctuating current.
- Unbalanced incoming utility supply
- Unequal transformer taps settings
- Large single phase distribution transformer on the system
- Open phase on the primary of a 3 phase transformer on the distribution system
- Faults or grounds in the power transformer
- Open delta connected transformer banks
- A blown fuse on a 3 phase bank of power factor improvement capacitors
- Unequal impedance in conductors of power supply wiring
- Unbalanced distribution of single phase loads such as lighting
- Heavy reactive single phase loads such as welders

How to calculate unbalance

- **%voltage unbalance= 100x (maximum deviation from average voltage) / (average voltage)**
- Example: With phase-to-phase voltages of The System is 430V, 435V, and 400V.
- The average Voltage=(430+435+400)/3=421V.
- The maximum Voltage deviation from Average Voltage=435-421=14V
- %voltage unbalance=14x100/421=3.32%
- The permissible limit in terms of percentage of negative phase sequence current over positive sequence current is 1.3% ideally but acceptable up to 2%.

Effects of unbalance Voltage on System and Equipment:

- The factors for voltage unbalances can be classified into two categories: normal factors and abnormal factors.
- Voltage imbalances due to normal factors, such as single-phase loads and three-phase transformer banks with open star-open delta connections, can generally be reduced by properly designing the system and installing suitable equipment and devices.
- Abnormal factors include series and shunt faults of circuits, bad electrical contacts of connectors or switches, asymmetrical breakdown of equipment or components, asynchronous burnout of three phase power fuses, single-phase operation of motors, etc. The abnormal factors just mentioned above might result in critical damage of systems and equipment.

(1) Increase Neutral Return Current

- The unequal distribution of loads between the three phases of the system cause the flow of unbalanced currents in the system, that produce unbalanced voltage drops on the electric lines. This increase in neutral current which cause line losses.
- If the system has balanced phase then Neutral current flow will be less on a system. We can save thousands to millions of rupees money by reduce losses be the reducing the neutral current flow in the system
- Thus unbalance in LV distribution network resulting in increase of neutral current.

(2) Voltage or Current Shift

- If the system is unbalanced, negative-sequence components or zero-sequence components or both may exist in the system.
- The resistance for negative sequence current is 1/6th of the positive sequence current, which means a small unbalance in voltage waveform will give more current and thus losses.

(3) Excessive power loss

- The unbalance Voltage always causes extra power loss in the system. The higher the voltage unbalance is the more power is dissipated means higher power bills.
- The imbalance of current will increase the I2R Losses
- Let's look at a simple exercise, In balance System The Load current in R Phase=200A, Y Phase=200A,B Phase=200A and in Unbalance System The Load current in R Phase=300A, Y Phase=200A,B Phase=100A,Consider Resistance of line are same in both case and all phases.
- In Balanced System:

- Total Load current =R+Y+B = 200+200+200=**600A.**
- Total Losses =R(I2R)+Y(I2R)+B(I2R)=40000+40000+40000=**120,000Watt.**
- In Un Balanced System:
- Total Load current =R+Y+B = 300+200+100=**600A.**
- Total Losses =R(I2R)+Y(I2R)+B(I2R)=90000+40000+10000=**140,000Watt.**
- Here Total Load current is same in both case but Losses in unbalance system is more than balance system.
- An unbalance of 1% is acceptable as it does not affect the cable. But above 1% it increases linearly and at 4% the de-rating is 20%. This means - 20% of the current flowing in the cable will be unproductive and thus the copper losses in the cable will increase by 25% at 4% unbalance.

(4) Motor failure

- In general, a three-phase motor fed by a balanced three-phase voltage with only positive-sequence component which produces only positive-sequence torque.
- **Reduce Motor life by heating:** Extra loss due to voltage imbalance will heat the motor windings, by increasing the operating temperature of Motor leads to the breakdown of winding insulation and might finally in motor failure. This may also decompose the grease or oil in the bearing and de-rate the motor windings. The voltage unbalance of 3% increases the heating by 20% for an induction motor.
- Winding insulation life is reduced by one-half for each 10°C increase in operating temperature
- **Vibration of Motor:** The negative-sequence voltage caused by voltage imbalance produces opposite torque and leads to motor vibration and noise. Severe voltage imbalance may even result in motor collapse.
- **Reduce Motor Life:** Heat generated by Unbalance Voltage may also reduce the Motor life
- **Reduce Efficiency:** In induction motors connected to unbalanced supply, the negative sequence currents flow along with positive sequence current resulting in decreased percentage of productive current and poor motor efficiency. Any unbalance above 3% hampers the motor efficiency.

Motor Efficiency %			
Motor Load % Full	**Voltage Unbalance**		
	Nominal	**1%**	**2.5%**
100	94.4	94.4	93.0
75	95.2	95.1	93.9
50	96.1	95.5	94.1

- Assume that the 100-HP motor tested was fully loaded and operated for 800 hours per year with an unbalanced voltage of 2.5%. With energy priced at 23Rs/KWH. the annual energy and cost savings calculation are
- With Normal Voltage
- Annual Energy Consumption=100HPx0.746X800X(100/94.4)x23=1454068Rs
- With Unbalanced Voltage
- Annual Energy Consumption=100HPx0.746X800X(100/93)x23=1475957Rs
- Annual Cost Savings = 1475957-1454068=21889Rs
- Overall savings may be much larger because an unbalanced supply voltage may power numerous motors and other electrical equipment.
- **Tripping of Motor:** Negative phase sequence current flowing due to unbalance can cause faults in the motor, resulting in, tripping or permanent damage of the electrical equipment
- **Reduce Capacity:** For motors, an unbalance of 5% will result in capacity reduction by 25%.
- **Tripping of VFD Drives:** The variable frequency or speed drives connected to an unbalanced system can trip off. VFD treats high level unbalances as phase fault and can trip on earth fault or missing phase fault.

(5) Harmonics in system by UPS:

- UPS or inverter supplies also perform with poor efficiency and inject more harmonic currents in case of unbalances in the system

(6) Decrease Life cycle of Equipment:

- Unbalanced Voltage increase I2R Losses which increase Temperature. High temperatures, exceeding the rated value of a device, will directly decrease the life cycle of the device and speed up the replacement cycle for the device, and significantly increase the costs of operation and maintenance.

(7) Relay malfunction

- Unbalanced Voltage flows Negative and Unbalanced Voltage of Voltage or Current.

- The high zero-sequence current in consequence of voltage imbalance may bring about malfunctions of relay operation or make the ground relay less sensitive. That may result in serious safety problems in the system.

(8) Inaccurate Measurement

- Negative and zero-sequence components of voltages or currents will give rise to inaccurate measurements in many kinds of meters.
- The imprecise measured values might affect the suitability of settings and coordination of relay protection systems and the correctness of decisions by some automated functions of the system.

(9) Decrease Capacity of transformers, cables and lines

- The capacity of transformers, cables and lines is reduced due to negative sequence components. The operational limit is determined by the RMS rating of the total current, due to 'useless' non-direct sequence currents the capacity of equipment is decrease.

(10) Increase Distribution Losses

- Distribution network losses can vary significantly depending on the load unbalance.
- Unbalance load increase I2R Losses of distribution Lines.

(11) Increase Energy Bill by increasing Maximum Demand

- Unbalanced Load increase maximum Demand of Electrical supply which is significantly effects on energy bill. By load balancing we can reduce energy bill.
- For Energy Consumption Energy Supply Company does not charge on kVA but on kW for Residential customers. This means that they are charged for the "actual" energy used and not charged for the "total" energy supplied. Thus the power factor and Maximum Demand do not impact residential customers.
- But Commercial, Industrial and H.T Connection charged by its maximum demand . We have to specify the maximum "demand"(in kVA) at the time of connection. During the month if you exceed your maximum "demand" you have to pay penalty (or extra price) for the same. That is the MDI penalty that appears on electricity bills.
- Let's assume That Two Company has same approved load of 40 KW and runs 30KW for 100 hours.
- Electricity charge = 65 Rs per kWh
- Demand charge = 210Rs per kW
- Example 1: Company A runs a 30 KW loads continuously for 100 hours but It's Maximum Demand is 50KW
- 30 KW x 100 hours = 3,000 KWh
- Energy Consumption Charge =3000x65=195000Rs
- Demand difference = 50 KW-40KW=10KW
- Demand Charges = 10X210=2100Rs
- Total Bill: 195000+2100=**197100Rs**
- Example 2: Company A runs a 30 KW loads continuously for 100 hours but It's Maximum Demand is 40W
- 30 KW x 100 hours = 3,000 KWh
- Energy Consumption Charge =3000x65=195000Rs
- Demand difference = 40 KW-40KW=0KW
- Demand Charges = 0X210=00Rs
- Total Bill: 195000+0=**195000Rs**

(12) Failure of Transformer

- Three-phase voltage with high unbalanced may cause the flux inside the transformer core to be asymmetrical.
- This asymmetrical flux will cause extra core loss, raise the winding temperature and may even cause transformer failure in a severe case.
- Ideally any distribution transformer gives best performance at 50% loading and every electrical distribution system is designed for it. But in case of unbalance the loading goes over 50% as the equipments draw more current.
- The efficiency of transformer under different loading conditions
- Full Load- 98.1%
- Half Load- 98.64%
- Unbalanced loads- 96.5%
- For a distribution transformer of 200KVA rating, the eddy currents accounts for 200W but in case of 5% voltage unbalance they can rise up to 720W.

(13) Bad / Loose connection of neutral wire

- In balance Load condition Bad connection of Neutral wire does not make more impact on distribution System but in unbalance load condition such type of Bad neutral connection make worse impact on distribution.

- The Three Phase power supplies a small a three-floor building. Each floor of this three-floor building is serviced by a single-phase feeder with a different phase. That is the first, second and third floor are serviced by phase R, Y and B. The external lighting load is connected only on R Phase.
- The supply transformer is rated at 150 kVA and connected delta-grounded wye to provide for 430/220 V three-phase four-wire service.
- This Transformer has a loose or Bad Neutral connection with the earth.
- The transformer delivers a load of 35 kVA at 220 V with 0.9 power factor lagging to each floor.
- During the daytime on, most of the Load of the Building are distributed equally over the three floors which is R Phase=30A, Y Phase =32A, B Phase=38A.
- In Daytime The Bad connection of Neutral does not effected the Distribution system due to equal load distribution of the System
- However it is not case in Nighttime. the Load on Y Phase and B Phase are negligible but R Phase Load is high compare to Y and B Phase.
- In R Phase due to High Electrical Load and The fluorescent lamps flash frequently during the Nighttime of external Lighting Load
- In Night time a bad electrical contact of the neutral wire of the supply makes the high contact resistance between the neutral wire and connector .which was about 15 kΩ.
- This extra high impedance caused an unusually high voltage drop in the phase a circuit. In this case, the voltage of phase a dropped from the normal 220V to 182.5V, about 17% based on the nominal voltage. If the contact impedance goes higher than 20 kΩ, it may result in more serious conditions such as extinguishing all lamps.
- This problem can be removed by fixing the bad connection and keeping the contact impedance near to zero.

Neutral Wire Contact Resistance	**Voltage across bad Connection Point**						**Voltage across Transformer Secondary Side**					
	Day Time			**Night Time**			**Day Time**			**Night Time**		
	R	Y	B	R	Y	B	R	Y	B	R	Y	B
Proper Connection (0Ω)	0v	0v	0v	0v	0v	0v	220v	220v	220v	220v	220v	220v
Bad Connection (15Ω)	0v	0v	0v	**40v**	0v	0v	220v	220v	220v	**182v**	220v	220v

(14) Neutral wire broken

- The effect of a broken neutral makes voltage imbalance in a Three Phase Four Wire System.
- For a Three Phase Four Wire System, high neutral wire impedance might enlarge a voltage imbalance (Some Phase Voltage increase while some Phase Voltage decreases).
- High Voltage damage the equipment connected and even destroy on other hand low voltage effect operation of equipments.
- The Three Phase star connected lighting loads are fed by a 430 V balanced three-phase voltage source. The fluorescent lamps are all rated at 220 V, 100 W each. The lamps are not equally in R Phase 5 No's of Bulbs are connected, in Y Phase 3 No's of Bulbs are connected and on B Phase 3 No's of Bulbs are Connected. And, the normal impedance of the neutral wire is 1Ω
- In unbalanced three phase load arrangement, high neutral wire impedance will enlarge the voltage across the neutral wire. The voltages of phases B and C at the load terminal raised to 255 V and 235 V, respectively, and gaining 16.15% and 5.77% based on rated voltage. These abnormally high phase voltages might damage the lamps in phase B and C.
- On the other hand, the voltage in phase A was reduced from 220V to 185V. That might cause the lamps to flash.
- If the broken neutral line problem is fixed, then the three phase voltages will go back to normal in near balanced status .however, if the loads are distributed equally to the three phases this problem can also be removed or minimized.

Conditions	**Voltage across the neutral wire**			**Voltage at the load terminal**		
	R	**Y**	**B**	**R**	**Y**	**B**
Normal Condition	1v	1v	1v	220v	220v	220v
Neutral Broken	0v	0v	0v	182v	255v	235v

(15) Unsuitable capacitor bank installation

- For reducing energy loss, utilities always force their customers to maintain the power factor within a limit. Penalty will be applied to the customers if their loads' power factors run outside the limits.

- Installation of shunt capacitor banks is the most common and cheapest manner to improve the power factor. However, unsuitable installation (single Phase Capacitor instead of Three Phase Capacitor) may make it worse.
- The supply transformer is rated at 150 kVA, 11kV/430 V, and supplies a three-phase load of 105 kVA with power factor 0.7 lagging.
- A single-phase 20KVAR capacitor bank is connected to B phase to improve system power. The impedance of the shunt capacitor bank is 1.805Ωper phase.
- This kind of single phase Capacitor installation should make the system unbalanced. This unsuitable installation consumes extra real power of 44355 W.
- The extra real power consumption = 1.732x2XV(RB) / 4xXc =(1.732x2x430) / (4x1.805) =44355W
- This case shows that the system balance should be considered when installing a capacitor bank to correct the system power factor for a three-phase power distribution system.

Remedial Action to prevent unbalances Load:

- All the single phase loads should be distributed on the three phase system such that they put equal load on three phases.
- Replacing the disturbing equipments i.e. with unbalanced three phase reactance.
- Reducing the harmonics also reduces the unbalance, which can be done by installing reactive or active filters. These filters reduce the negative phase sequence currents by injecting a compensating current wave.
- In case the disturbing loads cannot be replaced or repaired, connect them with high voltage side this reduces the effects in terms of percentage and even controlled disturbance in low voltage side.
- Motors with unbalanced phase reactance should be replaced and re-winded.
- Distribution of single-phase loads equally to all phases.
- Single-phase regulators have been installed that can be used to correct the unbalance but care must be exercised to ensure that they are controlled carefully not to introduce further unbalance.
- Passive network systems and active power electronic systems such as static var compensators and line conditioners also have been suggested for unbalance correction.
- Load balancing.
- Use of passive networks and static VAR compensators.
- Equipment that is sensitive to voltage unbalance should not be connected to systems which supply single-phase loads.
- Effect of voltage unbalance on ac variable speed drives can be reduced by properly sizing ac side and dc link reactors
- Tight all Neutral Connections of the System.
- Install Proper size of Capacitor Bank to the System.
- Load Scheduling, where the loads in an electrical network are scheduled in a way to turn on and off at precise times to prevent the overloading of any one phase.
- Manual Load Shifting, where an electrician opens a breaker panel and physically removes the loads from one phase and inserts them onto another phase.
- Load Shedding, where the loads in an electrical network are immediately turned off in order to instantly "rebalance" the phases. This is usually done by ranking the loads in a network by how long they can be turned off before it affects operations

Chapter: 59 Vibration Damper in Transmission Line

Introduction:

- Wind-induced vibration of overhead conductors is common worldwide and can cause conductor fatigue Near a hardware attachment.
- As the need for transmission of communication signals increase, many Optical Ground Wires (OPWG) are replacing traditional ground wires.
- In the last twenty years All Aluminum Alloy Conductors (AAAC) have been a popular choice for overhead conductors due to advantages in both electrical and mechanical characteristics. Unfortunately AAAC is known to be prone to Aeolian vibration.
- Vibration dampers are widely used to control Aeolian vibration of the conductors and earth wires including Optical Ground Wires (OPGW).
- In recent years, AAAC conductor has been a popular choice for transmission lines due to its high electrical carrying capacity and high mechanical tension to mass ratio. The high tension to mass ratio allows AAAC conductors to be strung at a higher tension and longer spans than traditional ACSR (Aluminum Conductor Steel Reinforced) conductors.
- Unfortunately the self-damping of conductor decreases as tension increases. The wind power into the conductor increases with span length. Hence AAAC conductors are likely to experience more severe vibration than ACSR.

What is Aeolian Vibration?

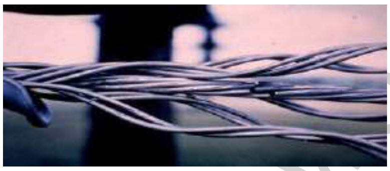
- Wind-induced vibration or Aeolian vibration of transmission line conductors is a common phenomenon under **smooth wind** conditions. The cause of vibration is that the vortexes shed alternatively from the top and bottom of the conductor at the leeward side of the conductor.
- The vortex shedding action creates an alternating pressure imbalance, inducing the conductor to move up and down at right angles to the direction of airflow.
- The conductor vibration results in cyclic bending of the conductor near hardware attachments, such as suspension clamps and consequently causes conductor fatigue and strand breakage.
- When a "smooth" stream of air passes across a cylindrical shape, such as a conductor or OHSW, vortices (eddies) are formed on the back side. These vortices alternate from the top and bottom surfaces, and create alternating pressures that tend to produce movement at right angles to the direction of the air flow. This is the mechanism that causes Aeolian vibration.
- The term "smooth" was used in the above description because unsmooth air (i.e., air with turbulence) will not generate the vortices and associated pressures. The degree of turbulence in the wind is affected both by the terrain over which it passes and the wind velocity itself.
- It is for these reasons that Aeolian vibration is generally produced by wind velocities below 15 miles per hour (MPH). Winds higher than 15 MPH usually contain a considerable amount of turbulence, except for special cases such as open bodies of water or canyons where the effect of the terrain is minimal.
- The frequency at which the vortices alternate from the top to bottom surfaces of conductors and shield wires can be closely approximated by the following relationship that is based on the Strouhal Number [2].
- **Vortex Frequency (Hertz) = 3.26 V / d**
- Where: V is the wind velocity component normal to the conductor or OHSW in miles per hour
- d is the conductor or OHSW diameter in inches
- 3.26 is an empirical aerodynamic constant
- One thing that is clear from the above equation is that the **frequency at which the vortices alternate is inversely proportional to the diameter of the conductor or OHSW.**
- The self damping characteristics of a conductor or OHSW are basically related to the freedom of movement or "looseness" between the individual strands or layers of the overall construction.
- In standard conductors the freedom of movement (self damping) will be reduced as the tension is increased. It is for this reason that vibration activity is most severe in the coldest months of the year when the tensions are the highest.
- Aeolian vibrations mostly occur at steady wind velocities from 1 to 7 m/s. With increasing wind turbulences the wind power input to the conductor will decrease. The intensity to induce vibrations depends on several

parameters such as type of conductors and clamps, tension, span length, topography in the surrounding, height and direction of the line as well as the frequency of occurrence of the vibration induced wind streams.

- Hence the smaller the conductor, the higher the frequency ranges of vibration of the conductor. The vibration damper should meet the requirement of frequency or wind velocity range and also have mechanical impedance closely matched to that of the conductor. The vibration dampers also need to be installed at suitable positions to ensure effectiveness across the frequency range.

Effect of Aeolian Vibration:

- It should be understood that the existence of Aeolian vibration on a transmission or distribution line doesn't necessarily constitute a problem. However, if the magnitude of the vibration is high enough, damage in the form of abrasion or fatigue failures will generally occur over a period of time.
- **Abrasion** is the wearing away of the surface of a conductor or OHSW and is generally associated with loose connections between the conductor or OHSW and attachment hardware or other conductor fittings.
- Abrasion damage can occur within the span itself at spacers Fatigue failures are the direct result of bending a material back and forth a sufficient amount over a sufficient number of cycles.
- In the case of a conductor or OHSW being subjected to Aeolian vibration, the maximum bending stresses occur at locations where the conductor or OHSW is being restrained from movement. Such restraint can occur in the span at the edge of clamps of spacers, spacer dampers and Stockbridge type dampers.
- However, the level of restraint, and therefore the level of bending stresses, is generally highest at the supporting structures.



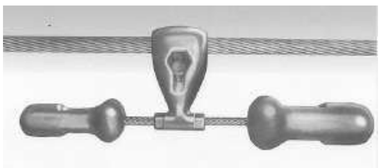
- When the bending stresses in a conductor or OHSW due to Aeolian vibration exceed the endurance limit, fatigue failures will occur.
- In a circular cross-section, such as a conductor or OHSW, the bending stress is zero at the center and increases to the maximum at the top and bottom surfaces (assuming the bending is about the horizontal axis). This means that the strands in the outer layer will be subjected to the highest level of bending stress and will logically be the first to fail in fatigue.

How Damper Works:

- When the damper is placed on a vibrating conductor, movement of the weights will produce bending of the steel strand. The bending of the strand causes the individual wires of the strand to rub together, thus dissipating energy. The size and shape of the weights and the overall geometry of the damper influence the amount of energy that will be dissipated for specific vibration frequencies.
- Since, as presented earlier, a span of tensioned conductor will vibrate at a number of different resonant frequencies under the influence of a range of wind velocities, an effective damper design must have the proper response over the range of frequencies expected for a specific conductor and span parameters.

1. VORTX/ Stockbridge Type:

- Some dampers, such as the VORTX Damper utilize two different weights and an asymmetric placement on the strand to provide the broadest effective frequency range possible.



- The "Stockbridge" type vibration damper is commonly used to control vibration of overhead conductors and OPGW. The vibration damper has a length of steel messenger cable. Two metallic weights are attached to the ends of the messenger cable. The centre clamp, which is attached to the messenger cable, is used to install the vibration damper onto the overhead conductor.

- Placement programs, such as those developed by PLP for the VORTX Damper, take into account span and terrain conditions, suspension types, conductor self-damping, and other factors to provide a specific location in the span where the damper or dampers will be most effective.
- The asymmetrical vibration damper is multi resonance system with inherent damping. The vibration energy is dissipated through inter-strand friction of the messenger cable around the resonance frequencies of the vibration damper. By increasing the number of resonances of the damper using asymmetrical design and increasing the damping capacity of the messenger cable the vibration damper is effective in reducing vibration over a wide frequency or wind velocity range.

2. Spiral Vibration Damper:

- For smaller diameter conductors (< 0.75”), overhead shield wires, and optical ground wires (OPGW), a different type of damper is available that is generally more effective than a Stockbridge type damper.

- The Spiral Vibration Damper (Figure 15) has been used successfully for over 35 years to control Aeolian vibration on these smaller sizes of conductors and wires.
- The Spiral Vibration Damper is an “impact” type damper made of a rugged non-metallic material that has a tight helix on one end that grips the conductor or wire. The remaining helixes have an inner diameter that is larger than the conductor or wire, such that they impact during Aeolian vibration activity. The impact pulses from the damper disrupt and negate the motion produced by the wind.

References:

1. Sarah Chao Sun. Dulhunty Power (Aust.). Australia
2. Joe Yung. Dulhunty Yangzhou Line Fittings, Canada.

Chapter: 60 What is Ferranti Effect

Introduction:

- A long transmission line draws a substantial quantity of charging current. If such a line is open circuited or very lightly loaded at the receiving end, Receiving end voltage being greater than sending end voltage in a transmission line is known as Ferranti effect.
- All electrical loads are inductive in nature and hence they consume lot of reactive power from the transmission lines. Hence there is voltage drop in the lines. Capacitors which supply reactive power are connected parallel to the transmission lines at the receiving end so as to compensate the reactive power consumed by the inductive loads.
- As the inductive load increases more of the capacitors are connected parallel via electronic switching. Thus reactive power consumed by inductive loads is supplied by the capacitors thereby reducing the consumption of reactive power from transmission line. However when the inductive loads are switched off the capacitors may still be in ON condition. The reactive power supplied by the capacitors adds on to the transmission lines due to the absence of inductance. As a result voltage at the receiving end or consumer end increases and is more than the voltage at the supply end. This is known as Ferranti effect.

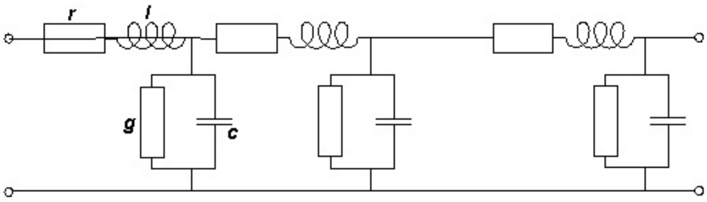
Why voltages rise on a long, unloaded transmission line?

- The Ferranti Effect occurs when current drawn by the distributed capacitance of the transmission line itself is greater than the current associated with the load at the receiving end of the line. Therefore, the Ferranti effect tends to be a bigger problem on lightly loaded lines, and especially on underground cable circuits where the shunt capacitance is greater than with a corresponding overhead line. This effect is due to the voltage drop across the line inductance (due to charging current) being in phase with the sending end voltages. As this voltage drop affects the sending end voltage, the receiving end voltage becomes greater. The Ferranti Effect will be more pronounced the longer the line and the higher the voltage applied.
- The Ferranti Effect is not a problem with lines that are loaded because line capacitive effect is constant independent of load, while inductance will vary with load. As inductive load is added, the VAR generated by the line capacitance is consumed by the load.

How to Reduce Ferranti Effect:

(1) Shunt Reactors and Series Capacitors:

- The need for large shunt reactors appeared when long power transmission lines for system voltage 220 kV & higher were built. The characteristic parameters of a line are the series inductance (due to the magnetic field around the conductors) & the shunt capacitance (due to the electrostatic field to earth). An equivalent diagram for a line is show in the figure below.
- Both the inductance & the capacitance are distributed along the length of the line. So are the series resistance and the admittance to earth. When the line is loaded, there is a voltage drop along the line due to the series inductance and the series resistance. When the line is energized but not loaded or only loaded with a small current, there is a voltage rise along the line (the Ferranti-effect)



- In this situation, the capacitance to earth draws a current through the line, which may be capacitive. When a capacitive current flows through the line inductance there will be a voltage rise along the line.
- To stabilize the line voltage the line inductance can be compensated by means of series capacitors and the line capacitance to earth by shunt reactors. Series capacitors are placed at different places along the line while shunt reactors are often installed in the stations at the ends of line. In this way, the voltage difference between the ends of the line is reduced both in amplitude and in phase angle.
- Shunt reactors may also be connected to the power system at junctures where several lines meet or to tertiary windings of transformers.

- Transmission cables have much higher capacitance to earth than overhead lines. Long submarine cables for system voltages of 100 KV and more need shunt reactors. The same goes for large urban networks to prevent excessive voltage rise when a high load suddenly falls out due to a failure.
- Shunt reactors contain the same components as power transformers, like windings, core, tank, bushings and insulating oil and are suitable for manufacturing in transformer factories. The main difference is the reactor core limbs, which have non-magnetic gaps inserted between packets of core steel.
- 3-phase reactors can also be made. These may have 3- or -5-limbed cores. In a 3-limbed core there is strong magnetic coupling between the three phases, while in a 5-limbed core the phases are magnetically independent due to the enclosing magnetic frame formed by the two yokes and the two unwound side-limbs.
- The neutral of shunt reactor may be directly earthed, earthed through an Earthing-reactor or unearthed.
- When the reactor neutral is directly earthed, the winding are normally designed with graded insulation in the earthed end. The main terminal is at the middle of the limb height, & the winding consists of two parallel-connected halves, one below & one above the main terminal. The insulation distance to the yokes can then be made relatively small. Sometimes a small extra winding for local electricity supply is inserted between the main winding & yoke.
- When energized the gaps are exposed to large pulsation compressive forced with a frequency of twice the frequency of the system voltage. The peak value of these forces may easily amount to 106 N/m2 (100 ton /m2). For this reason the design of the core must be very solid, & the modulus of elasticity of the non-magnetic (& non-metallic) material used in gaps must be high (small compression) in order to avoid large vibration amplitudes with high sound level consequently. The material in the gaps must also be stable to avoid escalating vibration amplitudes in the end.
- Testing of reactors requires capacitive power in the test field equal to the nominal power of the reactor while a transformer can be tested with a reactive power equal to 10 – 20% of the transformer power rating by feeding the transformer with nominal current in short –circuit condition.
- The loss in the various parts of the reactor (12R, iron loss & additional loss) cannot be separated by measurement. It is thus preferable, in order to avoid corrections to reference temperature, to perform the loss measurement when the average temperature of the winding is practically equal to the reference temperature.

(2) Phase shifting transformer help operators load and unload transmission lines

- Power flow between two buses can be expressed as:
- **Power Flow = (Vs*Vr / X) * Sine of the Power Angle.**
- In other words: power flow (in watts) between two buses will be equal to the voltage on the sending bus multiplied by the voltage on the receiving bus divided by the line reactance, multiplied by the sine of the power angle between the two buses.
- This leaves grid operators with at least two options for making a path more conducive to power flow, or if desired, making a path look less conducive to power flow. The two options are to (1) adjust line reactance and (2) adjust power angle. The Phase Shifting Transformer (PST) affects the second option, i.e. adjusting power angle.
- The physical appearance of the PST device is noteworthy, being one of the few transformer types where the physical height and construction of the primary bushings is the same as the secondary bushings. This makes sense since both bushing sets are at the same potential. Internally, the primary voltage of a PST is bussed directly to the secondary bushings, with one important addition. The primary voltage is applied to a delta-wound transformer primary that has adjustable taps that inject "opposing phase" signals. For instance the A-B primary winding has a C phase injection, the B-C winding is injected with A, and the C-A winding is injected with B. These injection points are simultaneously adjustable taps that result in an adjustable shift of power angle.
- Since power angle is a direct contributor to the Power Flow formula provided above (in the numerator, not the denominator), changing the PST tap settings can increase power angle making the path more conducive to power flow. The PST tap settings can also decrease power angle making the path less conducive to power flow. (Remember that "power flows downhill on angle".)
- Why is this important? Many transmission paths naturally have less impedance by virtue of their construction and length, and these paths can carry scheduled flow as well as unscheduled flow from parallel (but higher impedance) paths. In some cases these low impedance paths become congested and PST devices and other devices and techniques may be used to relieve the congestion. This is particularly the case in regions where transmission paths are less densely developed.

Chapter: 61 what is Corona Effect

Introduction:

- One of the phenomena associated with all energized electrical devices, including high-voltage transmission lines, is corona. The localized electric field near a conductor can be sufficiently concentrated to ionize air close to the conductors. This can result in a partial discharge of electrical energy called a corona discharge, or corona.

What is Corona:

- Electric transmission lines can generate a small amount of sound energy as a result of corona.
- Corona is a phenomenon associated with all transmission lines. Under certain conditions, the localized electric field near energized components and conductors can produce a tiny electric discharge or corona that causes the surrounding air molecules to ionize, or undergo a slight localized change of electric charge.
- Utility companies try to reduce the amount of corona because in addition to the low levels of noise that result, corona is a power loss, and in extreme cases, it can damage system components over time.
- Corona occurs on all types of transmission lines, but it becomes more noticeable at higher voltages (345 kV and higher). Under fair weather conditions, the audible noise from corona is minor and rarelynoticed.
- During wet and humid conditions, water drops collect on the conductors and increase corona activity. Under these conditions, a crackling or humming sound may be heard in the immediate vicinity of the line.
- Corona results in a power loss. Power losses like corona result in operating inefficiencies and increase the cost of service for all ratepayers; amajor concern in transmission line design is the reduction of losses.

Source of Corona:

- The amount of corona produced by a transmission line is a function of the voltage of the line,the diameter of the conductors, the locations of the conductors in relation to each other, the elevation of the line above sea level, the condition of the conductors and hardware, and the local weather conditions. Power flow does not affect the amount of corona produced by a transmission line.
- The electric field gradient is greatest at the surface of the conductor. Large-diameter conductors have lower electric field gradients at the conductor surface and, hence, lower corona than smaller conductors, everything else being equal. The conductors chosen for the Calumet to the line were selected to have large diameters and to utilize a twoconductor bundle. This reduces the potential to create audible noise.
- Irregularities (such as nicks and scrapes on the conductor surface or sharp edges on suspension hardware) concentrate the electric field at these locations and thus increase the electric field gradient and the resulting corona at these spots. Similarly, foreign objects on the conductor surface, such as dust or insects, can cause irregularities on the surface that are asource for corona.
- Corona also increases at higher elevations where the density of the atmosphere is less than at sea level. Audible noise will vary with elevation. An increase in 1000 feet of elevation will result in an increase in audible noise of approximately 1 dB (A). Audible noise at 5000 feet in elevation will 5 dB (A) higher than the same audible noise at sea level, all other things being equal. The new Calumet to Comanche 345 kV double circuit line was modeled with anelevation of 6000 feet.
- Raindrops, snow, fog, hoarfrost, and condensation accumulated on the conductor surface are also sources of surface irregularities that can increase corona. During fair weather, the number of these condensed water droplets or ice crystals is usually small and the coronaeffect is also small.
- However, during wet weather, the number of these sources increases (for instance due to rain drops standing on the conductor) and corona effects are therefore greater.
- During wet or foul weather conditions, the conductor will produce the greatest amount of corona noise. However, during heavy rain the noise generated by the falling rain drops hitting the ground will typically be greater than the noise generated by corona and thus will mask the audible noise from the transmission line.
- Corona produced on a transmission line can be reduced by the design of the transmission line and the selection of hardware and conductors used for the construction of the line. For instance the use of conductor hangers that have rounded rather than sharp edges and no protruding bolts with sharp edges will reduce corona. The conductors themselves can be made with larger diameters and handled so that they have smooth surfaces without nicks or burrs or scrapes in the conductor strands. The transmission lines proposed here are designedto reduce corona generation.

Types of Corona:

- There are three types of corona.

1. A glow discharge occurs at a gradient of approximately 20 kV rms/cm. Glow discharge is a light glow off sharp points that does not generate objectionable RIV/TVI or cause any audible noise.
2. At about 25 kV rms/cm, negative polarity "brush" discharges occur. So named because the appearance is similar to the round ends of a bottle brush. The audible noise associated with brush corona is generally a continuous background type of hissing or frying noise.
3. At a gradient of around 30 kVrms/cm positive polarity plume corona is generated; so named because of its general resemblance to a plume. When viewed in the dark it has a concentrated stem that branches and merges into a violet-colored, tree-like halo. The audible noise associated with plume corona is a rather intense snapping and hissing sound. Plume corona generates significant RIV/TVI.

- These observations are based on fair weather conditions. Under wet conditions virtually all energized electrodes will be in corona of one form or another.
- Many are under the impression that the dielectric strength of air is greater under dry conditions. That is not true. In fact, the dielectric strength of air increases with increased moisture up to the dewpoint when moisture begins to condense on the surface of insulators and other components of the line.

Physical Parameters of Corona:

- Corona is caused by the ionization of the media (air) surrounding the electrode (conductor)
- Corona onset is a function of voltage , relative air density and relative humidity

1) Corona and the Electric Field

- Corona is NOT solely a function of the Electric Field
- Corona is a function of the electric field on the surface of the electrode (conductor)
- Corona is also a function of the radius of curvature of the electrode (conductor)
- Corona is also a function of the rate of decay of the electric field away from the electrode (conductor)
- For the preceding reasons, selecting the conductor with the smallest electric field at its surface is not correct.

2) Corona and the Relative Air Density

- Corona has an inverse relationship with air density
- Standard line designs that perform well at sea level, may have significant corona issues if used on lines that are installed over mountainous areas

3) Corona and the Humidity

- Corona has an inverse relationship with humidity at power frequencies
- Fair weather corona is more prevalent in low humidity environments

4) Corona Is Dependent Surface Condition of the Conductors

- Corona is enhanced by irregularities on the conductor surface
- Irregularities include: dust, insects, burrs and scratches and water drops present on new conductors
- Corona will generally be greater on new conductors and will decrease to a steady-state value over a period of approximately one year in-service
- Corona is significantly increased in foul weather.

Methods to reduce Corona Discharge Effect:

1) By minimizing the voltage stress and electric field gradient.

- This is accomplished by using utilizing good high voltage design practices, i.e., maximizing the distance between conductors that have large voltage differentials, using conductors with large radii, and avoiding parts that have sharp points or sharp edges.

2) Surface Treatments:

- Corona inception voltage can sometimes be increased by using a surface treatment, such as a semiconductor layer, high voltage putty or corona dope.

3) Homogenous Insulators:

- Use a good, homogeneous insulator. Void free solids, such as properly prepared silicone and epoxy potting materials work well.

4) If you are limited to using air as your insulator,

- then you are left with geometry as the critical parameter. Finally, ensure that steps are taken to reduce or eliminate unwanted voltage transients, which can cause corona to start.

5) Using Bundled Conductors:

- on our 345 kV lines, we have installed multiple conductors per phase. This is a common way of increasing the effective diameter of the conductor, which in turn results in less resistance, which in turn reduces losses.

6) Elimination of sharp points:

- Electric charges tend to form on sharp points; therefore when practicable we strive to eliminate sharp points on transmission line components.

7) Using Corona rings:

- On certain new 345 kV structures, we are now installing corona rings. These rings have smooth round surfaces which are designed to distribute charge across a wider area, thereby reducing the electric field and the resulting corona discharges.

8) Whether:

- Corona phenomena much worse in foul weather, high altitude

9) New Conductor:

- New conductors can lead to poor corona performance for a while.

10) By increasing the spacing between the conductors:

- Corona Discharge Effect can be reduced by increasing the clearance spacing between the phases of the transmission lines. However increase in the phase's results in heavier metal supports. Cost and Space requirement increases.

11) By increasing the diameter of the conductor:

- Diameter of the conductor can be increased to reduce the corona discharge effect. By using hollow conductors corona discharge effect can be improved.

Sources of Corona and Arcing in Polymer Insulators:

- Loose hardware
- Contamination and surface tracking
- Missing corona rings
- Damaged or incorrectly installed corona ring
- Damaged end fittings or end fitting seal
- Exposed internal rod due to: Carbonized internal rod by internal discharges Split sheath due to weathering

Electro Magnetic Inductions:

- EM1 field or radio noise field from high-voltage transmission lines are caused by corona, which is essentially due to the electrical breakdown of the air surrounding the conductors at higher voltage.
- When the conductor surface electric field exceeds the corona onset electric field, a partial electrical breakdown occurs in the surrounding air medium near the conductor surface and is called the corona discharge. The increase of conductor surface gradient takes place with increase of supply voltage. In addition, organic contamination or attachment -of water droplets also may contribute to localized field enhancement.
- When organic particles or water droplets are attached to the conductor surface, the charge accumulation at that point increases which enhances the local electric field. The intensification of surface gradientlocally leads to the corona discharge.
- The streamer generated during corona discharge, transports electric charge into the surrounding air during the discharge cycle. These moving charges contribute directly to the noise fields. 'They also cause currents to be induced on the transmission line conductors. Since the charge is moved by a time varying electric field, it is equivalent to a current pulse and this When a communication line passes near the corridor of a HV or EHV transmission line, if the frequency of the radiated EM signal due to corona matches with that of the transmitted signal on the communication line, then the communication signal may get distorted. To mitigate this effect, the communication line should pass at a safe distance away from thetransmission line.
- Hence there is a need to estimate the radiated EM1 signal in dB at a given distance from the HV or EHV transmission line. In this paper, radiated EM1 in dB is computed for a single conductor high voltage over headline. This theoretical result is compared with the published experimental results available in the literature. In the computational work, earth is considered as an infinitely conducting ground.

Physical description of corona and Electro Magnetic Induction:

- When alternating supply voltage energizes the conductor, the conductor surface electric field exceeds the corona on set electric field of the conductor. The corona discharge occurs in both positive and negative half cycle. So the corona is divided into positive and negative coronadepending upon the polarity of the supply voltage.
- When the conductor is positive with respect to ground, an electron avalanche moves rapidly into the conductor leaving the heavy positive-ion charge cloud close to conductor, which drifts away.
- The rapid movements of electrons and motion of positive ions gives the steep front of the pulse, while the further drift ofpositive ions will give slow tail of the corona pulse.
- When conductor is negative with respect to the ground, an electron avalanche moves away from the energized conductor and the positive heavy ions move towards the conductor. Since the heavy positive ions are, moving towards the higher electric field, their motion is very rapid which gives rise to a much sharper pulse than the positive pulse. Due to rapid moment of the electrons from the conductor surface, the electric field regains its original value at conductor surface very quickly than in the case of positive polarity. Thus the negative corona pulses are lower in amplitude and lower in rise and fall times as compared to positive corona pulses. They have also higher repetition rates than the positive pulse

Corona Detection:

- LightUltraviolet radiation: Corona can be visible in the form of light, typically a purple glow, as corona generally consists of micro arcs. Darkening the environment can help to visualize the corona.
- Sound (hissing, or cracking as caused by explosive gas expansions): You can often hear corona hissing or cracking Sound.
- In addition,we can sometimes smell the presence of ozone that was produced by the corona.
- Salts, sometimes seen as white powder deposits on Conductor.
- Mechanical erosion of surfaces by ion bombardment
- Heat (although generally very little, and primarily in the insulator)
- Carbon deposits, thereby creating a path for severe arcing
- The corona discharges in insulation systems result in voltage transients. These pulses are superimposed on the applied voltage and may be detected, which is precisely what corona detection equipment looks for. In its most basic form, the following diagram is a corona (or partial discharge) measuring system:
- It is important that the voltage source and the coupling capacitor exhibit low noise so as not to obscure the corona. In its simplest form the pulse detection network is a resistor monitored by an oscilloscope. Don't dismiss this simple technique as crude, as we once used this method to observe the presence of corona in an improperly terminated high voltage connector, even after a dedicated corona tester failed to find any. Commercially available corona detectors include electronic types (as above) as well as ultrasonic types.

Corona Calculations:

- The following corona calculations are from Dielectric Phenomena in High Voltage Engineering

1. **For Concentric Cylinders in Air:**

- Corona will not form when RO / RI < 2.718. (Arcing will occur instead when the voltage is too high.)

2. **For Parallel Wires in Air:**

- Corona will not form when X / r < 5.85. (Arcing will occur instead when the voltage is too high.)

3. **For Equal Spheres in Air:**

- Corona will not form when X / R < 2.04. (Arcing will occur instead when the voltage is too high.)
- Arcing difficult to avoid when X / R < 8

  Where
  - RO = Radius of outer concentric sphere
  - RI = Radius of inner concentric sphere
  - R = Sphere radius
  - r = wire radius
  - X = Distance between wires or between spheres

Effects of Corona:

1) Audible Noise

- During corona activity, transmission lines (primarily those rated at 345 kV and above) can generate a small amount of sound energy. This audible noise can increase during foul weather conditions. Water drops may collect on the surface of the conductors and increase corona activity so that a crackling or humming sound may be heard near a transmission line. Transmission line audible noise is measured in decibels using a special weighting scale, the "A" scale that responds to different sound characteristics similar to the response of the human ear. Audible noise levels on typical 230 kV lines are very low and are usually not noticeable. For example, the calculated rainy weather audible noise for a 230 kV transmission line at the right-of-way edge is about 25 dBA, which is less than ambient levels in a library and much less than background noise for wind and rain.

2) Radios and Television Interference:

- Overhead transmission lines do not, as a general rule, interfere with radio or TV reception.
- There are two potential sources for interference: corona and gap discharges. As described above, corona discharges can sometimes generate unwanted electrical signals.
- Corona-generated electrical noise decreases with distance from a transmission line and also decreases with higher frequencies (when it is a problem, it is usually for AM radio and not the higher frequencies associated with TV signals).
- Corona interference to radio and television reception is usually not a design problem for transmission lines rated at 230 kV and lower. Calculated radio and TV interference levels in fair weather and in rain are extremely low at the edge of the right-of-way for a 230 kV transmission line.
- Gap discharges are different from corona. Gap discharges can develop on power lines at any voltage. They can take place at tiny electrical separations (gaps) that can develop between mechanically connected metal parts. A small electric spark discharges across the gap and can create unwanted electrical noise. The severity of gap discharge interference depends on the strength and quality of the transmitted radio or TV signal, the quality of the radio or TV set and antenna system, and the distance between the receiver and power line. (The large majority of interference complaints are found to be attributable to sources other than power lines: poor signal quality, poor antenna, door bells, and appliances such as heating pads, sewing machines, freezers, ignition systems, aquarium thermostats, fluorescent lights, etc.).
- Gap discharges can occur on broken or poorly fitting line hardware, such as insulators, clamps, or brackets. In addition, tiny electrical arcs can develop on the surface of dirty or contaminated insulators, but this interference source is less significant than gap discharge.
- Hardware is designed to be problem-free, but corrosion, wind motion, gunshot damage, and insufficient maintenance contribute to gap formation. Generally, interference due to gap discharges is less frequent for high-voltage transmission lines than lower-voltage lines. The reasons that transmission lines have fewer problems include: predominate use of steel structures, fewer structures, greater mechanical load on hardware, and different design andmaintenance standards.
- Gap discharge interference can be avoided or minimized by proper design of the transmission line hardware parts, use of electrical bonding where necessary, and by careful tightening of fastenings during construction. Individual sources of gap discharge noise can be readily located and corrected. Arcing on contaminated insulators can be prevented by increasing the insulation in high contamination areas and with periodic washing of insulator strings.

3) Gaseous Effluents

- Corona activity in the air can produce very tiny amounts of gaseous effluents: ozone and NOX. Ozone is a naturally occurring part of the air, with typical rural ambient levels ranging from about 10 to 30 parts per billion (ppb) at night and peaks at approximately 100 ppb. In urban areas, concentrations exceeding 100 ppb are common. After a thunderstorm, the air may contain 50 to 150 ppb of ozone, and levels of several hundred ppb have been recorded in large cities and in commercial airliners.
- Ozone is also given off by welding equipment, copy machines, air fresheners, and many household appliances. The National Ambient Air Quality Standard for Oxidants (ozone is usually 90 to 95 percent of the oxidants in the air) is120 ppb, not to be exceeded as a peak concentration on more than one day a year.
- In general, the most sensitive ozone measurement instrumentation can measure about 1 ppb. Typical calculated maximum concentrations of ozone at ground level for 230 kV transmission lines during heavy rain are far below levels that the most sensitive instruments can measure and thousands of times less than ambient levels. Therefore, the proposed transmission lines would not create any significant adverse effects in the ambient air qualityof the project area.

4) Induced Currents

- Small electric currents can be induced by electric fields in metallic objects close to transmission lines. Metallic roofs, vehicles, vineyard trellises, and fences are examples of objects that can develop a small electric charge in proximity to high voltage transmission lines. Object characteristics, degree of grounding, and electric field strength affect theamount of induced charge.

- An electric current can flow when an object has an induced charge and a path to ground is presented. The amount of current flow is determined by theimpedance of the object to ground and the voltage induced between the object and ground.
- The amount of induced current that can flow is important to evaluate because of the potential for nuisance shocks to people and the possibility of other effects such as fuelignition.
- The amount of induced current can be used to evaluate the potential for harmful or other effects. As an example, when an average woman or man grips an energized conductor, the threshold for perception of an electric current is 0.73 milli ampere (mA) and 1.1 mA, respectively. If the current is gradually increased beyond a person's perception threshold, it becomes bothersome and possibly startling.
- However, before the current flows in a shock situation, contact must be made, and in the process of establishing contact a small arc occurs. This causes a withdrawal reaction that, in some cases, may be a hazard if the involuntary nature of the reaction causes a fall or other accident.
- The proposed 230 kV transmission lines will have the highest electric field within the right-of-way, approximately 0.2 to 1.5 kV per meter (kV/m), and approximately 0.1 to 0.9 kV/m at the edge of the right-of-way. These fields are less than many other 230 kV transmission lines due to the use of cross-phasing on the double-circuit lines and higher clearance above ground. Induced currents have been calculated for common objects for a set of worst-case theoretical assumptions: the object is perfectly insulated from ground, located in the highest field, and touched by a perfectly grounded person. Even though the maximum electric field only occurs on a small portion of the right-of-way, and perfect insulation and grounding states are not always common, the calculated induced current values are very lowtherefore, in most situations, even in the highest field location, induced currents are below the threshold of perception and are far below hazardous levels.
- Agricultural operations can occur on or near a transmission line right-of-way. Irrigation systems often incorporate long runs of metallic pipes that can be subject to magnetic field induction when located parallel and close to transmission lines. Because the irrigation pipes contact moist soil, electric field induction is generally negligible, but annoying currents could still be experienced from magnetic field coupling to the pipe. Pipe runs laid at right angles to the transmission line will minimize magnetically induced currents, although such a layout may not always be feasible. If there are induction problems, they can be mitigated by grounding and/or insulating the pipe runs. Operation of irrigation systems beneath transmission lines presents another safety concern. If the system uses a high-pressure nozzle to project a stream of water, the water may make contact with the energized transmission line conductor. Generally, the water stream consists of solid and broken portions. If the solid stream contacts an energized conductor, an electric current could flow down the water stream to someone contacting the high-pressure nozzle. Transmission line contact by the broken-up part of the water stream is unlikely to present any hazard.

5) Fuel Ignition

- If a vehicle were to be refuelled under a high-voltage transmission line, a possible safety concern could be the potential for accidental fuel ignition. The source of fuel ignition couldbe a spark discharge into fuel vapours collected in the filling tube near the top of the gas tank.
- The spark discharge would be due to current induced in a vehicle (insulated from ground) by the electric field of the transmission line and discharged to ground through a metallic refueling container held by a well-grounded person. Theoretical calculations show that if a number of unlikely conditions exist simultaneously, a spark could release enough energy to ignite gasoline vapors. This could not occur if a vehicle were simply driven or parked under a transmission line. Rather, several specific conditions would need to be satisfied: A large gasoline-powered vehicle would have to be parked in an electric field of about 5 kV/m or greater. A person would have to be refueling the vehicle while standing on damp earth and while the vehicle is on dry asphalt or gravel. The fuel vapors and air would have to mix in an optimum proportion. Finally, the pouring spout must be metallic. The chances of having all the conditions necessary for fuel ignition present at the same time are extremely small.
- Very large vehicles (necessary to collect larger amounts of electric charge) are often diesel-powered, and diesel fuel is less volatile and more difficult to ignite. The proposed 230 kV transmission line electric field levels are too low (about 0.2-1.5 kV/m on the right-of-way) for the minimum energy necessary for fuel ignition under any practical circumstances.

6) Cardiac Pacemakers

- One area of concern related to the electric and magnetic fields of transmission lines has been the possibility of interference with cardiac pacemakers. There are two general types of pacemakers: asynchronous and synchronous. The asynchronous pacemaker pulses at a predetermined rate. It is practically immune to interference because it has no sensing circuitry and is not exceptionally complex. The synchronous pacemaker, on the other hand, pulses only when its sensing circuitry determines that pacing is necessary.

- Interference resulting from the transmission line electric or magnetic field can cause a spurious signal in the pacemaker's sensing circuitry. However, when these pacemakers detect a spurious signal, such as a 60 hertz (Hz) signal, they are programmed to revert to an asynchronous or fixed pacing mode of operation and return to synchronous operation within a specified time after the signal is no longer detected. The potential for pacer interference depends on the manufacturer, model, and implantation method, among other factors.
- Studies have determined thresholds for interference of the most sensitive units to be about 2,000 to 12,000 milli gauss (mG) for magnetic fields and about 1.5 to 2.0 kV/m for electric fields. The electric and magnetic fields at the right-of-way edge are below these values, and on the right-of-way, only the lower bound electric field value of 1.5 kV/m is reached. Therefore, the potential impact would not be significant.

7) Computer Interference

- Personal computer monitors can be susceptible to 60 Hz magnetic field interference. Magnetic field interference results in disturbances to the image displayed on the monitor, often described as screen distortion, "jitter," or other visual defects. In most cases it is annoying, and at its worst, it can prevent use of the monitor. Magnetic fields occur in the normal operation of the electric power system.
- This type of interference is a recognized problem by the video monitor industry. As a result, there are manufacturers who specialize in monitor interference solutions and shielding equipment. Possible solutions to this problem include: relocation of the monitor, use of magnetic shield enclosures, software programs, and replacement of cathode ray tube monitors with liquid crystal displays that are not susceptible to 60 Hz magnetic field interference. Because these solutions are widely available to computer users, potential impacts would be less than significant

Corona Ring:

- The ring, which surrounds the energized end of the transformer bushing, serves two functions.
- It is a corona ring that is intended to electrically shield the bushing terminal and connections. It does so by reducing the voltage gradient to a level well below the ionizing gradient of the surrounding air at the maximum transformer output voltage.
- It's also a grading ring, which helps electrically grade the external voltage on the bushing from line to ground (at the bushing flange). The bushing is likely a condenser bushing, which contains a capacitance-graded core to grade the voltage radically from 100% at the central conductor to ground at the flange and, axially from ground to the top and bottom ends of the core.

- Grounding the test transformer following a circuit breaker test is necessary for safety but you are grounding the entire test circuit; not just the corona ring. I suspect the corona ring just happens to be a convenient attachment point for the hook on your ground stick.
- Die cast are usually 380, sand and permanent mold 356 or A356, and fabricated rings are usually made from 6061 thin wall tubing or pipe that is formed and welded; with appropriate brackets and other mounting provisions.
- Corona grading ring should be designed to reduce the critical dielectric voltage gradient (typ. 20 to 30 kVrms/cm) to prevent corona effect, internal discharge and reduce E-field in live parts and fitting that cause radio/ TV interference (RIV), audio noise and losses. Corona ring could also help to smooth the voltage profile distributing the voltage more uniform along the insulator preventing concentration of over stresses.
- For porcelain post insulators, some manufacturer recommends one corona ring and for 500 kV and above two rings. However, for composite insulator the corona ring is recommended for 220/230 kV. Most equipment manufacturer provide corona ring base on testing such surge arrester, switches, CT's/PTs

Difference between Arcing Horn Gap and Corona Ring:

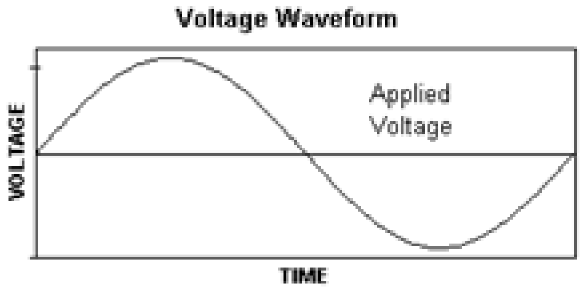
- At transmission line voltage the arcing horns, when the breaker is closed normally have nothing except corona from the tips and arc marks, the instant the breaker begins to open an arc is established across the gap between the arc horns, when the gap is long enough the arc breaks. The plan is to keep the sliding contacts from getting arc metal removal so the contacts maintain low resistance, arcing horns are sacrificial.
- At switchgear voltage, there are arc chutes and usually puffers to extinguish the arc during breaker opening, the arc chutes may be of a sand-crystal cast material (like space shuttle heat tiles), asbestos layers, and electrical insulating board to protect the works during an explosive event when temperatures get hotter than the sun. There is specific NFPA training for arc flash exposure.
- Arcing horns are also commonly used to protect insulation from impulse and other overvoltages. The horn gap (distance between arcing horns) is set to ensure that flashover occurs across the gap rather than along the insulation surface thereby protecting the insulation surface and preventing arc termination and associated damage to the end terminals or line and ground end hardware. They may also be used to connect a surge arrester to protect transformers and other equipment from overvoltage surges (gapped arrester). A gapped connection is one method of preventing line lockout in the event of arrester failure
- Corona rings are meant to distribute the electrical field and neither the hardware protected or the corona ring should have corona, the typical line voltage that corona rings are applied is 150KV and higher, altitude or high temperatures can reduce the voltage to 138KV lines. Properly designed corona rings do not have corona.
- Corona can appear to start and stop at essentially the same voltage, there are other variables. Corona produces light (from UV thru visible and into the infrared), sound (thru all wavelengths), ozone, and nitric acid (in the presence of moisture).
- Arcing arrestors were used long ago, some of the old-old transmission lines. They were opposing arcing fingers mounted in parallel with the insulators; the gap determined the flash-over voltage. The intent was to protect insulators from lightening surges. I don't know if those old lines are energized anymore. You don't see arcing fingers on modern (post WWII war) transmission lines.
- To break an arc the voltage must be decreased below about 60% of the voltage an arc starts at, thus if a transmission line insulator arcing arrestor flashes over and maintains an arc the line is going to be shutdown. Thus arcing arrestors (without an arc extinguishing capability) decrease the reliability of a transmission line.

References:

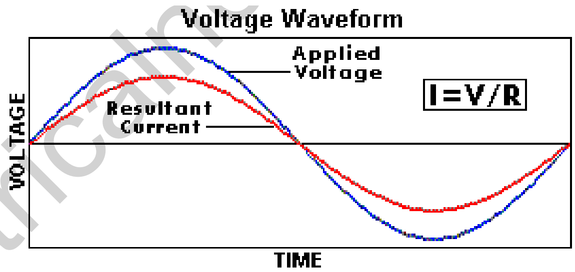
1. American Conference of Governmental Industrial Hygienists. 2001
2. American National Standards Institute. 2002.
3. Deno, D. W. and J. M. Silva. 1987. “Transmission Line Electric Field Shielding by Objects.”
4. Evan Mayerhoff
5. P. Sarma, Maruvada , "Corona Performance of High-Voltage Transmission Lines".
6. F. W.Peek, "Dielectric phenomena in High Voltage Engineering" 3'd edition,
7. EDM International, Inc.
8. Dave Phillips
9. **Stefan Brzeziński,**

What is Harmonic?

- Harmonics are sinusoidal voltages or currents having frequencies that are whole multiples of the frequency at which the supply system is designed to operate (e.g. 50Hz or 60 Hz).
- Harmonics are simply a technique to analyze the current drawn by computers, electronic ballasts, variable frequency drives and other equipment which have modem "transformer-less" power supplies.
- There are two important concepts to bear in mind with regard to power system harmonics.
- The first is the nature of harmonic-current producing loads (non-linear loads) and the second is the way in which harmonic currents flow and how the resulting harmonic voltages develop.
- There is a law in electrical engineering called Ohm's Law. This basic law states that when a voltage is applied across a resistance, current will flow. This is how all electrical equipment operates. The voltage we apply across our equipment is a sine wave which operates 60 Hertz (cycles per second).



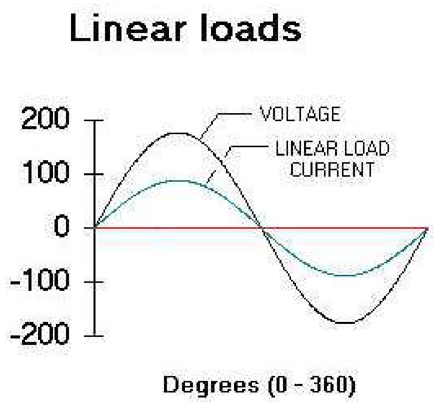
- To generate this voltage sine wave. It has (relatively) constant amplitude and constant frequency.
- Once this voltage is applied to a device, Ohm's Law kicks in. Ohm's Law states that current equal's voltage divided by resistance. Expressed mathematically**I=V/R**
- Expressed graphically, the current ends up being another sine wave, since the resistance is a constant number. Ohm's Law dictates that the frequency of the current wave is also 60 Hertz. In the real world, this is true; although the two sine waves may not align perfectly (as a power factor) the current wave will indeed be a 60 Hertz sine wave.



- Since an applied voltage sine wave will cause a sinusoidal current to be drawn, systems which exhibit this behaviour are called linear systems. Incandescent lamps, heaters and, to a great extent, motors are linear systems.
- Some of our modem equipment however does not fit this category. Computers, variable frequency drives, electronic ballasts and uninterruptable power supply systems are non-linear systems. In these systems, the resistance is not a constant and in fact, varies during each sine wave. This occurs because the resistance of the device is not a constant. The resistance in fact, changes during each sine wave

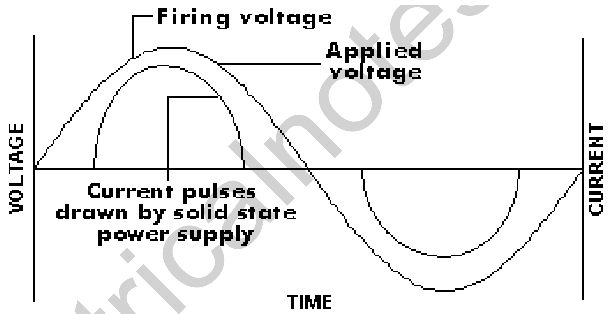
Linear and Non-linear loads (motors, heaters and incandescent lamps):

- A linear element in a power system is a component in which the current is proportional to the voltage.
- In general, this means that the current wave shape will be the same as the voltage (See Figure). Typical examples of linear loads include motors, heaters and incandescent lamps.

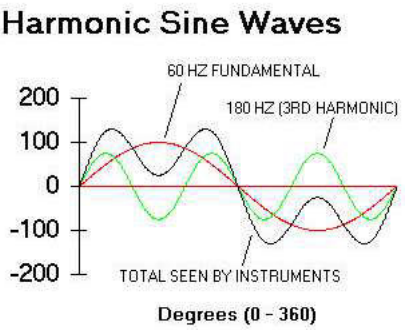


Non-Linear System (Computers, VFDS, Electronic Ballasts):

- As inFigure As we apply a voltage to a solid state power supply, the current drawn is (approximately) zero until a critical “firing voltage” is reached on the sine wave. At this firing voltage, the transistor (or other device) gates or allows current to be conducted.
- This current typically increases over time until the peak of the sine wave and decreases until the critical firing voltage is reached on the “downward side” of the sine wave. The device then shuts off and current goes to zero. The same thing occurs on the negative side of the sine wave with a second negative pulse of current being drawn. The current drawn then is a series of positive and negative pulses, and not the sine wave drawn by linear systems.
- Some systems have different shaped waveforms such as square waves. These types of systems are often called non-linear systems. The power supplies which draw this type of current are called switched mode power supplies. Once these pulse currents are formed, we have a difficult time analyzing their effect. Power engineers are taught to analyze the effects of sine waves on power systems. Analyzing the effects of these pulses is much more difficult.



- The current drawn by non-linear loads is not sinusoidal but it is periodic, meaning that the current wave looks the same from cycle to cycle. Periodic waveforms can be described mathematically as a series of sinusoidal waveforms that have been summed together.

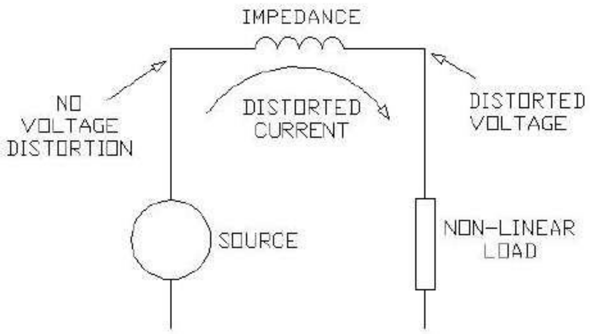


- The sinusoidal components are integer multiples of the fundamental where the fundamental, in the United States, is 60 Hz. The only way to measure a voltage or current that contains harmonics is to use a true-RMS reading meter. If an averaging meter is used, which is the most common type, the error can be Significant.
- Each term in the series is referred to as a harmonic of the fundamental. The third harmonic would have a frequency of three times 60 Hz or 180 Hz. Symmetrical waves contain only odd harmonics and un-symmetrical waves contain even and odd harmonics.

- A symmetrical wave is one in which the positive portion of the wave is identical to the negative portion of the wave. An un-symmetrical wave contains a DC component (or offset) or the load is such that the positive portion of the wave is different than the negative portion. An example of un-symmetrical wave would be a half wave rectifier.
- Most power system elements are symmetrical. They produce only odd harmonics and have no DC offset.

Harmonic current flow:

- When a non-linear load draws current that current passes through all of the impedance that is between the load and the system source .As a result of the current flow, harmonic voltages are produced by impedance in the system for each harmonic.



- These voltages sum and when added to the nominal voltage produce voltage distortion. The magnitude of the voltage distortion depends on the source impedance and the harmonic voltages produced.
- If the source impedance is low then the voltage distortion will be low. If a significant portion of the load becomes non-linear (harmonic currents increase) and/or when a resonant condition prevails (system impedance increases), the voltage can increase dramatically.

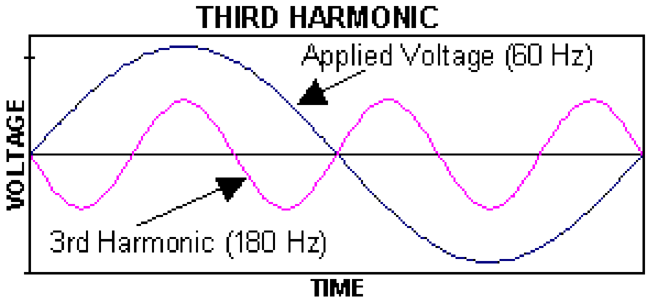
Harmonic currents can produce a number of problems:

1. Equipment and Conductor heating
2. Equipment malfunction
3. Equipment failure
4. Communications interference
5. Fuse and breaker miss-operation
6. Process problems

How harmonics are generated:

- In an ideal clean power system, **the current and voltage waveforms are pure sinusoids**. In practice, non-sinusoidal currents are available due to result of the current flowing in the load is not linearly related to the applied voltage.
- In a simple circuit containing only linear circuit elements resistance, inductance and capacitance. The current which flows is proportional to the applied voltage (at a particular frequency) so that, if a sinusoidal voltage is applied, a sinusoidal current will flow. Note that where there is a reactive element there will be a phase shift between the voltage and current waveforms the power factor is reduced, but the circuit can still be linear.
- But in The situation where the load is a simple full-wave rectifier and capacitor, such as the input stage of a typical switched mode power supply (SMPS). In this case, current flows only when the supply voltage exceeds that stored on the reservoir capacitor, i.e. close to the peak of the voltage sine wave, as shown by the shape of the load line.
- Any cyclical waveform can be deconstructed into a sinusoid at the fundamental frequency plus a number of sinusoids at harmonic frequencies. Thus the distorted current waveform in the figure can be represented by the fundamental plus a percentage of second harmonic plus a percentage of third harmonic and so on, possibly up to the thirtieth harmonic.
- For symmetrical waveforms, i.e. where the positive and negative half cycles are the same shape and magnitude, all the **even numbered harmonics is zero.** Even harmonics are now relatively rare but were common when half wave rectification was widely used.
- The frequencies we use are multiples of the fundamental frequency, 60 Hz. We call these multiple frequencies harmonics. The second harmonic is two times 60 Hertz, or 120 Hz. The third harmonic is 180 Hertz and so on. In

our three phase power systems, the "even" harmonics (second, fourth, sixth, etc.) cancel, so we only need deal with the "odd" harmonics.



- This figure shows the fundamental and the third harmonic. There are three cycles of the third harmonic for each single cycle of the fundamental. If we add these two waveforms, we get a non-sinusoidal waveform.
- This resultant now starts to form the peaks that are indicative of the pulses drawn by switch mode power supplies. If we add in other harmonics, we can model any distorted periodic waveform, such as square waves generated by UPS of VFD systems. It is important to remember these harmonics are simply a mathematical model. The pulses or square waves, or other distorted waveforms are what we actually see if we were to put an oscilloscope on the building's wiring systems.
- These current pulses, because of Ohm's Law, will also begin to distort the voltage waveforms in the building. This voltage distortion can cause premature failure of electronic devices.
- On three phase systems, the three phases of the power system are 120' out of phase. The current on phase B occurs 120 deg (1/3cycle) after the current on A. Likewise, the current on phase C occurs 120' after the current on phase B. Because of this, our 60 Hertz (fundamental) currents actually cancel on the neutral. If we have balanced 60 Hertz currents on our three phase conductors, our neutral current will be zero. It can be shown mathematically that the neutral current (assuming only 60 Hertz is present) will never exceed the highest loaded phase conductor. Thus, our over current protection on our phase conductors also protects the neutral conductor, even though we do not put an over current protective device in the neutral conductor. We protect the neutral by the mathematics. When harmonic currents are present, this math breaks down. The third harmonic of each of the three phase conductors is exactly in phase. When these harmonic currents come together on the neutral, rather than cancel, they actually add and we can have more current on the neutral conductor than on phase conductors. Our neutral conductors are no longer protected by mathematics!
- These harmonic currents create heat. This heat over a period of time will raise the temperature of the neutral conductor. This rise in temperature can overheat the surrounding conductors and cause insulation failure. These currents also will overheat the transformer sources which supply the power system. This is the most obvious symptom of harmonics problems; overheating neutral conductors and transformers. Other symptoms include:

1. Nuisance tripping of circuit breakers
2. Malfunction of UPS systems and generator systems
3. Metering problems
4. Computer malfunctions
5. Overvoltage problems

Types of equipment that generate harmonics:

- Harmonic load currents are generated by all non-linear loads. These include:
- **For Single phase loads, e.g.**
  - A. Switched mode power supplies (SMPS)
  - B. Electronic fluorescent lighting ballasts
  - C. Compact fluorescent lamps (CFL)
  - D. Small uninterruptible power supplies (UPS) units
- **For Three phase loads, e.g.**
  - A. Variable speed drives
  - B. Large UPS units

Single phase loads

1) Switched mode power supplies (SMPS)

- The majority of modern electronic units use switched mode power supplies (SMPS).

- These differ from older units in that the traditional step-down transformer and rectifier is replaced by direct controlled rectification of the supply to charge a reservoir capacitor from which the direct current for the load is derived by a method appropriate to the output voltage and current required.
- The advantageto the equipment manufacturer is that the size, cost and weight is significantly reduced and the power unit can be made in almost any required form factor.
- The disadvantage to everyone else is that, rather than drawing continuous current from the supply, the power supply unit draws pulses of current which contain large amounts of third and higher harmonics and significant high frequency components .
- A simple filter is fitted at the supply input to bypass the high frequency components from line and neutral to ground but it has no effect on the harmonic currents that flow back to the supply.

2) Single phase UPS units exhibit very similar characteristics to SMPS.

- For high power units there has been a recent trend towards socalled power factor corrected inputs.
- The aim is to make the power supply load look like a resistive load so that the input current appears sinusoidal and in phase with the applied voltage. It is achieved by drawing input current as a high frequency triangular waveform that is averaged by the input filter to a sinusoid.
- This extra level of sophistication is not yet readily applicable to the low-cost units that make up most of the load in commercial and industrial installations. It remains to be seen what problems the wide-scale application of this technology may involve!

3) Fluorescent lighting ballast

- Electronic lighting ballasts have become popular in recent years following claims for improved efficiency. Overall they are only a little more efficient than the best magnetic ballasts and in fact, most of the gain is attributable to the lamp being more efficient when driven at high frequency rather than to the electronic ballast itself.
- Their chief advantage is that the light level can be maintained over an extended lifetime by feedback control of the running current a practice that reduces the overall lifetime efficiency.
- Their great disadvantage is that they generate harmonics in the supply current. So called power-factor corrected types are available at higher ratings that reduce the harmonic problems, but at a cost penalty. Smaller units are usually uncorrected.

4) Compact fluorescent lamps (CFL)

- CFL are now being sold as replacements for tungsten filament bulbs. A miniature electronic ballast, housed in the connector casing, controls a folded 8mm diameter fluorescent tube.
- CFLs rated at 11 watt are sold as replacements for a 60 watt filament lamp and have a life expectancy of 8000 hours.
- The harmonic current spectrum is shown in the figure. These lamps are being widely used to replace filament bulbs in domestic properties and especially in hotels where serious harmonic problems are suddenly becoming common.

Three phase loads

Variable Speed Drives / UPS:

- Variable speed controllers, UPS units and DC converters in general are usually based on the three-phase bridge, also known as the six-pulse bridge because there are six pulses per cycle (one per half cycle per phase) on the DC output.
- The six pulse bridge produces harmonics at 6n +/- 1, i.e. at one more and one less than each multiple of six. In theory, the magnitude of each harmonic is the reciprocal of the harmonic number, so there would be 20% fifth harmonic and 9% eleventh harmonic, etc.
- The magnitude of the harmonics is significantly reduced by the use of a twelve-pulse bridge. This is effectively two six-pulse bridges, fed from a star and a delta transformer winding, providing a 30 degrees phase shift between them.
- The 6n harmonics are theoretically removed, but in practice, the amount of reduction depends on the matching of the converters and is typically by a factor between 20 and 50. The 12n harmonics remain unchanged. Not only is the total harmonic current reduced, but also those that remain are of a higher order making the design of the filter much easier.
- Often the equipment manufacturer will have taken some steps to reduce the magnitudes of the harmonic currents, perhaps by the addition of a filter or series inductors. In the past this has led some manufacturers to

claim that their equipment is ‘G5/3’ compliant. Since G5/3 is a planning standard applicable to a complete installation, it cannot be said to have been met without knowledge of every piece of equipment on the site.

- A further increase in the number of pulses to 24, achieved by using two parallel twelve-pulse units with a phase shift of 15 degrees, reduces the total harmonic current to about 4.5%. The extra sophistication increases cost, of course, so this type of controller would be used only when absolutely necessary to comply with the electricity suppliers’ limits.

Problems caused by harmonics

- Harmonic currents cause problems both on the supply system and within the installation.
- Harmonic problems within the installation
- **Problems caused by harmonic currents:**
  1. overloading of neutrals
  2. overheating of transformers
  3. nuisance tripping of circuit breakers
  4. over-stressing of power factor correction capacitors
  5. skin effect
- **Problems caused by harmonic voltages:**
  1. voltage distortion
  2. induction motors
  3. zero-crossing noise
  4. Problems caused when harmonic currents reach the supply.

Problems caused by harmonic currents:

1) Neutral conductor over-heating

- In a three-phase system the voltage waveform from each phase to the neutral so that, when each phase is equally loaded, the°star point is displaced by 120 combined current in the neutral is zero.
- When the loads are not balanced only the net out of balance current flows in the neutral. In the past, installers (with the approval of the standards authorities) have taken advantage of this fact by installing half-sized neutral conductors. However, although the fundamental currents cancel out, the harmonic currents do not - in fact those that are an odd multiple of three times the fundamental, the ‘triple-N’ harmonics, add in the neutral.
- The third°phase currents, are introduced at 120 harmonic of each phase is identical, being three times the frequency and one-third of a (fundamental) cycle offset.
- The effective third harmonic neutral current is shown at the bottom. In this case, 70% third harmonic current in each phase results in 210% current in the neutral.
- Case studies in commercial buildings generally show neutral currents between 150% and 210% of the phase currents, often in a half-sized conductor!
- There is some confusion as to how designers should deal with this issue.
- The simple solution, where single-cored cables are used, is to install a double sized neutral, either as two separate conductors or as one single large conductor.
- The situation where multi-cored cables are used is not so simple. The ratings of multi-core cables (for example as given in IEC 60364–5-523 Table 52 and BS 7671 Appendix 4) assume that the load is balanced and the neutral conductor carries no current, in other words, only three of the four or five cores carry current and generate heat. Since the cable current carrying capacity is determined solely by the amount of heat that it can dissipate at the maximum permitted temperature, it follows that cables carrying triple-N currents must be de-rated.
- In the example illustrated above, the cable is carrying five units of current – three in the phases and two in the neutral – while it was rated for three units. It should be de-rated to about 60% of the normal rating.
- IEC 60364-5-523 Annex C (Informative) suggests a range of de-rating factors according to the triple-N harmonic current present. Figure 13 shows de-rating factor against triple-N harmonic content for the de-rating described in IEC 60364-5-523 Annex C and for the thermal method used above.

2) Effects on transformers

- Transformers are affected in two ways by harmonics.
- **Firstly, the eddy current losses**:
- Normally about 10% of the loss at full load increase with the square of the harmonic number.

- In practice, for a fully loaded transformer supplying a load comprising IT equipment the total transformer losses would be twice as high as for an equivalent linear load.
- This results in a much higher operating temperature and a shorter life. In fact, under these circumstances the lifetime would reduce from around 40 years to more like 40 days! Fortunately, few transformers are fully loaded, but the effect must be taken into account when selecting plant.
- **The second effect concerns the triple-N harmonics**:
- When reflected back to a delta winding they are all in phase, so the triple-N harmonic currents circulate in the winding. The triple-N harmonics are effectively absorbed in the winding and do not propagate onto the supply, so delta wound transformers are useful as isolating transformers. Note that all other, non triple-N, harmonics pass through. The circulating current has to be taken into account when rating the transformer.

3) Nuisance tripping of circuit breakers

- Residual current circuit breakers (RCCB) operate by summing the current in the phase and neutral conductors and, if the result is not within the rated limit, disconnecting the power from the load. Nuisance tripping can occur in the presence of harmonics for two reasons.
- Firstly, the RCCB, being an electromechanical device, may not sum the higher frequency components correctly and therefore trips erroneously.
- Secondly, the kind of equipment that generates harmonics also generates switching noise that must be filtered at the equipment power connection. The filters normally used for this purpose have a capacitor from line and neutral to ground, and so leak a small current to earth.
- This current is limited by standards to less than 3.5mA, and is usually much lower, but when equipment is connected to one circuit the leakage current can be sufficient to trip the RCCB. The situation is easily overcome by providing more circuits, each supplying fewer loads.
- **Nuisance tripping of miniature circuit breakers (MCB)** is usually caused because the current flowing in the circuit is higher than that expected from calculation or simple measurement due to the presence of harmonic currents.
- Most portable measuring instruments do not measure true RMS values and can underestimate non-sinusoidal currents by 40%.

4) Over-stressing of power factor correction capacitors

- Power-factor correction capacitors are provided in order to draw a current with a leading phase angle to offset lagging current drawn by an inductive load such as induction motors.
- The effective equivalent circuit for a PFC capacitor with a non-linear load. The impedance of the PFC capacitor reduces as frequency rises, while the source impedance is generally inductive and increases with frequency. The capacitor is therefore likely to carry quite high harmonic currents and, unless it has been specifically designed to handle them, damage can result.
- A potentially more serious problem is that the capacitor and the stray inductance of the supply system can resonate at or near one of the harmonic frequencies (which, of course, occur at 100 Hz intervals). When this happens very large voltages and currents can be generated, often leading to the catastrophic failure of the capacitor system.
- Resonance can be avoided by adding an inductance in series with the capacitor such that the combination is just inductive at the lowest significant harmonic. This solution also limits the harmonic current that can flow in the capacitor. The physical size of the inductor can be a problem, especially when low order harmonics are present.

5) Skin effect

- Alternating current tends to flow on the outer surface of a conductor. This is known as skin effect and is more pronounced at high frequencies.
- Skin effect is normally ignored because it has very little effect at power supply frequencies but above about 350 Hz, i.e. the seventh harmonic and above, skin effect will become significant, causing additional loss and heating. Where harmonic currents are present, designers should take skin effect into account and de-rate cables accordingly.
- Multiple cable cores or laminated bus bars can be used to help overcome this problem. Note also that the mounting systems of bus bars must be designed to avoid mechanical resonance at harmonic frequencies.

Problems caused by harmonic voltages:

1) voltage distortion

- Because the supply has source impedance, harmonic load currents give rise to harmonic voltage distortion on the voltage waveform (this is the origin of 'flat topping').
- There are two elements to the impedance: that of the internal cabling from the point of common coupling (PCC), and that inherent in the supply at the PCC, e.g. the local supply transformer.
- The distorted load current drawn by the non-linear load causes a distorted voltage drop in the cable impedance. The resultant distorted voltage waveform is applied to all other loads connected to the same circuit, causing harmonic currents to flow in them - even if they are linear loads.
- **Solution:** The solution is to separate circuits supplying harmonic generating loads from those supplying loads which are sensitive to harmonics, as shown in Figure 16. Here separate circuits feed the linear and non-linear loads from the point of common coupling, so that the voltage distortion caused by the non-linear load does not affect the linear load.
- When considering the magnitude of harmonic voltage distortion it should be remembered that when the load is transferred to a UPS or standby generator during a power failure the source impedance and the resulting voltage distortion will be much higher.
- Where local transformers are installed, they should be selected to have sufficiently low output impedance and to have sufficient capacity to withstand the additional heating, in other words, by selecting an appropriately oversized transformer.
- Note that it is not appropriate to select a transformer design in which the increase in capacity is achieved simply by forced cooling – such a unit will run at higher internal temperatures and have a reduced service life. Forced cooling should be reserved for emergency use only and never relied upon for normal running.

2) Induction Motors

- Harmonic voltage distortion causes increased eddy current losses in motors in the same way as in transformers. However, additional losses arise due to the generation of harmonic fields in the stator, each of which is trying to rotate the motor at a different speed either forwards or backwards. High frequency currents induced in the rotor further increase losses.
- Where harmonic voltage distortion is present motors should be de-rated to take account of the additional losses.

3) Zero-crossing noise

- Many electronic controllers detect the point at which the supply voltage crosses zero volts to determine when loads should be turned on. This is done because switching inductive loads at zero voltage does not generate transients, so reducing electromagnetic interference (EMI) and stress on the semiconductor switching devices.
- When harmonics or transients are present on the supply the rate of change of voltage at the crossing becomes faster and more difficult to identify, leading to erratic operation. There may in fact be several zero-crossings per half cycle.

4) Harmonic problems affecting the supply

- When a harmonic current is drawn from the supply it gives rise to a harmonic voltage drop proportional to the source impedance at the point of common coupling (PCC) and the current.
- Since the supply network is generally inductive, the source impedance is higher at higher frequencies. Of course, the voltage at the PCC is already distorted by the harmonic currents drawn by other consumers and by the distortion inherent in transformers, and each consumer makes an additional contribution.

Remedies to Reduce Harmonic Problems:

1) Over sizing Neutral Conductors

- In three phase circuits with shared neutrals, it is common to oversize the neutral conductor up to 200% when the load served consists of non-linear loads. For example, most manufacturers of system furniture provide a 10 AWG conductor with 35 amp terminations for a neutral shared with the three 12 AWG phase conductors.
- In feeders that have a large amount of non-linear load, the feeder neutral conductor and panel board bus bar should also be oversized.

2) Using Separate Neutral Conductors

- On three phase branch circuits, another philosophy is to not combine neutrals, but to run separate neutral conductors for each phase conductor. This increases the copper use by 33%. While this successfully eliminates the addition of the harmonic currents on the branch circuit neutrals, the panel board neutral bus and feeder neutral conductor still must be oversized.

- Over sizing Transformers and Generators: The over sizing of equipment for increased thermal capacity should also be used for transformers and generators which serve harmonics-producing loads. The larger equipment contains more copper.

3) Passive filters

- Passive filters are used to provide a low impedance path for harmonic currents so that they flow in the filter and not the supply.
- The filter may be designed for a single harmonic or for a broad band depending on requirements.
- Simple series band stop filters are sometimes proposed, either in the phase or in the neutral. A series filter is intended to block harmonic currents rather than provide a controlled path for them so there is a large harmonic voltage drop across it.
- This harmonic voltage appears across the supply on the load side. Since the supply voltage is heavily distorted it is no longer within the standards for which equipment was designed and warranted. Some equipment is relatively insensitive to this distortion, but some is very sensitive. Series filters can be useful in certain circumstances, but should be carefully applied; they cannot be recommended as a general purpose solution.

4) Isolation transformers

- As mentioned previously, triple-N currents circulate in the delta windings of transformers. Although this is a problem for transformer manufacturers and specifiers - the extra load has to be taken into account it is beneficial to systems designers because it isolates triple-N harmonics from the supply.
- The same effect can be obtained by using a 'zig-zag' wound transformer. Zig-zag transformers are star configuration auto transformers with a particular phase relationship between the windings that are connected in shunt with the supply.

5) Active Filters

- The solutions mentioned so far have been suited only to particular harmonics, the isolating transformer being useful only for triple-N harmonics and passive filters only for their designed harmonic frequency. In some installations the harmonic content is less predictable.
- In many IT installations for example, the equipment mix and location is constantly changing so that the harmonic culture is also constantly changing. A convenient solution is the active filter or active conditioner.
- The active filter is a shunt device. A current transformer measures the harmonic content of the load current, and controls a current generator to produce an exact replica that is fed back onto the supply on the next cycle. Since the harmonic current is sourced from the active conditioner, only fundamental current is drawn from the supply. In practice, harmonic current magnitudes are reduced by 90%, and, because the source impedance at harmonic frequencies is reduced, voltage distortion is reduced.

6) K-Rated Transformers

- Special transformers have been developed to accommodate the additional heating caused by these harmonic currents. These types of transformers are now commonly specified for new computer rooms and computer lab

7) Special Transformers

- There are several special types of transformer connections which can cancel harmonics. For example, the traditional delta-wye transformer connection will trap all the triplen harmonics (third, ninth, fifteenth, twenty-first, etc.) in the delta.
- Additional special winding connections can be used to cancel other harmonics on balanced loads. These systems also use more copper. These special transformers are often specified in computer rooms with well balanced harmonic producing loads such as multiple input mainframes or matched DASD peripherals.

8) Filtering

- While many filtersdo not work particularly well at this frequency range, special electronic tracking filters can work very well to eliminate harmonics.
- These filters are presently relatively expensive but should be considered for thorough harmonic elimination.

9) Special Metering

- Standard clamp-on ammeters are only sensitive to 60 Hertz current, so they only tell part of the story. New "true RMS" meters will sense current up to the kilohertz range. These meters should be used to detect harmonic currents. The difference between a reading on an old style clamp-on ammeter and a true RMS ammeter will give you. an indication of the amount of harmonic current present.
- The measures described above only solve the symptoms of the problem. To solve the problem we must specify low harmonic equipment. This is most easily done when specifying electronic ballasts. Several manufacturers

make electronic ballasts which produce less than 15 % harmonics. These ballasts should be considered for any ballast retrofit or any new project. Until low harmonics computers are available, segregating these harmonic loads on different circuits, different panel boards or the use of transformers should be considered. This segregation of “dirty” and “clean” loads is fundamental to electrical design today. This equates to more branch circuits and more panel boards, thus more copper usage.

References:

1. “Electric Utility Power Systems”. A text book by John Smith &McGraw -Hill.
2. “Harmonics Made Simple” by R. Fehr, P.E.
3. Schaffner EMC - IEC 61000-3-2 Harmonics Standards Overview
4. JURNAL TEKNIK GELAGAR,
5. J. Van den Keybus1, B. Bolsens2, K. De Brabandere, R. Belmans
6. Martin J. Mohlenkamp
7. J. Arillaga, et al, “Power System Harmonics”
8. R.C. Dugan, D.T. Rizy, “Harmonic Considerations for Electrical Distribution Feeders”,

Chapter: 63 What is Demand Factor-Diversity Factor-Utilization Factor-Load Factor

(1) Demand factor (in IEC, Maximum Utilization factor (Ku)):

- The word "demand" itself says the meaning of Demand Factor. The ratio of the maximum coincident demand of a system, or part of a system, to the total connected load of the system.
- **Demand Factor = Maximum demand / Total connected load**
- For example, an oversized motor 20 Kw drives a constant 15 Kw load whenever it is ON. The motor demand factor is then 15/20 =0.75= 75 %.
- Demand Factor is express as a percentage (%) or in a ratio (less than 1).
- ***Demand factor is always < =1.***
- Demand Factor is always change with the time to time or hours to hours of use and it will not constant.
- The connected load is always known so it will be easy to calculate the maximum demand if the demand factor for a certain supply is known at different time intervals and seasons.
- ***The lower the demand factor, the less system capacity required to serve the connected load.***
- **Calculation:**
- (1) A Residence Consumer has 10 No's Lamp of 400 W but at the same time It is possible that only 9 No's of Bulbs are used at the same time. Here Total Connected load is 10x40=400 W. Consumer maximum demand is 9x40=360 W. Demand Facto of this Load = 360/400 =0.9 or 90%.
- (2) One Consumer have 10 lights at 60 Kw each in Kitchen, the load is 60 Kw x 10 = 600 KW. This will be true only if All lights are Turns ON the same time (Demand factor=100% or 1)
- For this Consumer it is observed that only half of the lights being turned ON at a time so we can say that the demand factor is 0.5 (50%). The estimated load = 600 Kw X 0.5 = 300 Kw.
- **Use of demand factors:**
- Feeder conductors should have sufficient Ampere Capacity to carry the load.The Ampere Capacity does not always be equal to the total of all loads on connected branch-circuits.
- This factor must be applied to each individual load, with particular attention to electric motors, which are very rarely operated at full load.
- As per National Electrical Code (NEC) demand factor may be applied to the total load. The demand factor permits a feeder ampearcity to be less than 100 percent of all the branch-circuit loads connected to it.
- Demand factor can be applied to calculate the size of the sub-main which is feeding a Sub panel or a fixed load like a motor etc. If the panel have total load of 250 kVA , considering a Demand factor of 0.8, we can size the feeder cable for 250 x 0.8= 200 kVA.
- Demand factors for buildings typically range between 50 and 80 % of the connected load.
- In an industrial installation this factor may be estimated on an average at 0.75 for motors.
- For incandescent-lighting loads, the factor always equals 1.

Demand Factor For Industrial Load	
Text Book of Design of Elect. Installation- Jain	
Electrical Load	**Demand Factor**
1 No of Motor	1
Up to 10 No's of Motor	0.75
Up to 20 No's of Motor	0.65
Up to 30 No's of Motor	0.6
Up to 40 No's of Motor	0.5
Up to 50 No's of Motor	0.4

Demand Factor	
Text Book of Design of Elect. Installation- Jain	
Utility	**Demand Factor**
Office ,School	0.4

Hospital	0.5
Air Port, Bank, Shops,	0.6
Restaurant, Factory,	0.7
Work Shop, Factory (24Hr Shift)	0.8
Arc Furnace	0.9
Compressor	0.5
Hand tools	0.4
Inductance Furnace	0.8

Demand Factor	
Saudi Electricity Company Distribution Standard	
Utility	**Demand Factor**
Residential	0.6
Commercial	0.7
Flats	0.7
Hotel	0.75
Mall	0.7
Restaurant	0.7
Office	0.7
School	0.8
Common Area in building	0.8
Public Facility	0.75
Street Light	0.9
Indoor Parking	0.8
Outdoor Parking	0.9
Park / Garden	0.8
Hospital	0.8
Workshops	0.6
Ware House	0.7
Farms	0.9
Fuel Station	0.7
Factories	0.9

Demand Factor	
Text Book of Principal of Power System-V.K.Mehta	
Utility	**Demand Factor**
Residence Load (<0.25 KW)	1
Residence Load (<0.5 KW)	0.6
Residence Load (>0.1 KW)	0.5
Restaurant	0.7
Theatre	0.6
Hotel	0.5
School	0.55
Small Industry	0.6
Store	0.7
Motor Load (up to 10HP)	0.75
Motor Load (10HP to 20HP)	0.65
Motor Load (20HP to 100HP)	0.55
Motor Load (Above 100HP)	0.50

(2) Diversity factor:

- Diversity Factor is ratio of the sum of the individual maximum demands of the various sub circuit of a system to the maximum demand of the whole system.
- **Diversity Factor = Sum of Individual Maximum Demands / Maximum Demand of the System.**
- Diversity Factor = Installed load / Running load.
- ***The diversity factor is always >= 1.***
- Diversity Factor is always >1 because sum of individual max. Demands >Max. Demand.
- In other terms, Diversity Factor (0 to 100%) is a fraction of Total Load that is particular item contributed to peak demand.70% diversity means that the device operates at its nominal or maximum load level 70% of the time that it is connected and turned ON.
- It is expressed as a percentage (%) or a ratio more than 1.
- **If we use diversity value in % than it should be multiply with Load and if we use in numerical value (>1) than it should be divided with Load.**
- Diversity occurs in an operating system because all loads connected to the System are not operating simultaneously or are not simultaneously operating at their maximum rating.The diversity factor shows that the whole electrical load does not equal the sum of its parts due to this time Interdependence (i.e. diverseness).
- In general terms we can say that diversityfactor refers to the percent of time available that a machine. 70% diversity means that the device operates at its nominal or maximum load level 70% of the time that it is connected and turned ON.
- Consider two Feeders with the same maximum demand but that occur at different intervals of time. When supplied by the same feeder, the demand on such is less the sum of the two demands. In electrical design, this condition is known as diversity.
- Diversity factor is an extended version of demand factor. It deals with maximum demand of different units at a time/Maximum demand of the entire system.
- **Greater the diversity factor, lesser is the cost of generation of power.**
- Many designers prefer to use unity as the diversity factor in calculations for planning conservatism because of plant load growth uncertainties. Local experience can justify using a diversity factor larger than unity, and smaller service entrance conductors and transformer requirements chosen accordingly.
- The diversity factor for all other installations will be different, and would be based upon a local evaluation of the loads to be applied at different moments in time. Assuming it to be 1.0 may, on some occasions, result in a supply feeder and equipment rating that is rather larger than the local installation warrants, and an over-investment in cable and equipment to handle the rated load current. It is better to evaluate the pattern of usage of the loads and calculate an acceptable diversity factor for each particular case.
- **Calculation:**
- One Main Feeder have two Sub feeder (Sub Feeder A and Sub Feeder B), Sub Feeder-Ahave demand at a time is 35 KW and Sub Feeder-B have demands at a time is 42 KW, but the maximum demand of Main Feeder is 70 KW.
- Total individual Maximum Demand =35+42=77 KW.
- Maximum Demand of whole System=70 KW
- So Diversity factor of The System= 77/70 =1.1
- Diversity factor can shoot up above 1.
- **Use of diversity factor:**
- The Diversity Factor is applied to each group of loads (e.g. being supplied from a distribution or sub-distribution board).
- Diversity factor is commonly used for a complete a coordination study for a system. This diversity factor is used to estimate the load of a particular node in the system.
- Diversity factor can be used to estimate the total load required for a facility or to size the Transformer
- Diversity factors have been developed for main feeders supplying a number of feeders, and typically 1.2 to 1.3 for Residence Consumer and 1.1 to 1.2 for Commercial Load 1.50 to 2.00 for power and lighting loads.
- Note: Reciprocal of the above ratio (will be more than 1) also is used in some other countries.
- Diversity factor is mostly used for distribution feeder size and transformer as well as to determine the maximum peak load and diversity factor is always based on knowing the process. You have to understand what will be on or off at a given time for different buildings and this will size the feeder. Note for typical buildings diversity factor is

always one. You have to estimate or have a data records to create 24 hours load graph and you can determine the maximum demand load for node then you can easily determine the feeder and transformer size.

- The diversity factor of a feeder would be the sum of the maximum demands of the individual consumers divided by the maximum demand of the feeder. In the same manner, it is possible to compute the diversity factor on a substation, a transmission line or a whole utility system.
- The residential load has the highest diversity factor. Industrial loads have low diversity factors usually of 1.4, street light practically unity and other loads vary between these limits.

Diversity Factor in distribution Network				
(Standard Handbook for Electrical Engineers" by Fink and Beaty)				
Elements of System	**Residential**	**Commercial**	**General Power**	**Large Industrial**
Between individual users	2.00	1.46	1.45	
Between transformers	1.30	1.30	1.35	1.05
Between feeders	1.15	1.15	1.15	1.05
Between substations	1.10	1.10	1.10	1.10
From users to transformers	2.00	1.46	1.44	
From users to feeder	2.60	1.90	1.95	1.15
From users to substation	3.00	2.18	2.24	1.32
From users to generating station	3.29	2.40	2.46	1.45

Diversity Factor for Distribution Switchboards	
Number of circuits	Diversity Factor in % (ks)
Assemblies entirely tested 2 and 3	90%
4 and 5	80%
6 to 9	70%
10 and more	60%
Assemblies partially tested in every case choose	100%

Diversity Factor as per IEC 60439	
Circuits Function	**Diversity Factor in % (ks)**
Lighting	90%
Heating and air conditioning	80%
Socket-outlets	70%
Lifts and catering hoist	
For the most powerful motor	100%
For the second most powerful motor	75%
For all motors	80%

Diversity Factor for Apartment block	
Apartment	Diversity Factor in % (ks)
2 To 4	1
5To 19	0.78
10To 14	0.63
15To 19	0.53
20To 24	0.49
25To 29	0.46
30 To 34	0.44
35 To 39	0.42
40To 40	0.41
50 To Above	0.40

Diversity Factor			
Text Book of Principal of Power System-V.K.Mehta			
Area	**Residence Ltg**	**Commercial Ltg**	**Ind. Ltg**
Between Consumer	3	1.5	1.5
Between Transformer	1.3	1.3	1.3
Between Feeder	1.2	1.2	1.2
Between S.S	1.1	1.1	1.1

(3) Load factor:

- The ratio of the Actual Load of equipment to Full load of equipment.
- **Load Factor=Actual Load / Full Load**
- It is the ratio of actual kilowatt-Hours used in a given period, divided by the total possible kilowatt -hours that could have been used in the same period at the peak KW level.
- **Load Factor = (energy (kWh per month)) / (peak demand (kW) x hours/month)**
- In other terms Load factor is defined as the ratio of Average load to maximum demand during a given period.
- **Load Factor= Average Load / Maximum Demand during given Time Period**
- ***The Load factor is always <=1.***
- Load Factor is always less than 1 because maximum demand is always more than average demand.
- Load Factor can be calculated for a single day, for a month or for a year.
- Load factor in other terms of efficiency.
- It is used for determining the overall cost per unit generated.
- Higher the load factor is GOOD and it will more Output of Plan, lesser the cost per unit which means an electricity generator can sell more electricity at a higher spark spread, Fixed costs are spread over more kWh of output. A power plant may be highly efficient at High load factors.
- Low load factor is a BED. A low load factor will use electricity inefficiently relative to what we could be if we were controlling our peak demand.A power plant may be less efficient at low load factors.
- For almost constant loads, the load factor isclose to unity.
- For Varying Load Factor is closed Zero.
- Load Factor is a measure of the effective utilization of the load and distribution equipment, i.e. higher load factor means better utilization of the transformer, line or cable.
- A high load factor means power usage is relatively constant. Low load factor shows that occasionally a high demand is set. To service that peak, capacity is sitting idle for long periods, thereby imposing higher costs on the system. Electrical rates are designed so that customers with high load factor are charged less overall per kWh.
- Sometimes utility companies will encourage industrial customers to improve their load factors.
- ***Load factor is term that does not appear on your utility bill, but does affect electricity costs. Load factor indicates how efficiently the customer is using peak demand.***
- **Calculation:**
- Motor of 20 hp drives a constant 15 hp load whenever it is on.
- The motor load factor is then 15/20 = 75%.

Demand Factor & Load Factor		
Introduction to Power Requirement for Building - J. Paul Guyer,		
Utility	**Demand Factor (%)**	**Load Factor (%)**
Communications – buildings	60-65	70-75
Telephone exchange building	55-70	20-25
Air passenger terminal building	65-80	28-32
Aircraft fire and rescue station	25-35	13-17
Aircraft line operations building	65-80	24-28
Academic instruction building	40-60	22-26
Applied instruction building	35-65	24-28
Chemistry and Toxicology Laboratory	70-80	22-28
Materials Laboratory	30-35	27-32
Physics Laboratory	70-80	22-28

Electrical and electronics laboratory	20-30	3-7
Cold storage warehouse	70-75	20-25
General warehouse	75-80	23-28
Controlled humidity warehouse	60-65	33-38
Hazardous/flammable storehouse	75-80	20-25
Disposal, salvage, scrap building	35-40	25-20
Hospital	38-42	45-50
Laboratory	32-37	20-25
K-6 schools	75-80	10-15
7-12 schools	65-70	12-17
Churches	65-70	5-25
Post Office	75-80	20-25
Retail store	65-70	25-32
Bank	75-80	20-25
Supermarket	55-60	25-30
Restaurant	45-75	15-25
Auto repair shop	40-60	15-20
Hobby shop, art/crafts	30-40	25-30
Bowling alley	70-75	10-15
Gymnasium	70-75	20-45
Skating rink	70-75	10-15
Indoor swimming pool	55-60	25-50
Theatres	45-55	8-13
Library	75-80	30-35
Golf clubhouse	75-80	15-20
Museum	75-80	30-35

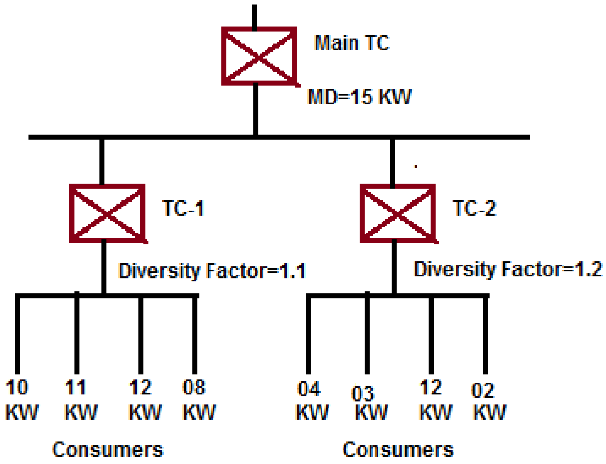
(4) Coincidence factor (in IEC, Factor of simultaneity (ks)):

- The reciprocal of diversity factor is coincidence factor
- The coincidence factor is the ratio of the maximum demand of a system, or part under consideration, to the sum of the individual maximum demands of the subdivisions
- **Coincidence factor = Maximum demand / Sum of individual maximum demands**
- Expressed as a percentage (%) or a ratio less than 1.
- ***The Confidence Factor is always <=1.***
- Usually Confidence Factor will decrease as the number of connected customer's increases.
- The factor ks is applied to each group of loads (e.g. distribution or sub-distribution board).
- The determination of these factors is the responsibility of the designer, since it requires a detailed knowledge of the installation and the conditions in which the individual circuits are to be exploited. For this reason, it is not possible to give precise values for general application.

(5) Maximum demand:

- The maximum demand of an installation is the maximum rate of consumption expressed in amperes, kW or kVA. It is generally taken as the average rate of consumption over a period of time. Example the 15-minute maximum kW demand for the week was 150 kW. Maximum demand does not include motor starting currents or other transient effects. Fault currents and overload currents are also excluded. Maximum demand in KW is relevant only for metering/tariff purposes.
- Maximum demand (often referred to as MD) is the largest current normally carried by circuits, switches and protective devices. It does not include the levels of current flowing under overload or short circuit conditions.
- Maximum Demand is a greatest of all demands that occur during a specific time
- The major disadvantage of allocating load using the diversity factors is that most utilities will not have a table of diversity factors and sometime it is not viable to determine accurate Diversity Factor. In this situation Maximum Demand is very helpful to calculate size of Feeder or TC.
- The kVA rating of all distribution transformers is always known for a feeder. The metered readings can be taken to each transformer based upon the transformer rating. An "allocation factor" (AF) can be calculate.

- Allocation Factor= Metered Demand (KVA) / Total KVA.
- **Equipment Demand= AF x Total KVA of Equipments**
- **Calculation:**
- Actual Loading or Size of TC-1 and TC-2.



- Total Load on TC-1 =10+11+12+08= 41 KW.
- Maximum Diversity Demand of TC-1= 41 / 1.1 = 37.3 KW.
- Total Load on TC-2 =4+3+12+02= 21 KW.
- Maximum Diversity Demand of TC-2= 21 / 1.2 = 17.5 KW.
- Total Load= 37.3 + 17.5 =54.8 KW.
- Allocating Factor (AF)= M.D / Total Load
- Allocating Factor (AF)= 0.27.
- **Actual Load on TC-1=0.27x37.3 = 1.20 KW.**
- **Actual Load on TC-2=0.27x17.5 = 4.8 KW.**
- Assessment of maximum demand is very easy for Resistive Load , For example, the maximum demand of a 240 V single-phase 8 kW shower heater can be calculated by dividing the power (8 kW) by the voltage (240 V) to give a current of 33.3 A. This calculation assumes a power factor of unity, which is a reasonable assumption for such a purely resistive load.
- Lighting circuits pose a special problem when determining MD. Discharge lamps are particularly difficult to assess, and current cannot be calculated simply by dividing lamp power by supply voltage. The reasons for this are Control gear losses result in additional current, the power factor is usually less than unity so current is greater, and Chokes and other control gear usually distort the waveform of the current so that it contains harmonics which are additional to the fundamental supply current.
- So long as the power factor of a discharge lighting circuit is not less than 0.85, the current demand for the circuit can be calculated from:
- current (A) = (lamp power (W) x 1.8) / supply voltage (V)
- For example, the steady state current demand of a 240 V circuit supplying ten 65 W fluorescent lamps would be: I = 10X65X1.8A / 240 = 4.88A
- Switches for circuits feeding discharge lamps must be rated at twice the current they are required to carry, unless they have been specially constructed to withstand the severe arcing resulting from the switching of such inductive and capacitive loads.

Where to use Demand and Diversity factor:

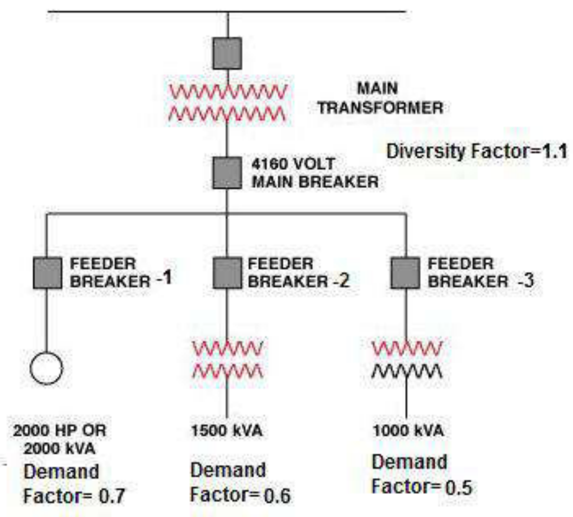
- There is generally confusion between Demand factor and Diversity factor. **Demand factors should be ideally applied to individual loads and diversity factor to a group of loads.**
- When you talk about 'diversity', there are naturally more than one or many loads involved.
- Demand factor can be applied to calculate the size of the sub-main, which is feeding a Sub panel or a fixed load like a motor etc,individual Load.
- Demand factors are more conservative and are used by NEC for service and feeder sizing.
- If the Sub panel have total load is 250 kVA , considering a Demand factor of 0.8, we can size the feeder cable for

250 x 0.8= 200 kVA.

- The Diversity Factor is applied to each group of loads (e.g. being supplied from a distribution or sub-distribution board), size the Transformer.
- Demand factors and diversity factors are used in design. For example, the sum of the connected loads supplied by a feeder is multiplied by the demand factor to determine the load for which the feeder must be sized. This load is termed the maximum demand of the feeder. The sum of the maximum demand loads for a number of subfeeders divided by the diversity factor for the sub feeders will give the maximum demand load to be supplied by the feeder from which the subfeeders are derived.

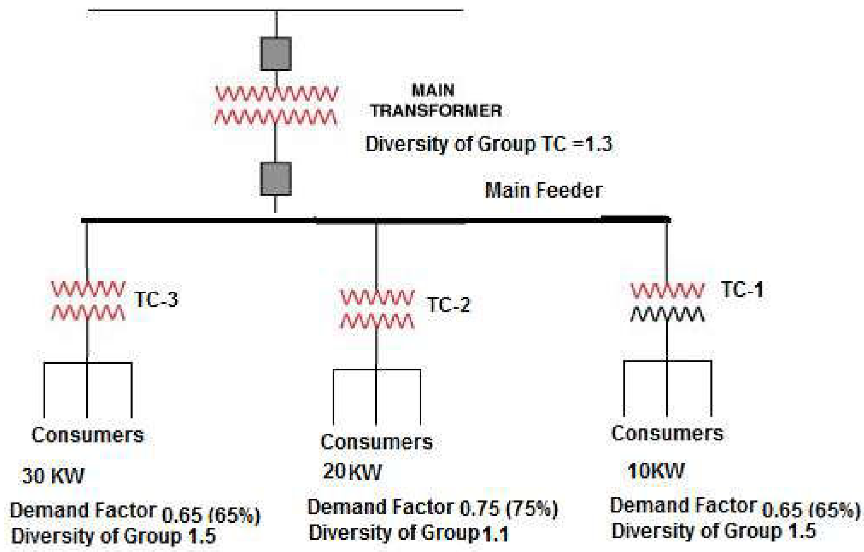
Calculate Size of Electrical Switchgear by Demand & Diversity Factor:

- The estimated electrical demand for all feeders served directly from the service entrance is calculated by multiplying the total connected loads by their demand factors and then adding all of these together. **This sum is divided by the diversity factor (frequently assumed to be unity) to calculate the service entrance demand** which is used to determine ampacity requirements for the service entrance conductors.
- When used Diversity and Demand Factor in an electrical design it should be applied as follows,the sum of the connected loads supplied by a feeder-circuit can be multiplied by the demand factor to determine the load used to size the components of the system.
- The sum of the maximum demand loads for two or more feeders is divided by the diversity factor for the feeders to derive the maximum demand load.
- **Example-1:** Calculate Size of Transformer having following details:



- Feeder Breaker-1 Demand Load= Feeder Breaker-1xDemand Factor.
- Feeder Breaker-1 Demand Load=2000x0.7=1400 KVA
- Feeder Breaker-2 Demand Load= Feeder Breaker-2xDemand Factor.
- Feeder Breaker-2 Demand Load=1500x0.6=900 KVA
- Feeder Breaker-3 Demand Load= Feeder Breaker-3xDemand Factor.
- Feeder Breaker-2 Demand Load=1000x0.5=500 KVA
- Total Feeder Breaker Demand=1400+900+500=2800KVA
- Transformer Demand Load= Total Feeder Breaker Demand / Diversity Factor.
- **Transformer Demand Load=2800/1.1 =2545 KVA**
- If we Calculated Total Load on Transformer without any Demand & Diversity=2000+1500+1000=4500KVA.
- But after Calculating Demand & Diversity Factor Total Load on Transformer =2545 KVA

- **Example-2:** Calculate Size of Main Feeder of Main Transformer having following Details:



- Sum of Maximum Demand of Customer on TC-1 =10 KWx0.65 =6.5 KW
- Sum of Maximum Demand of Customer on TC-2 =20 KWx0.75 =15 KW
- Sum of Maximum Demand of Customer on TC-3 =30 KWx0.65 =19.5 KW
- As Diversity of Consumer Connected on TC-1 is 1.5 so,
- Maximum Demand on TC-1 =6.5 KW/1.5 = 4 KW.
- As Diversity of Consumer Connected on TC-2 is 1.1 so,
- Maximum Demand on TC-2 =15 KW/1.1 = 14 KW
- As Diversity of Consumer Connected on TC-3 is 1.5 so,
- Maximum Demand on TC-3 =19.5 KW/1.5 = 13 KW.
- Individual Maximum Demand on Main Transformer =04+14+13= 31 KW.
- **Maximum Demand on Main Feeder =04+14+13 / 1.3 =24 KW**

Significance of Load Factor and Diversity Factor

- Load factor and diversity factor play an important part in the cost of the supply of electrical energy. Higher the values of load factor and diversity factors, lower will be the overall cost per unit generated.
- The capital cost of the power station depends upon the capacity of the power station. Lower the maximum demand of the power station, the lower is the capacity required and therefore lower is the capital cost of the plant. With a given number of consumers the higher the diversity factor of their loads, the smaller will be the capacity of the plant required and consequently the fixed charges due to capital investment will be much reduced.
- Similarly higher load factor means more average load or more number of units generated for a given maximum demand and therefore overall cost per unit of electrical energy generated is reduced due to distribution of standing charges which are proportional to maximum demand and independent of number of units generated.
- Thus the suppliers should always try to improve the load factor as well as diversity factor by inducing the consumers to use the electrical energy during off peak hours and they may be charged at lower rates for such schemes.

Chapter: 64 Guideline for Electrical Network for Building / Small Area

1) Calculate Electrical Load:

- Find out built up area in Sqft.of per flat per House/Dwelling unit.
- Multiply area in Sqft. by Load/Sqft according to following Table

Type of Load	Load/Sqft
Industrial	100 Watt/Sqft
Commercial	30 Watt/Sqft
Domestic	15 Watt/Sqft

- Apply the diversity factor and Compute the load of all dwelling units in the area.

Type of Load	Diversity Factor
Industrial	0.5
Commercial	0.8
Domestic	0.4

- Add the load of common services such as Auditorium, Street Lights, Lifts and Water Pumps etc. For simplicity purpose 0.5kW/dwelling units may be considered as common load.
- Compute the "Total Load" of the area by adding load observed at above.
- Apply the power factor of 0.8 to determine the load in KVA.
- Compute the Load in KVA= "Total Load"/0.8
- **Take transformer loading of 65%** considering the network arrangement Ring Main Circuit.

2) Decide voltage grade for Electrical Load:

- If load is equal to or more than 2.50MVA, the area shall be fed through 33kV feeder. For such loads, the land space for 33/11kV Sub-station shall have to be allocated by builder / Society/ Authority.
- For load between 1 MVA to 2.5MVA, dedicated 11kV feeder shall be preferred.
- For load below 1 MVA, existing 11kV feed can be tapped through VCB or RMU.

3) Decide Size of Transformer:

- Select T.C Size of 25 KVA,63 KVA,100 KVA,200 KVA or 400 KVA according to your Load.
- The maximum capacity of distribution transformer acceptable is 400 kVA as a standard capacity.
- Only two-no of transformer at one location shall be acceptable. If there is more number of transformers HT shall be required to extend using underground cables to locate additional transformer.

4) RMU / LT Panel:

- Either VCB or Ring Main Circuit shall be used to control transformers. There cables should have metering arrangement at 11kV. The protection system at incoming supply shall be using numerical relays.
- On LT side of transformer, LT main feeder pillar shall be provided. The Incoming shall be protected by MCCB/SFU.
- The distribution pillar-box shall be connected into Ring Main Unit.
- The incomer of distribution pillar shall have MCCB / SFU. The outgoing shall have HRC fuses.

5) The LT cables from T.C to LT panel / Main feeder pillar:

- Decide Size of LT Cable from T.C to LT Panel as per following Table.

Transformer Size	Cable
630kVA transformers	2 no x 1C x 630 Sq mm, Al, XLPE Cable
400kVA transformers	1 no x 1C x 630 Sq mm, Al, XLPE
250kVA transformers	3 ½ C x 400 Sq mm, Al, XLPE
160kVA transformers	3 ½ C x 300 Sq mm, Al, XLPE
100kVA transformers	3 ½ C x 150 Sq mm, Al, XLPE

6) Considering various Factors & Length of Cable:

- The factors for **cable loading shall be taken as 70%.**

- The factor for **multiplicity of cables from same cable trench shall be 80%.**
- The suggested **maximum length of LT cable feeder shall be 250 Mtrs**.
- The LT cables shall be connected in ring main circuit.
- The load on sub-feeder pillar shall be restricted to 150kW.

7) LT cables from main feeder pillars to distribution pillar boxes:

Load on distribution pillar	LT Cable Size
Up to 50kW	3 ½ C x 150 sqmm, AL, XLPE
Up to 100kW	3 ½ C x 300 sqmm, AL, XLPE
Up to 150 kW	3 ½ C x 400sqmm, AL, XLPE

8) Calculate Voltage Drop and T&D Losses:

- The entire system has to be designed for a **voltage drop of 2.0%** from11kV Side of transformer to metering equipment at end consumer premises.
- The entire system has to be designed for **T&D losses of service maximum 2.0% from** 11kV to end consumer meter including of service cable.

Reference:

1. NPC Limited.
2. Electrical code.

Chapter: 65 Type-Size and Location of Capacitor in Electrical System

Type of Capacitor Bank as per Its Application:

(1) Fixed type capacitor banks

- The reactive power supplied by the fixed capacitor bank is constant irrespective of any variations in the power factor and the load of the receivers.
- These capacitor banks are switched on either manually (circuit breaker/ switch) or semi automatically by a remote-controlled contactor.
- This arrangement uses one or more capacitor to provide a constant level of compensation.
- These capacitors are applied at the terminals of inductive loads (mainly motors), at bus bars

Disadvantage:

- Manual ON/OFF operation.
- Not meet the require kvar under varying loads.
- Penalty by electricity authority.
- Power factor also varies as a function of the load requirements so it is difficult to maintain a consistent power factor by use of Fixed Compensation i.e. fixed capacitors.
- Fixed Capacitor may provide leading power factor under light load conditions, Due to This result in over voltages, saturation of transformers, mal-operation of diesel generating sets, penalties by electric supply authorities.

Application:

- Where the load factor is reasonably constant.
- Electrical installations with constant load operating 24 hours a day
- Reactive compensation of transformers.
- Individual compensation of motors.
- Where the kvar rating of the capacitors is less than, or equal to 15% of the supply transformer rating, a fixed value of compensation is appropriate.
- **Size of Fixed Capacitor bank Qc ≤ 15% kVA transformer**

(2) Automatic type capacitor banks

- The reactive power supplied by the capacitor bank **can be adjusted** according to variations in the power factor and the load of the receivers.
- These capacitor banks are made up of a combination of capacitor steps (step = capacitor + contactor) connected in parallel. Switching on and off of all or part of the capacitor bank is controlled by an integrated power factor controller.
- The equipment is applied at points in an installation where the active-power or reactive power Variations are relatively large, for example:
- At the bus bars of a main distribution switch-board,
- At the terminals of a heavily-loaded feeder cable.
- Where the kvar rating of the capacitors is less than, or equal to 15% of the supply transformer rating, a fixed value of compensation is appropriate.Above the 15% level, it is advisable to install an automatically-controlled bank of capacitors.
- Control is usually provided by contactors. For compensation of highly fluctuating loads, fast and highly repetitive connection of capacitors is necessary, and static switches must be used.

Types of APFC:

- Automatic Power Factor correction equipment is divided into three major categories:
- (1) **Standard** = Capacitor + Fuse + Contactor + Controller
- (2) **Detuned** = Capacitor + Detuning Reactor + Fuse + Contactor + Controller
- (3) **Filtered** = Capacitor + Filter Reactor + Fuse + Contactor + Controller.

Advantage:

- Consistently high power factor under fluctuating loads.
- Prevention of leading power factor.
- Eliminate power factor penalty.
- Lower energy consumption by reducing losses.
- Continuously sense and monitor load.
- Automatically switch on/off relevant capacitors steps for consistent power factor.
- Ensures easy user interface.
- Automatically variation, without manual intervention, the compensation to suit the load requirements.

Application:

- Variable load electrical installations.
- Compensation of main LV distribution boards or major outgoing lines.
- Above the 15% level, it is advisable to install an automatically-controlled bank of capacitors.
- **Size of Automatic Capacitor bank Qc >15% kVA transformer**

Method	Advantages	Disadvantages
Individual capacitors	Most technically efficient, most flexible	Higher installation & maintenance cost
Fixed bank	Most economical, fewer installations	Less flexible, requires switches and/or circuit breakers
Automatic bank	Best for variable loads, prevents over voltages, low installation cost	Higher equipment cost
Combination	Most practical for larger numbers of motors	Least flexible

Type of Capacitor as per Construction:

1) Standard duty Capacitor:

- **Construction:** Rectangular & Cylindrical(Resin filled / Resin coated-Dry)
- **Application:**
- Steady inductive load.
- Non linear up to 10%.
- For Agriculture duty.

2) Heavy-duty:

- Construction: Rectangular & Cylindrical (Resin filled / Resin coated-Dry/oil/gas)
- **Application:**
- Suitable for fluctuating load.
- Non linear up to 20%.
- Suitable for APFC Panel.
- Harmonic filtering

3) LT Capacitor:

- **Application:**
- Suitable for fluctuating load.
- Non linear up to 20%.
- Suitable for APFC Panel & Harmonic filter application.

Selecting Size of Capacitor Bank:

- The size of the inductive load is large enough to select the minimum size of capacitors that is practical. For HT capacitors the minimum ratings that are practical are as follows:

System Voltage	Minimum rating of capacitor bank
3.3 KV , 6.6KV	75 Kvar
11 KV	200 Kvar
22 KV	400 Kvar
33 KV	600 Kvar

- Unit sizes lower than above is not practical and economical to manufacture.

- When capacitors are connected directly across motors it must be ensured that the rated current of the capacitor bank should not exceed 90% of the no-load current of the motor to avoid self-excitation of the motor and also over compensation.
- Precaution must be taken to ensure the live parts of the equipment to be compensated should not be handled for 10 minutes (in case of HT equipment) after disconnection of supply.
- Crane motors or like, where the motors can be rotated by mechanical load and motors with electrical braking systems, should never be compensated by capacitors directly across motor terminals.
- **For direct compensation across transformers the capacitor rating should not exceed 90 % of the no-load KVA of the motor.**

Selection of Capacitor as per Non-Liner Load:

- For power Factor correction it is need to first decide which Type of capacitor is used.
- Selection of Capacitor is depending upon many factor i.e. operating life, Number of Operation, Peak Inrush current withstand capacity.
- For selection of Capacitor we have to calculate Total Non Liner Load like UPS, Rectifier, Arc/Induction Furnace, AC/DC Drives, Computer, CFL Blubs, and CNC Machines.
- Calculation of Non liner Load, Example: Transformer Rating 1MVA,Non Liner Load 100KVA
- % of non Liner Load= (Non Liner Load/Transformer Capacity) x100 = (100/1000) x100=10%.
- According to Non Linear Load Select Capacitor as per Following Table.

% Non Liner Load	Type of Capacitor
<=10%	Standard Duty
Up to 15%	Heavy Duty
Up to 20%	Super Heavy Duty
Up to 25%	Capacitor +Reactor (Detuned)
Above 30%	

Configuration of Capacitor:

- Power factor correction capacitor banks can be configured in the following ways:
- (1) Delta connected Bank.
- (2) Star-Solidly Grounded Bank.
- (3) Star-Ungrounded Bank.

(1) Star-Solidly Grounded

- Initial cost of the bank may be lower since the neutral does not have to be insulated from ground.
- Capacitor switch recovery voltages are reduced
- High inrush currents may occur in the station ground system.
- The grounded-Star arrangement provides a low-impedance fault path which may require revision to the existing system ground protection scheme.
- Typically not applied to ungrounded systems. When applied to resistance-grounded systems, difficulty in coordination between capacitor fuses and upstream ground protection relays (consider coordination of 40 A fuses with a 400 A grounded system).
- Application: Typical for smaller installations (since auxiliary equipment is not required)

(2) Star-Ungrounded

- Industrial and commercial capacitor banks are normally connected ungrounded Star, with paralleled units to make up the total kvar. It is recommended that a minimum of 4 paralleled units to be applied to limit the over voltage on the remaining units when one is removed from the circuit. If only one unit is needed to make the total kvar, the units in the other phases will not be overloaded if it fails.
- In industrial or commercial power systems the capacitors are not grounded for a variety of reasons. Industrial systems are often resistance grounded. A grounded Star connection on the capacitor bank would provide a path for zero sequence currents and the possibility of a false operation of ground fault relays. Also, the protective relay scheme would be sensitive to system line-to-ground voltage Unbalance, which could also result in false relay tripping.
- Application: In Industrial and Commercial.

(3) Delta-connected Banks

- Delta-connected banks are generally used only at distributions voltages and are configured with a Single series group of capacitors rated at line-to-line voltage.
- With only one series group of units no overvoltage occurs across the remaining capacitor units from the isolation of a faulted capacitor unit. Therefore, unbalance detection is not required for protection and they are not treated further in this paper.
- Application: In Distribution System.

Effect of series and Parallel Connection of capacitor:

Parallel Connection:

- This is the most popular method of connection. The capacitor is connected in parallel to the unit.
- The voltage rating of the capacitor is usually the same as or a little higher than the system voltage.

Series Connection:

- This method of connection is not much common. Even though the voltage regulation is much high in this method,
- It has many disadvantages. One is that because of the series connection, in a short circuit condition the capacitor should be able to withstand the high current.
- The other is that due to the series connection due to the inductivity of the line there can be a resonance occurring at a certain capacitive value. This will lead to very low impedance and may cause very high currents to flow through the lines.

Size of Circuit Breaker, Fuse and Conductor of Capacitor Bank:

Thermal and Magnetic setting of a Circuit breaker:

(1) Size of Circuit Breaker:

- 1.3 to 1.5x Capacitor Current (In) for Standard Duty/Heavy Duty/Energy Capacitors
- 1.31×In for Heavy Duty/Energy Capacitors with 5.6% Detuned Reactor(Tuning Factor 4.3)
- 1.19×In for Heavy Duty/Energy Capacitors with 7% Detuned Reactor(Tuning Factor 3.8)
- 1.12×In for Heavy Duty/Energy Capacitors with 14% Detuned Reactor(Tuning Factor 2.7)
- Note: Restrictions in Thermal settings of system with Detuned reactors are due to limitation of IMP (Maximum Permissible current) of the Detuned reactor.

(2) Thermal Setting of Circuit Breaker:

- **1.5x Capacitor Current (In)** for Standard Duty/Heavy Duty/Energy Capacitors

(3) Magnetic Setting of Circuit Breaker:

- 5 to10 x Capacitor Current (In) for Standard Duty/Heavy Duty/Energy Capacitors
- Example :150kvar,400v, 50Hz Capacitor
- Us = 400V, Qs = 150kvar,Un = 400V, Qn = 150kvar
- In = 150000/400√3 = 216A
- Circuit Breaker Rating = 216 x 1.5 = 324A
- Select a 400A Circuit Breaker.
- Circuit Breaker thermal setting = 216 x 1.5 = 324 Amp
- Conclusion:- Select a Circuit Breaker of 400A with Thermal Setting at 324A and
- Magnetic Setting (Short Circuit) at 3240A

Fuse Selection

- The rating must be chosen to allow the thermal protection to be set to:
- 1.5 to 2.0 x Capacitor Current (In) for Standard Duty/Heavy Duty/Energy Capacitors.
- 1.35×In for Heavy Duty/Energy Capacitors with 5.7% Detuned Reactor (Tuning Factor 4.3)
- 1.2×In for Heavy Duty/Energy Capacitors with 7% Detuned Reactor (Tuning Factor 3.8)
- 1.15×In for Heavy Duty/Energy Capacitors with 14% Detuned Reactor(Tuning Factor 2.7)
- For Star-solidly grounded systems: Fuse > = 135% of rated capacitor current (includes overvoltage, capacitor tolerances, and harmonics).
- For Star -ungrounded systems: Fuse > = 125% of rated capacitor current (includes overvoltage, capacitor tolerances, and harmonics).
- Care should be taken when using NEMA Type T and K tin links which are rated 150%. In this case, the divide the fuse rating by 1.50.
- Example 1: 150kvar,400v, 50Hz Capacitor

- Us = 400V; Qs = 150kvar, Un = 400V; Qn = 150kvar.
- Capacitor Current =150x1000/400 =375 Amp
- To determine line current, we must divide the 375 amps by √ 3
- In (Line Current) = 375/√3 = 216A
- HRC Fuse Rating = 216 x1.65 = 356A to
- HRC Fuse Rating = 216 x 2.0 = 432A so Select Fuse Size 400 Amp

Problems with Fusing of Small Ungrounded Banks

- Example: 12.47 kV, 1500 Kvar Capacitor bank made of three 3 No's of 500 Kvar single-phase units.
- Nominal Capacitor Current=1500/1.732x12.47=69.44 amp
- Size of Fuse=1.5x69.44 =104 Amp= 100 Amp Fuse.
- If a capacitor fails, we say that It may approximately take 3x line current. (3 x 69.44 A = 208.32 A).
- It will take a 100 A fuse approximately 500 seconds to clear this fault (3 x 69.44 A = 208.32 A). The capacitor case will rupture long before the fuse clears the fault.
- The solution is using smaller units with individual fusing. Consider 5 No's of 100 kVAR capacitors per phase, each with a 25 A fuse. The clear time for a 25 A fuse @ 208.32 A is below the published capacitor rupture curve.

Size of Conductor for Capacitor Connections:

- Size of capacitor circuit conductors should be at least 135% of the rated capacitor current in accordance with NEC Article 460.8 (2005 Edition).

Size of capacitor for Transformer No-Load compensation.

Fixed compensation

- The transformer works on the principle of Mutual Induction. The transformer will consume reactive power for magnetizing purpose. Following size of Capacitor Bank is required to reduce reactive component (No Load Losses) of Transformer.

Selection of capacitor for transformer no-load compensation	
KVA Rating of the Transformer	**Kvar Required for compensation**
Up to and including 315 KVA	5% of KVA Transformer Rating
315 to 1000 KVA	6% of KVA Transformer Rating
Above 1000 KVA	8% of KVA Transformer Rating

Sizing of capacitor for motor compensation:

- The capacitor provides a local source of reactive current. With respect to inductive motor load, this reactive power is the magnetizing or "no load current"which the motor requires to operate.
- A capacitor is properly sized when its full load current rating is 90% of the no-load current of the motor. This 90% rating avoids overcorrection and the accompanying problems such as over voltages.

If no-load current is known:

- The most accurate method of selecting a capacitor is to take the no load current of the motor, and multiply by 0.90 (90%).
- Example: Size a capacitor for a 100HP, 460V 3-phase motor which has a full load current of 124 amps and a no-load current of 37 amps.
- Size of Capacitor =No load amps(37 Amp) X 90% = 33 Kvar

If the no load current is not known:

- If the no-load current is unknown, a reasonable estimate for 3-phase motors is to take the full load amps and multiply by 30%. Then multiply it by 90% rating figure being used to avoid overcorrection and over voltages.
- Example: Size a capacitor for a 75HP, 460V 3-phase motor which has a full load current of 92 amps and an unknown no-load current.
- No-load current of Motor=Full load Current (92 Amp) X 30% = 28 Amp estimated no-load Current.
- Size of Capacitor =No load amps (28 Amp) X 90% = 25 Kvar.

Thumb Rule:

- **It is widely accepted to use a thumb rule that Motor compensation required in kvar is equal to 33% of the Motor Rating in HP.**

Placement of Power Capacitor Bank for Motor:

- Capacitors installed for motor applications based on the number of motors to have power factor correction. If only a single motor or a small number of motors require power factor correction, the capacitor can be installed at each motor such that it is switched on and off with the motor.
- **Required Precaution for selecting Capacitor for Motor:**
- The care should be taken in deciding the Kvar rating of the capacitor in relation to the magnetizing kVA of the machine. If the rating is too high, It may damage to both motor and capacitor
- As the motor, while still in rotation after disconnection from the supply, it may act as a generator by self excitation and produce a voltage higher than the supply voltage. If the motor is switched on again before the speed has fallen to about 80% of the normal running speed, the high voltage will be superimposed on the supply circuits and there may be a risk of damaging other types of equipment.
- As a general rule the correct size of capacitor for individual correction of a motor should have a kvar rating not exceeding 85% of the normal No Load magnetizing KVA of the machine.
- If several motors connected to a single bus and require power factor correction, install the capacitor(s) at the bus.
- **Where do not installed Capacitor on Motor:**
- Do not install capacitors directly onto a motor circuit under the following conditions:
- (1) If solid-state starters are used.
- (2) If open-transition starting is used.
- (3) If the motor is subject to repetitive switching, jogging, inching, or plugging.
- (4) If a multi-speed motor is used.
- (5) If a reversing motor is used.
- (6) If a high-inertia load is connected to the motor.
- Fixed power capacitor banks can be installed in a non-harmonic producing electrical system at the feeder, load or service entrance. Since power capacitor banks are reactive power generators, the most logical place to install them is directly at the load where the reactive power is consumed. Three options exist for installing a power capacitor bank at the motor.

Location 1 (The line side of the starter):

- Install between the upstream circuit breaker and the contactor.
- This location should be used for the motor loads with high inertia, where disconnecting the motor with the power capacitor bank can turn the motor into a self excited generator, motors that are jogged, plugged or reversed, motors that start frequently, multi-speed motors, starters that disconnect and reconnect capacitor units during cycling and starters with open transition.

Advantage:

- Larger, more cost effective capacitor banks can be installed as they supply kvar to several motors. This is recommended for jogging motors, multispeed motors and reversing applications.

Disadvantages:

- Since capacitors are not switched with the motors, overcorrection can occur if all motors are not running.
- Since reactive current must be carried a greater distance, there are higher line losses and larger voltage drops.

Application:

- Large banks of fixed kVAR with fusing on each phase.
- automatically switched banks

Location 2 (Between the overload relay and the starter):

- Install between the contactor and the overload relay.
- This location can be used in existing installations when the overload ratings surpass the National Electrical Code requirements.
- With this option the overload relay can be set for nameplate full load current of motor. Otherwise the same as Option 1.
- No extra switch or fuses required.
- Contactor serves as capacitor disconnect.
- Change overload relays to compensate for reduced motor current.
- Too much Kvar can damage motors.
- Calculate new (reduced) motor current. Set overload relays for this new motor FLA.
- **FLA (New) =P.F (Old)/P.F (New) x FLA (Name Plate)**

Application:

- Usually the best location for individual capacitors.

Location 3 (The motor side of the overload relay):

- Install directly at the single speed induction motor terminals (on the secondary of the overload relay).
- This location can be used in existing installations when no overload change is required and in new installations in which the overloads can be sized in accordance with reduced current draw.
- When correcting the power factor for an entire facility, fixed power capacitor banks are usually installed on feeder circuits or at the service entrance.
- Fixed power capacitor banks should only be used when the facility's load is fairly constant. When a power capacitor bank is connected to a feeder or service entrance a circuit breaker or a fused disconnect switch must be provided.
- New motor installations in which overloads can be sized in accordance with reduced current draw
- Existing motors when no overload change is required.

Advantage:

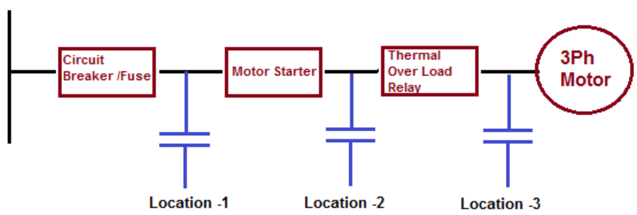
- Can be switched on or off with the motors, eliminating the need for separate switching devices or over current protection. Also, only energized when the motor is running.
- Since Kvar is located where it is required, line losses and voltage drops are minimized; while system capacity is maximized.

Disadvantage:

- Installation costs are higher when a large number of individual motors need correction.
- Overload relay settings must be changed to account for lower motor current draw.

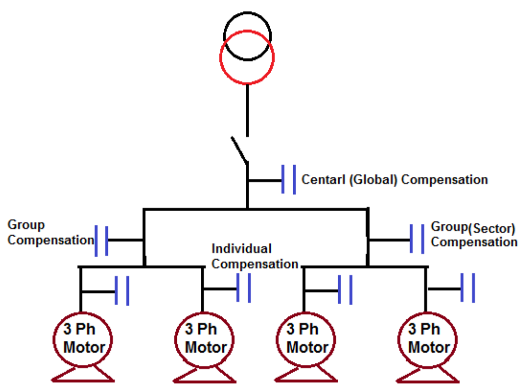
Application:

- Usually the best location for individual capacitors.



Placement of capacitors in Distribution system:

- The location of low voltage capacitors in Distribution System effect on the mode of compensation, which may be global (one location for the entire installation), by sectors (section-by-section), at load level, or some combination of the last two.
- In principle, the ideal compensation is applied at a point of consumption and at the level required at any instant.



(A) Global compensation:

- **Principle**
- The capacitor bank is connected to the bus bars of the main LV distribution board to compensation of reactive energy of whole installation and it remains in service during the period of normal load.

- **Advantages**
- Reduces the tariff penalties for excessive consumption of kvars.
- Reduces the apparent power kVA demand, on which standing charges are usually based
- Relieves Reactive energy of Transformer , which is then able to accept more load if necessary
- **Limitation:**
- Reactive current still flows in all conductors of cables leaving (i.e. downstream of) the main LV distribution board. For this reason, the sizing of these cables and power losses in them are not improved by the global mode of compensation.
- The losses in the cables (I2R) are not reduced.
- **Application:**
- Where a load is continuous and stable, global compensation can be applied
- No billing of reactive energy.
- This is the most economical solution, as all the power is concentrated at one point and the expansion coefficient makes it possible to optimize the capacitor banks
- Makes less demands on the transformer.

(B) Compensation by sector:

- **Principle:**
- Capacitor banks are connected to bus bars of each local distribution Panel.
- Most part of the installation System can benefits from this arrangement, mostly the feeder cables from the main distribution Panel to each of the local distribution Panel.
- **Advantages:**
- Reduces the tariff penalties for excessive consumption of kvar.
- Reduces the apparent power Kva demand, on which standing charges are usually based.
- The size of the cables supplying the local distribution boards may be reduced, or will have additional capacity for possible load increases.
- Losses in the same cables will be reduced.
- No billing of reactive energy.
- Makes less demands on the supply Feeders and reduces the heat losses in these Feeders.
- Incorporates the expansion of each sector.
- Makes less demands on the transformer.
- Remains economical
- **Limitation:**
- Reactive current still flows in all cables downstream of the local distribution Boards.
- For the above reason, the sizing of these cables, and the power losses in them, are not improved by compensation by sector
- Where large changes in loads occur, there is always a risk of overcompensation and consequent overvoltage problems.
- **Application:**
- Compensation by sector is recommended when the installation is extensive, and where the load/time patterns differ from one part of the installation to another.
- This configuration is convenient for a very widespread factory Area, with workshops having different load factors.

(C) Individual compensation:

- **Principle**
- Capacitors are connected directly to the terminals of inductive circuit (Near to motors). Individual compensation should be considered when the power of the motor is significant with respect to the declared power requirement (kVA) of the installation.
- The kvar rating of the capacitor bank is in the order of 25% of the kW rating of the motor.
- Complementary compensation at the origin of the installation (transformer) may also be beneficial.
- Directly at the Load terminals Ex. Motors, a Steady load gives maximum benefit to Users.

- The capacitor bank is connected right at the inductive load terminals (especially large motors). This configuration is well adapted when the load power is significant compared to the subscribed power. This is the technical ideal configuration, as the reactive energy is produced exactly where it is needed, and adjusted to the demand.
- **Advantages**
- Reduces the tariff penalties for excessive consumption of kvars
- Reduces the apparent power kVA demand
- Reduces the size of all cables as well as the cable losses.
- No billing of reactive energy
- From a technical point of view this is the ideal solution, as the reactive energy is produced at the point where it is consumed. Heat losses (RI2) are therefore reduced in all the lines.
- Makes less demands on the transformer.
- **Limitation:**
- Significant reactive currents no longer exist in the installation.
- Not recommended for Electronics Drives.
- Most costly solution due to the high number of installations.
- The fact that the expansion coefficient is not incorporated.
- **Application:**
- Individual compensation should be considered when the power of motor is significant with respect to power of the installation.

Common Capacitor Reactive Power Ratings:

Voltage	Kvar Rating	Number of Phases
216	5, 7.5, 131/3, 20, 25	1 or 3
240	2.5, 5, 7.5,10, 25, 20, 25, 50	1 or 3
480	5, 10, 15, 20 25, 35, 50, 60, 100	1 or 3
600	5, 10, 15, 20 25, 35, 50, 60, 100	1 or 3
2,400	50, 100, 150, 200	1
2,770	50, 100, 150, 200	1
7,200	50, 100, 150, 200,300,400	1
12,470	50, 100, 150, 200,300,400	1
13,800	50, 100, 150, 200,300,400	

- The following formula will give the actual current drawn by a capacitor at a voltage and frequency other than the rated.
- **IM = IN (Us x Fs)/UN x FN.**
- UN = Capacitor rated voltage Us = System voltage IM = Measure capacitor current IN = Capacitor rated current FN = Capacitor rated frequency Fs= System Frequency.

Chapter: 66 Type of Overhead Conductors

Properties of Overhead Bare Conductors:

- Current Carrying Capacity
- Strength
- Weight
- Diameter
- Corrosion Resistance
- Creep Rate
- Thermal Coefficient of Expansion
- Fatigue Strength
- Operating Temperature
- Short Circuit Current/Temperature
- Thermal Stability
- Cost

Categories of Overhead Conductors:

1) Homogeneous Conductors:

- Copper
- AAC(All Aluminum Conductor)
- AAAC (All Aluminum Alloy Conductor)
- The core consists of a single strand identical to the outer strands. Since all the strands are the same diameter, one can show that the innermost layer always consists of 6 strands, the second layer of 12 strands, etc., making conductors having 1, 7, 19, 37, 61, 91, or 128 strands.

2) Non-Homogeneous Conductors:

- ACAR (Aluminum Conductor Alloy Reinforced)
- ACSR (Aluminum Conductor Steel Reinforced)
- ACSS (Aluminum Conductor Steel Supported)
- AACSR (Aluminum Alloy Conductor Steel Reinforced.
- The strands in the core may or may not be of the same diameter. In a 30/7
- ACSR conductor the aluminum and steel strands are of the same diameter. In a 30/19
- ACSR they are not. Within the core or within the outer layers, however, the number of strands always increases by 6 in each succeeding layer. Thus, in 26/7 ACSR, the number of layers in the inner layer of aluminum is 10 and in the outer layer 16

Categories of Overhead Conductors

- VR (Vibration Resistance)
- Non-Specular
- ACSR / SD (Self Damping)

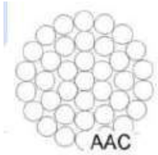
Choices of overhead depend upon:

- **Power Delivery Requirements**
- Current Carrying Capacity
- Electrical Losses
- **Line Design Requirements**
- Distances to be Spanned
- Sag and Clearance Requirements
- **Environmental Considerations**
- Ice and Wind Loading
- Ambient Temperatures

Type of Overhead Conductor:

1) AAC (All Aluminum Conductors)

- AAC is made up of one or more strands of hard drawn 1350 Aluminum Alloy.
- AAC has had limited use in transmission lines and rural distribution because of the long spans utilized.
- Good Conductivity -61.2% IACS
- Good Corrosion Resistance
- High Conductivity to Weight Ratio.
- Moderate Strength

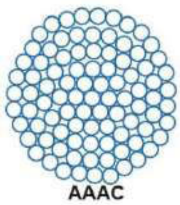


Typical Application

- Short spans where maximum current transfer is required.
- The excellent corrosion resistance of aluminum has made AAC a conductor of choice in coastal areas.
- Because of its relatively poor strength-to-weight ratio, AAC has seen extensive use in urban areas where spans are usually short but high conductivity is required.
- These conductors are used in low, medium and high voltage overhead lines.

2) AAAC (All Aluminum Alloy Conductors)

- AAAC are made out of high strength Aluminum-Magnesium-Silicon alloy.
- AAAC with different variants of electrical grade Alloys type 6101 and 6201.
- These conductors are designed to get better strength to weight ratio and offers improved electrical characteristics, excellent sag-tension characteristics and superior corrosion resistance when compared with ACSR.
- Equivalent aluminum alloy conductors have approximately the same ampacity and strength as their ACSR counterparts with a much improved strength-to-weight ratio, and also exhibit substantially better electrical loss characteristics than their equivalent single layer ACSR constructions. The thermal coefficient of expansion is greater than that of ACSR.
- As compared to conventional ACSR, lighter weight, comparable strength & current carrying capacity, lower electrical losses and superior corrosion resistance have given AAAC a wide acceptance in the distribution and transmission lines.



Features

- High strength to weight ratio
- Better sag characteristics
- Improved electrical properties
- Excellent resistance to corrosion

Specifications

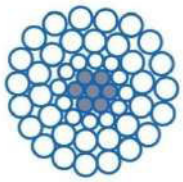
- Higher Tensile Strength
- Excellent Corrosion Resistance
- Good Strength to Weight Ratio
- Lower Electrical Losses
- Moderate Conductivity –52.5% IACS

Typical Application

- Transmission and Distribution applications in corrosive environments, ACSR replacement.

3) ACAR (Aluminum Conductor Al. Alloy Reinforced)

- Aluminum Conductor Alloy Reinforced (ACAR) is formed by concentrically stranded Wires of Aluminum 1350 on high strength Aluminum-Magnesium-Silicon (AlMgSi) Alloy core.
- The number of wires of Aluminum 1350 & AlMgSi alloy depends on the cable design.
- Even though the general design comprises a stranded core of AlMgSi alloy strands, in certain cable constructions the wires of AlMgSi Alloy strands can be distributed in layers throughout the Aluminum 1350 strands.
- ACAR has got a better mechanical and electrical properties as compared to an equivalent conductors of ACSR,AAC or AAAC.
- A very good balance between the mechanical and electrical properties therefore makes ACAR the best choice where the ampacity , strength , and light weight are the main consideration of the line design.
- These conductors are extensively used in overhead transmission and distribution lines.



Features

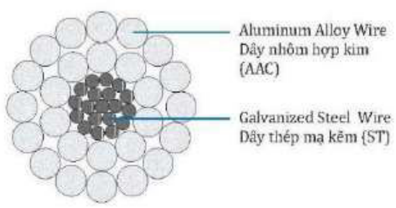
- Improved strength to weight ratio
- Improved mechanical properties
- Improved electrical properties
- Excellent resistance to corrosion Specifications
- Balance of Mechanical & Electrical
- Excellent Corrosion Resistance
- Variable Strength to Weight Ratio
- Higher Conductivity than AAAC
- Custom Designed, diameter equivalent to ACSR most common.

Typical Application

- Used for both transmission and distribution circuits.

4) AACSR - Aluminum Alloy Conductor Steel Reinforced

- AACSR is a concentrically stranded conductor composed of one or more layers of Aluminum-Magnesium-Silicon alloy wire stranded with a high-strength coated steel core.
- The core may be single wire or stranded depending on the size. Core wire for AACSR is available with Class A, B or C galvanizing; or aluminum clad (AW).
- Additional corrosion protection is available through the application of grease to the core or infusion of the complete cable with grease

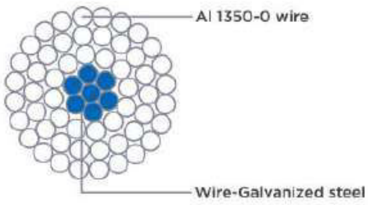


Features

- Offers optimal strength for line design
- Improved strength to weight ratio
- Ideal for extra long spans and heavy load conditions
- Excellent resistance to corrosion

5) ACSS - Aluminum Conductors Steel Supported.

- ACSS is a composite concentric-lay stranded conductor with one or more layers of hard drawn and annealed 1350-0 aluminum wires on a central core of steel.
- In an ACSS, under normal operating conditions, the mechanical load is mainly derived from the steel core as aluminum in fully annealed stage does not contribute much towards the mechanical strength.
- Steel core wires are protected from corrosion by selecting an appropriate coating of the wire like galvanizing, mischmetal alloy coating or aluminum clad. The type of coating is selected to suit the environment to which the conductor is exposed and operating temperature of the conductor
- ACSS are suitable for operating at high temperature without losing the mechanical properties.
- The final sag-tension performance is not affected by the long term creep of aluminum.

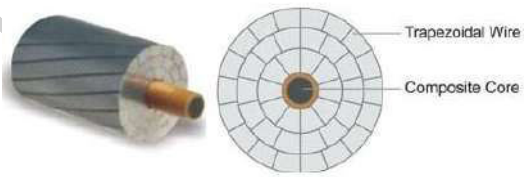


Features

- Improved conductivity
- High current carrying capacity
- Very low sag at high temperature
- High degree of immunity to vibration fatigue
- Better self damping property

6) ACCC - Aluminum Conductor Composite Core

- Aluminum Conductor Composite Core (ACCC) is a concentrically stranded conductor with one or more layers of trapezoidal shaped hard drawn and annealed 1350-0 aluminum wires on a central core of high strength Carbon and glass fiber composite.
- The ACCC Conductor uses a carbon fiber core that is 25% stronger and 60% lighter than a traditional steel core.
- This allows with the help of trapezoidal shaped strands the ability to increase the conductor's aluminum content by over 28% without increasing the conductor's overall diameter or weight.



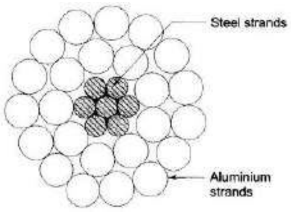
Features

- Excellent Sag properties
- Increased current carrying capacity
- High operating temperature
- Excellent strength to weight ratio
- Highly energy efficient.

7) ACSR (Aluminum Conductor Steel Reinforced)

- Aluminum Conductor Steel Reinforced (ACSR) is concentrically stranded conductor with one or more layers of hard drawn 1350-H19 aluminum wire on galvanized steel wire core.
- The core can be single wire or stranded depending on the size.
- Steel wire core is available in Class A, B or Class C galvanization for corrosion protection.
- Additional corrosion protection is available through the application of grease to the core or infusion of the complete cable with grease.

- The proportion of steel and aluminum in an ACSR conductor can be selected based on the mechanical strength and current carrying capacity demanded by each application.
- ACSR conductors are recognized for their record of economy, dependability and favorable strength / weight ratio. ACSR conductors combine the light weight and good conductivity of aluminum with the high tensile strength and ruggedness of steel.
- In line design, this can provide higher tensions, less sag, and longer span lengths than obtainable with most other types of overhead conductors.
- The steel strands are added as mechanical reinforcements.
- ACSR conductors are recognized for their record of economy, dependability and favorable strength / weight ratio.
- ACSR conductors combine the light weight and good conductivity of aluminum with the high tensile strength and ruggedness of steel.
- In line design, this can provide higher tensions, less sag, and longer span lengths than obtainable with most other types of overhead conductors.
- The steel strands are added as mechanical reinforcements.
- The cross sections above illustrate some common stranding.
- The steel core wires are protected from corrosion by galvanizing.
- The standard Class A zinc coating is usually adequate for ordinary environments.
- For greater protection, Class B and C galvanized coatings may be specified.
- The product is available with conductor corrosion resistant inhibitor treatment applied to the central steel component.



Features

- High Tensile strength
- Better sag properties
- Economic design
- Suitable for remote applications involving long spans
- Good Ampacity
- Good Thermal Characteristics
- High Strength to Weight Ratio
- Low sag
- High Tensile Strength

Typical Application

- Commonly used for both transmission and distribution circuits.
- Compact Aluminum Conductors, Steel Reinforced (ACSR) are used for overhead distribution and transmission lines.

Trap Wire Constructions

- **AAC/TW**: (Trapezoidal Shaped 1350-H19 Aluminum Strands)
- **ACSR/TW:** (Trapezoidal Shaped 1350-H19 Aluminum Conductor -Galvanized –Zinc or AW Coated Steel Core Wires)
- **ACSS/TW:** (Trapezoidal Shaped 1350-O Aluminum Conductor-Zinc –5% Mischmetal Aluminum Alloy or AW Coated Steel Core wires)
- **Comparison of ACSR/TW Type Number with Equivalent Stranding of ACSR**

Type Number	Conventional ACSR Stranding
3	36/1
5	42/7
6	18/1
7	45/7

8	84/19
10	22/7
13	54/7
13	54/49
13	24/7
16	26/7

- The equivalent stranding is that stranding of conventional ACSR that has the same area of aluminum and steel as a given ACSR/TW type. The ACSR/TW type number is the approximate ratio of the area of steel to the area of aluminum in percent.

a) ACSR/AS - Aluminum Conductor, Aluminum Clad Steel Reinforced

- ACSR/AS or ACSR/AWare concentrically stranded conductors with one or more layers of hard drawn 1350-H19 aluminum wires on Aluminum Clad steel wire core.
- The core can be single wire or stranded depending on the size.
- The mechanical properties of ACSR/AS conductors are similar to ACSR conductors but offers improved ampacity and resistance to corrosion because of the presence of aluminum clad steel wires in the core.
- These conductors are better replacement for ACSR conductors where corrosive conditions are severe.

Features

- Good mechanical properties
- Improved electrical characteristics
- Excellent corrosion resistance
- Better Sag properties

b) ACSS/AW - Aluminum Conductors –Aluminum Clad Steel Supported

- ACSS/AW or ACSS/AS is a composite concentric-lay stranded conductor with one or more layers of hard drawn and annealed 1350-0 aluminum wires on a central core of aluminum clad steel core.
- In an ACSS/AW ,under normal operating conditions, the mechanical load is mainly derived from the steel core as aluminum in fully annealed stage does not contribute much towards the mechanical strength.
- Aluminum Clad steel has got an excellent resistance towards corrosion.
- ACSS/AW are can be safely operated upto 250oC continuously without losing the mechanical properties.
- The final sag-tension performance is not affected by the long term creep of aluminum.

Features

- Improved conductivity
- High current carrying capacity
- Suitable for high temperature
- Excellent corrosion resistance
- Very low sag at high temperature
- High degree of immunity to vibration fatigue
- Better self damping property

c) ACSR/TW – Trapezoidal Shaped 1350-H19 wire Aluminum Conductor, Steel-Reinforced

- Shaped Wire Compact Concentric-Lay-Stranded Aluminum Conductor, Steel-Reinforced (ACSR/TW) is a concentrically stranded conductor , made with trapezoidal shaped 1350-H19 wires over a high strength steel core.
- There are two possible design variants. In one case ACSR/TW conductors are designed to have an equal aluminum cross sectional area as that of a standard ACSR which results in a smaller conductor diameter maintaining the same ampacity level but reduced wind loading parameters.
- In the second design, diameter of the conductor is maintained to that of a standard ACSR which results in a significantly lower conductor resistance and increased current rating with the same conductor diameter.
- manufactures ACSR/TW with Galvanized steel (in Class A, Class B & Class C), Zn-5Al mischmetal coated steel or Aluminum clad steel core

Features

- High Tensile strength
- Better sag properties
- Reduced drag properties
- Low wind and ice loading parameters

- suitable for remote applications involving long spans

d) ACSS/TW - Shaped Wire Aluminum Conductors Steel Supported

- Shaped Wire Compact Concentric-Lay-Stranded Aluminum Conductor, Steel-Supported (ACSS/TW) is a concentrically stranded conductor with one or more layers of trapezoidal shaped hard drawn and annealed 1350-0 aluminum wires on a central core of steel.
- ACSS/TW can either be designed to have an equal aluminum cross sectional area as that of a standard ACSS which results in a smaller conductor diameter maintaining the same ampacity level but reduced wind loading parameters or with diameter equal to that of a standard ACSS which results in a significantly higher aluminum area, lower conductor resistance and increased current rating.
- ACSS/TW is designed to operate continuously at elevated temperatures, it sags less under emergency electrical loadings than ACSR/TW, excellent self-damping properties, and its final sags are not affected by long-term creep of aluminum.
- ACSS/TW also provides many design possibilities in new line construction: i.e., reduced tower cost, decreased sag, increased self-damping properties, increased operating temperature and improved corrosion resistance.
- The coating of steel core is selected to suit the environment to which the conductor is exposed and operating temperature of the conductor

Features

- High Operating temperature
- Improved current carrying capacity
- Better sag properties
- Excellent self-damping properties
- Reduced drag properties .Low wind and ice loading parameters

Decide Number of Conductor and Layer of Conductor:

- If N: number of conductors [strands], d: Diameter of strands,X: number of layers.
- Usually the relation between N&X take as followed.
- **N= 3X2-3X+1**
- If N is given we can used the above relation get X, then we can get the total Diameter of cable as
- **dT= (2X-1)d.**
- If Total Number of Conductor (N)=19 Than 19=3x2-3x+1. So Number of Layer (x)=3
- Than Diameter of Cable dT = (2x-1)d =5d

What is the history behind the ACSS/TW Product?

- In 1974, Reynolds Metals patented the ACSS conductor design. Its original name was Steel Supported Aluminum Conductor (SSAC). The original patents have expired and the product is now known as ACSS. There are currently three major North American conductor manufacturers that offer ACSS products both round wire and trapezoidal wire (TW).
- The TW enhancement to ACSS was transferred from existing technology developed for ACSR (Aluminum Conductor Steel Reinforced) and AAC (All Aluminum Conductor) TW conductors. ACSS/TW is typically manufactured to meet the aluminum cross-sectional area of a standard round conductor, but allows the overall diameter to be reduced by approximately 10 percent. ACSS/TW can also be manufactured to meet the existing diameter of a standard conductor, incorporating 20 percent to 25 percent more aluminum cross-sectional area.

What does ACSS or ACSS/TW look like?

- From the outside, ACSS and ACSS/TW conductors look like traditional ACSR. All are manufactured with steel cores and aluminum outer strands. The key difference is that the ACSR aluminum is made from hard drawn aluminum, while ACSS uses soft aluminum (i.e. annealed, or "O" temper). In the ACSS/TW trapezoidal conductor, the aluminum strands are not round but trapezoidal shaped.

What is so special about using annealed aluminum strands:

- Both ACSR and ACSS conductors are made from two different metals-aluminum and steel. Consequently, the composite conductor behavior is determined by the combined electrical and mechanical properties of the two materials that make up the conductor. Although ACSR and ACSS are made with 1350 alloy aluminum, their electrical and mechanical properties are very different.

- Electrically, the conductivity of hard drawn aluminum in ACSR is 61.2 percent; whereas, soft aluminum has a conductivity of 63 percent relative to copper (100 percent). This means that the soft aluminum in ACSS is more efficient at transporting power. Mechanically, the tensile strength (resistance to breaking) of hard drawn aluminum in ACSR is approximately three times that of soft aluminum. This means that the aluminum in ACSS conductor contributes much less to the overall strength, and the composite conductor behaves more like steel.

What are the consequences of elevated conductor temperature on ACSR:

- When ACSR conductors are operated at temperatures in excess of approximately 93 C, the aluminum starts to anneal. The annealing weakens the conductor and can potentially cause the conductor to break under high wind or ice conditions. To prevent this from happening, utilities generally limit conductor temperatures to 75 C for an ACSR conductor.
- ACSS/TW and ACSS conductors are manufactured using soft (annealed) aluminum, where operation at higher temperatures has no further effect on the aluminum's tensile strength. Compared to regular ACSR, predictable installation parameters can be calculated for the ACSS/TW conductors to take into consideration the sag and tension performance at the higher temperatures.

What is the temperature rating of ACSS:

- The original temperature limit of 200 C has been
- in existence for almost 30 years and has proven itself. This was based on a 245 C temperature limit established by steel core manufacturers for the galvanized coating of the steel. Operation of the ACSS product at higher temperature (e.g. 250 C) warrants the use of an enhanced type of galvanizing, which provides more durable high temperature endurance performance (Misch Metal-zinc/aluminum alloy coating). Another option for high temperatures is aluminum clad steel.

How high can the operating temperature realistically go:

- Theoretically, the 250 C rating would provide the ability to carry more power through transmission lines. However, the question must be asked, "Is it wise to operate an electrical system at that high of a temperature?"
- The amount of electrical current passing through the conductor combined with environmental conditions determines the operating temperature of the conductor. Electrical current causes the following:
- A) The higher the current, the hotter the conductor and the greater the power losses. Ideally, lines are designed to minimize these power losses and keep normal day-to-day power loads well below the 200 C operating temperature limits.
- B) The hotter the conductor, the more it will sag and to compensate, the use of larger and/or stronger structures would be required.
- C) Electrical current also passes through the conductor joints (splices) and end fittings (dead ends), forming "weak links" that can mechanically and electrically fail because of overheating. Conductor supports and insulators also become more susceptible to failure. To sum things up, pushing the temperature limit to 250 C remains an unproven condition.

What are the best applications for use of the ACSS and ACSS/TW products:

- System reliability issues push the need for the use of ACSS. Utilities are being pressured to demonstrate system reliability. The ACSS/TW conductor could enable a tremendous emergency load carrying capability that the utility could call upon when needed.
- Cyclic Loads and Peak Demand can be accommodated using ACSS/TW because it can operate at temperatures higher than ACSR. ACSS/TW enables utilities to plan for future situations of increased power requirements because ACSS/TW has power carrying capacity already built into the system.
- Utilities can also turn to ACSS products in situations where they need additional power capacity along existing right-of-ways, but are facing the environmental challenges of building new lines. The ACSS/TW reconductoring option may be the only solution available to upgrade lines with minimal changes along existing routes.

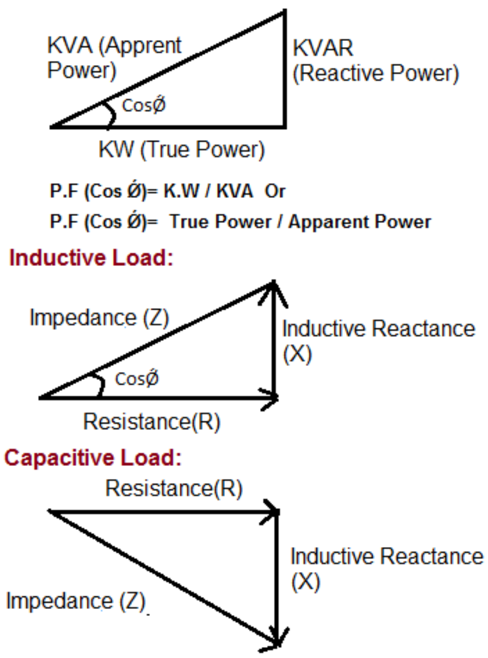
References:

- Maharashtra State Elect Company, General Cables, Phoenix Wire and Cable Corp, G L Prasad, CME Wires and Cables, Wellington Service Centre.

Chapter: 67 what is Power Factor

Introduction:

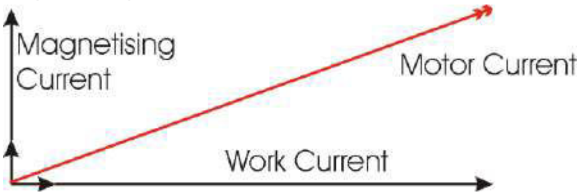
- Power factor is the ratio between the KW and the KVA drawn by an electrical load where the KW is the actual load power and the KVA is the apparent load power. It is a measure of how effectively the current is being converted into useful work output and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system.
- All current flow causes losses both in the supply and distribution system. A load with a power factor of 1.0 results in the most efficient loading of the supply. A load with a power factor of say 0.8 results in much higher losses in the supply system and a higher bill for the consumer. A comparatively small improvement in power factor can bring about a significant reduction in losses **since losses are proportional to the square of the current.**
- When the power factor is less than one the 'missing' power is known as reactive power which unfortunately is necessary to provide a magnetizing field required by motors and other inductive loads to perform their desired functions. Reactive power can also be interpreted as wattles, magnetizing or wasted power and it represents an extra burden on the electricity supply system and on the consumer's bill.
- A poor power factor is usually the result of a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or a distorted current waveform. A poor power factor is generally due to an inductive load such as an induction motor, a power transformer, and ballast in a luminary, a welding set or an induction furnace. A distorted current waveform can be the result of a rectifier, an inverter, a variable speed drive, a switched mode power supply, discharge lighting or other electronic loads.A poor power factor due to inductive loads can be improved by the addition of power factor correction equipment, but a poor power factor due to a distorted current waveform requires the addition harmonic filters.
- Some inverters are quoted as having a power factor of better than 0.95 when, in reality, the true power factor is between 0.5 and 0.75. The figure of 0.95 is based on the cosine of the angle between the voltage and current but does not take into account that the current waveform is discontinuous and therefore contributes to increased losses.
- An inductive load requires a magnetic field to operate and in creating such a magnetic field causes the current to be out of phase with the voltage (the current lags the voltage). Power factor correction is the process of compensating for the lagging current by creating a leading current by connecting capacitors to the supply.



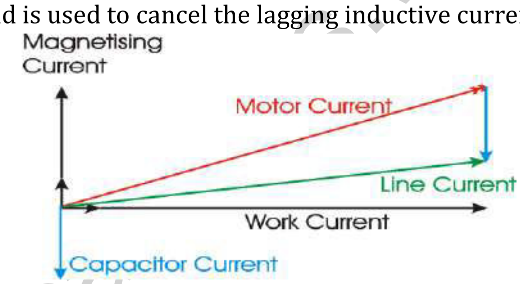
- **KW is Working Power (also called Actual Power or Active Power or Real Power).**
- It is the power that actually powers the equipment and performs useful work.
- **KVAR is Reactive Power: It** is the power that magnetic equipment (transformer, motor and relay)needs to produce the magnetizing flux.
- **KVA is Apparent Power:** It is the "vectorial summation" of KVAR and KW.

Displacement Power Factor Correction.

- An induction motor draws current from the supply that is made up of resistive components and inductive components. The resistive components are (1) Load current (2) Loss current and the inductive components are (1) Leakage reactance (2) Magnetizing current.



- The current due to the leakage reactance is dependent on the total current drawn by the motor, but the magnetizing current is independent of the load on the motor. **The magnetizing current will typically be between 20% and 60% of the rated full load current of the motor.** The magnetizing current is the current that establishes the flux in the iron and is very necessary if the motor is going to operate.
- The magnetizing current does not actually contribute to the actual work output of the motor. It allows the motor to work properly. The magnetizing current and the leakage reactance can be considered passenger components of current that will not affect the power drawn by the motor, but will contribute to the power dissipated in the supply and distribution system.
- Take for example a motor with a current draw of 100 Amps and a power factor of 0.75 the resistive component of the current is 75 Amps and this is what the KWh meter measures. The higher current will result in an increase in the distribution losses of (100 x 100) /(75 x 75) = 1.777 or a 78% increase in the supply losses.
- In the interest of reducing the losses in the distribution system, power factor correction is added to neutralize a portion of the magnetizing current of the motor. Typically, the corrected power factor will be 0.92 to 0.95
- Power factor correction is achieved by the addition of capacitors in parallel with the connected motor circuits and can be applied at the starter, or applied at the switchboard or distribution panel. The resulting capacitive current is leading current and is used to cancel the lagging inductive current flowing from the supply.



Displacement Static Correction (Static Compensation).

- As a large proportion of the inductive or lagging current on the supply is due to the magnetizing current of induction motors, it is easy to correct each individual motor by connecting the correction capacitors to the motor starters.
- With static correction, it is important that **the capacitive current is less than the inductive magnetizing current of the induction motor.** In many installations employing static power factor correction, the correction capacitors are connected directly in parallel with the motor windings.
- When the motor is Off Line, the capacitors are also Off Line. When the motor is connected to the supply, the capacitors are also connected providing correction at all times that the motor is connected to the supply. This removes the requirement for any expensive power factor monitoring and control equipment.
- In this situation, the capacitors remain connected to the motor terminals as the motor slows down. An induction motor, while connected to the supply, is driven by a rotating magnetic field in the stator which induces current into the rotor. When the motor is disconnected from the supply, there is for a period of time, a magnetic field associated with the rotor. As the motor decelerates, it generates voltage out its terminals at a frequency which is related to its speed.
- The capacitors connected across the motor terminals, form a resonant circuit with the motor inductance. If the motor is critically corrected, (corrected to a power factor of 1.0) the inductive reactance equals the capacitive reactance at the line frequency and therefore the resonant frequency is equal to the line frequency. If the motor is over corrected, the resonant frequency will be below the line frequency. If the frequency of the voltage generated by the decelerating motor passes through the resonant frequency of the corrected motor, there will be high

currents and voltages around the motor/capacitor circuit. This can result in severe damage to the capacitors and motor. It is imperative that motors are never over corrected or critically corrected when static correction is employed.

- **Static power factor correction should provide capacitive current equal to 80% of the magnetizing current,** which is essentially the open shaft current of the motor.
- The magnetizing current for induction motors can vary considerably. Typically, magnetizing currents for large **two pole machines can be as low as 20% of the rated current of the motor while smaller low speed motors can have a magnetizing current as high as 60% of the rated full load current of the motor**
- Where the open shaft current cannot be measured, and the magnetizing current is not quoted, an approximate level for the maximum correction that can be applied can be calculated from the half load characteristics of the motor. It is dangerous to base correction on the full load characteristics of the motor as in some cases, motors can exhibit a high leakage reactance and correction to 0.95 at full load will result in over correction under no load, or disconnected conditions.
- Static correction is commonly applied by using on e contactor to control both the motor and the capacitors. It is better practice to use two contactors, one for the motor and one for the capacitors. Where one contactor is employed, it should be up sized for the capacitive load. The use of a second contactor eliminates the problems of resonance between the motor and the capacitors.

How Capacitors Work

- Induction motors, transformers and many other electrical loads require magnetizing current (kvar) as well as actual power (kW). By representing these components of apparent power (kVA) as the sides of a right triangle, we can determine the apparent power from the right triangle rule: kVA2 = kW2 + kVAR2.
- To reduce the kva required for any given load, you must shorten the line that represents the kvar. This is precisely what capacitors do. By supplying kvar right at the load, the capacitors relieve the utility of the burden of carrying the extra kvar. This makes the utility transmission/distribution system more efficient, reducing cost for the utility and their customers. The ratio of actual power to apparent power is usually expressed in percentage and is called power factor.

What Causes Low Power Factor:

- Power factor is defined as the ratio of KW to KVA, we see that low power factor results when KW is small in relation to KVA. Inductive loads. Inductive loads (which are sources of Reactive Power) include:

1. Transformers
2. Induction motors
3. Induction generators (wind mill generators)
4. High intensity discharge (HID) lighting

- These inductive loads constitute a major portion of the power consumed in industrial complexes.
- Reactive power (KVAR) required by inductive loads increases the amount of apparent power (KVA) in your distribution system .This increase in reactive and apparent power results in a larger angle (measured between KW and KVA). Recall that, as increases, cosine (or power factor) decreases.

Why We Improve Power Factor:

- We need to improve power factor for several different reasons. Some of the benefits of improving your power factor include:

1) Lower utility fees by:

- **(a) Reducing peak KW billing demand:**
- Inductive loads, which require reactive power, caused your low power factor. This increase in required reactive power (KVAR) causes an increase in required apparent power (KVA), which is what the utility is supplying. So, a facility's low power factor causes the utility to have to increase its generation and transmission capacity in order to handle this extra demand.
- By lowering your power factor, you use less KVAR. This results in less KW, which equates to a dollar savings from the utility.
- **(b) Eliminating the power factor penalty:**
- Utilities usually charge customers an additional fee when their power factor is less than 0.95. (In fact, some utilities are not obligated to deliver electricity to their customer at any time the customer's power factor falls below 0.85.) Thus, you can avoid this additional fee by increasing your power factor.

2) Increased system capacity and reduced system losses in your electrical system

- By adding capacitors (KVAR generators) to the system, the power factor is improved and the KW capacity of the system is increased.
- For example: 1000 KVA transformer with an 80% power factor provides 800 KW (600 KVAR) of power to the main bus.
- By increasing the power factor to 90%, more KW can be supplied for the same amount of KVA.
- 1000 KVA = (900 KW)2 + (? KVAR)2
- KVAR = 436
- The KW capacity of the system increases to 900 KW and the utility supplies only 436 KVAR.
- Uncorrected power factor causes power system losses in your distribution system. By improving your power factor, these losses can be reduced. With the current rise in the cost of energy, increased facility efficiency is very desirable. And with lower system losses, you are also able to add additional load to your system.

3) Increased voltage level in your electrical system and cooler, more efficient motors

- As mentioned above, uncorrected power factor causes power system losses in your distribution system. As power losses increase, you may experience voltage drops. Excessive voltage drops can cause overheating and premature failure of motors and other inductive equipment. So, by raising your power factor, you will minimize these voltage drops along feeder cables and avoid related problems. Your motors will run cooler and be more efficient, with a slight increase in capacity and starting torque.

Automatic Power Factor Correction (APFC) Panel for PF Improving:

1. Please check if required kVAr of capacitors are installed.
1. Check the type of capacitor installed is suitable for application or the capacitors are de rated.
2. Check if the capacitors are permanently 'ON'. The Capacitor are not switched off
3. When the load is not working, under such condition the average power factor is found to be lower side.
4. Check whether all the capacitors are operated in APFC depending upon the load operation.
5. Check whether the APFC installed in the installation is working or not. Check the CT connection is taken from the main incomer side of transformer, after the fix compensation of transformer.
6. Check if the load demand in the system is increased.
7. Check if power transformer compensation is provided.

Thumb Rule for Size of Capacitor (if HP is known).

- The compensation for motor should be calculated taking the details from the rating plate of motor Or
- **the capacitor should be rated for 1/3 of HP**

Required Capacitor For Transformer Compensation:

Transformer	Required Capacitor (Kvar)
<= 315 KVA T.C	5% of KVA
315kVA To 1000 kVA	6% of KVA
>= 1000 kVA	8% of KVA

Where to connect capacitor:

- Fix compensation should be provided to take care of power transformer. Power and distribution transformers, which work on the principle of electro-magnetic induction, consume reactive power for their own needs even when its secondary is not connected to any load. The power factor will be very low under such situation.
- To improve the power factor it is required to connect a fixed capacitor or capacitor bank at the LT side of the Transformer. For approximate kVAr of capacitors required
- If the installation is having various small loads with the mixture of large loads then the APFC should be recommended. Note that **APFC should have minimum step rating of 10% as smaller step.**
- If loads are small then the capacitor should be connected parallel to load. The connection should be such that whenever the loads are switched on the capacitor also switches on along with the load.
- Note that APFC panel can maintain the power factor on L.T side of transformer and it is necessary to provide fix compensation for Power transformer.
- In case there is no transformer in the installation, then the C.T for sensing power factor should be provided at the incoming of main switch of the plant.

Calculation for Required Capacitor:

- Suppose Actual P.F is 0.8, Required P.F is 0.98 and Total Load is 516KVA.
- Power factor = kwh / kvah
- **kW = kVA x Power Factor**
- kW = 516 x 0.8 = 412.8
- **Required capacitor = kW x Multiplying Factor**
- Required capacitor= (0.8 x 516) x Multiplying Factor
- Required capacitor = 412.8 x 0.547 (See Table to find Value according to P.F 0.8 to P.F of 0.98)
- **Required capacitor = 225.80 kVar**

Multiplying factor for calculating KVAR											
					Target PF						
0.6	**0.9**	**0.91**	**0.92**	**0.93**	**0.94**	**0.95**	**0.96**	**0.97**	**0.98**	**0.99**	**1**
0.6	0.849	0.878	0.907	0.938	0.970	1.005	1.042	1.083	1.130	1.191	1.333
0.61	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.157	1.299
0.62	0.781	0.810	0.839	0.870	0.903	0.937	0.974	1.015	1.062	1.123	1.265
0.63	0.748	0.777	0.807	0.837	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.716	0.745	0.775	0.805	0.838	0.872	0.909	0.950	0.998	1.058	1.201
0.65	0.685	0.714	0.743	0.774	0.806	0.840	0.877	0.919	0.966	1.027	1.169
0.66	0.654	0.683	0.712	0.743	0.775	0.810	0.847	0.888	0.935	0.996	1.138
0.67	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.966	1.108
0.68	0.594	0.623	0.652	0.683	0.715	0.750	0.787	0.828	0.875	0.936	1.078
0.69	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.907	1.049
0.7	0.536	0.565	0.594	0.625	0.657	0.692	0.729	0.770	0.817	0.878	1.020
0.71	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.452	0.481	0.510	0.541	0.573	0.608	0.645	0.686	0.733	0.794	0.936
0.74	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.371	0.400	0.429	0.460	0.492	0.526	0.563	0.605	0.652	0.713	0.855
0.77	0.344	0.373	0.403	0.433	0.466	0.500	0.537	0.578	0.626	0.686	0.829
0.78	0.318	0.347	0.376	0.407	0.439	0.474	0.511	0.552	0.599	0.660	0.802
0.79	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.634	0.776
0.8	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.608	0.750
0.81	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.556	0.698
0.83	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.530	0.672
0.84	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85	0.135	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86	0.109	0.138	0.167	0.198	0.230	0.265	0.302	0.343	0.390	0.451	0.593
0.87	0.082	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88	0.055	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89	0.028	0.057	0.086	0.117	0.149	0.184	0.221	0.262	0.309	0.370	0.512
0.9		0.029	0.058	0.089	0.121	0.156	0.193	0.234	0.281	0.342	0.484
0.91			0.030	0.060	0.093	0.127	0.164	0.205	0.253	0.313	0.456
0.92				0.031	0.063	0.097	0.134	0.175	0.223	0.284	0.426
0.93					0.032	0.067	0.104	0.145	0.192	0.253	0.395
0.94						0.034	0.071	0.112	0.160	0.220	0.363
0.95							0.037	0.078	0.126	0.186	0.329

Testing of Capacitor at Site:

Measurement of Voltage:

- Check the voltage using multimeter at capacitor terminals.
- The current output of 440 volt capacitor connected to a system of 415 volt will be lesser than rated value.
- Table no -1 & 2give you the resultant kVAr output of the capacitor due to variation in supply voltage.
- The kVAr of capacitor will not be same if voltage applied to the capacitor and frequency changes. The example given below shows how to calculate capacitor current from the measured value at site.
- **Example :**
- Name plate details:15kVAr, 3 phases, 440v, and 50Hz capacitor.
- Measured voltage : 425v , Measured frequency - 48.5Hz
- **Kvar = (fM / fR) x (VM / VR)2 x kvar**
- Kvar = (48.5/50) x (425 / 440)**2** x 15 = 13.57kVAr.
- Name plate details: 15kVAr, 3 phases, 415v, and 50Hz capacitor.
- Measured voltage : 425v, Measured frequency - 48.5Hz
- Kvar = (fM / fR) x (VM / VR)**2** x KVAR= (48.5/50) x (425 / 415)**2** x 15= 15.26 KVAR

Three Phase 440V Capacitor				
kVAr 440V	**Line current 440V**	**kVAr at 415V**	**Line Current at 415V**	**Measured capacitance across two terminals with third terminal open.(Micro farad) 440V**
5	6.56	4.45	6.188	41.10
7.5	9.84	6.67	9.28	61.66
10	13.12	8.90	12.38	82.21
12.5	16.4	11.12	15.47	102.76
15	19.68	13,34	18.56	123.31
20	26.24	17.79	24.75	164.42
25	32.80	22.24	30.94	205,52

Three Phase 415V Capacitor				
kVAr 415V	**Line current 415V**	**kVAr at 440V**	**Line Current at 415V**	**Measured capacitance across two terminals with third terminal open.(Micro farad) 415V**
5	6.55	5.62	7.38	46.21
7.5	10.43	8.43	11.06	69.31
10	13.91	11.24	14.75	92.41
12.5	17.39	14.05	18.44	116.51
15	20.87	16.86	22.13	138.62
20	27.82	22.48	29.50	184.82
25	34.78	38.10	36.88	231.03

Measurement of Current:

- The capacitor current can be measured using Multi meter.
- Make a record of measurement data of individual phase and other parameter.
- Check whether the current measured is within the limit value with respect to supply voltage & data given in the name plate of capacitor Refer formulafor calculation
- Formula for calculating rated current of capacitor with rated supply voltage and frequency.
- **l = KVAR x 103 / (3 X V(L-L))**
- **Example:** 15kVAr, 3 phase, 440v, 50Hz capacitor.
- l = KVAR x 10**3** / (3 X V(L-L)) = (15 x 1000) / (1.732 x 440) = 19.68 Amp
- 15KVAR, 3 phases, 415v, 50Hz capacitor
- l = KVAR x 10**3** / (3 X V(L-L)) = (15 x 1000) / (1.732 x 415) = 20.87 Amps

Discharge of Capacitor:

- L.T power capacitors are provided with discharge resistor to discharge the capacitor which is limited to one min. The resistor is provided as per IS 13340.

- Switch off the supply to the capacitor and wait for 1 minute and then short the terminals of capacitor to ensure that the capacitor is completely discharged.
- This shorting of terminals ensures the safety while handling the capacitor
- Discharge of capacitor also becomes necessary for the safety of meter used for capacitance measurement.

Termination and Mounting:

- Ensure that the capacitor is mounted vertically.
- The earthing of capacitor should be done before charging.
- The applied voltage should not exceed more than 10%. Refer technical specification of capacitor.
- The capacitor should be provided with the short circuit protection device as indicated in following Table

KVAr	HRC Fuse	Cable Amps
5	12 Amps	12 Amps
7.5	25 Amps	25 Amps
10	32 Amps	32 Amps
12.5	32 Amps	32 Amps
15	50 Amps	50 Amps
20	50 Amps	50 Amps
25	63 Amps	63 Amps
50	125 Amps	125 Amps
75	200 Amps	200 Amps
100	200 Amps	250 Amps

Use of capacitor in APFC panel

- Once the capacitor is switched off it should not be switched on again within 60 seconds so that the capacitor is completely discharged. The switching time in the relay provided in the APFC panel should be set for 60 seconds for individual steps to discharge as per IS 13340.
- If the capacitor is switched manually or if you are switching capacitors connected in parallel with each other then "ON" delay timer (60sec) should be provided.
- The capacitor mounted in the panel should have min gap of 25-30 mm between the capacitor and 50 mm around the capacitor to the panel enclosure.
- In case of banking a min gap of 25mm between the phase to phase and 19mm between the phases to earth should be maintained. Ensure that the banking bus bar is rated for 1.8 times rated current of bank.
- The panel should have provision for cross ventilation, the louver / fan as per IS 13340.
- For use of reactor and filter in the panel fan should be provided for cooling.
- Short circuit protection device (HRC fuse / MCCB) should not exceed **1.8 x rated current of capacitor.**
- In case of detuned filter banks MCCB is recommended for short circuit protection.

Chapter: 68 11KV/415V Overhead Line Specification as per REC

1) 11KV LIGHTNING ARRESTER (IS: 3070 (Pt-II)).

- **Voltage Rating:**
- The rated voltage of lightning arresters shall be 9 KV (rms).
- This will be applicable to the effectively earthed 11 KV systems co-efficient of earth not exceeding 80 percent as per IS: 4004 with all the transformer neutrals directly earthed.
- **Normal Discharge Current Rating:** 5 KA.
- **Tests:**
- The following routine and type tests as laid down in IS : 3070 (Part-I) shall be carried out.
- Routine Test: Dry Power frequency spark over test.
- Type Tests (Confirmation) :
  1. Voltage withstands tests of arrester insulation.
  2. Power frequency spark over test
  3. Hundred percent 1.2/550 microsecond impulse spark over test
  4. Front-of-wave impulse spark over test.
  5. Residual voltage test.
  6. Impulse current withstand test.
  7. Operating duty test.
  8. Temperature cycle test on porcelain housing.
  9. Porosity test on porcelain components.
  10. Galvanizing test on metal parts.

2) 11 KV Drop Out Fuse Cut Outs (IS: 9385 (part-I to III).)

- The distribution fuse cut outs shall be outdoor, open, drop-out expulsion type fuse cut-outs suitable for installation in 50 Hz, 11 KV distribution system.
- The rated voltage shall be 12 KV.
- The rated current shall be 100 A.

1) Rated Lighting Impulse withstands Voltage:

- To earth and between poles 75 KV (Peak)
- Across the isolating distance of fuse base 86 KV (Peak)

2) Rated One Minute Power Frequency Withstand Voltage (Wet & Dry)

- To earth and between poles 28 KV (rms)
- Across the isolating distance 32 KV (rms)

3) Temperature Rise Limit:

- Copper contacts silver faced 650C
- Terminals 500C
- Metal parts acting as spring The temperature shall not reach such a value that Elasticity of the metal is changed
- **Rated Breaking Capacity:** The rated breaking capacity shall be 8 KA (Asymmetrical).

4) Construction Details:

- The cut outs shall be of single vent type (downward) having a front connected fuse carrier suitable for angle mounting.
- All ferrous parts shall be hot dip galvanized in accordance with the latest version of IS : 2632. Nuts and bolts shall conform to IS : 1364. Spring washers shall be electro-galvanized.

5) Fuse Base Top Assembly:

- The top current carrying parts shall be made of a highly conductive copper alloy and the contact portion shall be silver plated for corrosion resistance and efficientcurrent flow.
- The contact shall have a socket cavity for latching and holding firmly the fuse carrier until the fault interruption is completed within the fuse.
- The top assembly shall have an aluminium alloy terminal connector. The top assembly shall be robust enough to absorb bulk of the forces during the fuse carrier closing and opening operations and shall not over-stress the spring contact. It shall also prohibit accidental opening of the fuse carrier due to vibrations orimpact.

6) Fuse Base Bottom Assembly:

- The conducting parts shall be made of high strength highly conductive copper alloy and the contact portion shall be silver plated for corrosion resistance and shall provide a low resistance current path from the bottom fuse carrier contacts to the bottom terminal connector.

7) Fuse Carrier Top Assembly:

- The fuse carrier top contact shall have a solid replaceable cap made from highly conductive, anticorrosive copper alloy and the contact portion shall be silverplated to provide a low resistance current path from the Fuse Base Top Contact to the Fuse Link.
- It shall make a firm contact with the button head of the fuse link and shall provide a protective enclosure to the fuse link to check spreading of arc during fault interruptions.
- The fuse carrier shall be provided with a cast bronze opening eye (pull ring) suitable for operation with a hook stick from the ground level to pull-out or close-in the fuse carrier by manual operation.

8) Fuse Carrier Bottom Assembly:

- The fuse carrier bottom assembly shall be made of bronze castings with silver plating at the contact points to efficiently transfer current to fuse base.
- It shall make smooth contact with the fuse base bottom assembly during closing operation. The bottom assembly shall have a lifting eye for the hook stick for removing or replacing the fuse carrier.

9) Fuse Base (Porcelain):

- The fuse base shall be a bird-proof, single unit porcelain insulator with a creepage distance (to earth) not less than 320 mm. The top and bottom assemblies as also the middle clamping hardware shall be either embedded in the porcelain insulator with sulphur cement or suitably clamped in position.
- For embedded components, the pull out strength should be such as to result in breaking of the porcelain before pull out occurs in a test. For porcelain insulators, the beam strength shall not be less than 1000 kg.

10)Fuse Tube:

- The fuse tube shall be made of fiber glass coated with ultraviolet inhibitor on the outer surface and having arc quenching bone fire liner inside.
- The tube shall have high burstingstrength to sustain high pressure of the gases during fault interruption.
- The inside diameter of the fuse tube shall be 17.5 mm. The solid cap of the fuse carrier shall clamp the button head of the fuse link, closing the top end of the fuse and allowing only the downward venting during faultinterruption.

11)Type Tests (IS: 9385 Part I & II):

- Dielectric tests
- Temperature rise test

12)Mounting Arrangement:

- The cutouts shall be provided with a suitable arrangement for mounting these on 74 X 40 mm or 100 X 50 mm channel cross arm in such a way that the center line of the base is at an angle of15 to 20 deg from the vertical and shall provide the necessary clearances from the support.
- Mounting arrangement shall be made of high strength galvanized steel flat and shall be robust enough to sustain the various stresses encountered during all operating conditions of the cutout.

3) 11 KV Porcelain Insulators (IS: 731 and IS: 3188):

- The porcelain shall be sound, free form defects, through verified and smoothly glazed. Unless otherwise specified, the glaze shall be brown color.
- The glaze shall cover all the porcelain parts of insulators except those areas which serve as support during firing are left unglazed for the purpose of assembly.
- The design of insulators shall be such that stresses due to expansion and contraction in any part of the insulator shall not lead to deterioration.
- The porcelain shall not engage directly with hard metal. Cement used in construction of insulators shall not cause fracture by expansion or loosening by contraction and proper care shall be taken to locate the individual parts correctly during cementing.
- The cement shall not give rise to chemical reaction with metal fittings and its thickness shall be as uniform as possible.
- The insulators should preferably be manufactured in automatic temperature controlled kilns to obtain uniform baking for better electrical and mechanical properties.
- Both pin and strain insulators shall conform to Type B of IS : 731. The strain insulators shall be of Tongue and Clevis type.

1) Test Voltage:

- Highest System Voltage : 12 KV (rms)
- Visible Discharge Test: 9 KV (rms)
- Wet Power Frequency Withstand Test 35 KV (rms)
- Power Frequency Puncture Withstand Test (Pin Insulator) : 105 KV (rms)
- Power Frequency Puncture Withstand Test (Strain Insulator):1.3 times the actual dry flashover voltage of the insulator.
- Impulse Voltage Withstand Test : 75 KV (rms)

2) Failing Load:

- Mechanical Failing Load (For Pin Insulators only) : The insulators shall be suitable for a minimum failing load of 10 KN applied in transverse director.
- Electro-Mechanical Failing Load (For Strain Insulators) : The insulators shall be suitable for a minimum failing load of 70 KN applied axially.

3) Creepage Distance:

- Highest System Voltage: 12KV
- Heavily Polluted Atmosphere Pin Insulator: 320mm
- Heavily Polluted Atmosphere Strain Insulator: 400mm

4) Tests: (As per IS: 731).

1. Visual examination
2. Verification of dimensions
3. Visible discharge test
4. Impulse Voltage withstand Test
5. Wet Power Frequency Voltage withstand Test
6. Temperature Cycle Test
7. Mechanical Failing Load Test
8. 24 hour Mechanical Strength Test for Strain Insulators
9. Puncture Test
10. Porosity Test
11. Galvanizing Test
12. Electro-Mechanical Failing Load Test

5) Routine Tests

1. Virtual examination
2. Mechanical routine test
3. Electrical routine test

6) Acceptance Test

1. Verification of Dimensions
2. Temperature Cycle Test
3. Electro-Mechanical Failing Load Test
4. Puncture Test
5. Porosity Test
6. Galvanizing Test

7) Marking:

- Name or trademark of manufacturer
- Month and year of manufacture
- Minimum failing load in KN
- ISI certificate mark, if any
- Markings on porcelain shall be printed and shall be supplied before firing.

4) Pin Insulators:

- The pins shall of single piece obtained preferably by the process of forging.
- They shall not be made by joining, welding, shrink fitting or any other process using more than one piece material. The pins shall be of good finish, free from flaws and other defects.

- The finish of the collar shall be such that sharp angle between the collar and the shank is avoided. Aluminium ferrous pins, nuts and washers, except those made of stainless steel, shall be galvanized. The threads of nuts and taped hole when cut after galvanizing shall be well oiled or greased.

1) Dimensions:

- Pins shall be of small steel head type S 165 P as per IS : 2486 (Part-II) having stalk length of 165 mm and shank length of 150 mm with minimum failing load of 10 KN.

2) Tests: (IS: 2486 (Part-I))

- Checking of threads on heads
- Galvanizing test
- Visual examination test
- Mechanical test
- Galvanizing test
- Mechanical test
- Visual examination test

3) Helically Formed Pin Insulator Ties:

- Helically formed ties used for holding the conductor on the pin insulator shall be made of aluminum alloy or aluminized steel or aluminum clad steel wires and shall conform to the requirements of IS : 12048. The ties shall be suitable for pin insulator dimensions of Pt.- I and conductor sizes specified.
- Elastomer pad for insulator shall be used with the ties to avoid abrasion of the conductor coming into direct contact with the insulator.

4) Cross arm strap conforming to IS: 2486 (Pt. – II).

- Aluminum alloy die cast thimble-clevis for attaching to the tongue of strain, insulator on one end and for accommodating the loop of the helically formed dead-end fitting at the other end in its smooth internal contour.
- The thimble shall be suitable for all sizes of ACSR conductors as specified. The thimble clevis shall be attached to the insulator by a steel cutting pin used with a non-ferrous split pin of brass or stainless steel.
- The thimble shall have clevis dimensions as per IS: 2486 (Pt – II).
- Helically formed dead end grip having a prefabricated loop to fit into the grooved contour of the thimble on one end and for application over the conductor at the other end.
- The formed fitting shall conform to the requirement of IS: 12048.

5) Fittings for strain Insulators of Ball & Socket Type:

- Cross arm strap conforming to IS: 2486 (Pt-II).
- Forged steel ball eye for attaching the socket end of the strain insulator to the cross arm strap.
- Forgings shall be made of steel as per IS: 2004. Aluminum alloy thimble-socket made out of permanent mould cast, high strength aluminum alloy for attaching to the strain insulator on one end and for accommodating the loop of the helically formed dead-end fittings at the other end in its smooth internal contour.
- The thimble socket shall be attached to the strain insulator with the help of locking pin as per the dimensions given in IS: 2486 (Pt-II).

6) Fittings for Strain Insulators of Tongue & Clevis Type

- The fittings shall consist of the following components:
- Cross arm strap conforming to IS:2486 (Pt.II)-1989.
- Aluminum alloy die cast thimble-clevis for attaching to the tongue of strain insulator on one end and for accommodating the loop of the helically formed dead-end fitting at the other end in its smooth internal contour. The thimble shall be suitable for all sizes of conductors ranging from 7/2.11mm to 7/3.35mm ACSR. The thimble clevis shall be attached tothe insulator by a steel cutter pin used with a non-ferrous split pin of brass or stainless steel. The thimble shall have clevis dimensions as per IS:2486 (Pt.II)-1989.
- Helically formed dead-end grip having a pre-fabricated loop to fit into the grooved contour of the thimble on one end and for application over the conductor at the other end. The formed fitting shall conform to the requirement ofIS:12048-1987.
- Note: As the helically formed fittings are made to suit specific sizes of conductors, the purchase should clearly specify the number of fittings required for each size of conductor

7) Fittings for strain Insulators with Conventional Dead end Clamps Alternative to Fitting Covered:

- Fittings for strain insulators with conventional dead-end clamps for use with tongue & clevis or ball & socket type insulators shall consist of the following components :

- Cross arms strap conforming to IS:2486 (Pt.II)-1989
- Dead-end clamp made of aluminum alloy to suit ACSR conductors from 7/2.11mm to 7/3.35mm. The ultimate strength of the clamp shall not be less than 3000 Kg. The shape and major dimensions of clamps suitable for B&S and T&C insulators are shown in figures 7 & 8 respectively.

5) Guy Strain Insulators (IS: 5300)

- The porcelain insulator shall be sound, free from defects, thoroughly verified and smoothly glazed.
- The design of the insulator shall be such that the stresses to expansion and contraction in any part of the insulator shall not lead to its deterioration.
- The glaze, unless otherwise specified, shall be brown in color.
- The glaze shall cover the entire porcelain surface parts except those areas that serve as supports during firing.

1) Type of Insulators:

- The standard guy strain insulators shall be designations 'A' and 'C' as per IS: 5300.
- The recommended type of guy strain insulators for use on guy wires of overhead lines of different voltage levels are as follows:
- Power Line Voltage :11KV
- Designation of Insulators: C
- Dry one minute Power Frequency withstand Voltage: 27 KV (rms)
- Wet one minute Power Frequency withstand Voltage: 13 KV (rms)
- Minimum Failing Load: 88(KN)

2) Tests: (IS: 5300).

- Visual examination
- Verification of dimensions
- Temperature cycle test
- Dry one-minute power frequency voltage withstand test
- Wet one-minute power frequency voltage withstand test
- Mechanical strength test
- Porosity test
- Acceptance Tests : (to be conducted in the following order)
- Verification of dimensions
- Temperature cycle test
- Mechanical strength test
- Porosity test

3) Marking:

- Name or trademark of the manufacturer.
- Year of manufacture.
- ISI certificate mark, if any
- Marking on porcelain shall be applied before firing.

4) Type of Insulators:

- The standard guy strain insulators shall be of designations 'A' and 'C' as per IS:5300.
- The recommended type of guy strain insulators for use on guy wires of overhead lines of different voltage levels are as follows :

Line Voltage	Designation of Insulator
415/240Volt	A Type
11KV	C Type
33KV	C Type (2 No's of Strings in Series).

5) Basic Insulator Level:

Designation of Insulator	Dry one min power frequency withstand	Wet one min power frequency withstand
A Type	18 KV (rms)	8 KV (rms)
C Type	27 KV (rms)	13 KV (rms)

6) Mechanical Strength:

- The insulators shall be suitable for the minimum failing loads specified as under:

Designation of Insulator	Minimum Failing Load
A Type	44 KN
C Type	88 KN

7) Routine Test : (IS 5300)

- Visual examination
- Verification of dimensions
- Temperature cycle test
- Dry one-minute power-frequency voltage withstand test
- Wet one-minute power frequency voltage withstand test
- Mechanical strength test
- Porosity test

8) Acceptance Tests: (IS 5300)

- Verification of dimensions
- Temperature cycle test
- Mechanical strength test
- Porosity test

6) Danger Notice Plates:

- As per provisions of IE Rules 1956, Danger Notice Plates in Hindi or English and, in addition, in the local language with the sign of skull and bones are required to be provided on power line supports and other installations. It is further stipulated in the I.E. Rules that such Notice Plates are not required to be provided on supports like PCC, tubular, wood, steel rails, etc. which cannot be climbed easily without the aid of ladder or special appliances.
- To adopt a uniform pattern and for helping easy procurement, a specification on Danger Notice Plates has been drawn up.

1) Standards: The Danger Notice Plates shall comply with IS:2551-1982.

2) Dimensions

- Two sizes of Danger Notice Plates as follows are recommended:
- For display at 415 V installations - 200x150mm
- For display at 11 KV (or higher voltages) installations - 250x200mm
- The corners of the plate shall be rounded off.
- The location of fixing holes as shown in Figs. 1 to 4 is provisional and can be modified to suit the requirements of the purchaser.

3) Lettering

- All letterings shall be centrally spaced. The dimensions of the letters, figures and their respective position shall be as shown in figs.
- The size of letters in the words in each language and spacing between them shall be so chosen that these are uniformly written in the space earmarked for them.

4) Languages

- Under Rule No. 35 of Indian Electricity Rules, 1956, the owner of every medium, high and extra high voltage installation is required to affix permanently in a conspicuous position a danger notice in Hindi or English and, in addition, in the local language, with the sign of skull and bones.
- The type and size of lettering to be done in Hindi is indicated in the specimen danger notice plates shown in Fig. 2 and 4 and those in English are shown in Figs.
- Adequate space has been provided in the specimen danger notice plates for having the letterings in local language for the equivalent of' Danger',' 415' '11000' and 'Volts'.

5) Material & Finishing:

- The plate shall be made from mild steel sheet of at least 1.6mm thick and vitreous enameled white, with letters, figures and the conventional skull and cross-bones in signal red color (refer IS:5-1978) on the front side. The rear side of the plate shall also be enameled.

6) Tests:

- The following tests shall be carried out :
- Visual examination as per IS:2551-1982
- Dimensional check as per IS:2551-1982

- Test for weather proofless as per IS:8709-1977 (or its latest version)

7) ACSR and AAC over head conductors:

- A Conference on Standardization of Specifications and Construction Practices in Rural Electrification was held on 4th and 5th January, 1971 in New Delhi. Besides the Rural Electrification Corporation, representatives of various State Electricity Boards, the Indian Standards Institution (BIS), Central Water & Power Commission (CEA), Central Board of Irrigation and Power and many other organizations participated in the discussions.
- Based on the consensus arrived at the Conference, REC Specification No. 1/1971 covering 7/2.21 mm (25 mm2 aluminum area) and 7/3.10mm (50mm2 aluminum area) AAC for use on LT lines and 7/2.59 mm (30mm2 aluminum area) and 7/3.35mm (50mm2 aluminum area) ACSR for use on 11 KV and LT lines was issued.
- Subsequently, the Specification was revised to incorporate an additional size of ACSR viz 7/2.11mm (20mm2 aluminum area) for use on 11 KV and LT lines and then again to incorporate three more sizes of ACSR viz. 7/3.35mm (50mm2 aluminum area), 7/4.09mm (80mm2 aluminum area) and 6/4.72mm + 7/1.57 mm (100mm2 aluminum area) for use on 33 KV lines.

1) Scope:

- This Specification covers the details of the conductors for use on 33 KV, 11 KV and LT overhead lines in rural electric distribution systems.
- The sizes of conductors standardized for lines of different voltages are indicated below :

2) 33KV Lines

- ACSR 7/3.35mm (50mm2 aluminum area)
- ACSR 7/4.09 mm (80mm2 aluminum area)
- ACSR 6/4.72 mm + 7/1.57 mm (100mm2 aluminum area)

3) 11 KV Lines

- ACSR 7/2.11 mm (20mm2 aluminum area)
- ACSR 7/2.59 mm (30mm2 aluminum area)
- ACSR 7/3.35 mm (50mm2 aluminum area)

4) LT Lines

- ACSR 7/2.11 mm (20mm2 aluminum area)
- ACSR 7/2.59 mm (30mm2 aluminum area)
- ACSR 7/3.35 mm (50mm2 aluminum area)
- AAC 7/2.21 mm (25mm2 aluminum area)
- AAC 7/3.10 mm (50mm2 aluminums area)

5) Joint in Wires & Conductors:

- All aluminums conductors: No joints shall be permitted in any wire.
- Aluminum Conductor Steel Reinforced :

6) Aluminum Wires:

- No two joints shall occur in the aluminums wires closer together than 15 meters.

7) Steel Wires:

- No joints shall be permitted in steel wires used for ACSR of Sizes 20mm2 aluminums area (7/2.11mm), 30mm2 aluminums area (7/2.59mm), 50mm2 aluminums area (7/3.35mm) and 80mm2 aluminums area (7/4.09 mm).
- In the case of ACSR of 100mm2 aluminums area (6/4.72mm + 7/1.57 mm) having seven galvanized steel wires, joints, in individual wires shall be permitted but no two such joints shall be less than 15 meters apart in the complete steel core.

8) Tests:

- The samples of individual wires for the tests shall normally be taken before stranding. The manufacturer shall carry out test on samples taken out at least from 10% of aluminums wire spools and 10% of steel wire coils. However, when desired by the purchaser, the test sample may be taken from the stranded wires.
- The wires used for all aluminums conductors shall comply with the following tests as per IS: 398.
- Breaking load test / Wrapping test / Resistance test
- The wires used for aluminums conductors, steel reinforced shall comply with the following tests as per IS:398
- Breaking load test / Ductility test / Wrapping test / Resistance test / Galvanizing test

9) Packing & Marking :(IS: 1778-1980)

- The gross mass for various conductors shall not exceed by more than 10% of the values given in the following

10) Conductor Size Gross Mass

- **AAC**
- 25mm2 Al. area (7/2.21 mm) 500 Kg.
- 50mm2 Al. area (7/3.10 mm) 500 Kg.
- **ACSR**
- 20mm2 Al. area (7/2.11 mm) 1000 Kg.
- 30mm2 Al. area (7/2.59 mm) 1000 Kg.
- 50mm2 Al. area (7/3.35 mm) 1500 Kg.
- 80mm2 Al. area (7/4.09 mm) 1500 Kg.
- 100mm2 Al. area (6/4.72mm + 7/1.57mm) 2000 Kg.

11) Conductor Size Normal conductor length

- **AAC**
- 25mm2 Al. area (7/2.21mm) 1.0 Km.
- 50mm2 Al. area (7/3.10mm) 1.0 Km.
- **ACSR**
- 20mm2 Al. area (7/2.11 mm) 2.0 Km.
- 30mm2 Al. area (7/2.59 mm) 2.0 Km.
- 50mm2 Al. area (7/3.35 mm) 2.0 Km.
- 80mm2 Al. area (7/4.09 mm) 1.5 Km.
- 100mm2 Al. area (6/4.72mm + 7/1.57mm) 2.0 Km.
- Longer lengths shall be acceptable.
- Short lengths, not less than 50% of the standard lengths, shall be acceptable to the maximum extent of 10% of the quantity ordered.

12) Marking:

- The following information shall be marked on each package:
- Manufacturers' name / Trade mark, if any / Drum or identification number / Size of conductor
- Number and lengths of conductor / Gross mass of the package / Net mass of conductor
- I.S.I certification mark, if any

8) Prestressed Cement Concrete Poles (F.O.S. 2.5) For 11 KV & LT Lines:

- A research project for evolving economical designs of cement concrete poles for use on 11 KV and LT Lines was entrusted to the Cement Research Institute (CRI) of India.
- The basic design parameters for these poles as given in Clause 6 of this Specification were approved by the Fifth Conference on standardization of Specifications and Construction Practices in Rural Electrification held in May, 1974.
- Some of these design parameters which were based on certain foreign codes/practices and certain other provisions of this Specification, although at variance with the stipulations of **IS:1678-** 1960, had been adopted to achieve economy in the designs. However, these modifications have since been incorporated in the revised IS:1678 - 1978.
- This Specification covers PCC poles with an overall length of 7.5 M, 8.0 M and 9.0 M suitable for use in overhead 11 KV and L.T. power lines and double pole structures for 11/0.4 KV substations.

Application Standard:

- **IS: 1678-1978**, Specification for pre stressed concrete poles for overhead power, traction and telecommunication lines.
- **IS: 2905-1966**. Methods of test for concrete poles for over-head power and telecommunication lines.
- **IS: 7321-1974**. Code of practice for selection, handling and erection of concrete poles for over-head power and telecommunication lines.

Average Permanent Load

- That fraction of the working load which may be considered of long duration over a period of one year.

Load Factor

- The ratio of ultimate transverse load to the transverse load at first crack.

Transverse

- The direction of the line bisecting the angle contained by the conductor at the pole. In the case of a straight run, this will be normal to the run of the line.

Transverse Load at First Crack

- For design, the transverse load at first crack shall be taken as not less than the value of the working load.

Working load

- The maximum load in the transverse direction, that is ever likely to occur, including the wind pressure on the pole.
- This load is assumed to act at a point 600 mm below the top with the butt end of the pole planted to the required depth as intended in the design.

Ultimate Failure

- The conditions existing when the pole ceases to sustain a load increment owing to either crushing of concrete, or snapping of the pre stressing tend on or permanent stretching of the steel in any part of the pole.

Ultimate Transverse Load

- The load at which failure occurs, when it is applied at a point 600 mm below the top and perpendicular to the axis of the pole along the transverse direction with the butt end of the pole planted to the required depth as intended in the design.

Application:

7.5 M and 8.0 M Poles

- These poles shall be used at tangent locations for 11KV and L.T. lines in wind pressure zones of 50 kg/M2, 75 Kg/M2 and 100 Kg/M2 in accordance with REC Construction Standards referred to in the following:

Pole length: 7.5M

- 11KV lines without earth wire L.T. lines, horizontal formation.
- Reference to REC Construction Standards: A-4, B-5

Pole length: 8M

- 11KV lines with earth wire L.T. lines, vertical formation.
- Reference to REC Construction Standards: A-5, B-6

9.0 M Poles

- These poles shall be used for double pole structures of distribution transformer centers as per REC Construction Standards F-1 to F-4 and for special locations in 11 KV and L.T. Lines, such as road crossings etc.

Materials:

(1) Cement

- The cement used in the manufacture of pre stressed concrete poles shall be ordinary or rapid hardening portland cement conforming to **IS: 269 – 1976** (Specification for ordinary and low heat port land cement) or **IS: 8041 E-1978** (Specification for rapid hardening port land cement).

(2) Aggregates

- Aggregates used for the manufacture of pre-stressed concrete poles shall conform to **IS : 383 - 1970** (Specification for coarse and fine aggregates from natural sources for concrete). The nominal maximum size of aggregates shall in no case exceed 12mm.

(3) Water

- Water should be free from chlorides, sulphates, other salts and organic matter. Potable water will be generally suitable.

(4) Admixtures

- Admixtures should not contain Calcium Chloride or other chlorides and salts which are likely to promote corrosion of pre-stressing steel.

(5) Pre-stressing Steel

- The pre-stressing steel wires, including those used as un tensioned wires should conform to **IS : 1785 (Part-I) - 1966** (Specification for plain hard drawn steel wire for pre stressed concrete. Part-I cold drawn stress relieved wire), **IS: 1785 (Part-II) - 1967** (Specification for plain hard-drawn steel wire)., or **IS : 6003 - 1970** (Specification for indented wire for pre-stressed concrete).
- The type designs given in Annexure-I are for plain wires of 4 mm diameter with a guaranteed ultimate strength of 175 Kg/mm2.

(6) The concrete mix:

- Itshall be designed to the requirements laid down for controlled concrete (also called design mix concrete) in **IS : 1343 - 1980** (Code of practice for pre stressed concrete) and **IS : 456 - 1978** (Code of practice for plain and reinforced concrete), subject to the following special conditions;
  - a) Minimum works cube strength at 28 days should be at least 420 Kg/cm2.
  - b) The concrete strength at transfer should be at least 210Kg/cm2.

c) The mix should contain at least 380 Kg. of cement per cubic meter of concrete.

d) The mix should contain as low a water content as is consistent with adequate workability. If it becomes necessary to add water to increase the workability, the cement content also should be raised in such a way that the original value of water cement ratio is maintained.

Design Requirements:

- The poles shall be planted directly in the ground with a planting depth of 1.5 meters.
- The working load on the poles should correspond to those that are likely to come on the pole during their service life. Designs given in Annexure-I are for 140 Kg. and 200 Kg. Applied at 0.6 M from top.
- The factor of safety for all these poles shall not be less than 2.5.
- The average permanent load should be 40% of the working load.
- The F.O.S. against first crack load shall be 1.0.
- At average permanent load, permissible tensile stress in concrete shall be 30 Kg/cm2.
- At the design value of first crack load, the modulus of rupture shall not exceed 55.2 kg/cm2 for M-420 concrete.
- The ultimate moment capacity in the longitudinal direction should be at least one fourth of that in the transverse direction.
- The maximum compressive stress in concrete at the time of transfer of pre stress should not exceed 0.8 times the cube strength.
- The concrete strength at transfer shall not be less than half the 28 days strength ensured in the design, i.e. 420 x 0.5= 210 Kg/cm2.
- For model check calculations on the design of poles, referred to in Annexure-I, a reference may be made to the REC "Manual on Manufacturing of solid PCC

Dimensions and Reinforcements:

- The cross-sectional dimensions and the details of pre stressing wire should conform to the particulars given in Annexure-I.
- The provisions of holes for fixing cross-arms and other fixtures should conform to the REC standards referred to in clause 4 of this specification and in accordance with the construction practices adopted by the State Electricity Boards.

Manufacture:

- All pre stressing wires and reinforcements shall be accurately fixed as shown in the drawings and maintained in position during manufacture. The un tensioned reinforcement, as indicated in the drawings, should be held in position by the use of stirrups which should go round all the wires.
- All wires shall be accurately stretched with uniform pre stress in each wire.
- Each wire or group of wires shall be anchored positively during casting. Care shall be taken to see that the anchorages do not yield before the concrete attains the necessary strength.

Cover

- The cover of concrete measured from the outside of the pre stressing tendon shall be normally 20 mm.

Welding & Lapping of Steel:

- The high tensile steel wire shall be continuous over the entire length of the tendon.
- Welding shall not be allowed in any case. However, jointing or coupling may be permitted provided the strength of the joint or coupling is not less than the strength of each individual wire.

Compacting

- Concrete shall be compacted by spinning, vibrating, shocking or other suitable mechanical means. Hand compaction shall not be permitted.

Curing

- The concrete shall be covered with a layer of sacking, canvas, hessian or similar absorbent material and kept constantly wet up to the time when the strength of concrete is at least equal to the minimum strength of concrete at transfer of pre stress. Thereafter, the pole may be removed from the mould and watered at intervals to prevent surface cracking of the unit, the interval should depend on the atmospheric humidity and temperature.

The pre stressing wires

- Itshall be de tensioned only after the concrete has attained the specified strength at transfer (i.e. 210 Kg/cm2). The cubes cast for the purpose of determining the strength at transfer should be cured, as far as possible, under conditions similar to those under which the poles are cured.

- The transfer stage shall be determined based on the daily tests carried out on concrete cubes till the specified strength indicated above is reached. Thereafter the test on concrete shall be carried out as detailed in **IS: 1343 -1960** (Code of practice for pre stressed concrete).
- The manufacturer shall supply when required by the purchaser or his representative, result of compressive test conducted in accordance with **IS : 456 -1964** (Code of practice for plain and reinforced concrete) on concrete cubes made from the concrete used for the poles.
- If the purchaser so desires, the manufacturer shall supply cubes for test purposes and such cubes shall be tested in accordance with **IS: 456 – 1964** (Code of practice for plain and reinforced concrete).
- The de tensioning shall be done by slowly releasing the wires, without imparting shock or sudden load to the poles. The rate of de tensioning may be controlled by any suitable means either mechanical (screw type) or hydraulic.
- The poles shall not be de tensioned or released by cutting the pre stressing wires using flames or bar croppers while the wires are still under tension.

Separate eye-hooks or holes:

- It shall be provided for handling and transport, one each at a distance of 0.15 times the overall length, from either end of the pole.
- Eye-hooks, if provided, should be properly anchored and should be on the face that has the shorter dimension of the cross-section. Holes, if provided for lifting purposes, should be perpendicular to the broad face of the pole.Stacking should be done in such a manner that the broad side of the pole is vertical. Each tier in the stack should be supported on timber sleepers located at 0.15 times the overall length, measured from the end. The timber supports in the stack should be aligned in a vertical line.
- Poles should be transported with their broad faces placed vertically and in such a manner that shocks are avoided. Supports should be so arranged that they are located approx. at a distance equal to 0.15 times the overall length from the ends. The erection of the pole should be carried out in such a way that the erection loads are applied so as to cause moment with respect to the major axis. i.e. the rope used for hoisting the pole should be parallel to the broader face of the pole.

Testing of Pole:

Transverse Strength Test

- Poles made from ordinary Portland cement shall be tested only on the completion of 28 days and poles made from rapid-hardening cement only on the completion of 14 days, after the day of manufacture.
- The pole may be tested in either horizontal or vertical position. If tested in horizontal position, provisions shall be made to compensate for the overhanging weight of the pole, for this purpose the over-hanging portion of the pole may be supported on a movable trolley or similar device.
- The pole shall be rigidly supported at the butt end for a distance equal to the agreed depth of planting i.e. 1.5 M. Load shall be applied at a point 600 mm from the top of the pole and shall be steadily and gradually increased to design value of the transverse load at first crack. The deflection at this load shall be measured.A pre stressed concrete pole shall be deemed not to have passed the test if visible cracks appear at a stage prior to the application of the design transverse load for the first crack.
- The load shall then be reduced to zero and increased gradually to a load equal to the first crack load plus 10% of the minimum ultimate transverse load, and held up for 2 minutes.
- This procedure shall be repeated until the load reaches the value of 80 per cent of the minimum ultimate transverse load and thereafter increased by 5 per cent of the minimum ultimate transverse load until failure occurs. Each time the load is applied, it shall be held for 2 minutes.
- The load applied to pre stressed concrete pole at the point of failure shall be measured to the nearest five Kilograms.
- The pole shall be deemed not to have passed the test if the observed ultimate transverse load is less than the design ultimate transverse load.

Measurement of Pole Cover

- After completion of the transverse strength test, the sample pole shall be taken and checked for cover.
- The cover of the pole shall be measured at 3 points, one within 1.8 meters from the butt end of the pole, the second within 0.6 meter from the top and the third at an intermediate point and the mean value compared with the specified value. The mean value of the measured cover should not differ by more than(±)1 mm from the specified cover. The individual values should not differ by more than (±) 3 mm from specified value. If these

requirements are not met, the workmanship with reference to aligning of the end plates and pre stressing wires and assembly of moulds should be improved and inspection at pre-production stage tightened suitably.

Pole Marking

- The pole shall be clearly and indelibly marked with the following particulars either during or after manufacture but before testing at a position so as to be easily read after erection in position.
  - a) Month and year of manufacture
  - b) Transverse strength of pole in Kg.
  - c) Maker's serial No. and mark

9) Main Points should be look after for Overhead Line Installation:

1) Overhead lines:

- The general precautions during storage and handling of shall be taken in accordance with relevant IS code.
- While laying the conductor shall be taken from top of the drum and the repeated in the direction of arrow on it.. Care shall be taken to avoid contact with steel works, fence, etc by giving soft wood protection, using wooden rollers.
- Proper tools shall be used during stringing work. During stringing operation standard sag table or chart shall be followed and care shall be taken to ensure that there are no kinks in the conductor. Joints in conductors shall be staggered. Mid span joints in conductors shall be avoided.
- After stringing the conductor, it shall be clamped permanently with shackle or strain clamps. An angle or section shall be selected while pulling up conductors.

2) Jumpers:

- While stringing, sufficient length shall of conductors be kept at shackle terminations for making jumpers. Jumpers shall be neat and as far as possible symmetrical to run of conductors. These shall be made to prevent occurrence of faults due to wind or birds. PG clamps may be preferred to binding of conductors at jumper location or service taps.

3) Cross Arms :

- The cross arms shall be made of MS Structural steel. The length of cross arms shall be suitable for accommodating the number of insulators on them with spacing of conductor. A gap of minimum 50 mm shall be left from the centre of pin hole to end of cross arm on either side. The cross arm shall be complete with pole clamp made of MS flat of size not less than 50 x 6 mm with necessary nuts, bolts, washers, etc. The length of cross arm for carrying guard wires shall always run not less than 300 mm beyond outer most bare conductor of configuration.
- Cross arms shall be properly clamped to the support taking into consideration the orientation oflines.

4) Porcelain insulators and fittings:

- The porcelain insulators shall be confirming to IS 731 – 1971 for overhead lines. This shall be glazed, crack / burr free.
- The insulator shall have adequate mechanical strength, high degree of resistance to electricalpuncture and resistance to climatic and atmospheric attack.
- All iron parts shall be hot dip galvanized & all joints shall be airtight. Pin insulators / shackle insulators / disc insulators shall be erected on cross arms and 'D' iron clamp shall be used or as specified by Engineer-in-charge. Shackle insulators shall be used in conjunction with 'D' iron clamps when configuration of conductor is vertical.
- These shall also be erected on cross arm at intermediate support in case of long lines, deviation fromstraight lines. Care shall be taken that insulators are not damaged during erection.

5) Binding material:

- Binding of conductor with the insulator shall be done with soft aluminum wire / conductor. The binding of conductor to insulator shall be sufficiently firm and tight to ensure that no intermittent contact develops. The end of binding wire shall be tightly twisted in close spaced spiral around the conductor to ensuregood electrical contact and strengthen the conductor.

6) Supports and spacing of poles:

- Support of overhead line shall be of adequate strength confirming in all respects to rules 76 of Indian electricity rules. Pole spacing and clearance between lowest conductor above the ground level across / along the street shall be in accordance with rule 85 of Indian electricity rules. Suitable foundation shall be provided for erection of poles.
- The foundation shall include excavation in all types of soil and rocks and back filling, RCC, reinforcement, formwork.Excavation for foundations for poles / stay / strut : After the location of supports / stay are pegged

accurately, the excavation work shall be taken up and care should be taken while excavating that pits are not oversized. The pit should be excavated in the direction of the line. The depth and size of pit shall be such that normally 1/6th of the length of pole is buried in the ground and suitable for foundation of support.

- For stay the position of pit shall normally be such stay makes as large an angle as possiblewith the support and it shall be in the range of 40 to 60 degrees.
- The length of stay rod shall project 450 mm above the ground level. The pit for strut shall be located at a distance not less than 1.8M from the pole.
- The depth of pit shall be such that at least 1.2M of the strut is buried in the ground.

7) Stay / strut:

- Stay set shall consist of stay rod, anchor plate, bow tightened / turn buckle, thimbles, stay wire and stain insulators.
- The stay rod shall be with stay grip in case of turn buckle is used instead of bow tightened. The entire stay set assembly shall be galvanized. The stay wire shall be either 7/4.0 mm diameter or 7/3.15 mm diameter GI having tensile strength of not less than 70 kgf/sq mm and confirming to IS 2141. T
- The anchor plate shall be of MS galvanized and not less than 300 mm x 300 mm x 6.4 mm thick. The stay rod / buckle rods shall be minimum 16/19 mm diameter galvanized steel rod having tensile strength not less than 42 kgf/sq mm. Minimum length of stay rod andbuckle shall be 1800 mm and 450 mm respectively.

8) Erection stay sets:

- The anchor plate shall be galvanized MS plate. The stay rod with anchor plate shall be embedded in cement concrete 1:3:6. A stay shall be provided at all angle and terminal poles. Double stay shall be provided at all dead ends and in such case, these shall be as far as possible to be set parallel to each other.

9) Cage guard:

- All metal supports of overhead lines and metallic fitting attached shall be permanently and effectively earthed. Cage guard / cradle guard shall be made of 6 SWG GI wire confirming to IS 2633 including netting, stretching and jointing of cage and lacing by 10/12 SWG GI wire, binding by 14/16 SWG GI wire.

10)Danger boards:

- All supports carrying HV lines shall be fitted with danger plates confirming to IS 2551 at height of 3 M from ground indicating the voltage of line. Thescript shall be both in 'English/Hindi'.

11)Anti climbing devices:

- Necessary arrangement for preventing unauthorized persons from ascending any of the supports and structure carrying HV lines without the aid of ladder or special appliance shall be made.
- Unless otherwise specified barbed wire confirming to IS 278 having four points barbed spaced 75 +/- 12 mm apart shall be wrapped helically with a pitch of 75 mm around the limb of support and firmly commencing from the height of 3.5 M and upto 5 or 6 M as directed by the engineer.

12)Lightning arrestor:

- Lightning arrestor suitable for HT lines shall be installed one unit per phase at terminations, transformer stations, etc.
- The devices shall be connectedahead of fuse provided if any. Independent earth electrode shall be provided for LA.
- The earth lead from earth electrode to LA shall be continuous. The LA shall confirm to IS 3070 and shall be non linear distribution class.
- The LA shall be non-linear type, distribution class, outdoor type suitable for effectively earthed system. The LA shall consist of line terminal stud, earth terminal stud, number of spark gaps in series with non-linear resistor, the whole assembly housed inside a hermetically sealed porcelain bushing.
- Neoprene rubber gasket shall be provided between metal caps and porcelainbushing. Non-linear resistor shall be silicon carbide blocks metalized at both ends to ensure good electrical contact between terminals, non-linear resistor & spark gaps.
- Mounting bracket shall be hot dip galvanized suitable for mounting LA on structure.

10) Cable Lying Directly in Ground:

- The method shall be adopted where the cable route is through open country, along road / lanes, etc and where no frequent excavations are encountered and re excavation is possible without affecting other work.

1) Width of trenches:

- The width of trench for laying single cable shall be 35 cm Where more than one cable are to be laid in the same trench in horizontal formation, width of trench shall be increased such that the inter-axial spacing between the cables for 415 volts shall be 20 cm and for 11 shall be 35 cm.

2) Depth of trenches:

- Where cables are laid in single formation, the total depth of trench shall not be less than 75 cm for cable up to 1.1 KV grade and shall not be less than 120 cm for cable above 1.1 KV grade. Wherever more than one tier formation is unavoidable and vertical formation is adopted, the depth of trench shall be increased by 30 cm for each additional tier to be formed.

3) Protective covering:

- Cable laid in trenches shall have covering of clean dry sand not less than 170 mm above the base cushion of sand before the protective cover is laid.
- The cables shall be protected by B class/second class brick of not less than 20 cm x 10 cm x 10 cm or protective cover placed on top of the sand and both sides of cable for full length of the cable to the satisfaction of Engineer-in-charge.

4) Back filling:

- The trenches shall be back filled wit excavated earth free from stones or other scrap edged debris and shall be rammed and watered, if necessary, in successive layers not exceeding 300 mm unless otherwise specified.

5) Route marker:

- Route marker shall be provided along straight runs of cables and at points of change in direction as approved by Engineer-in-charge and in general at intervals not exceeding 100 meters in straight run. Route marker shall be made out of 100 mm x 100 mm x 5 mm GI/Al plate bolted or welded on 35 mm x 35 mm x 6 mm MS angle iron of 600 mm long.
- Such route markers shall be mounted and grouted parallel to and 0.5 meter away from the side of trench. The work "cable" with voltage grading and size of cable shall be inscribed on the marker.

Chapter:69 Analysis the Truth behind Household Power Savers

Introduction:

- A Household power saving devices has recently received a lot of attention from both consumers and manufacturers. It is generally used in residential homes to save energy and to reduce electricity bills. It is a small device which is to be plugged in any of the AC sockets in the house (Mostly near Energy Meter). Moreover, some of the companies claim that their power savers save up to 40% of the energy.
- Many people believe that the claims made by the power saver manufacturing companies are false. Almost all people who buy power savers do it to reduce their electricity bills. Many people who have used these power savers said that they could reduce their electricity bills with the devices; however the reduction was not as much as they had expected. Moreover, they could not figure out if the reduction in electricity bills was due to the power savers or because of their efforts to reduce their electrical usage. There have been several serious discussions about the genuineness of the device. In This Note, We will try to find the real truth behind these power savers which claim to save as much as 40% of energy.

Working Principle of Power Saver as per Manufacture:

- A Power Saver is a device which plugs in to power socket. Apparently just by keeping the device connected it will immediately reduce your power consumption. Typical claims are savings between 25% and 40%.
- It is known that the electricity that comes to our homes is not stable in nature. There are many fluctuations, raise and falls, and surges/Spikes in this current. This unstable current cannot be used by any of the household appliances. Moreover, the fluctuating current wastes the electric current from the circuit by converting electrical energy into heat energy. This heat energy not only gets wasted to the atmosphere, but also harms the appliances and wiring circuit.
- **Power Saver stores the electricity inside of it using a system of capacitors** and they release it in a smoother way to normal without the spikes. The systems also automatically remove carbon from the circuit which also encourages a smoother electrical flow. This means that we will have less power spikes. More of the electricity flowing around circuit can be used to power appliances than before. Basically, it is claimed that Power savers work on the principle of surge protection technology. Power savers work on straightening this unstable electric current to provide a smooth and constant output. The fluctuation in voltage is unpredictable and cannot be controlled. However, the power savers utilize current fluctuation to provide a usable power by acting like a filter and allowing only smooth current to pass through the circuit. Power savers use capacitors for this purpose. When there is a surge of current in the circuit, the capacitor of the power saver stores the excess current and releases it when there is a sudden drop. Thus, only smooth output current comes out of the device.
- Moreover, a power saver also removes any type of carbon in the system, which facilitates further smoother flow. The main advantage of power savers is not that they provide a **backup system in times of low current,** but that it protects the household appliances. It is known that a sudden rise in the power can destroy the electrical appliance. Thus, the power saver not only protects the appliance but also increases its life. Moreover, they also reduce the energy consumption and thus the electricity bills.
- The amount of power saved by a power saver depends on the number of appliances on the circuit. Also, the system takes at least a week to adapt itself fully to the circuit, before it starts showing its peak performance. The maximum amount of voltage savings will be seen in areas where in the current fluctuation is the highest.

Household Power Saver Scam Review:

- Power Factor Correction for residential customers (home owners) is a scam? At most, each unit is worth as an investment. Power factor correction does make sense for some commercial / industrial customers.
- Many Companies promoting and advertise that their Power Saver unit are able to save domestic residential power consumption by employing an **"active power factor correction"** method on the supply line. The concept seems pretty impressive as the concept is true and legally accepted. But practically, we will find that it's not feasible.
- To support above statement First we need to understand three terms.
- Type of Electrical Load of House,
- Basic Power Terminology (KW, KVA, KVAR).
- Electrical Tariff method of Electricity Company for Household Consumer and Industrial Consumer.
- There are basically two kinds of load that exists in every house: one that is resistive like incandescent lamps, heaters etc. and the other that's capacitive or inductive like ACs, refrigerators, computers, etc.

- The power factor of a Resistive Load like toaster or ordinary incandescent light bulb is 1 (one). Devices with coils or capacitors (like pumps, fans and florescent light bulb ballasts)-Reactive Load have power factors less than one. When the power factor is less than 1, the current and voltage are out of phase. This is due to energy being stored and released into inductors (motor coil) or capacitors on every AC cycle (usually 50 or 60 times per second).
- There are three terms need to be understood when dealing with alternating (AC) power.
- First Term is kilowatt (kW) and it represents **Real power.** Real power can perform work. **Utility meters on the side of House measure this quantity (Real Power) and Power Company charge for it.**
- The second term is reactive power, measured in KVAR. Unlike kW, it cannot perform work. **Residential customers do not pay for KVAR, and utility meters on houses do not record it too.**
- The third term is apparent power, referred to as KVA. By use of multi meters we can measure current and voltage and then multiply the readings together we get apparent power in VA.
- Power Factor = Real Power (Watts) /Apparent Power (VA),
- Therefore, **Real Power (Watts) = Apparent Power × PF = Voltage × Ampere × PF**.
- Ideally a PF = 1, or unity, for an appliance defines a clean and a desired power consumption mostly Household Equipments (The dissipated output power becomes equal to the applied input power). In the above formula we can see that if PF is less than 1, the amperes (current consumption) of the appliances increase, and vice verse.
- With AC Resistive Load, the voltage is always in phase with the current and constitutes an ideal power factor equal to 1. However, with inductive or capacitive loads, the current waveform lags behind the voltage waveform and is not in tandem. This happens due to the inherent properties of these devices to store and release energy with the changing AC waveform, and this causes an overall distorted wave form, lowering the net PF of the appliance.
- Manufacture claim that the above problem may be solved by installing a well-calculated inductor/capacitor network and switching it automatically and appropriately to correct these fluctuations. A power saver unit is designed exactly for this purpose. This correction is able to bring the level of PF very close to unity, thus improving the apparent power to a great extent. **An improved apparent power would mean less CURRENT consumption by all the domestic appliances**. So far everything looks fine, but what's the use of the above correction? **The Utility Bill Which We pay is never based on Apparent Power (KVA) but it is based on Real Power (KW). The utility bill that we pay is never for the Apparent Power- it's for the Real Power.**
- **By Reducing Current Consumption Does Not Reduce Power Bills of Household Consumer.**

Study of Power Saver in Domestic Load:

- Let us try to study Household's Reactive-Resistive Electrical Load and Voltage Spike Characteristic by example.

(1) Power Saver in Reactive Load of Home:

- Let's take One Example for reactive Load: A refrigerator having a rated Real Power of 100 watts at 220 V AC has a PF = 0.6. So Power=Volt X Ampere X P.F becomes 100 = 220 × A × 0.6 Therefore, A = 0.75 Ampere
- Now suppose after Installing Power Saver if the PF is brought to about 0.9, the above result will now show as: 100 = 220 × A × 0.9 And A = 0.5 Ampere
- In the second expression we clearly show that a reduction in current consumption by the refrigerator, but interestingly in both the above cases, the **Real Power remains the same**, i.e. the refrigerator continues to consume **100 watts,** and therefore the utility bill remains the same. This simply proves that although the PF correction done by an energy saver may decrease the Amperage of the appliances, **it can never bring down their power consumption and the electric Bill amount.**
- Reactive power is not a problem for a Reactive Load of Home appliances like A.C, Freeze, motor for its operation. **It is a problem for the electric utility company when they charge for KW only**. If two customers both use the same amount of real energy but one has a power factor of 0.5, then that customer also draws double the current. This increased current requires the Power Company to use larger transformers, wiring and related equipment. To recover these costs Power Company charged a Penalty to industrial customers for their Low power factors and give them benefits if they improve their Power Factor in. **Residential customers (homes) are never charged extra for their reactive Power.**

(2) Power Saver in Resistive Load of Home:

- Since a resistive load does not carry a PF so there is not any issue regarding filtering of Voltage and Current, So Power = Voltage X Current.

(3) In Voltage Spike/Fluctuation condition of Household Appliances:

- In above discussion simply proves that as long as the voltage and the current are constant, the consumed power will also be constant. However, if there's any rise in the input voltage because of a fluctuation, then as explained above your appliances will be forced to consume a proportionate amount of power. This becomes more apparent because current, being a function of voltage, also rises proportionately. However, this rise in the power consumption will be negligibly small; the following simple math will prove this.

- Consider a bulb consuming 100 watts of power at 220 volts. This simply means at 240 volts it will use up about 109 watts of power. The rise is just of around 9% and since such fluctuations are pretty seldom, this value may be furthermore reduced to less than 1%, and that is negligible.
- Thus the above discussions convincingly prove that energy savers can never work and the concept is not practically feasible.

What happens when Power Saver is installed?

- The Fig shows the result of using Power Saver. The air conditioner (which has a large compressor motor) is still consuming reactive power but it is being supplied by a nearby capacitor (which is what is in those "KVAR" boxes). If you were to mount it at the air conditioner and switch it on with the air conditioner plus you sized the capacitor perfectly, then there would be no reactive power on the line going back to the fuse panel. If the wire between your fuse panels is very long and undersized, reducing the current would result in it running cooler and having a higher voltage at the air conditioner. These savings due to cooler wiring is minimal.
- A further complication is that if you install the "KVAR" unit at the fuse panel, it does nothing for the heat losses except for the two feet of huge wire between the fuse panel and the utility meter. Many KVAR units are marketed as boxes that you install at a single location. If your power factor box is too large, then it will be providing reactive power for something else, perhaps your neighbor.

Conclusion:

- Power factor correction devices improve power quality but do not generally improve energy efficiency (**meaning they would not reduce your energy bill**). There are several reasons why their energy efficiency claims could be exaggerated.
- First, residential customers are not charged for **KVA-hour usage, but by kilowatt-hour usage**. This means that any savings in energy demand will not directly result in lowering a residential user's utility bill.
- Second, the only potential for real power savings would occur if the product were only put near in the circuit while a reactive load (such as a motor) were running, and taken out of the circuit when the motor is not running. This is impractical, given that there are several motors in a typical home that can come on at any time (refrigerator, air conditioner, HVAC blower, vacuum cleaner, etc.), but the Power Saver itself is intended for permanent, unattended connection near the house breaker panel. And certainly not in the way the manufacturers recommend that they be installed, that is, permanently connecting them at the main panel. Doing that drags the power factor capacitive when the inductive motors are off and could create some real problems with ringing voltages.
- The KVAR needs to be sized perfectly to balance the inductive loads. Since our motors cycle on and off and we don't use the air conditioner in the winter, there is no way to get it sized properly unless we have something to monitor the line and switch it on and off capacity (capacitors) as necessary.
- Adding a capacitor can increase the line voltage to dangerous levels because it interacts with the incoming power transmission lines.
- Adding a capacitor to a line that has harmonic frequencies (created by some electronic equipment) on it can result in unwanted resonance and high currents.
- For commercial facilities, power factor correction will rarely be cost-effective based on energy savings alone. The bulk of cost savings power factor correction can offer is in the form of **avoided utility charges for low power factor**. Energy savings are usually below 1% and always below 3% of load, the higher percentage occurring where motors are a large fraction of the overall load of a facility. Energy savings alone do not make an installation cost effective.

Chapter: 70 How Reactive Power Helpful to Maintain a System Healthy

Introduction:

- We always in practice to reduce reactive power to improve system efficiency .This are acceptable at some level. If system is purely resistively or capacitance it make cause some problem in Electrical system. Alternating systems supply or consume two kind of power: real power and reactive power.
- Real power accomplishes useful work while reactive power supports the voltage that must be controlled for system reliability. Reactive power has a profound effect on the security of power systems because it affects voltages throughout the system.
- Find important discussion regarding importance about Reactive Power and how it is useful to maintain System voltage healthy

Importance of Reactive Power:

- Voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse.
- Decreasing reactive power causing voltage to fall while increasing it causing voltage to rise. A voltage collapse may be occurs when the system try to serve much more load than the voltage can support.
- When reactive power supply lower voltage, as voltage drops current must increase to maintain power supplied, causing system to consume more reactive power and the voltage drops further . If the current increase too much, transmission lines go off line, overloading other lines and potentially causing cascading failures.
- If the voltage drops too low, some generators will disconnect automatically to protect themselves. Voltage collapse occurs when an increase in load or less generation or transmission facilities causes dropping voltage, which causes a further reduction in reactive power from capacitor and line charging, and still there further voltage reductions. If voltage reduction continues, these will cause additional elements to trip, leading further reduction in voltage and loss of the load. The result in these entire progressive and uncontrollable declines in voltage is that the system unable to provide the reactive power required supplying the reactive power demands

Necessary to Control of Voltage and Reactive Power:

- Voltage control and reactive power management are two aspects of a single activity that both supports reliability and facilitates commercial transactions across transmission networks.
- On an alternatingcurrent (AC) power system, **voltage is controlled by managing production and absorption of reactive power.**
- There are three reasons why it is necessary to manage reactive power and control voltage.
- First, both customer and powersystem equipment are designed to operate within a range of voltages, usually within±5% of the nominal voltage. At low voltages, many types of equipment perform poorly, light bulbs provide less illumination, induction motors can overheat and be damaged, and some electronic equipment will not operate at. High voltages can damage equipment and shorten their lifetimes.
- Second, reactive power consumes transmission and generation resources. To maximize the amount of real powerthat can be transferred across a congested transmission interface, reactivepower flows must be minimized. Similarly, reactivepower production can limit a generator's realpower capability.
- Third, moving reactive power on the transmission system incurs realpower losses. Both capacity and energy must be supplied to replace these losses.
- Voltage control is complicated by two additional factors.
- First, the transmission system itself is a nonlinear consumer of reactive power, depending on system loading. At very light loading the system generates reactive power that must be absorbed, while at heavy loading the system consumes a large amount of reactive power that must be replaced. The system's reactivepower requirements also dependon the generation and transmission configuration.
- Consequently, system reactive requirements vary in time as load levels and load and generation patterns change. The bulkpower system is composed of many pieces of equipment, any one of which can fail at any time. Therefore, the system is designed to withstand the loss of any single piece of equipment and to continue operating without impacting any customers. That is, the system is designed to withstand a single contingency.The

loss of a generator or a major transmission line can have the compounding effect of reducing the reactive supply and, at the same time, reconfiguring flows such that the system is consuming additional reactive power.

- At least a portion of the reactive supply must be capable of responding quickly to changing reactivepower demands and to maintain acceptable voltages throughout the system. Thus, just as an electrical system requires realpower reserves to respond to contingencies, so too it must maintain reactive-power reserves.
- Loads can also be both real and reactive. The reactive portion of the load could be served from the transmission system. Reactive loads incur more voltage drop and reactive losses in the transmission system than do similar size(MVA) real loads.
- **System operation has three objectives when managing reactive power and voltages.**
- First, it must maintain adequate voltages throughout the transmission and distribution system for both current and contingency conditions.
- Second, it seeks to minimize congestion of realpower flows.
- Third, it seeks to minimize realpower losses.

Basic concept of Reactive Power

1) Why We Need Reactive Power:

- Active power is the energy supplied to run a motor, heat a home, or illuminate an electric light bulb. Reactive power provides the important function of regulating voltage.
- If voltage on the system is not high enough, active power cannot be supplied.
- Reactive power is used to provide the voltage levels necessary for active power to do useful work.
- **Reactive power is essential to move active power through the transmission and distribution system to the customer .Reactive power is required to maintain the voltage to deliver active power (watts) through transmission lines.**
- Motor loads and other loads require reactive power to convert the flow of electrons into useful work.
- When there is not enough reactive power, the voltage sags down and it is not possible to push thepower demanded by loads through the lines."

2) Reactive Power is a Byproduct of AC Systems

- Transformers, Transmission lines, and motors require reactive power. Electric motors need reactive power to produce magnetic fields for their operation.
- Transformers and transmission lines introduce inductance as well as resistance

1. Both oppose the flow of current
2. Must raise the voltage higher to push the power through the inductance of the lines
3. Unless capacitance is introduced to offset inductance

3) How Voltages Controlled by Reactive Power:

- Voltages are controlled by providing sufficient reactive power control margin to supply needs through

1. Shunt capacitor and reactor compensations
2. Dynamic compensation
3. Proper voltage schedule of generation.

- Voltages are controlled by predicting and correcting reactive power demand from loads

4) Reactive Power and Power Factor

- Reactive power is present when the voltage and current are not in phase

1. One waveform leads the other
2. Phase angle not equal to 0°
3. Power factor less than unity

- Measured in volt-ampere reactive (VAR)
- Produced when the current waveform leads voltage waveform (Leading power factor)
- Vice versa, consumed when the current waveform lags voltage (lagging power factor)

5) Reactive Power Limitations:

- Reactive power does not travel very far.
- Usually necessary to produce it close to the location where it is needed
- A supplier/source close to the location of the need is in a much better position to provide reactive power versus one that is located far from the location of the need
- Reactive power supplies are closely tied to the ability to deliver real or active power.

Reactive Power Caused Absence of Electrical supply - BLACKOUT:

- The quality of the electrical energy supply can be evaluated basing on a number of parameters. However, the most important will be always the presence of electrical energy and the number and duration of interrupts.
- When consumption of electrical energy is high, the demand on inductive reactive power increases at the same proportion. In this moment, the transmission lines (that are well loaded) introduce an extra inductive reactive power.The local sources of capacitive reactive power become insufficient. It is necessary to deliver more of the reactive power from generators of power plants.
- It might happen that they are already fully loaded and the reactive power will have to be delivered from more distant places. Transmission of reactive power will load more the lines, which in turn will introduce more reactive power. The voltage on customer side will decrease further. Local control of voltage by means of autotransformers will lead to increase of current (to get the same power) and this in turn will increase voltage drops in lines. In one moment this process can go like avalanche reducing voltage to zero. In mean time most of the generators in power plants will switch off due to unacceptably low voltage what of course will deteriorate the situation.
- Insufficient reactive power leading to voltage collapse has been a causal factor in major blackouts in the worldwide. Voltage collapse occurred in United States in the blackout of July 2, 1996, and August10, 1996 on the West Coast
- While August 14, 2003, blackout in the United States and Canada was not due to a voltage collapse as that term has traditionally used by power system engineers, the task force final report said that**" Insufficient reactive power was an issue in the blackout"** and the report also "overestimation of dynamics reactive output of system generation " as common factor among major outages in the United States.
- **Demand for reactive power was unusually high because of a large volume of long-distance transmissions streaming through Ohio to areas, including Canada, than needed to import power to meet local demand. But the supply of reactive power was low because some plants were out of service and, possibly, because other plants were not producing enough of it."**

Problem of Reactive Power:

- Though reactive power is needed to run many electrical devices, it can cause harmful effects on appliances and other motorized loads, as well as electrical infrastructure. Since the current flowing through electrical system is higher than that necessary to do the required work, excess power dissipates in the form of heat as the reactive current flows through resistive components like wires, switches and transformers. Keep in mind that whenever energy is expended, you pay. It makes no difference whether the energy is expended in the form of heat or useful work.
- We can determine how much reactive power electrical devices use by measuring their power factor, the ratio between real power and true power. A power factor of 1 (i.e. 100%) ideally means that all electrical power is applied towards real work. Homes typically have overall power factors in the range of 70% to 85%, depending upon which appliances may be running. Newer homes with the latest in energy efficient appliances can have an overall power factor of 90%.
- Electric companies correct for power factor around industrial complexes, or they will request the offending customer to do so, or they will charge for reactive power. Electric companies are not worried about residential service because the impact on their distribution grid is not as severe as in heavily industrialized areas. However, it is true that power factor correction assists the electric company by reducing demand for electricity, thereby allowing them to satisfy service needs elsewhere.
- Power factor correction will not raise your electric bill or do harm to your electrical devices. The technology has been successfully applied throughout industry for years. When sized properly, power factor correction will enhance the electrical efficiency and longevity of inductive loads. Power factor correction can have adverse side effects (e.g. harmonics) on sensitive industrialized equipment if not handled by knowledgeable, experienced professionals. Power factor correction on residential dwellings is limited to the capacity of the electrical panel (200 amp max) and does not over compensate household inductive loads. By increasing the efficiency of electrical systems, energy demand and its environmental impact is lessened

Profound effects of Reactive Power in Various elements of Power System:

1) Generation:

- An electricpower generator's primary function is to convert fuel into electric power.Almost all generators also have considerable control over their terminal voltage and reactive-power output.
- The ability of generator to provide reactive support depends on its realpower production. Like most electric equipment, generators are limited by their currentcarrying capability. Near rated voltage, this capability becomes an MVA limit for the armature of the generator rather than a MW limitation.
- Production of reactive power involves increasing the magnetic field to raise the generator's terminal voltage. Increasing the magnetic field requires increasing the current in the rotating field winding. Absorption of reactive power is limited by the magnetic-flux pattern in the stator, which results in excessive heating of the stator-end iron, the core-end heating limit.
- The synchronizing torque is also reduced when absorbing large amounts of reactive power, which can also limit generator capability to reduce the chance of losing synchronism with the system.
- The generator prime mover (e.g., the steam turbine) is usually designed with less capacity than the electric generator, resulting in the prime-mover limit. The designers recognize that the **generator will be producing reactive power and supporting system voltage most of the time**. Providing a prime mover capable of delivering all the mechanical power the generator can convert to electricity when it is neither producing nor absorbing reactive power would result in underutilization of the prime mover.
- To produce or absorb additional VARs beyond these limits would require a reduction in the realpower output of the unit. Control over the reactive output and the terminal voltage of the generator is provided by adjusting the DC current in the generator's rotating field .Control can be automatic, continuous, and fast.
- The inherent characteristics of the generator help maintain system voltage. At any given field setting, the generator has a specific terminal voltage it is attempting to hold. If the system voltage declines, the generator will inject reactive power into the power system, tending to raise system voltage. If the system voltage rises, the reactive output of the generator will drop, and ultimately reactive power will flow into the generator, tending to lower system voltage. The voltage regulator will accentuate this behavior by driving the field current in the appropriate direction to obtain the desired system voltage.

2) Synchronous Condensers:

- Every synchronous machine (motor or generator) with a controllable field has the reactivepower capabilities discussed above.
- Synchronous motors are occasionally used to provide dynamic voltage support to the power system as they provide mechanical power to their load. Some combustion turbines and hydro units are designed to allow the generator to operate without its mechanical power source simply to provide the reactive power capability to the power system when the real power generation is unavailable or not needed. Synchronous machines that are designed exclusively to provide reactive support are called synchronous condensers.
- Synchronous condensers have all of the response speed and controllability advantages of generators without the need to construct the rest of the power plant (e.g., fuel-handling equipment and boilers). Because they are rotating machines with moving parts and auxiliary systems, they may require significantly more maintenance than staticalternatives. They also consume real power equal to about 3% of the machine's reactive-power rating.

3) Capacitors & Inductors:

- Capacitors and inductors (which are sometimes called reactors) are passive devices that generate or absorb reactive power. They accomplish this without significant realpower losses or operating expense.
- **The output of capacitors and inductors is proportional to the square of the voltage**. Thus, a capacitor bank (or inductor) rated at 100 MVAR will produce (or absorb) only 90 MVAR when the voltage dips to 0.95 pu but it will produce (or absorb) 110 MVAR when the voltage rises to 1.05 pu. This relationship is helpful when inductors are employed to hold voltages down.
- The inductor absorbs more when voltages are highest and the device is needed most. The relationship is unfortunate for the more common case where capacitors are employed to support voltages. In the extreme case, voltages fall, and capacitors contribute less, resulting in a further degradation in voltage and even less support from the capacitors; ultimately, voltage collapses and outages occur.
- Inductors are discrete devices designed to absorb a specific amount of reactive power at a specific voltage. They can be switched on or off but offer no variable control.
- Capacitor banks are composed of individual capacitor cans, typically 200 kVAR or less each. The cans are connected in series and parallel to obtain the desired capacitorbank voltage and capacity rating. Like inductors, capacitor banks are discrete devices but they are often configured with several steps to provide a limited amount of variable control which makes it a disadvantagecompared to synchronous motor.

4) Static VAR Compensators :(SVCs)

- An SVC combines conventional capacitors and inductors with fast switching capability. Switching takes place in the sub cycle timeframe (i.e. in less than 1/60 of a second), providing a continuous range of control. The range can be designed to span from absorbing to generating reactive power. Consequently, the controls can be designed to provide very fast and effective reactive support and voltage control.
- Because SVCs use capacitors, they suffer from the same degradation in reactive capability as voltage drops. They also do not have the shortterm overload capability of generators and synchronous condensers. SVC applications usually require harmonic filters to reduce the amount of harmonics injected into the power system.

5) Static Synchronous Compensators :(STATCOMs)

- The STATCOM is a solid-state shunt device that generates or absorbs reactive power and is one member of a family of devices known as flexible AC transmission system.
- The STATCOM is similar to the SVC in response speed, control capabilities, and the use of power electronics. Rather than using conventional capacitors and inductors combined with fast switches, however, the STATCOM uses power electronics to synthesize the reactive power output. Consequently, output capability is generally symmetric, providing as much capability for production as absorption.
- The solid-state nature of the STATCOM means that, similar to the SVC, the controls can be designed to provide very fast and effective voltage control. While not having the short-term overload capability of generators and synchronous condensers, STATCOM capacity does not suffer as seriously as SVCs and capacitors do from degraded voltage.
- STATCOMs are current limited so their MVAR capability responds linearly to voltage as opposed to the voltage squared relationship of SVCs and capacitors. This attribute greatly increases the usefulness of STATCOMs in preventing voltage collapse.

6) Distributed Generation:

- Distributing generation resources throughout the power system can have a beneficial effect if the generation has the ability to supply reactive power. Without this ability to control reactivepower output, performance of the transmission and distribution system can be degraded.
- Induction generators were an attractive choice for small, grid-connected generation, primarily because they are relatively inexpensive. They do not require synchronizing and have mechanical characteristics that are appealing for some applications (wind, for example). They also absorb reactive power rather than generate it, and are not controllable. If the output from the generator fluctuates (as wind does), the reactive demand of the generator fluctuates as well, compounding voltage-control problems for the transmission system.
- Induction generators can be compensated with static capacitors, but this strategy does not address the fluctuation problem or provide controlled voltage support. Many distributed generation resources are now being coupled to the grid through solid-state power electronics to allow the prime mover's speed to vary independently of the power-system frequency. For wind, this use of solid-state electronics can improve the energy capture.
- For gas-fired micro turbines, power electronics equipment allows them to operate at very high speeds. Photovoltaic's generate direct current and require inverters to couple them to the power system. Energy-storage devices (e.g., batteries, flywheels, and superconducting magnetic-energy storage devices) are often distributed as well and require solid-state inverters to interface with the grid. This increased use of a solid-state interface between the devices and the power system has the added benefit of providing full reactive-power control, similar to that of a STATCOM.
- In fact, most devices do not have to be providing active power for the full range of reactive control to be available. The generation prime mover, e.g. turbine, can be out of service while the reactive component is fully functional. This technological development (solid-state power electronics) has turned a potential problem into a benefit, allowing distributed resources to contribute to voltage control.

7) Transmission Side:

- Unavoidable consequence of loads operation is presence of reactive power, associated with phase shifting between voltage and current.
- Some portion of this power is compensated on customer side, while the rest is loading the network. The supply contracts do not require a cosφ equal to one. The reactive power is also used by the transmission lines owner for controlling the voltages.
- **Reactive component of current adds to the loads current and increases the voltage drops across network impedances**. Adjusting the reactive power flow the operator change voltage drops in lines and in this way the voltage at customer connection point.

- The voltage on customer side depends on everything what happens on the way from generator to customer loads. All nodes, connation points of other transmission lines, distribution station and other equipment contribute to reactive power flow.
- A transmission line itself is also a source of reactive power. A line that is open on the other end (without load) is like a capacitor and is a source of capacitive (leading) reactive power. The lengthwise inductances without current are not magnetized and do not introduce any reactive components. On the other hand, when a line is conducting high current, the contribution of the lengthwise inductances is prevalent and the line itself becomes a source of inductive (lagging) reactive power. For each line can be calculated a characteristic value of power flow.
- If the transmitted power is more than pre define Value, the line will introduce additionally inductive reactive power, and if it is below pre define Value, the line will introduce capacitive reactive power. The pre define Value depends on the voltage: for 400 kV line is about 32% of the nominal transmission power, for 220 kV line is about 28% and for 110 kV line is about 22%. The percentage will vary accordingly to construction parameters.
- The reactive power introduced by the lines themselves is really a nuisance for the transmission system operator. In the night, when the demand is low it is necessary to connect parallel reactors for consuming the additional capacitive reactive power of the lines. Sometimes it is necessary to switch off a low-loaded line (what definitely affect the system reliability). In peak hours not only the customer loads cause big voltage drops but also the inductive reactive power of the lines adds to the total power flow and causes further voltage drops.
- The voltage and reactive power control has some limitations. A big part of reactive power is generated in power plant unites. The generators can deliver smoothly adjustable leading and lagging reactive power without any fuel costs.
- However, the reactive power occupies the generation capacity and reduces the active power production. Furthermore, it is not worth to transmit reactive power for long distance (because of active power losses). Control provided "on the way" in transmission line, connation nodes, distribution station and other points requires installation of capacitors or\and reactors.
- They are often used with transformer tap changing system. The range of voltage control depends on their size. The control mayconsist e.g. in setting the transformer voltage higher and thenreducing it by reactive currents flow.
- If the transformer voltage reaches the highest value and all capacitors are in operation, the voltage on customer side cannot be further increase. On the other hand when a reduction is required the limit is set by maximal reactive power of reactors and the lowest tap of transformer.

Planning and Assessment Practices to control Voltage & Reactive Power:

- Transmission and Distribution planners must determine in advance the required type and location of reactive correction.

1) Static vs. Dynamic Voltage Support

- The type of reactive compensation required is based on the time needed for voltage recovery.
- Static Compensation is ideal for second and minute responses. (Capacitors, reactors, tap changes).
- Dynamic Compensation is ideal for instantaneous responses. (condensers, generators)
- A proper balance of static and dynamic voltage support is needed to maintain voltage levels within an acceptable range.

2) Reactive Reserves during Varying Operating Conditions

- The system capacitors, reactors, and condensers should be operated to supply the normal reactive load.As the load increases or following a contingency, additional capacitors should be switched on or reactors removed to maintain acceptable system voltages.
- The reactive capability of the generators should be largely reserved for contingencies on the EHV system or to support voltages during extreme system operating conditions.
- Load shedding schemes must be implemented if a desired voltage is unattainable thru reactive power reserves

3) Voltage Coordination

- The reactive sources must be coordinated to ensure that adequate voltages are maintained everywhere on the interconnected system during all possible system conditions. Maintaining acceptable system voltages involves the coordination of sources and sinks which include:

1. Plant voltage schedules
2. Transformer tap settings
3. Reactive device settings

4. Load shedding schemes.

- The consequences of uncoordinated of above operations would include:

1. Increased reactive power losses
2. A reduction in reactive margin available for contingencies and extreme light load conditions
3. Excessive switching of shunt capacitors or reactors
4. Increased probability of voltage collapse conditions.

- **Plant Voltage Schedule**
- Each power plant is requested to maintain a particular voltage on the system bus to which the plant is connected. The assigned schedule will permit the generating unit to typically operate:

1. In the middle of its reactive capability range during normal conditions
2. At the high end of its reactive capability range during contingencies
3. "Under excited" or absorb reactive power under extreme light load conditions.

- **Transformer Tap Settings**
- Transformer taps must be coordinated with each other and with nearby generating station voltage schedules.
- The transformer taps should be selected so that secondary voltages remain below equipment limits during light load conditions.
- **Reactive Device Settings**
- Capacitors on the low voltage networks should be set to switch "on" to maintain voltages during peak and contingency conditions. And "Off" when no longer required supporting voltage levels.
- **Load Shedding Schemes**
- Load shedding schemes must be implemented as a "last resort" to maintain acceptable voltages.

4) Voltage and Reactive Power Control

- Requires the coordination work of all Transmission and Distribution disciplines.
- **Transmission needs to:**

a. Forecast the reactive demand and required reserve margin
b. Plan, engineer, and install the required type and location of reactive correction
c. Maintain reactive devices for proper compensation
d. Maintain meters to ensure accurate data
e. Recommend the proper load shedding scheme if necessary.

- **Distribution needs to:**

a. Fully compensate distribution loads before Transmission reactive compensation is considered
b. Maintain reactive devices for proper compensation
c. Maintain meters to ensure accurate data
d. Install and test automatic under voltage load shedding schemes

References:

1. Samir Aganoviş,
2. Zoran Gajiş,
3. Grzegorz Blajszczak- Warsaw, Poland,
4. Gianfranco Chicco
5. Robert P. O'Connell-Williams Power Company
6. Harry L. Terhune-American Transmission Company,
7. Abraham Lomi, Fernando Alvarado, Blagoy Borissov, Laurence D. Kirsch
8. Robert Thomas,.
9. OAK RIDGE NATIONAL LABORATORY.

Chapter: 71 Effect of High Voltage Transmission Lines on Humans and Plants

Introduction:

- By increasing population of the world, towns are expanding, many buildings construct near high voltage overhead power transmission lines. The increase of power demand has increased the need for transmitting huge amount of power over long distances. Large transmission lines configurations with high voltage and current levels generate large values of electric and magnetic fields stresses which affect the human being and the nearby objects located at ground surfaces. This needs to be investigating the effects of electromagnetic fields near the transmission lines on human health.
- The electricity system produces extremely low frequency electromagnetic field which comes under Non ionizing radiations which can cause health effects. Apart from human effect, the electrostatic coupling & electromagnetic interference of high voltage transmission lines have impact on plants and telecommunication equipments mainly operating in frequency range below UHF.

- **IS Power Line EMF safe?**
- This is the controversy Discussion directly eludes on Government Regulation policy and Power Company. There are lots of supporting documents and research paper in favour and criticize this arguments.

What is The Electric and Magnetic fields?

- Electric and magnetic fields, often referred to as electromagnetic fields or EMF, occur naturally and as a result of the Power generation, Power Transmission, Power distribution and use of electric power.
- EMF is fields of force and is created by electric voltage and current. They occur around electrical devices or whenever power lines are energized.
- **Electric fields** are due to voltage so they are present in electrical appliances and cords whenever the electric cord to an appliance is plugged into an outlet (even if the appliance is turned off).
- Electric fields (E) exist whenever a (+) or (-) electrical charge is present. They exert forces on other charges within the field. Any electrical wire that is charged will produce an electric field (i.e. Electric field produces charging of bodies, discharge currents, biological effects and sparks). This field exists even when there is no current flowing. The higher the voltage, the stronger is electric field at any given distance from the wire.
- The strength of the electric field is typically measured in volts per meter (V/m) or in kilovolts per meter (kV/m). Electric fields are weakened by objects like trees, buildings, and vehicles. Burying power lines can eliminate human exposure to electric fields from this source.
- **Magnetic fields** result from the motion of the electric charge or current, such as when there is current flowing through a power line or when an appliance is plugged in and turned on. Appliances which are plugged in but not turned on do not produce magnetic fields.
- Magnetic field lines run in circles around the conductor (i.e. produces magnetic induction on objects and induced currents inside human and animal (or any other conducting) bodies causing possible health effects and a multitude of interference problems). The higher the current, thegreater the strength of the magnetic field.
- Magnetic fields are typically measured in tesla (T) or more commonly, in gauss (G) and milli gauss (mG). One tesla equals 10,000 gauss and one gauss equals 1,000 milli gauss.
- The strength of an EMF decreases significantly with increasing distance from the source.
- The Strength of an electric field is proportional to the voltage of the source. Thus, the electric fields beneath high voltage transmission lines far exceed those below the lower voltage distribution lines. The magnetic field strength, by contrast, is proportional to the current in the lines, so that a low voltage distribution line with a high

current load may produce a magnetic field that is as high as those produced by some high voltage transmission lines.

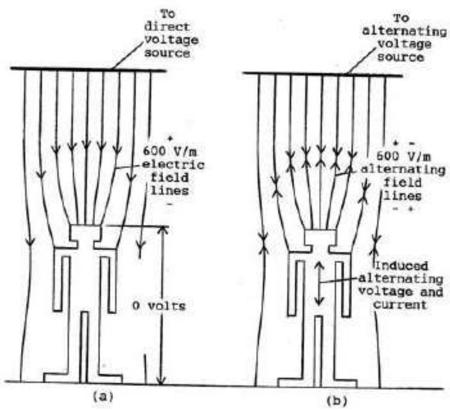
- In fact, electric distribution systems account for a far higher proportion of the population's exposure to magnetic fields than the larger and more visible high voltage transmission lines.
- **Electrical field:** the part of the EMF that can easily be shielded.
- **Magnetic field:** part of the EMF that can penetrate stone, steel and human flesh. In fact, when it comes to magnetic fields, human flesh and bone has the same penetrability as air!
- **Both fields are invisible and perfectly silent:** People who live in an area with electric power, some level of artificial EMF is surrounding them.
- The magnetic field strength produced from a transmission line is proportional to: load current, phase to phase spacing, and the inverse square of the distance from the line.
- Many previous works studied the effect of different parameters on the produced magnetic field such as: the distance from the line, the conductor height, line shielding and transmission line configuration and compaction.

Electric and Magnetic Field (EMF) Effects:

- Extremely high voltages in EHV lines cause electrostatic effects, where as short circuit currents & line loading currents are responsible for electromagnetic effects. The effect of these electrostatic fields is seen prominent with living things like humans, plants, animals along with vehicles, fences & buried pipes under & close to these lines.

(1) EMF Effects Human beings:

- The human body is a composed of some biological materials like blood, bone, brain, lungs, muscle, skin etc. The permeability of human body is equals to permeability of air but within a human body has different electromagnetic values at a certain frequency for different material.
- The human body contains free electric charges (largely in ion-rich fluids such as blood and lymph) that move in response to forces exerted by charges on and currents flowing in nearby power lines. The processes that produce these body currents are called **electric and magnetic induction.**
- In electric induction, charges on a power line attract or repel free charges within the body. Since body fluids are good conductors of electricity, charges in the body move to its surface under the influence of this electric force. For example, a positively charged overhead transmission line induces negative charges to flow to the surfaces on the upper part of the body. Since the charge on power lines alternates from positive to negative many times each second, the charges induced on the body surface alternate also. Negative charges induced on the upper part of the body one instant flow into the lower part of the body the next instant. Thus, **power-frequency electric fields induce currents in the body (Eddy Current) as well as charges on its surface.**



- The currents induced in the body by magnetic fields are greatest near the periphery of the body and smallest at the center of the body.
- It is believed that, the magnetic field might induce a voltage in the tissue of human body which causes a current to flow through it due to its conductivity of around them.
- The magnetic field has influence on tissues in the human body. These influences may be beneficial or harmful depending upon its nature.
- The magnitude of surface charge and internal body currents that are induced by any given source of power-frequency fields depends on many factors. These include the magnitude of the charges and currents in the source, the distance of the body from the source, the presence of other objects that might shield or concentrate the field, and body posture, shape, and orientation. **For this reason the surface charges and currents which a given field induces are very different for different Human and animals.**

- When a person who is isolated from ground by some insulating material comes in close proximity to an overhead transmission line, an electrostatic field is set in the body of human being, having a resistance of about 2000 ohms.
- When the same person touches a grounded object, it will discharge through his body causing a large amount of discharge current to flow through the body. Discharge currents from 50-60 Hz electromagnetic fields are weaker than natural currents in the body, such as those from the electrical activity of the brain and heart.
- For human beings the limit for undisturbed field is 15 kV/m, R.M.S., to experience possible shock. When designing a transmission lines this limit is not crossed, in addition to this proper care has been taken in order to keep minimum clearance between transmission lines.

Short term Health Problem

- According to research and publications put out by the World Health Organization(WHO), EMF such as those from power lines, can also cause:
- Headaches.
- Fatigue
- Anxiety
- Insomnia
- Prickling and/or burning skin
- Rashes
- Muscle pain

Long term Health Problem:

- Following serious health Problems may be arise due to EMF effects on human Body
- **Risk of damaging DNA.**
- Our body acts like an energy wave broadcaster and receiver, incorporating and responding to EMFs. In fact, scientific research has demonstrated that every cell in your body may have its own EMF, helping to regulate important functions and keep you healthy.
- Strong, artificial EMFs like those from power lines can scramble and interfere with your body's natural EMF, harming everything from your sleep cycles and stress levels to your immune response and DNA!
- **Risk of Cancer**
- After hundreds of international studies, the evidence linking EMFs to cancers and other health problems is loud and clear. High Voltage power lines are the most obvious and dangerous culprits, but the same EMFs exist in gradually decreasing levels all along the grid, from substations to transformers to homes.
- **Risk of Leukemia:**
- Researchers found that children living within 650 feet of power lines had a 70% greater risk for leukemia than children living 2,000 feet away or more.(As per British Medical Journal, June, 2005)
- **Risk of Neurodegenerative disease:**
- "Several studies have identified occupational exposure to extremely low-frequency electromagnetic fields (EMF) as a potential risk factor for neurodegenerative disease."(As per Epidemiology, 2003 Jul; 14(4):413-9)
- **Risk of Miscarriage:**
- There is "strong prospective evidence that prenatal maximum magnetic field exposure above a certain level (possibly around 16 mG) may be associated with miscarriage risk." (As per Epidemiology, 2002 Jan; 13(1):9-20)

(2) EMF Effects on Animals

- Many researchers are studying the effect of Electrostatic field on animals. In order to do so they keeps the cages of animals under high Electrostatic field of about 30 kV/m. The results of these Experiments are shocking as animals (are kept below high Electrostatic field their body acquires a charge & when they try to drink water, a spark usually jumps from their nose to the grounded Pipe) like hens are unable to pick up grain because of chattering of their beaks which also affects their growth.

(3) EMF Effects on Plant Life

- Most of the areas in agricultural and forestlands where high power transmission lines pass. The voltage level of high power transmission Lines are 400KV, 230KV, 110KV, 66KV etc. The electromagnetic field from high power transmission lines affects the growth of plants.
- Gradually increases or decreases and reaches to maximum current or minimum current and thereafter it starts to fall down to lowest current or raises to maximum current or a constant current. Again the current, it evinces with little fluctuations till the next day morning.

- Current in Power transmission lines varies according to Load (it depending upon the amount of electricity consumed by the consumers). Hence the effect of EMF (due to current flowing in the power lines) upon the growth of plants under the high power transmission lines remains unaltered throughout the year.
- From various practically study it was found that the response of the crop to EMF from 110 KV and 230 KV Power lines showed variations among themselves. Based on the results the growth characteristics like shoot length, root length, leaf area, leaf fresh weight, specific leaf weight, shoot/root ratio, total biomass content and total water content of the four crop plants were reduced significantly over the control plants.
- Similar trend were observed in the biochemical characteristics like chlorophyll.
- Reduced growth and physiological parameter was primarily due to the effect of reduced cell division and cell enlargement. Further the growth was stunted which may be due to poor action of hormones responsible for cell division and cell enlargement.
- The bio-chemical changes produced in this plant due to EMF stress quite obvious and it affects the production leading to economic loss.
- It is concluded that the reduced growth parameter shown in the crop plants would indicates that the EMF has exerted a stress on that plants and this EMF stress was quite obvious and it affects the production leading to economic loss. So further research activities are needed to safe guard plants from EMF stress.

(4) EMF Effects on Vehicles parked near Line

- When a vehicle is parked under high voltage transmission line an electrostatic field is developed in it. When a person who is grounded touches it a discharge current flows through the human being. In order to avoid this parking lots are located below the transmission lines the recommended clearance is 17 m for 345 kV and 20 m for 400 kV lines.

(5) EMF Effects on Pipe Line/Fence/Cables:

- A fence, irrigation pipe, pipeline, electrical distribution line forms a conducting loops when it is grounded at both ends. The earth forms the other portion of the loop. The magnetic field from a transmission line can induce a current to flow in such a loop if it is oriented parallel to the line. If only one end of the fence is grounded, then an induced voltage appears across the open end of the loop. The possibility for a shock exists if a person closes the loop at the open end by contacting both the ground and the conductor.
- For fences, buried cables, and pipe lines proper care has been taken to prevent them from charging due to Electrostatic field. When using pipelines which are more than 3 km in length & 15 cm in Diameter they must be buried at least 30 laterally from the line center.

(6) EMF Effects on Maintenance Worker:

- For providing continuous and uninterrupted supply of electric power to consumers maintenance operations of power lines are often performed with systems energized or live.
- This is live line maintenance or hot line maintenance. The electric fields and magnetic fields associated with these power lines may affect the health of live line workers. Its electric field and current densities affect the health of humans and cause several diseases by affecting majority parts of the human body. These electric field and current densities affects humans of all stages and causes short term diseases in them and sometimes death also.

Contradiction of EMF Effect on Human Health:

- There are two reasons why electromagnetic fields associated with power systems could pose no threat to human health.
- First, The EMF from power lines and appliances are of extremely low frequency and low energy. They are non-ionizing and are markedly different in frequency from ionizing radiation such as X-rays and gamma rays. As a comparison, transmission lines have a low frequency of 60Hz while television transmitters have higher frequencies in the 55 to 890 MHZ range. Microwaves have even higher frequencies, 1,000 MHZ and above. Ionizing radiation, such as X-rays and gamma rays, has frequencies above 1015 Hz. The energy from higher-frequency fields is absorbed more readily by biological material. Microwaves can be absorbed by water in body tissues and cause heating which can be harmful, depending upon the degree of heating that occurs. X-rays have so much energy that they can ionize (form charged particles) and break up molecules of genetic material (DNA) and no genetic material, leading to cell death or mutation. In contrast, extremely low frequency EMF does not have enough energy to heat body tissues or cause ionization.
- Second, all cells in the body maintain large natural electric fields across their outer membranes. These naturally occurring fields are at least 100 times more intense than those that can be induced by exposure to common power-frequency fields. However, despite the low energy of power-frequency fields and the very small perturbations that they make to the natural fields within the body.

- When an external agent such as an ELF fields lightly perturbs a process in the cell, other processes may compensate for it so that there is no overall disturbance to the organism. Some perturbations may be within the ranges of disturbances that a system can experience and still function properly.
- During Research on health effects of electric and magnetic fields, it has come forward that electric field intensity exposure of about 1-10 mv/m in tissue interact with cells but not proved to be harmful. But strong fields cause harmful effects when their magnitude exceeds stimulation thresholds for neural tissues (central nervous system and brain), muscle and heart

Surface Current Density(mA/m2)	Health Effect
<1	Absence of any established effects.
1 To 10	Minor biological effects.
10 To 100	Well established effects (a) Visual effect. (b) Possible nervous system effect
100 To 1000	Changes in central nervous System
>1000	Ventricular Fibrillation (Heart Condition 0. Health hazards.

- In India it is stipulated that electric field intensity should not exceed 4.16 kV/m and magnetic field intensity should not exceed 100μT in public areas.
- Even when effect is demonstrated consistently on the cellular level in laboratory experiments, it is hard to predict whether and how they will affect the whole organism. Processes at the individual cell level are integrated through complex mechanisms in the animal.

Mitigation of EMF Effect of Transmission Line:

1) Line shielding:

- There are two basic 60-Hz magnetic field mitigation (reduction) methods: passive and active.
- Passive magnetic field mitigation includes rigid magnetic shielding with ferromagnetic and highly conductive materials, and the use of passive shield wires installed near transmission lines that generate opposing cancellation fields from electromagnetic induction.
- Active magnetic field mitigation uses electronic feedback to sense a varying 60-Hz magnetic field, then generates a proportionally opposing (nulling) cancellation field within a defined area (room or building) surrounded by cancellation coils. Ideally, when the two opposing 180-degree out- of-phase magnetic fields of equal magnitude intersect, the resultant magnetic field is completely cancelled (nullified). This technology has been successfully applied in both residential and commercial environments to mitigate magnetic fields from overhead transmission and distribution lines, and underground residential distribution (URD) lines.

2) Line Configuration and Compaction

- Line compaction means that, bringing the conductors close together keeping the minimum (safe) phase-to-phase spacing constant. Keeping all the parameters the same and the only variable is the phase-to- phase spacing. The magnetic field is proportional to the dimensions of the phase-to-phase spacing.
- Other studies showed that, increasing the distance between phases by increasing the height of the central phase conductor above the level of the other phase conductors leads to the reduction of the peak value of the magnetic field.
- Reducing the phase-to-phase distance, leads to the decrease of the magnetic field. This reduction between phases is limited by the electrical insulation level between phases.
- (A) For single circuit lines, compaction causes a great reduction to the maximum magnetic field values. This reduction of magnetic field allows for lower conductor heights above the ground. This leads to transmit the same power on shorter towers. This gives a great reduction of the tower cost.
- (B) For double circuit lines, some studies showed that, the use of optimum phase arrangement causes a drastic reduction to the maximum magnetic field values for both conventional and compact lines i.e. with vertical conductor

3) Grounding:

- Induced currents are always present in electric fields under transmission lines and will be present. However, there must be a policy to ground metal objects, such as fences, that are located on the right-of-way. The grounding eliminates these objects as sources of induced current and voltage shocks. Multiple grounding points are used to provide redundant paths for induced current flow and mitigate nuisance shocks.

4) Providing Right of Way(R.O.W):

- Overhead transmission systems required strips of land to be designed as right-of-ways (R.O.W.). These strips of land are usually evaluated to decrease the effects of the energized line including magnetic and electric field effects.

5) Maintaining Proper Clearance:

- Unlike fences or buildings, mobile objects such as vehicles and farm machinery cannot be grounded permanently. Limiting the possibility of induced currents from such objects to persons is accomplished by maintaining proper clearances for above-ground conductors tend to limit field strengths to levels that do not represent a hazard or nuisance.
- Limiting access area by increasing conductor clearances in areas where large vehicles could be present.

Conclusion:

- Based on the review and analysis and other research projects it is of the opinion that there is no conclusive and convincing evidence that exposure to extremely low frequency EMF emanated from nearby high voltage Transmission lines is causally associated with an increased incidence of cancer or other detrimental health effects in humans. Even if it is assumed that there is an increased risk of cancer as implied in some epidemiologic studies, the empirical relative risk appears to be fairly small in magnitude and the observed association appears to be tenuous. Although the possibility is still remain about the verse effect on health by EMF.

References:

- SSGBCOE&T, Electronics and Communication Engineering-Girish Kulkarni1, Dr.W.Z.Gandhare
- Pharmacology, School of Medicine, Chung-Ang University, Seoul, Korea-Sung-Hyuk Yim, Ji-Hoon Jeong.
- Electrical Engineering Department, Shoubra, Benha University, Cairo, Egypt- Nagat Mohamed Kamel Abdel-Gawad.
- Madurai Kamaraj University-S. Somasekaran.
- Electrical Engineering Department at King Fahd University of Petroleum & Minerals- J. M. Bakhashwain, M. H. Shwehdi, U. M. Johar and A. A. AL-Naim.
- Dept. of Electrical Engineering. College of Engineering - University of Tikrit-Iraq- Ghanim Thiab Hasan, Kamil Jadu Ali, Mahmood Ali Ahmed.

Chapter: 72 How to Save Electrical Energy at Home

Introduction:

- In our home we use lot of electrical equipment like TV, Freeze, Washing machine, Mp3 player. Music system, computer laptop. But we have not adequate knowledge for how to use this electrical equipment in proper way Due to this ignorance we are paying more electricity Bill which we are not actually use.
- **Do you know in actual we are consuming more electricity or paying more amounts what we actually not use it?**
- According to the energy auditors we can easily save between 5 and 10% of their energy consumption (and costs) by changing our behavior such as switching electrical equipment off at the mains rather than leaving it on standby, turning off lights when they're not being used
- By saving Electrical energy will directly reflected to saving money so it is very necessary to under stood ghost unit or amount which we are paying without using the appliances.
- The major appliances in your home -- refrigerators, clothes washers, dishwashers -- account for a big chunk of your monthly utility bill. And if your refrigerator or washing machine is more than a decade old, you're spending a lot more on energy than you need to.
- Today's major appliances don't hog energy the way older models do because they must meet minimum federal energy efficiency standards. These standards have been tightened over the years, so any new appliance you buy today has to use less energy than the model you're replacing. For instance, if you buy one of today's most energy-efficient refrigerators, it will use less than half the energy of a model that's 12 years old or older.

1) Save Energy in Lighting

- Get into the habit of turning lights off when you leave a room. ----Saving Energy 0.5 %
- Use task lighting (table and desktop lamps) instead of room lighting.
- Take advantage of daylight
- De-dust lighting fixtures to maintain illumination-----Saving Energy 1 %
- Compact fluorescent bulbs (CFL):

1. CFL use 75% less energy than Normal bulbs.
2. CFL are four times more energy efficient than Normal bulbs.
3. CFL can last up to ten times longer than a normal bulb.

- Use electronic chokes. in place of conventional copper chokes.----Saving Energy 2 %
- Get into the habit of turning lights off when you leave a room.
- Use only one bulb for light fittings with more than one light bulb, or replace additional bulbs with a lower wattage version.
- Use energy-saving light bulbs that can last up to ten times longer than a normal bulb and use significantly less energy. A single 20- to 25-watt energy-saving bulb provides as much light as a 100-watt ordinary bulb.
- Use tungsten halogen bulbs for spotlights—they last longer and are up to 100% more efficient.
- Fit external lights with a motion sensor.
- Use high frequency fittings for fluorescent tubes because they cut flicker and are even more efficient than energy-saving light bulbs. They are suitable for kitchens, halls, workshops and garages.

2) Save on Your Fridge & Freezer:

- Defrost your fridge regularly.
- Check that the door seals are strong and intact.
- Don't stand Freezer's Back Side too near the Wall.
- Avoid putting warm or hot food in the fridge or freezer—it requires more energy to cool it down.
- Clean condenser coils twice a year.
- Get rid of old refrigerators! They use twice the energy as new Energy Star® models.
- Keep refrigerators full but not overcrowded.
- Defrost your fridge regularly. When ice builds up, your freezer uses more electricity. If it frosts up again quickly, check that the door seals are strong and intact.
- Do not stand the fridge next to the oven or other hot appliances if you can help it. Also ensure there is plenty of ventilation space behind and above it.
- Keep the fridge at 40°F and the freezer at 0°F. Empty and then turn your fridge off if you go on a long vacation (but make sure you leave the door open).

- Aim to keep your fridge at least three-quarters full to maintain maximum efficiency. A full fridge is a healthy fridge.
- Avoid putting warm or hot food in the fridge or freezer—it requires more energy to cool it down.

3) Air Condition Unit:

- For Home Purpose use Window unit Instead Of Split Unit.
- For Office and Commercial Purpose Use Split AC instead of Window unit.
- Consider installing a programmable t. Just set the times and temperatures to match your schedule and you will save money and be comfortably cool when you return home.
- Get air conditioner maintenance each year.
- Checks the condenser coils, the evaporator coils, the blower wheel, the filter, the lubrication and the electrical contacts.
- Replace worn and dirty equipment for maximum efficiency.
- Replace air conditioner filters every month.
- Turn off central air conditioning 30 minutes before leaving your home.
- Consider using ceiling or portable fans to circulate and cool the air.
- Try increasing your air conditioner temperature. Even 1 degree higher could mean significant savings, and you will probably not notice the difference.
- Keep central air conditioner usage to a minimum—or even turn the unit off—if you plan to go away.
- Consider installing a programmable thermostat. Just set the times and temperatures to match your schedule and you will save money and be comfortably cool when you return home.
- Get air conditioner maintenance each year—ensure your service person checks the condenser coils, the evaporator coils, the blower wheel, the filter, the lubrication and the electrical contacts. Replace worn and dirty equipment for maximum efficiency.
- Replace air conditioner filters every month.
- Buy the proper size equipment to meet your family's needs—an oversized air conditioner unit will waste energy.
- If you have a furnace, replace it at the same time as your air conditioner system. Why? Because it is your furnace fan that blows cool air around your home, and a newer furnace fan provides improved air circulation all year round, plus saves energy costs.

4) Water Heater:

- Check your hot water temperature. It does not need to be any higher than 140°F for washing purposes.
- Plug the basin or bath when you run any hot water.
- Use a timer to make sure the heating and hot water are only on when needed.
- Insulate your hot water pipes to prevent heat loss, and your water will stay hotter for longer. Plus, you will also use less energy to heat it. And simply fitting a jacket onto your hot water tank can cut waste by up to three quarters.
- Take showers—a bath consumes 5 times more hot water. Buy a low-flow showerhead for more efficiency and it will pay for itself in no time.
- Avoid washing dishes under hot running water, and do not pre-rinse before using the dishwasher.
- Repair dripping hot water taps immediately
- Make sure hot water taps are always turned off properly.

5) Washing Machine:

- Wash full loads of Washing Machine—you will use your machine less often, saving time, and it is more energy-efficient.
- Wash at a lower temperature or the economy setting to save even more.
- Use the spin cycle, and then hang washing out rather than tumble drying—your clothes and linens will smell fresher!
- If you need to tumble dry, try a lower temperature setting.
- Use your dryer for consecutive loads, because the built-up heat between loads will use less energy.

6) Oven/Electrical Cooker:

- Make sure your oven door closes tightly.
- Use a microwave rather than conventional oven, when possible.
- Keep the center of the pan over the element, and keep the lid on when cooking on the stovetop.

- Only boil the amount of water that you need—just ensure there is enough water to cover the heating element. Turn the element or electric kettle down as soon as it reaches the boiling point.

7) Computer/Laptop:

- Buy a laptop instead of a desktop, if practical. ----Saving Energy 5 %.
- If you buy a desktop, get an LCD screen instead of an outdated CRT.
- Use sleep-mode when not in use helps cut energy costs by approx 40%.
- Turn off the monitor; this device alone uses more than half the system's energy.
- Screen savers save computer screens, not energy.
- Use separate On/Off switch Socket Instead of One.
- Laser printers use more electricity than inkjet printers.

8) Fan

- A ceiling fan in operation throughout night will gobble up 22 units in a month.
- There is a wrong notion that fan at more speed would consume more current.
- Fan running at slow speed would waste energy as heat in the regulator.
- The ordinary regulator would take 20 watts extra at low speed.
- The energy loss can be compensated by using electronic regulator

9) Buy efficient electric appliances.

- They use two to 10 times less electricity for the same functionality, and are mostly higher quality products that last longer than the less efficient ones. In short, efficient appliances save you lots of energy and money.
- In many countries, efficiency rating labels are mandatory on most appliances. Look Energy Star label is used.
- The label gives you information on the annual electricity consumption. In the paragraphs below, we provide some indication of the consumption of the most efficient appliances to use as a rough guide when shopping. Lists of brands and models and where to find them are country-specific and so cannot be listed here, but check the links on this page for more detailed information.
- Average consumption of electric appliances in different regions in the world, compared with the high efficient models on the market

Know Your Ghost consumers:

- Identify the **"Ghost consumers"** which consume power - not because they are in use, but because they are plugged in and are in stand-by mode.
- The TV consumes **10 watt power** When It's is in Standby Mode.
- Ex. TV is in stand-by-mode for 10 hours a Day.
- Energy Consumption / Day= 10 X 10 = 100 Watts. = 0.1 KWH.
- Energy consumption / Month= 1X100X30=3000 Watts=3KWH (Unit).
- Energy Consumption in Rupees. = 3 X 4 = 12 Rs/Month.
- The TV consumes **5 watt power** when we don't plug out from switch Board.
- Ex. TV is in UN Plug Mode for 10 hours a Day.
- Energy Consumption / Day= 5 X 10 = 50 Watts. = 0.05 KWH.
- Energy consumption / Month= 1X50X30= 1500 Watts=1.5 KWH (Unit).
- Energy Consumption in Rupees. = 1.5 X 4 = 6 Rs/Month.
- The cell phone charger uses **3 watt per hour** when plugged.
- Mosquito mats consume **5 watts per hour**.
- If you use an electric geyser, do not leave it in thermostat mode, for it causes standing losses of **1 To 1.5 units.**

Lighting and Voltage Surge

- Lightning can create voltage surges in several of the following ways. Lightning can score a direct hit on your house. It can strike the overhead power line which enters your house, or a main power line that is blocks away from your home. Lightning can strike branch circuitry wiring in the walls of your house. Lightning can strike an object near your home such as a tree or the ground itself and cause a surge. Voltage surges can be created by cloud to cloud lightning near your home. A highly charged cloud which passes over your home can also induce a voltage surge.
- Voltage surges can also be caused by standard on and off switching activities of large electric motors or pieces of equipment. These surges can be created by a neighbor, or by a business or manufacturing facility some distance from your house. These surges are insidious and for the most part are silent. They can occur with little or no warning.

Methodology to Suppress Lighting and Voltage Surge:

- When a voltage surge is created, it wants to equalize itself and it wants to do it as quickly as possible. These things seem to have very little patience. The surges will do whatever it takes to equalize or neutralize themselves, even if it means short circuiting all of your electronic equipment.
- The method of providing maximum protection for equipment is quite simple. Create a pathway for the voltage surge (electricity) to get to and into the ground outside your house as quickly as possible. This is not, in most cases, a difficult task.
- The first step is simple. Create an excellent grounding system for your household electrical system. The vast majority of homes do not have an excellent grounding system. Many homes have a single grounding rod and /or a metallic underground water pipe which are part of the electrical grounding system. In most cases, this is inadequate. The reason is somewhat easy to explain. Imagine putting a two inch fire hose into your kitchen sink and opening the nozzle to the full on position. I doubt that the drain in your sink could handle all of the water. Your grounding system would react in the same way to a massive voltage surge. Just as the water jumps out of the sink, the electricity jumps from the grounding system and looks for places to go. Frequently it looks for the microchips in your electronic devices. They are an easy target. They offer a path of least resistance.
- Voltage surges want to be directed to the grounding system, and when they do, they want to get into the ground around your house in a hurry. You can achieve this by driving numerous grounding rods into virgin soil around your house. These rods should be UL approved and connected by a continuous heavy solid copper wire which is welded to each grounding rod. This solid copper wire begins on the grounding bar inside of your electrical panel and terminates at the last grounding rod. Avoid using clamps if at all possible. Over time, the connection at the clamp can corrode or become loose creating tremendous resistance. This will act as a roadblock to the electricity trying to get into the ground around your home.
- The grounding rods should be at least ten feet apart from one another. They should be located in soil which readily accepts electricity. Moist clay soils are very desirable. Rocky, sandy, or soils with gravel generally have high resistance factors. Electricity has a tough time dissipating into them. Resistance readings should be in the range of 10 to 30 ohms. The lower the better.
- The second step in household surge protection is to install a lightning arrester inside of your electric service panel. These devices can be extremely effective in intercepting large voltage surges which travel in the electric powerlines. These devices capture the voltage surges and 'bleed' them off to the grounding wire which we just spoke of. If for some reason you do not have a large enough grounding wire, or enough ground rods, the arrester cannot do its job. It must be able to send the surge quickly to the ground outside of your house. These arresters range in price from $50.00 to $175.00. Almost every manufacturer of circuit breakers makes one to fit inside their panel. They can be installed by a homeowner who is experienced in dealing with high voltage panels. If you do not have this capability, have an experienced electrician install it for you.
- The final step in the protection plan is to install 'point of use' surge suppression devices. Often you will see these called 'transient voltage surge suppressors'. These are your last line of defense. They are capable of only stopping the leftover voltage surge which got past the grounding system and the lightning arrester. They cannot protect your electronic devices by themselves. They must be used in conjunction with the grounding system and the lightning arresters. Do not be lulled into a false sense of security if you merely use one of these devices!

- The 'point of use' surge suppression devices are available in various levels of quality. Some are much better than others. What sets them apart are several things. Generally speaking, you look to see how fast their response time is. This is often referred to as clamping speed. Also, look to see how high of a voltage surge they will suppress. Make sure that the device has a 500 volt maximum UL rated suppression level. Check to see if it has an indicator, either visual or audio, which lets you know if it is not working. The better units offer both, in case you install the device out of sight. Check to see if it offers a variety of modes with respect to protection. For example, does the device offer protection for surges which occur between the 'hot' and neutral, between 'hot' and ground, as well as between neutral and ground. There is a difference! Check to see if it monitors the normal sine waves of regular household current. Surges can cause irregularities in these wave patterns. Good transient surge suppression devices 'devour' these voltage spikes. Finally, check the joule rating. Attempt to locate a device which has a joule rating of 140 or higher. Electrical supply houses often are the best place to look for these high quality devices.
- Some devices can also protect your phone equipment at the same time. This is very important for those individuals who have computer modems. Massive voltage surges can come across phone lines as well. These surges can enter your computer through the telephone line! Don't forget to protect this line as well. Also, be sure the telephone ground wire is tied to the upgraded electrical grounding system.

What is a surge arrester?

- Surge arresters are devices that help prevent damage to apparatus due to high voltages. The arrester provides a low-impedance path to ground for the current from a lightning strike or transient voltage and then restores to a normal operating conditions.
- A surge arrester may be compared to a relief valve on a boiler or hot water heater. It will release high pressure until a normal operating condition is reached. When the pressure is returned to normal, the safety valve is ready for the next operation.
- When a high voltage (greater than the normal line voltage) exists on the line, the arrester immediately furnishes a path to ground and thus limits and drains off the excess voltage. The arrester must provide this relief and then prevent any further flow of current to ground. The arrester has two functions; it must provide a point in the circuit at which an over-voltage pulse can pass to ground and second, to prevent any follow-up current from flowing to ground.

Causes of over voltages:

- Internal causes
- External causes
- **Internal causes**
- Switching surge
- Insulation failure
- Arcing ground
- Resonance
- **Switching surge:** The overvoltages produced on the power system due to switching are known as switching surge.
- **Insulation failure:** The most common case of insulation failure in a power system is the grounding of conductors (i.e. insulation failure between line and earth) which may cause overvoltage in the system.
- **Arcing ground:** The phenomenon of intermittent arc taking place in line to ground fault of a 3phase system with consequent production of transients is known as arcing ground.
- **Resonance:** It occurs in an electrical system when inductive reactance of the circuit becomes equal to capacitive reactance. Under resonance , the impedance of the circuit is equal to resistance of the circuit and the p.f is unity.

Types of Lightning strokes

(1) Direct stroke

- In direct stroke, the lightning discharge is directly from the cloud to the subject equipment. From the line, the current path may be over the insulator down the pole to the ground.

(2) Indirect stroke

- Indirect stroke results from the electrostatically induced charges on the conductors due to the presence of charge clouds.

Harmful Effects of lightning:

- **The travelling waves produced due to lightning will shatter the insulators.**
- **If the** travelling waves hit the windings of a transformer or generator it may cause considerable damage.

Protection against Lightning

- Different types of protective devices are:-

1) The Earthing screen

- The power station & sub-station can be protected against direct lightning strokes by providing earthing screens.
- On occurrence of direct stroke on the station, screen provides a low resistance path by which lightning surges are conducted to ground.
- Limitation:
- It does not provide protection against the travelling waves which may reach the equipments in the station.

2) Overhead ground wires

- It is the most effective way of providing protection to transmission lines against direct lightning strokes.
- It provides damping effect on any disturbance traveling along the lines as it acts as a short-circuited secondary.
- Limitation:
- It requires additional cost.
- There is a possibility of its breaking and falling across the line conductors, thereby causing a short-circuit fault.

3) Lightning Arresters

- It is a protective device which conducts the high voltage surge on the power system to ground
- The earthing screen and ground wires fail to provide protection against traveling waves. The lightning arrester provides protection against surges.

AC Power Surge Arrester

1) Type 1 Surge Protectors

- Type 1 surge protectors are designed to be installed where a direct lightning strike risk is high, especially when the building is equipped with external lightning protection system (LPS or lightning rod).
- In this situation IEC 61643-11 standards require the Class I test to be applied to surge protectors : this test is characterized by the injection of 10/350 μs impulse current in order to simulate the direct lightning strike consequence. Therefore these Type 1 surge protectors must be especially powerful to conduct this high energy impulse current.

2) Type 2 surge protectors

- Type 2 surge protectors are designed to be installed at the beginning of the installation, in the main switchboard, or close to sensitive terminals, on installations without LPS (lightning rods).
- These protectors are tested following the Class II test from IEC61643-11 based on 8/20 μs impulse current injection.

3) Type 3 surge protectors

- In case of very sensitive or remote equipment, secondary stage of surge protectors is required : these low energy SPDs could be Type 2 or Type 3. Type 3 SPDs are tested with a combination waveform (1,2/50 μs - 8/20 μs) following Class III test.

Types of Lightning Arrestors according to Class:

(1) Station Class

- Station class arrestors are typically used in electrical power stations or substations and other high voltage structures and areas.
- These arrestors protect against both lightning and over-voltages, when the electrical device has more current in the system than it is designed to handle.
- These arrestors are designed to protect equipment **above the 20 mVA range**.

(2) Intermediate Class

- Like station class arrestors, intermediate class arrestors protect against surges from lightning and over-voltages, but are designed to be used in medium voltage equipment areas, such as electrical utility stations, substations, transformers or other substation equipment.
- These arrestors are designed for use on equipment in the range of **1 to 20 mVA.**

(3) Distribution Class

- Distribution class arrestors are most commonly found on transformers, both dry-type and liquid-filled.
- These arrestors are found on equipment rated at **1000 kVA or less.**
- These arrestors are sometimes found on exposed lines that have direct connections to rotating machines.

(4) Secondary Class

- Secondary class lightning arrestors are designed to protect most homes and businesses from lightning strikes, and are required by most electrical codes, according to, Inc., an electrical power protection company.
- These arrestors cause high voltage overages to ground, though they do not short all the over voltage from a surge. Secondary class arrestors offer the least amount of protection to electrical systems, and typically do not protect solid state technology, or anything that has a microprocessor.

Choosing the Right AC Power Surge Arrester:

- AC power surge protectors is designed to cover all possible configurations in low voltage installations. They are available in many versions, which differ in:
- Type or test class (1 , 2 or 3)
- Operating voltage (Uc)
- AC network configuration (Single/3-Phase)
- Discharge currents (Iimp, Imax, In)
- Protection level (Up)
- Protection technology
- Features (redundancy, differential mode, plug-in, remote signaling).
- The surge protection selection must be done following the local electrical code requirements (i.e.: minimum rating for In) and specific conditions (i.e.: high lightning density).

Working Principle of LA:

- The earthing screen and ground wires can well protect the electrical system against direct lightning strokes but they fail to provide protection against travelling waves, which may reach the terminal apparatus. The lightning arresters or surge diverters provide protection against such surges. A lightning arrester or a surge diverter is a protective device, which conducts the high voltage surges on the power system to the ground
- The earthing screen and ground wires can well protect the electrical system against direct lightning strokes but they fail to provide protection against travelling waves, which may reach the terminal apparatus. The lightning arresters or surge diverters provide protection against such surges. A lightning arrester or a surge diverter is a protective device, which conducts the high voltage surges on the power system to the ground

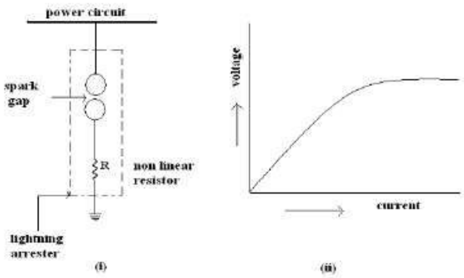


fig 7

- Fig shows the basic form of a surge diverter. It consists of a spark gap in series with a non-linear resistor. One end of the diverter is connected to the terminal of the equipment to be protected and the other end is effectively grounded. The length of the gap is so set that normal voltage is not enough to cause an arc but a dangerously high voltage will break down the air insulation and form an arc. The property of the non-linear resistance is that its resistance increases as the voltage (or current) increases and vice-versa. This is clear from the volt/amp characteristic of the resistor shown in Fig
- The action of the lightning arrester or surge diverter is as under:
- Under normal operation, the lightning arrester is off the line i.e. it conducts no current to earth or the gap is non-conducting
- On the occurrence of over voltage, the air insulation across the gap breaks down and an arc is formed providing a low resistance path for the surge to the ground. In this way, the excess charge on the line due to the surge is harmlessly conducted through the arrester to the ground instead of being sent back over the line.

- It is worthwhile to mention the function of non-linear resistor in the operation of arrester. As the gap sparks over due to over voltage, the arc would be a short-circuit on the power system and may cause power-follow current in the arrester. Since the characteristic of the resistor is to offer low resistance to high voltage (or current), it gives the effect of short-circuit. After the surge is over, the resistor offers high resistance to make the gap non-conducting.

Type of Lighting Arrestor for Out Door Applications:

- There are several types of lightning arresters in general use. They differ only in constructional details but operate on the same principle, providing low resistance path for the surges to the round.

1. Rod arrester
2. Horn gap arrester
3. Multi gap arrester
4. Expulsion type lightning arrester
5. Valve type lightning arrester

(I) Rod Gap Arrestor:

- It is a very simple type of diverter and consists of two 1.5 cm rods, which are bent at right angles with a gap in between as shown in Fig.
- One rod is connected to the line circuit and the other rod is connected to earth. The distance between gap and insulator (i.e. distance P) must not be less than one third of the gap length so that the arc may not reach the insulator and damage it. Generally, the gap length is so adjusted that breakdown should occur at 80% of spark-voltage in order to avoid cascading of very steep wave fronts across the insulators.
- The string of insulators for an overhead line on the bushing of transformer has frequently a rod gap across it. Fig 8 shows the rod gap across the bushing of a transformer. Under normal operating conditions, the gap remains non-conducting. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth. In this way excess charge on the line due to the surge is harmlessly conducted to earth
- **Limitations:**
- (i) After the surge is over, the arc in the gap is maintained by the normal supply voltage, leading to short-circuit on the system.
- (ii) The rods may melt or get damaged due to excessive heat produced by the arc.
- (iii) The climatic conditions (e.g. rain, humidity, temperature etc.) affect the performance of rod gap arrester.
- (iv) The polarity of the f the surge also affects the performance of this arrester.
- Due to the above limitations, the rod gap arrester is only used as a back-up protection in case of main arresters.

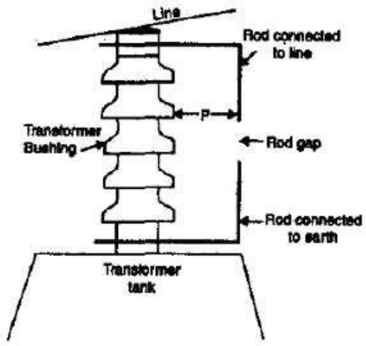


fig 8

(II) Horn Gap Arrester:

- Fig shows the horn gap arrester. It consists of a horn shaped metal rods A and B separated by a small air gap. The horns are so constructed that distance between them gradually increases towards the top as shown.
- The horns are mounted on porcelain insulators. One end of horn is connected to the line through a resistance and choke coil L while the other end is effectively grounded.
- The resistance R helps in limiting the follow current to a small value. The choke coil is so designed that it offers small reactance at normal power frequency but a very high reactance at transient frequency. Thus the choke does not allow the transients to enter the apparatus to be protected.
- The gap between the horns is so adjusted that normal supply voltage is not enough to cause an arc across the gap.

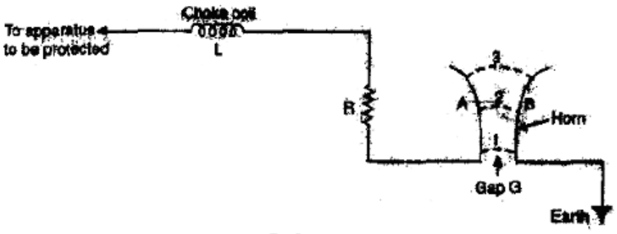


fig 9

- Under normal conditions, the gap is non-conducting i.e. normal supply voltage is insufficient to initiate the arc between the gap. On the occurrence of an over voltage, spark-over takes place across the small gap G. The heated air around the arc and the magnetic effect of the arc cause the arc to travel up the gap. The arc moves progressively into positions 1,2 and 3.
- At some position of the arc (position 3), the distance may be too great for the voltage to maintain the arc; consequently, the arc is extinguished. The excess charge on the line is thus conducted through the arrester to the ground.

(III) Multi Gap Arrester:

- Fig shows the **multi gap arrester**. It consists of a series of metallic (generally alloy of zinc) cylinders insulated from one another and separated by small intervals of air gaps. The first cylinder (i.e. A) in the series is connected to the line and the others to the ground through a series resistance. The series resistance limits the power arc. By the inclusion of series resistance, the degree of protection against traveling waves is reduced.
- In order to overcome this difficulty, some of the gaps (B to C in Fig) are shunted by resistance. Under normal conditions, the point B is at earth potential and the normal supply voltage is unable to break down the series gaps. On the occurrence an over voltage, the breakdown of series gaps A to B occurs.
- The heavy current after breakdown will choose the straight – through path to earth via the shunted gaps B and C, instead of the alternative path through the shunt resistance.

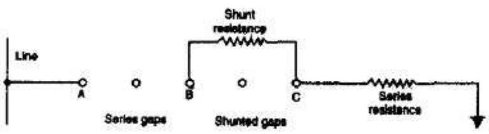


fig 10

- Hence the surge is over, the arcs B to C go out and any power current following the surge is limited by the two resistances (shunt resistance and series resistance) which are now in series. The current is too small to maintain the arcs in the gaps A to B and normal conditions are restored. Such arresters can be employed where system voltage does not exceed 33kV.

(IV) Expulsion Type Arrester:

- This type of arrester is also called 'protector tube' and is commonly used on system operating at voltages up to 33kV. Fig shows the essential parts of an expulsion type lightning arrester.
- It essentially consists of a rod gap AA' in series with a second gap enclosed within the fiber tube. The gap in the fiber tube is formed by two electrodes. The upper electrode is connected to rod gap and the lower electrode to the earth. One expulsion arrester is placed under each line conductor. Fig shows the installation of expulsion arrester on an overhead line.

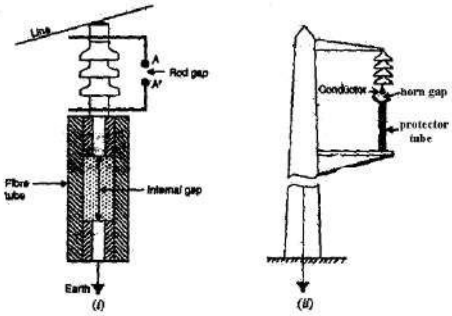


fig 11

- On the occurrence of an over voltage on the line, the series gap AA' spanned and an arc is stuck between the electrodes in the tube. The heat of the arc vaporizes some of the fiber of tube walls resulting in the production of neutral gas. In an extremely short time, the gas builds up high pressure and is expelled through the lower electrode, which is hollow. As the gas leaves the tube violently it carries away ionized air around the arc. This de ionizing effect is generally so strong that the arc goes out at a current zero and will not be re-established.

Advantages:

- They are not very expensive.
- (ii)They are improved form of rod gap arresters as they block the flow of power frequency follow currents
- (iii)They can be easily installed.

Limitations:

- (i)An expulsion type arrester can perform only limited number of operations as during each operation some of the fiber material is used up.
- (ii) This type of arrester cannot be mounted on enclosed equipment due to discharge of gases during operation.
- (iii)Due to the poor volt/am characteristic of the arrester, it is not suitable for protection of expensive equipment

(V) Valve Type Arrester:

- **Valve type arresters** incorporate non linear resistors and are extensively used on systems, operating at high voltages. Fig shows the various parts of a valve type arrester. It consists of two assemblies (i) series spark gaps and (ii) non-linear resistor discs in series. The non-linear elements are connected in series with the spark gaps. Both the assemblies are accommodated in tight porcelain container.
- **The spark gap** is a multiple assembly consisting of a number of identical spark gaps in series. Each gap consists of two electrodes with fixed gap spacing. The voltage distribution across the gap is line raised by means of additional resistance elements called grading resistors across the gap. The spacing of the series gaps is such that it will withstand the normal circuit voltage. However an over voltage will cause the gap to break down causing the surge current to ground via the non-linear resistors.
- **The non-linear resistor discs** are made of inorganic compound such as thyrite or metrosil. These discs are connected in series. The non-linear resistors have the property of offering a high resistance to current flow when normal system voltage is applied, but a low resistance to the flow of high surge currents. In other words, the resistance of these non-linear elements decreases with the increase in current through them and vice-versa.

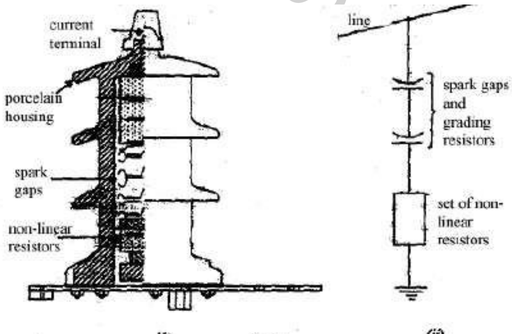


fig 12

Working.

- Under normal conditions, the normal system voltage is insufficient to cause the break down of air gap assembly. On the occurrence of an over voltage, the breakdown of the series spark gap takes place and the surge current is conducted to earth via the non-linear resistors. Since the magnitude of surge current is very large, the non-linear elements will offer a very low resistance to the passage of surge. The result is that the surge will rapidly go to earth instead of being sent back over the line. When the surge is over, the non-linear resistors assume high resistance to stop the flow of current.

(VI) Silicon carbide arresters:

- A great number of silicon carbide arresters are still in service. The silicon carbide arrester has some unusual electrical characteristics. It has a very high resistance to low voltage, but a very low resistance to high-voltage.
- When lightning strikes or a transient voltage occurs on the system, there is a sudden rise in voltage and current. The silicon carbide resistance breaks down allowing the current to be conducted to ground. After the surge has passed, the resistance of the silicon carbide blocks increases allowing normal operation.
- The silicon carbide arrester uses nonlinear resistors made of bonded silicon carbide placed in series with gaps. The function of the gaps is to isolate the resistors from the normal steady-state system voltage. One major drawback is the gaps require elaborate design to ensure consistent spark-over level and positive clearing (resealing) after a surge passes. It should be recognized that over a period of operations that melted particles of copper might form which could lead to a reduction of the breakdown voltage due to the pinpoint effect. Over a

period of time, the arrester gap will break down at small over voltages or even at normal operating voltages. Extreme care should be taken on arresters that have failed but the over pressure relief valve did not operate.

(VII) Metal Oxide Arrestor:

- The MOV arrester is the arrester usually installed today
- The metal oxide arresters are without gaps, unlike the SIC arrester. This "gap-less" design eliminates the high heat associated with the arcing discharges.
- The MOV arrester has two-voltage rating: duty cycle and maximum continuous operating voltage, unlike the silicon carbide that just has the duty cycle rating. A metal-oxide surge arrester utilizing zinc-oxide blocks provides the best performance, as surge voltage conduction starts and stops promptly at a precise voltage level, thereby improving system protection. Failure is reduced, as there is no air gap contamination possibility; but there is always a small value of leakage current present at operating frequency.
- It is important for the test personnel to be aware that when a metal oxide arrester is disconnected from an energized line a small amount of static charge can be retained by the arrester. As a safety precaution, the tester should install a temporary ground to discharge any stored energy.
- **Duty cycle rating:** The silicon carbide and MOV arrester have a duty cycle rating in KV, which is determined by duty cycle testing. Duty cycle testing of an arrester is performed by subjecting an arrester to an AC rms voltage equal to its rating for 24 minutes. During which the arrester must be able to withstand lightning surges at 1-minute intervals.
- **Maximum continuous operating voltage rating***:* The MCOV rating is usually 80 to 90% of the duty cycle rating.

Maintenanceof LA:

- Cleaning the outside of the arrester housing.
- The line should be de-energized before handling the arrester.
- The earth connection should be checked periodically.
- To record the readings of the surge counter.
- The line lead is securely fastened to the line conductor and arrester
- The ground lead is securely fastened to the arrester terminal and ground.

Chapter:74 Selection of Surge Protective Device (SPD)

Introduction:

- A device which diverts or limits surge current is called Surge protective devices (SPD).
- SPD protect electrical equipment against over voltages caused by lightning or Switching. It is wired in parallel to the equipment which is needed to be protected.
- Once the surge voltage exceeds SPD's rating it starts to conduct energy directly to the electrical grounding system. An SPD has a very low resistance during this time and give low resistance path the energy to ground. Once the surge is over it gives high resistance path to current.
- SPD is previously known as Transient Voltage Surge Suppressors (TVS) or Secondary Surge Arresters.
- Underwriter laboratories ,UL 1449 Listed SPDs are now designated as either Type 1, Type 2 or Type 3 and intended for use on AC power systems rated Less than 1000vrms

Principle:

- SPD is used to limit transient over voltages of atmospheric or Switching Surge and gives path to the excessive current to earth hence limit the overvoltage to a value that is not hazardous for the electrical installation.

Causes of Surges:

- **External Surge:**
- lightning strikes :Direct Stroke , Indirect Stroke
- **Internal Surge:**
- **Switching Surge:**
- Switching on/off of inductive loads.
- Tripped circuit breakers and fuses.
- Short circuits.
- Malfunctions caused by the power company.
- **Insulation Failures:**
- **Arcing Ground:**
- Ignition and interruption to electric arc.

Difference between Surge arrestor (Lighting Arrestor) and Surge Suppressor:

- Surge arresters and Surge Suppressor both are used to protect equipment from surges. But, there is confusion between the application of surge arrestors / Lighting arrestor and surge suppressors.
- The main differences between a lightning arrester and a surge arrester are its fault clearing time and it's position
- Both are doing the same job, but still both are not same.

Lighting Arrestor / Surge Arrestor:

- Surge Arresters are widely also known Lightning arresters.
- Surge arresters are devices installed on Over head lines, substations etc to avoid a Lighting surge and other Surges of an additional current/ voltage/charge due to various faults occurring.
- In the past year when nonlinear / solid-state devices (computers, PLC and drives) were not used. The Electrical Load is mostly Linear Load. Utility companies and end users were concerned with how to protect electrical distribution systems from lightning surges to ensure that voltage surges did not exceed the basic insulation level (BIL) of the conductor wires, transformers and other equipment.
- Hence Surge arrestors / Lighting arrestors were developed for use in low, medium and high voltage applications at various points in the transmission and distribution system.
- Surge Arrestor provide low resistance path between the phase conductor and ground. LA did not concern with the loads if it cleared within a few cycles.
- Arrestors are still used in the electrical industry primarily along the transmission lines and upstream of a facility's service entrance.
- Arrestors are available in various classes depending upon their withstand capability (e.g., station vs. distribution class). At the service entrance location on low voltage systems (600V and below), Lightning arrestors were designed to protect the electrical distribution system and not the sensitive solid-state equipment.
- Economically, surge arresters are better than surge protectors. Different surge arresters are available based on their withstanding capability. The main problem with them is that they are designed for protecting large electrical distribution systems from lightning surges, and not for sensitive solid state equipment.
- **Applications:** The surge arrester is best to protect insulation of transformers, panel boards, and wirings. However, it doesn't work well for solid state components.

Surge Suppressor / Surge Protector (called TVSS):

- In today's we mostly use solid-state (nonlinear) loads like electronic equipment, drives, PLCs, computers, electronic ballasts, telecommunication equipment. Non Linear is about 70% of utility loads. The solid-state components will be damaged by the surges.
- Using Surge suppressors at the service entrance and key branch panels, the surge will be effectively reduced to under 100V.
- If a TVSS and lightning arrestor are both used at a service entrance switchboard, the TVSS will "turn on" earlier and shunt most of the surge current. Many water-treatment plants, telecommunication facilities, hospitals, schools and heavy industrial plants utilize TVSSs instead of surge arrestors to provide protection against the effects of lightning, utility switching, switching electric motors.
- **Applications:** They are used in water treatment plants, hospitals, schools, and telecommunication facilities.

Size of Surge Protection Device (SPD) does not depend on Panel Size:

- The kA rating of an SPD (surge rating) is one of the most misleading terms. We normally use 50KA SPD to protect 50KA panel.
- The kA rating of the surge arresters has nothing to do with the fault current rating of electrical distribution board. We can fit a 40kA surge arrester in a domestic board with a fault current rating of less than 5kA
- When a surge enters a panel, it does not know the size of the panel. So It is totally miscalculation for use 50KA SPD for 50KA Panel
- There is a normal Practice that larger panels need larger SPD, but **surges are indifferent to panel size.**
- The largest surge that can enter a building's wiring is 10kA, as explained in the IEEE C62.41 standard. So why would we need a SPD rated for 100KA or 200kA.

Size of Surge Protection Device (SPD) depends upon Location of Panel:

- Panel location within the electrical system is more important than the panel's size.
- The location of the panel within the facility is much more important. IEEE C62.41.2 defines the types of expected surges within a facility as:
- **Category C:** Service Entrance, more severe environment: **10kV, 10kA surge**
- **Category B:** Downstream more than 30feet from category C, less severe environment: **6kV, 3kA surge**
- **Category A:** Further downstream, more than 60 feet from category C, least severe environment: 6kV, 0.5kA surge
- When selecting the appropriate kA rating for an SPD.
- **Category C: 100kA to 200kA per phase**
- **Category B: 50kA to 100kA per phase**
- **Category A: 50kA to 100kA per phase**

Large Size of Surge Protection Device (SPD) does not give better Protection:

- Most SPDs use a metal oxide varistor (MOV) as the main limiting device. If an MOV is rated for 10kA and having a 10kA surge, it would use 100% of its capacity. The surge will degrade the MOV a little bit.
- Now if we use 20KA SPD so this SPD has two 10kA MOVs in parallel. The MOVs will equally split the 10kA surge, so each would take 5kA. In this case, each MOV have only used 50% of their capacity which degrades the MOV much less than 10KA SPD
- Again It is totally misleading that two parallel path (in 20KA SPD) absorb surge faster or better than single path SPD (like 10KA SPD) of same rating.
- **The main purpose of having MOVs in parallel is to increase the longevity or Life of the SPD.**
- Again, It is need to clear that it is subjective and at some point we are only adding cost by incorporating more MOV's and receiving little benefit.
- **Larger kA ratings are for redundancy & longer life only.**

SPD can not give 100% Protection against All Types of electrical disturbance

- There is a misconception about SPDs is that they are designed to protect against all Electrical problems.
- **SPD is not designed to protect against excessive voltage at the fundamental power frequency**. It is design to give protection against surges (by direct lighting or voltage surges in line at remote location).
- **SPD can not give Protection against Poor Power Quality (Harmonics)**
- Some SPDs contain filtering to remove high frequency noise (50 kHz to 250 kHz), But SPD cannot filter harmonic loads (3rd through 50th harmonic equals180 to 3000 Hz).
- **SPD can not give Protection against Under Voltage.**
- SPD can not give protection against under voltage problems.
- **SPD can not give Protection against direct lighting Strikes.**
- An SPD can not prevent damage caused by a direct lightning strike. A direct lightning strike causes induced surges on the power line that are reduced by the SPD But SPD can not Protect against Lighting Strikes near SPD Location.
- **SPD can not give protection against temporary overvoltage.**
- Temporary overvoltage is caused by a severe fault in the utility power or due to problems with the ground (poor or nonexistent N-G bond).

- Temporary overvoltage occurs when the Voltage exceeds the nominal voltage for a short duration (millisecond to a few minutes).
- If the voltage exceeds 25% of the nominal system voltage, the SPD and other loads may become damaged.

Selection of Surge Protection device (SPD):

The Size, performance and specification of SPD depend on following characteristics

Current characteristic of SPD

- **I:**Surge Current Rating (KA),
- **In:** Nominal Discharge Current (In),
- **Imax:** Maximum discharge Current (Imax)
- Short Circuit Current Rating (SCCR).

Voltage characteristic of SPD

- **Uc:** Maximum Continuous Operating Voltage (MCOV),
- **Up:** Voltage Protection Rating (VPR) or surge voltage rating (SVR) or Clamping Voltage.
- **TOV:** Temporary Over Voltage.

(1) Surge Current Ratings (I):

- **The peak surge current ratings of SPD are generally based on the sum of Line-neutral and Line-ground current.**
- A peak ampere rating per phase. (I.e. L-N 100 kA, L-G 100 kA provides 200 kA/phase).
- Other Specification like MCOV, VPR, In and SCCR that have clearly defined test criteria, but for Surge Current there is no specified Test Criteria or industry-standard hence different SPD manufacturers to create their own definitions of peak ampere surge current ratings.
- Please note that selection of **Higher Surge Current Ratings don't always gives Better Protection but it is provide loner life.**
- IEEE Clearly states that "The selection of a surge current rating for an SPD should be matched to the expected surge environment and the expected or desired useful life of the device."
- Selection of Surge Rating for an SPD depends on The location of the SPD within the electrical distribution & environmental surroundings condition of Site.
- Following surge current ratings based on SPD location within the electrical distribution.

Surge current ratings based on SPD location	
Location	**Surge Current**
Service Entrance Locations	240 kA
Distribution Locations	120KA to 160 kA
Branch Locations	50KA to 120 kA

(2) Nominal discharge current rating (In):

- The Nominal Discharge Current is the peak value of surge current conducted through the SPD. It has 8/20µs Impulse current Waveform .The SPD must function after 15 applied surges.
- Nominal discharge Current shows durability of SPD. The highest nominal discharge current rating is 20kA.
- **Example :** calculate In for Maximum peak current(Surge Current): I=200 kA (the maximum level of natural lightning where 5% of strikes are bigger than 100 kA)
- Assume that for perfect current sharing 50 % to ground and 50 % to the electrical network
- Network configuration is 3 Phases + Neutral (n=4)
  In = Surge Current X Current path to Ground (%) / No of Path =200 x 0.5 / 4 = 25 kA
- The Nominal discharge current values, with a 8/20µs wave shape as per UL 1449 are
- **Type 1 SPD (In)= 10KA or 20 kA**
- **Type 2 SPD (In)= 3KA ,5KA,10KA or 20 kA**
- The Nominal discharge current value as per IEEE C62.41 is 200A to 10KA.
- The Nominal discharge current value as per NFPA is 20KA

(3) Maximum discharge current (Imax):

- The maximum surge current between any one phase and neutral that the SPD can withstand for a single strike of 8/20µs or 10/350µs current is called Maximum discharge current of SPD.
- This is the maximum value of a surge current that can be diverted by the surge protective device.
- current surges have two different wave shapes

- Lightning currents is a long wave shape (10/350µs) which represents direct lightning strike.
- Short wave shape (8/20 µs) which represents a indirect strike;
- lmax is the maximum value of a short wave shape current and limp is the value of a long wave shape current; the value lmax or limp has to be adapted to the expected value of the possible lightning currents.
- **Imax > In**

(4) Short circuit current rating (SCCR):

- Maximum symmetrical fault current, at rated voltage, that the SPD can withstand without sustaining damage is called SCCR of SPD.
- Every electrical system has an available short circuit current. This is the amount of current that can be delivered by the system at a particular point in a short circuit situation.
- SCCR shoes that Measure of how much current the electrical utility can supply during a fault condition.
- SCCR is not a surge rating but it is the maximum allowable current a SPD can interrupt in the event of a failure.
- NEC Article 285.6 says that the SPD to be installed where the available fault current is less than the SCCR rating of the SPD unit.

Typical available short circuit currents	
Load	**short circuit currents of SPD**
Residential	5KA to 10kA
Small commercial	14KA to 42kA
Large commercial/industrial	42kA to 65kA
Large industrial/utility/downtown in large cities	100kA to 200kA
At a sub panel	120kA to 160kA provides good protection and life
Point of use SPDs	80kA to 100kA perform well

(5) Calculating Maximum Continuous Operating Voltage (MCOV or Uc):

- When Surge Protector are installed to protect systems from lightning or switching surges, it should be installed between the phase and earth. Hence MCOV of the installed arrester must be equal or higher to the continuous voltage between the phase and earth.
- On three phase systems, the line to ground voltage is equal to the phase to phase voltage divided by 1.73
- **For example**: on a 440kV transmission system, the nominal system phase to phase voltage is 440kV therefore the line to earth voltage would be 440/1.73=254kV. Since all systems have some regulation error. If the regulation is 10%, then the line to ground voltage could be 254x 1.10 = 280kV. The MCOV or Uc or an arrester for this system at a minimum should be 280kV.

Typical MCOVs	
System	**MCOV**
120V system	150V MCOV
240V system	320V MCOV
480V system	550V MCOV

- Selecting SPD with too low of a voltage rating will result in SPD failure
- Selecting SPD with too high of a voltage rating will result in reduced protection

(6) Calculating Line to Ground Voltage:

- The maximum rms voltage that can be applied to each mode of the SPD is called MCOV
- When a three phase power system have a fault between one of the Phase to earth, the Voltage of two healthy phases to ground increase. Since Arrestor is mostly connect between Phase and Earth hence Voltage across LA terminals also Increase.
- This increase in voltage will remain across the arrester until a system breaker operates and breaks or interrupts the fault. This is a very significant event in the life of an arrester and must be accounted for during the voltage rating selection of an arrester.
- There are some rules of thumb and graphs that can be used, but these are quit crude and difficult at best to use. Annex C of IEEE standard C62.22 and Annex A of IEC 60099-5 cover this subject.
- For distribution systems where the system and transformer impedances are relatively unknown, a worst case scenario is used for each type of system. The voltage rise during a fault in these cases is determined by multiplying the line to ground voltage by

Type of System	Ground Fault Factor

Solidly Grounded 4 wire systems	1.25
Uni-grounded 3 wire systems	1.4
Impedance grounded systems	1.73
Isolated Ground Systems and Delta Systems	1.73

- **For example:** In a 440kV multi-grounded system, the maximum continuous line to ground voltage = Phase to Phase Voltage /1.73 =440/1.73=254kV. The voltage during a ground fault on the un faulted phases can reach 254 x 1.25 or = 318kV rms. This is the voltage an arrester will see across its terminals for as long as the fault exists.

(7) Voltage protection level (UP at In):

- This is the maximum voltage across the terminals of the SPD when it is active. This voltage is reached when the current flowing in the SPD is equal to Nominal discharge current (In).
- The voltage protection level must be below the overvoltage withstand capability of the loads.
- In the event of lightning strokes, the voltage across the terminals of the SPD generally remains less than Up.
- While diverting the surge current to the ground Voltage Protection Level (Up) must not exceed the voltage withstand value of the equipment connected downstream.
- Suppressed Voltage Rating (SVR) was part of an earlier version of UL 1449 Edition and is no longer used in the UL 1449 standard. The SVR was replaced by VPR.

(8) Temporary Over Voltage (TOV):

- It is used to describe temporary Surge which can arise as a fault of faults within medium & Low voltage.
- **UTov=1.45X Uo**, where Uo= Nominal Line to earth Voltage.
- For 230/440V System UTov=1.45X230 = 333.33Volt

Type of SPD:

Type 1 SPD:

- **Protection for :** Transient Over voltages due to Direct Lightning Strokes
- **Location :** It is installed at any location between the secondary of the utility service transformer and the service entrance primary disconnection
- It is installed in the main electrical switchboard when the building is equipped with a lightning protection system.
- It protects against external surges caused by lightning or utility capacitor bank switching.
- These devices to discharging a very high lightning current from earth to the power distribution system.
- **Current ratings:** 10Ka to 35Ka – 10/350µs wave form.
- **Required Dedicated Fuse / Circuit Breaker for SPD :** No
- **Risk Factor : Very strong risk Area**

Type 2 SPD:

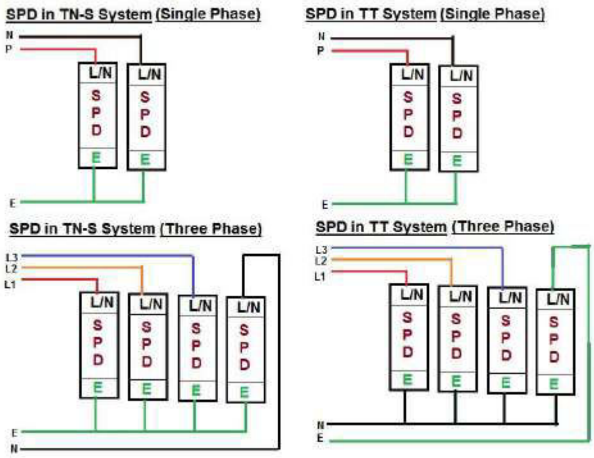
- **Protection for:** Transient Over voltages due to Switching and Indirect Lightning Stroke.
- **Location:** It is installed in the main distribution switchboard.
- It is designed to discharge the currents generated by indirect lightning strokes and causing induced or conducted overvoltage on the power distribution network.
- It protects against residual lightning energy, motor driven surges and other internally generated surges.
- **Current ratings:** 5Ka to 200 Ka – 8/20µs wave form.
- **Required Dedicated Fuse / Circuit Breaker for SPD :** May or May Not
- **Risk Factor :** Common risk Area

Type 3 SPD:

- **Protection for:** Sensitive Loads.
- It is installed as a supplement to Type 2 devices and to reduce the overvoltage at the terminals of sensitive equipment.
- Their current discharge capacity is very limited. As a consequence they cannot be used alone.
- Installed at minimum conductor length of 10 meters (30 feet) from the electrical service panel to the point of utilization
- Provides point-of-use protection, easily replaceable and it provides the last line of defense against a lightning strike.
- **Risk Factor :** Very strong & common risk Area

Connection of SPD in Distribution Box.

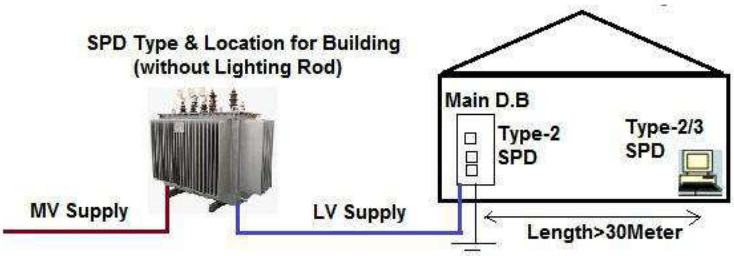
- In common mode: Phase to earth or neutral to earth
- In differential mode: Phase to phase or phase to neutral



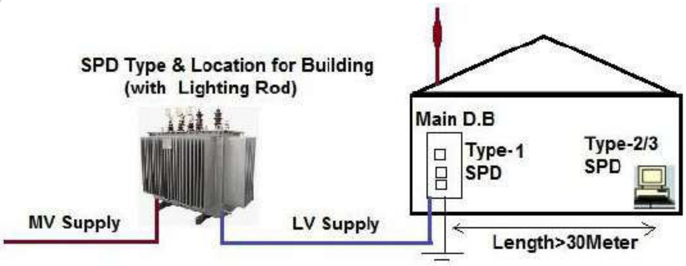
Factors effect on SPD Performance:

(1) Location of Surge Protection Device:

- Lightning protection should be installed on a overall viewpoint of Protection.
- For large industrial plants, data centers, hospitals, a **risk assessment** method must be used to guide in choosing optimal distance.
- In other cases like housing, offices, buildings Where there is not or less sensitive industrial risks, we may adopt following principle to select SPD.**Type 2** surge protective device should be installed in the electrical installation's incoming Main switchboard.
- If the distance between that surge protective device and the equipment to be protected is more than 30 meters, than additional surge protective device **(Type 2 or Type 3)** should be installed near the equipment.



- When the building is equipped with a lightning protection system, a **Type 1** surge protective device must be installed at the incoming Main Switch Board. There exist surge protective devices combining Type 1 and Type 2 in the same enclosure.



- The Lightning rods have to be located on the highest points of the structure, taking into account the location of the grounding, and that the path of the down conductors are as short and straight as possible .

(2) Size of Down Conductor:

- Lightning is a phenomenon that generates a high frequency voltage. The length of the cables must be taken into account in cases of high frequency.
- The down conductors may be tapes, stranded wire or solid round.
- The minimum cross section must be **50mm2.**

- 1 meter of cable crossed by a lightning current generates an overvoltage of 1,000V.
- Mandatory in Standard IEC 60364-5-534:
- **L (length of cables) < 50cm,**
- **Cable cross-section of Cable (S) < $16mm^2$ (Type 1).**
- **Cable cross-section of Cable (S) < $4mm^2$ (Type 2).**

(3) Placement of Down Conductor

- Down conductor will be placed on the outside of the structure.
- When it is impossible to make a down conductor on the outside, conductors can be introduced in a non-flammable insulating pipe, with a minimum section of 2000 mm2, for this purpose.
- The down conductors on the inside decrease the effectiveness of lightning protection, increase the risk of over voltages penetration of and difficult the verification and maintenance of installation.

(4) Number of Down Conductor

- At least one down conductor for every lightning rod. A minimum of two down conductor when,
- (1) The horizontal Projection length of the conductor exceeds its vertical projection length.
- (2) The height of the structure is greater than 28 meters.
- Equipotential bonding will be made between the conductors at ground level and every 20 meters.
- According to UNE 21186:
- (1) Each lightning rod shall be grounded by two down conductors.
- (2) It will be necessary 4 down conductors on buildings higher than 60 meters.
- (3) It should be placed whenever possible in the 4 corners of the building.

(5) Path of Down Conductor

- The down conductor routes will the shortest path, straight and direct to grounding.
- We should avoiding elevations above 40 cm with slope equal to or greater than 45°.
- The radii of curves shall not be less than 20 cm and direction changes less than 90°.
- The route will be chosen so as to avoid proximity to electrical conduits, telephone, data and its crossing with them.
- In any case, when we can not avoid an intersection conduit must be placed inside a metallic shield that extended 1 m to each side of the crossing, and the shield should bind to the down conductor.

(6) Safety Distance:

- According CTE SU8:
- **Safety distance (m) = 0.1 x L**
- L = vertical distance from the point where it is considered the proximity to the grounding of the metal mass
- Safety distance to outdoor gas pipelines ≥ 5 m.
- According to UNE 21186:
- Safety distance for 1 no of down conductor (m) = 0.16 x L
- Safety distance for 2 No of down conductors (m) = 0.08 x L
- Safety distance for 4 No of down conductors (m) = 0.04 x L
- L = length of the down conductor from the point where it is considered the separation distance to the point where is located the nearest equipotential point.

(7) Earthing:

- There will be 1 grounding system for each down conductor.

(8) Lighting Counter:

- The lightning counter must be installed over the more direct down conductor, above the joint control, and in all cases, about **2 meters above the ground.**

(9) Size of Surge Protection Device:

- A type 2 surge protective device depends mainly on the exposure zone (moderate, medium, high).
- Type-2 SPD has discharge capacity **(Imax) of 20 kA, 40 kA, 65 kA (8/20 µs).**
- Type 1 SPD has minimum discharge capacity **(Imax) of 12.5 kA (10/350).**
- Higher values may be required by the risk assessment when it’s required.
- **For residential or light commercial locations:** a surge current rating of **20 kA to 70 kA (8/20 µs)** per phase should be sufficient. Installations in

- **For high-lightning areas:** SPDs with higher surge current ratings of **40 kA to 120 kA**, to provide a longer service life and higher reliability.

Typical System Voltage & MCOV rating (As per IEEE):

Typical IEEE System Voltages			
Normal (Line to Line) Voltage (KV rms)	Maximum (Line to Line) Voltage (KV rms)	Maximum (Line to Ground) Voltage (KV rms)	Min MCOV
kV rms	kV rms	kV rms	kV rms
2.40	2.52	1.46	1.46
4.16	4.37	2.52	2.52
4.80	5.04	2.91	2.91
6.90	7.25	4.19	4.19
8.32	8.74	5.05	5.05
12.0	12.6	7.28	7.28
12.5	13.1	7.57	7.57
13.2	13.9	8.01	8.01
13.8	14.5	8.38	8.38
20.8	21.8	12.6	12.6
22.9	24.0	13.9	13.9
23.0	24.2	14.0	14.0
24.9	26.2	15.1	15.1
27.6	29.0	16.8	16.8
34.5	36.2	20.9	20.9
46.0	48.3	27.9	27.9
69.0	72.5	41.9	41.9
115.0	121	69.8	69.8
138.0	145	83.8	83.8
161.0	169	98	97.7
230.0	242	140	140
345.0	362	209	209
500.0	525	303	303
765.0	800	462	462

Typical System Voltage & MCOV rating (As per IEC):

Typical IEC System Voltages			
Normal (Line to Line) Voltage (KV rms)	Maximum (Line to Line) Voltage (KV rms)	Maximum (Line to Ground) Voltage (KV rms)	Minimum Uc
kV rms	kV rms	kV rms	kV rms
3.3	3.7	2.1	2.1
6.6	7.3	4.2	4.2
10.0	11.5	6.6	6.6
11.0	12.0	6.9	6.9
16.4	18.0	10.4	10.4
22.0	24.0	13.9	13.9
33.0	36.3	21.0	21.0
47.0	52	30.1	30.1
66.0	72	41.6	41.6
91.0	100	57.8	57.8
110.0	123	71.1	71.1
132.0	145	83.8	83.8
155.0	170	98.3	98.3
220.0	245	142	142
275.0	300	173	173

330.0	362	209	209
400.0	420	243	243

SPD and Fuse / CB co-ordination chart:

Fuse/CB co-ordination chart			
Incoming feeder fuse rating (A)	**Incoming feeder CB Rating (A)**	**SPD fuse rating (A)**	**SPD CB rating (A)**
16	6	10	4
25	10	16	6
32	16	20	10
40	20	25	16
63	32	40	20
80	40	50	25
125	63	80	40
160	80	100	50
250	125	160	80
500	250	320	160

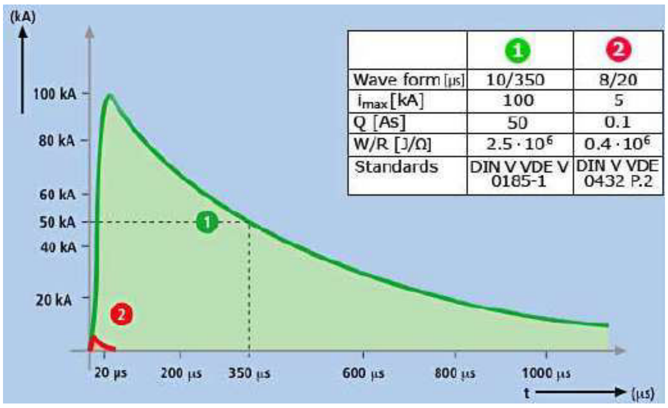
Sample Specifications of SPD for 277/480V Supply System

- **Voltage :**277/480V 3Ø WYE, 480V 3Ø Delta
- **Frequency:** 50/60Hz
- **Surge Technology:** 40mm MOV
- **Nominal Discharge Rating (IN):**20kA
- **Maximum Continuous Operating Voltage (MCOV):** 320V
- L-L=640V / L-N=320A / L-G=320A / G-N=320A
- **Maximum Surge Current, Per Mode (Per Phase) :** 200kA (400kA
- **Voltage Protection Rating (VPR) (Clamping) :** 800V(L-N)/700V(L-L)
- **Short Circuit Current Rating (SCCR):** 10kA
- **Connection Type:** Parallel Connection

Reason for Failure of SPD:

- Most SPDs will last for many years. The things that cause sudden failure are
- External supply faults such as overvoltage -faulty transformer, MV lines
- Local supply faults -broken or ungrounded neutral.
- Wrongly-selected SPD voltage.
- A surge in excess of the SPD’s rating.

Classes of surge arrestors according to impulse current:



- **1 = Test impulse current for lightning current arresters**
- **2 = Test impulse current for surge arresters**

- There are 3 x main categories of lightning surge arresters.
- Class 1/A - (10/350) lightning current arresters, which can withstand direct lightning
- Class 2/B - (8/20) surge arresters, to protect against induced surge currents
- Class 3/C - (8/20) surge arresters, to protect against induced surge currents

Meaning of 20kA (8/20µS) impulse current.

- In 8/20µS. The first value (8) is the rise time (from 10% to 90% of peak). The second value (20) is the duration for the test transient to decrease to half its peak value.

Standard for SPD:

- Underwriter laboratories—UL 1449 (3rd Edition 2009)
- IEEE C62.45 (2002)
- NECT National Electrical Code Articles 245, 680 and 800.
- NFPAT 780 Lightning protection code recommendations for the use of surge protection devices at a facility service entrance.

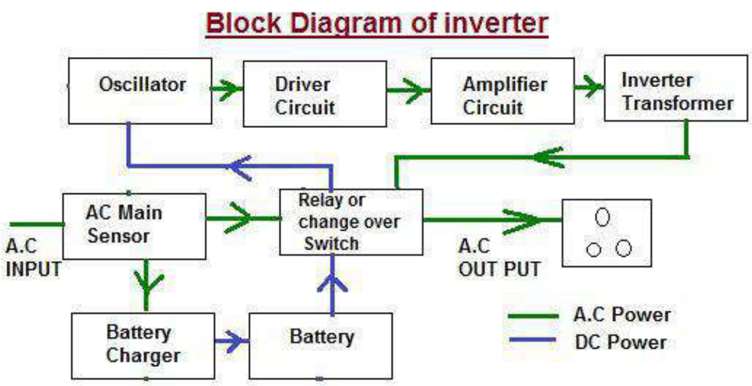
Chapter: 75 Selection of Various Types of Inverters

Introduction:

- In this modern society, electricity has vital role on the most daily activities for domestic and industrial utilization of electric power for operations.
- An inverter is used to provide uninterrupted 220V AC supply to the load connected to its output socket. It provides constant AC supply at its output socket, even when the AC mains supply is not available.
- There are many factors, which are affecting on selecting of the best inverter for our application

Block Diagram of Inverter:

- Power inverter is a device that converts electrical power from DC form to AC form using electronic circuits. It is typical application is to convert battery voltage into conventional household AC voltage to use Equipments, when an AC power is not available.
- There are two methods, in which the low voltage DC power is inserted into AC Power.
- In First Method first is the conversion of the low voltage DC power to a high voltage DC source, an then It is the conversion of the high DC source to an AC waveform using pulse width modulation.
- In Second method the outcome would be to first convert the low voltage DC power to AC, and then use a transformer to boost the voltage to 220 volts.
- The widely used method in the current residential inverter is the second.
- An Inverter not only converts the DC Voltage of battery to 220V V AC Signals but also charge the Battery when the AC mains are present.
- The block diagram shown above is a simple depiction of the way an Inverter Works.



When the AC mains power supply is available.

- When the Utility Company AC mains supply is available.
- A.C Main Sensor: the AC sensor senses it and the 230V A.C supply feeds to the Relay and battery charger.
- Relay or Change over Switch: AC main sensor activates a relay and this relay will directly pass the 230V AC mains supply to the Load.
- Battery Charger: Battery Charger converts line A.C Voltage to DC Voltage and Charges the Battery even when A.C Power is available.
- Battery: Battery is charged and it is stopped when it is full charged.

When the AC mains power supply is not available.

- When the AC mains power supply is not available.
- Relay or Change over Switch: AC main sensor activates a relay and this relay will connected to battery in absent of the AC mains supply.
- Battery: Battery is providing DC Power to Oscillator circuit through Relay.
- Oscillator Circuit: An oscillator circuit inside the inverter use pulse width modulator to generate the 50Hz frequency required to generate AC supply by the inverter.
- The battery DC supply is connected to the Oscillator. The flip-flop converts the incoming signal into signals with changing polarity such that in a two-signal with changing polarity.
- The first is positive while the second is negative and vice versa. This process is repeated 50times per second to give an alternating signal with 50Hz frequency. This alternating signal is known as "MOS Drive Signal ".

- Driver Circuit: The MOS drive signals are given to the base of driver transistor which separated into two different channels.
- Amplifier Circuit: The transistors amplify the 50Hz MOS drive signal at their base to a sufficient level and output them from the emitter.
- Inverter Transformer: The transformer used for this is a center-tapping which divides the primary into two equal sections.
- This center-tapping is connected to the positive terminal of the battery. Two ends of the primary are connected to the negative terminal of the battery through switches S1 and S2.
- MOSFETs or Transistors are used for the switching operation. These MOSFETs or Transistors are connected to the primary winding of the inverter transformer.
- When these switching devices receive the MOS drive signal from the driver circuit, they start switching between ON & OFF states at a rate of 50 Hz. This switching action of the MOSFETs or Transistors creates a 50Hz current to the primary of the inverter transformer. This results in a 220V AC or 2300V AC (depending on the winding ratio of the inverter transformer) at the secondary or the inverter transformer. This secondary voltage is made available at the output socket of the inverter by a changeover relay.

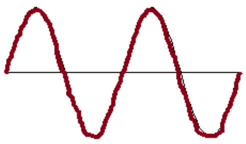
Type of Inverter

- The inverters are classified by depending on their output

1) Sine wave
2) Modified sine wave
3) Square wave.

(I) Sine Wave Inverter:

- In utility Company Sine wave generated by rotating AC machinery and sine waves is a natural product of rotating AC machinery.
- Pure sine wave inverters provide an output same as a sine wave which is similar to the utility supplied grid power, hence Pure Sine Wave inverter produces a better and cleaner current



Sine Wave

- All commercial instruments are designed to run on pure sine wave. Characteristics of such devices are greatly depending upon the input wave shape. A change in wave shape will affect the performance and efficiency of the appliances.
- Sine Wave guarantees by Sine way Inverter is pure so the equipment will work to its full specifications as per its design. Appliances like Motors, refrigerators, Ovens etc will generate full power on pure sine wave input only.
- A few appliances, such as Toaster, light dimmers, and some battery chargers require a sine wave to work propellerly. Operation of these appliances in Square or stepped waves will considerably affect the life of such equipment due to the generation of heat.
- Distortion in the sine wave creates humming noise in transformers, and audio devices
- Some time we noticed that audio amplifiers, Televisions, Fluorescent lamps etc make noise on inverter power. This indicates that inverter output is not pure sine wave.
- It is always advisable and recommended to go for a pure sine wave inverter for the safety and effective performance of your appliances.

Advantages:

- Output voltage wave form is pure sine wave with very low harmonic distortion and clean power like utility Supplied electricity.
- Inductive loads like microwave ovens and motors run faster, quieter and cooler.
- Reduces audible and electrical noise in fans, fluorescent lights, audio amplifiers, TV, Game consoles, Fax, and answering machines.
- This type of inverters will save your current bill compared to square wave inverters.
- Prevents crashes in computers, weird print out, and glitches and noise in monitors.
- Back up time will be better than square wave inverters.

Disadvantages:

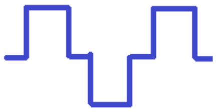
- Sine wave inverters are 2 to 3 times expensive compared to square wave and modified sine wave inverters.

Application:

- More sensitive electrical or electronic items
- Desktop computers, laptops, Laser printers, photocopiers,
- Camera battery chargers, cell phone chargers,
- Mixer,
- Fluorescent lights with electronic ballasts ,
- Digital clocks ,
- Sewing machines with speed/microprocessor control ,
- Medical equipment,
- Small house hold water pumping motors, Drives etc.

(II) Modified Sine Wave:

- A modified sine wave inverter has a waveform like a square wave, but with an extra step.
- Modified sine wave is a simulation of the pure sine wave output when the inverter sharply drops or increases voltage to switch polarity. As a result, the output form closely matches pure sine wave but still has much greater distortions.
- A modified sine wave inverter will work fine with most equipment, although the efficiency or power will be reduced with some.



Modified Sine Wave

- The devices are usually about 70% efficient, so we can expect some significant power losses if we are using a modified sine wave inverter in your system.
- Motors, such as refrigerator motor, pumps, fans etc will use more power from the inverter due to lower efficiency. Most motors will use about 20% more power.
- Some fluorescent lights will not operate quite as bright, and some may buzz or make annoying humming noises.
- Because the modified sine wave is noisier and rougher than a pure sine wave, clocks and timers may run faster or not work at all. They also have some parts of the wave that are not 50 Hz, which can make clocks run fast. Items such as bread makers and light dimmers may not work at all in many cases appliances that use electronic temperature controls will not control. The most common is on such things as variable speed drills will only have two speeds on and off.
- The difference between Sine wave and modified Sine wave inverter is the cost. Sine wave is considerably more expensive. We can find it practical way from it .We can install a small Pure Sine Wave inverter for any "special need" and also a larger Modified Sine Wave inverter for the rest of our applications.

Advantages:

- Cheaper than pure sine wave inverters
- Output correction waveform; relatively stable; suitable for ordinary personal users with TV, fan, lamp, computer, hot pot etc.
- Output wave form have a very low harmonic distortion compare to Square wave inverter

Disadvantages:

- Lower efficiency than pure sine wave inverters.
- Power Loss is more compared to sine wave inverter.
- Modified Sine Wave output is not suitable for continuous long time operation of certain appliances with capacitive and electromagnetic devices such as a fridge, microwave oven and most kinds of motors, printers as well as capacitive fluorescent lights etc
- Some fans with synchronous motors may slightly increase in speed (RPM) when powered by a modified sine wave inverter. This is not harmful to the fan or to the inverter.
- Certain rechargers for small nickel-cadmium batteries can be damaged if plugged into a modified sine wave inverter

Application:

- Some household appliances and power tools.
- Inductive loads like micro ovens and motors.
- Fans and fluorescent lights,
- Audio amplifiers, TVs, game consoles, fax and answering machines.

(III) Square Wave Inverter:

- The Output wave form of the Inverter is like square.
- This is old-fashioned and the cheapest inverters, but the hardest to use.
- A square wave inverter will run simple things like tools with universal motors without a problem, but not much else.

Sqare Wave

- The current we get from grid is neither square wave nor pure sine wave, it's nearly sine wave. So, our electronic devices like fan and tube light will emit some buzz noise while operating in square wave current. In some rare cases, these square wave inverters have spoiled the speed control dimmers of ceiling fans.
- In the form of square wave, The load voltage must be switched majorly from high voltage to low Voltage, without using for an intermediate step of 0Volt.
- The main reason for this fault is high voltage output. Normally, voltage output from square wave inverters is 230 volt to 290 volt, hence it is not recommended to sensitive electronic devices like computers.
- They just flip the voltage from plus to minus creating a square waveform. They are not very efficient because the square wave has a lot of power in higher harmonics that cannot be used by many appliances. Synchronous motors, for example, use the 50Hz component and turn the rest of the frequencies into heat
- Square wave inverters are seldom seen any more.

Advantages:

- It is very cheap

Disadvantages:

- Life of Application is less.
- Speed control of some equipment is not possible
- Voltage Variation is high.
- Large 3rd and 5th harmonic components which burn power and severely cut down on the efficiency of devices

Application:

- Low-cost AC motor drives
- Some electronic ballast for fluorescent lamps

Comparison of Inverters:

Comparison of Different Type of Inverter			
	Square Wave	**Stepped Sine Wave**	**Pure Sine Wave**
Safety of Appliances	Less	Moderate	High
Life of Appliances	Less	Moderate	High
Battery Life	Less	Moderate	High
Noise Level	High	Moderate	Normal
Heat generation	High	Low	Normal
Suitability for appliances	No	Not recommended for prolonged use	Yes

How to Select Batteries for Inverter

- Batter is the vital part of inverter. Performance and life of an inverter is greatly depends upon battery.
- There are three types of batteries available in market.

1) Flat Plate,
2) Tubular and
3) Maintenance Free.

- Without getting too much into details, all we can say is that Tubular Batteries are the best choice for inverters. They may cost slightly more than Flat Plate, but they will last longer.
- Maintenance Free batteries may sound good, but they have lesser life (4-5 years as compared to 7-8 years of a tubular battery).
- But the most important thing to run batteries for a longer time is to make sure that it is topped (filled) with distilled or RO water frequently and the fluid levels are maintained.

A) Lead Acid Battery (Flat Plate):

- Lead acid batteries known as "Automotive Battery".
- Lead-acid batteries are the oldest type of rechargeable battery. Most of the inverters batteries are lead acids battery of different types.
- It is used for automotive purpose are termed as "High Cycle" lead acid batteries.
- These batteries are designed to provide high current for a very short duration (To start the vehicles).

- Automotive lead acid batteries are not designed to be regularly discharged by more **than 25%** of their rated capacity. Here the requirement of inverter is totally different.
- Inverter requires "Deep Cycle" type batteries to provide continuous power which can be discharged at least **50%** of their rated capacity.
- Some good deep cycle batteries can be discharged over **80%** of their capacity. Deep Cycle batteries have specially designed thick plates to withstand frequent charging and discharging.
- Lead acid batteries require regular maintenance. You have to check the electrolyte level and require to be topped up on regular intervals. These batteries release poisonous gases during charging and discharging. If you don't keep the batteries in a properly ventilated place, it can invite serious health problems.
- We have to keep the terminals of normal lead acid batteries corrosion free by applying petroleum jelly or grease regularly.

Advantage:

- This light weighed inverter battery.
- Price is Economical and quite cost-effective
- This is the most common type of inverter battery.
- It is a rechargeable and generates a large amount of current.
- Battery life is approximately 3-4 years.

Disadvantage:

- We need maintain it regularly, such checking the electrolyte level, topping up with distilled water etc.
- Need well-ventilated place while installing a lead acid inverter battery.
- Not Safer in use.

Application:

- Suitable for small domestic Inverter.

B) Tubular Battery

- This is the most popular and efficient among all types of inverter batteries.
- Together with robust grid design, superb efficiency, long operational life and requirement of low maintenance tubular inverter battery is the most preferable choice of all.

- This is the most popular segment of inverter batteries used in domestic and industrial applications.

Advantage:

- Long life (5 Years)
- High electrical efficiency.
- Less Maintenance (Less number of water toppings)

Disadvantage:

- Cost of tubular batteries can go up to double of a normal flat plate battery

Application:

- Suitable for both domestic and industrial Inverter.

C) Maintenance Free Battery

- As the name indicates there is no need of maintaining the batteries. No need of filling distilled water at regular intervals. This is possible because of a special type of electrolyte which need not be replenished.
- Maintenance free batteries also called as sealed batteries and do not need any regular maintenance to function impeccably.
- Apart from that other best feature is safety. Maintenance free batteries do not emit any poisonous or harmful gases.

Advantage:

- It is costlier, But the money is worth to invest.
- It is sealed lead acid batteries which do not require topping up or additional ventilation
- They are more durable and safer than normal lead acid inverter battery.

Disadvantage:

- Cost is very high as compared with normal lead acid batteries.
- Life is comparatively low (3 To 4 Years)
- Scrap value is not much more.

Comparison of various types of Batteries

Comparison of various types of Batteries			
	Flat Plate Batteries	**Tubular Batteries**	**Maintenance Free Batteries**
			
Cost	Low	High	High
Safety	Low	Low	High
Efficiency	Low	High	Medium
Maintenance	High	Medium	Low
Water toppings	High	Medium	Low
Releases harmful gases	Yes	Yes	No
Ventilation requirement	Yes	Yes	No
Scrap Value	High	High	Low
Weight	Low	High	Depend on the model.
Battery Life Span	Low (3 Yrs)	High(5 Yrs)	Medium (3 to 4 Yrs)
Suitable	For Low power cut areas as their designed cycle life is low.		

How to select Right Inverter

- Before buying an inverter for, it is very important to understand what the right inverter for our requirement for that is we do understand the basics criteria of Inverter.
- In order to make a good estimate of your power needs, you'll need to take a look at all of the devices you plan on plugging into your new inverter.
- If we only need to use one device at a time, then that's the only one you'll need to look at. However, you'll need to add together the numbers from multiple devices (like an LCD screen and a video game system) if you plan on using them at the same time.

(I) Power Requirement:

- One of the most important factors that we must know before buying an inverter is Power requirement.
- Power requirement means all electrical appliances (like fan, tube lights, television,Pumps, CFL etc.), we want to run at the time of power failure. The power requirement is simply addition of the power consumed by various electrical equipments.
- The thing we must understand that Inverter is not a Generator. Inverter has its own limitations. If power requirement is more than our estimation, then an inverter alone cannot create demands effectively.
- High power inverter can run our refrigerator and air conditioners, but battery will not last more than few hours. Hence it better to estimate Inverter Load Carefully
- The selection of correct size Inverter is very important, If we need to power small appliances like energy efficient light bulbs, we do not need to buy a 2000W power inverter because it will consume more power even in standby mode and work very inefficiently with small appliances. On the other hand, if we connect a coffee machine to a 150W inverter we will quickly blow a fuse, Therefore power estimation is important thing.
- **The size of Inverter depends on the watts (or amps) of what we want to run. It is recommend that we choose at least 10% to 20% more than our requirement.**
- Suppose you want 1No Fans, 1No Tube lights, 1No CFL and 1No television to operate at the time of power failure. Therefore, the total power requirement to be (1x90 + 1x50 + 1x25 + 1x120) = 285 watts. Here Total Load is 285 watts.

(II) Surge Power (Starting Power):

- Starting and running power requirement of all electric appliances are different.
- Starting power of Electrical Equipment is several times greater than their normal working power.
- An 18 Watts CFL takes around 25 Watts power to start and after few seconds it works on 18 Watts. Some appliances like Refrigerator, Washing Machine etc take almost double power to start as compared to the normal running power.
- For example Gridding Machine have normal working power 1000W, their starting power is higher than 4000W, so inverters with continuous power 2000W are not suitable because their peak power is limited by 4000W.
- For selecting right Inverter, Always take into account starting power requirements of your equipment, especially devices with electric motors, Electronics Choke, Capacity, inductive Load.
- The Size of the inverter should be chosen based on the power consumption of your load.
- **Resistive loads:**
- All resistive loads like toaster, coffee maker, electric range, iron, Incandescent lamps, flood lighting. Laser Printers use Nichrome resistance wire in their heating
- **The Starting Power or Surge Power rating should be 6 times the Watt rating**
- **Inductive Loads:**
- All Inductive Load like induction motor, reciprocating pumps and compressors, refrigeration, air-conditioning, Oxygen Concentrators have more starting current.
- **The Starting current (LRA) should be 5 times the full load current (FLA).**
- **Capacitive Loads:**
- Switched Mode Power Supplies (SMPS), electronic equipment like battery chargers, computers, audio and video devices, radio etc.
- **The Starting Power or Surge Power rating should be 3 times the Watt rating**
- **Microwaves:**
- **The Initial power consummation by the microwave will be 2 times the cooking power.**
- **A Water Supply Pump:**
- **The starting surge can be 3 times the normal running rating of the pump**
- The inverter should, therefore, be sized adequately to withstand the high inrush current

Type of Device	Starting Factor	Type of Device	Starting Factor
Air conditioner	5	Portable Kerosene / Diesel Fuel Heater	3
Refrigerator / Freezer	5	Circular Saw	3
Air Compressor	4	Bench Grinder	3
Sump Pump / Well Pump /	3	Incandescent / Halogen / Quartz	3

Submersible Pump		Lamps	
Dishwasher	**3**	Laser Printer / Other Devices using Quartz Lamps for heating	**4**
Clothes Washer	**3**	Switched Mode Power Supplies	**3**
Microwave	**2**	Photographic Strobe / Flash Ltg	**4**
Furnace Fan	**3**	Industrial Motor	**3**

(III) Rating (VA rating) of the inverter:

- It stands for the Volt ampere rating. It is the voltage and current supplied by the inverter to the equipments.
- If an inverter operates with 100% efficiency, then the power requirement of the electrical items and power supplied by inverter is same. But 100% or ideal conditions does not exist in real. Most inverters have the efficiency range from 60 % to 80%. This efficiency is also called power factor of an inverter and is simply the ratio of power required by the appliances to power supplied by an inverter. Power factor of most inverters ranges from 0.6 to 0.8.
- **Rating of inverter (VA) =Power consumed by equipments (watts) / Power factor (efficiency).**
- Power of inverter (VA) = 535/0.7 = 765 VA
- In the market 800 VA inverters are available. So Size of an inverter with **800 VA.**

(IV) Type of Battery

- The performance and Life of an inverter depends on the battery Quality.
- Battery stores the energy needed to run appliances during power cut.
- There are three Type of Battery
- Lead Acid Battery
- Tubular Battery
- Maintenance Free Battery
- Normally high power Lead Acid batteries are used to power inverters.

(V) Battery Capacity (Ah):

- Capacity of a battery is expressed in terms of Ampere Hour (Ah). It is decide the back up hours of Inverter.
- It indicates the rate of current a battery can supply for a given duration. If the capacity of a battery is 100 Ah, that battery can supply 100 Ampere current for 1 Hour or 1 Ampere Current for 100 Hrs
- **Battery capacity = Power requirement (watts) x Back up hours (hrs) / Battery Voltage (volts) x Battery Efficiency x No of Battery**
- Example: If Inverter Load is 390 Watt, We need 3 hours back up and Battery Voltage is 12V, Battery Efficiency is 90%
- Battery Capacity = (390 x3) / 12x0.9x1 = **109 Ah**
- Therefore a battery capacity of 120 Ah.
- In reality battery performance degrades with usage, so you are recommended to buy 5-10% higher capacity battery.
- Therefore a battery with a capacity of 150 Ah is suitable for our requirement.
- If we use series - parallel battery combination for backup is
- **Backup capacity(hours) = N series X Volts X Battery Ah X N parallel / (UPS capacity in VA)**
- Where, N series = no. of batteries in series and N parallel = no. of parallel battery banks

(VI) Backup Time (Hr):

- **Backup (hours) = Battery Ah X Battery Voltage X Inverter Efficiency / Total Load (Watt)**

(VII) Battery Voltage (12V, 24V or 48V):

- We can choose Battery Voltage of 12V, 24Vor 48V for inverter. The selection is very important for Voltage drop and Cable size of Inverter.
- To control load current within limit, as load increase, We should select higher size of Battery Voltage.

Watt	Volt	Amp	Cable Resistance(Ω)	Voltage Drop (V)
1000	12	**83**	0.01	0.8
2000	24	**83**	0.01	0.8
4000	48	**83**	0.01	0.8

- As per above table, as the load increase, by selecting higher voltage,load current within limit.

- Let's take example of selecting different voltage for same load (Watt)

Watt	Volt	Amp	Cable Resistance(Ω)	Voltage Drop (V)
4200	12	350	0.01	3.50
4200	24	175	0.01	1.75
4200	48	87.5	0.01	0.88

- At Higher Load (Watt), by selecting lower voltage (12V). The load current is high. The higher the current needs the bigger the components. High currents require large diameter cables and fuses, which are expensive and the entire system is not safe.
- By only doubling the voltage we can get double the power (Watt) at the same current.
- 12 Volt used to be a standard for extra low voltage power systems. Today, mostly systems are 24V or 48V and include a 230V AC inverter. This means the wiring of the house does not have to be different from any other grid-connected household and cabling cost is greatly reduced.
- The Battery Cost for higher Voltage is not more for same rating of Battery. For 12KW Load, Instead of buying a battery which has a capacity of 1000AH at 12V, (12KWH) we can rearrange the battery as a 24V 500AH (12KWH) or 48V 250AH (12KWH). The total power available from the battery is exactly the same, but with lower losses in the cabling and inverter.
- A higher volt inverter will be more expensive than a lower volt one, and for small setups, that extra expense is unnecessary. If we are going to have high load demands, it makes more sense to go with a higher-volt inverter for a variety of reasons.

(VIII) Battery Charger:

- The battery capacity is limited to the size of the charger. Usually, the battery capacity should be no more than 12x the maximum charge current i.e. a 5A charger can only accommodate 60AH of batteries (5 x 12 =60).
- If discharges are expected to be less frequent than once in every 10 days, we may use formula of 20x the maximum charge current.

(IX) Discharge Rate:

- Lead acid batteries have few Amps hour if the discharge rate is fast.
- Generally, the lead acid battery discharge rate is slow. It is 20 hours.
- At high discharge rate, the capacity of the battery drops steeply. Suppose the battery is 10 Ah and its discharge rate is 1C. One hour discharge of the battery at the rate of 1C (10 Amps in 1 hour), the capacity reduces to 5 Ah in one hour.
- Suppose we want to run a load at 20 Amps for 1hour. Then the capacity of the battery is **20A x 1 Hour = 20Ah.**
- Keep discharge rate to maximum 80%. Then the battery capacity should be **20Ah / 0.8 = 25 Ah**
- So a 25 Ah battery can give 20 Amps current for 1 hour to run the load.
- But it is better to drain the battery to 50% only then, **25 Ah / 0.5 = 50 Ah.**
- Hence it is better to use a 50Ah battery to run the load at 20 Amps per Hour to keep 50% charge in the battery.

Battery Capacity	Hours of Discharge
100	20
90	10
87	8
83	6
80	5
70	3
60	2
50	1

Chapter: 76 Selection of Various Types of UPS

Introduction:

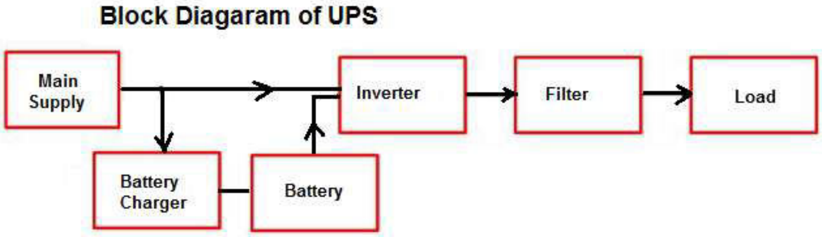
- Whenever there is a power cut, electricity supply to Computer, Desktop or other critical appliances is cut off and they stop working. However, if we have a backup supply device such as UPS, we can ensure uninterrupted supply of power to appliances to be not bothered with power cuts.
- Electrical power supply comes from utility companies is not pure it has different Electrical abnormalities like surges, under voltage, Over Voltage, Voltage dips, voltage spikes, Noise and harmonics. These Electrical abnormalities can cause serious damage to Electronics equipments, Data Systems, Computer or Desktop.
- To decrease the risk of power supply distortion, UPS systems are frequently integrated in electrical networks. Electronic power supply equipment makers can offer consistent, high-quality power flow for various Electrical / Electronic load gear likes continuous industrial processing applications, medical services, emergency gear, telecommunications, & computerized data systems.
- Today's UPS systems usually provide some level of power conditioning and protection against fluctuations in voltage from the grid.

UPS:

- UPS means uninterrupted power supply.
- Uninterruptible power supply (UPS) provides uninterrupted power to the equipment. It means switching time from power cut to battery power is vey less hence important equipment like computer, desktop is not switch off and we can lose data.
- A UPS is a complete system that is consisting of many parts that include batteries, a charge controller, circuitry any transfer switch for switching between the mains and back-up battery, and an inverter. An inverter is needed because the battery can only store DC power and we need to convert that back to AC in order to match the appliances connected in the main power line.
- **UPS= Battery charger + Inverter**
- **UPS is nothing but inverter with inbuilt battery charger.**
- UPS is used only to backup your system. If we connect desktop computer on inverter. Inverter takes some seconds to give battery power to equipment hence equipment shutdowns for some second in any power loss condition and we can lose important data of desktop or computer.
- Inverter is not suitable for computer backup due to the delay in switching.
- One of more useful functions of UPS is to provide surge protection so connected devices can be protected from line Surge and does not damage. UPS is also capable of conditioning the power from the lines to provide clean and stable power throughout.

Block Diagram of UPS:

- The block diagram of this UPS is shown as below



- The mains power comes to the UPS. The AC is converted to DC and this DC is constantly charging the battery. The output of the battery is fed to the Sine wave inverter and it converts DC to AC and this feeds the equipment. Since power out is always drawn from the battery, there is no time lag when mains switches off, it just stops the battery from being charged and the UPS continues to supply power till the battery runs out.
- **Battery Charger (Rectifier):** To convert AC Power (from Power Grid) to DC Power to charge Battery
- **Battery:** To provide DC Power.
- **Inverter:** To convert DC Power (from Battery) to AC Power (to power load i.e., electrical and electronic equipment.)

- **Controller:** To control functions of Rectifier (Charger) and Inverter. (i.e., when to start or stop charging battery, when to start or stop power from battery to load, how fast to change from Grid Power to Battery Power and so on)

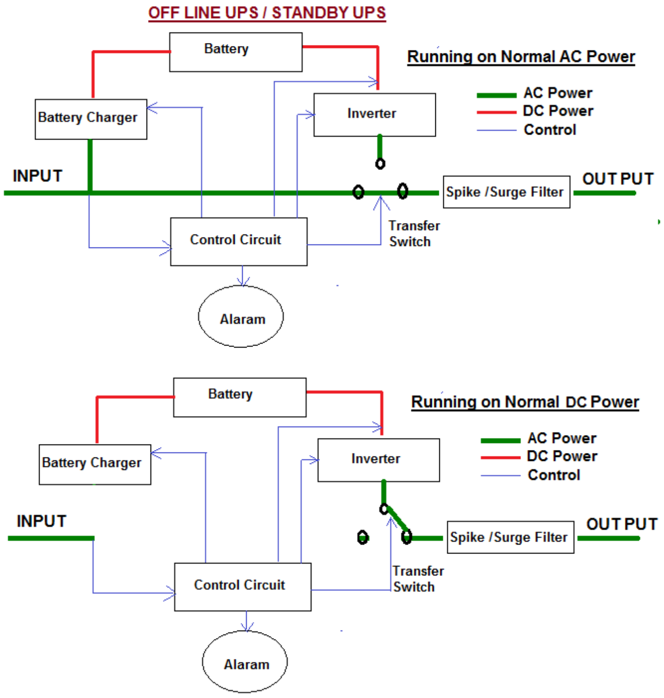
Type of UPS:

- The UPS is mainly categorized into three types according to their functions. They are as
  (1) Offline Standby (where system or data loss is an inconvenience)
  (2) Line-interactive (system or data loss is a serious problem).
  (3) Online/Double Conversion (system or data loss is unacceptable).

(I) OFFLINE UPS / Standby UPS:

- Off-line UPS systems are so-called "OFF Line" because load is normally connected directly to the incoming AC mains. When the incoming AC mains fails or fall below a pre-determined level, then the offline UPS turns on its internal DC-AC inverter circuitry, which is powered from an internal storage battery.
- For switching purpose UPS consists mechanically / Static switches which immediately connect the load on its DC-AC inverter output under the mains power failure condition. During this changeover there is an inevitable break in power to the load of typically **2 to 10 milliseconds**. In practice, however, most loads can ride through this period without any problems.
- The switching process causes a momentary lapse in power which is dangerous for certain highly-sensitive equipment. This is why technically, the standby UPS is not considered a "true UPS", as it is not truly "uninterruptible".
- The typical lapse time 5ms,is well within tolerance for normal desktop computers

Circuit Diagram:



Working Function:

- **Normal Condition:**
- In Normal Power Condition, power supply will continuously provide to Load with some filtering (typically the same as on a surge protection power strip) from the utility.
- In Normal Condition Battery is charged continuous charge through Battery Charger
- Battery charger convert AC power to DC Power and this DC Power charged Battery.
- **Power outage Condition:**
- When utility power fails, the device will start its internal inverter.
- When utility power fails mechanically transfer Switch Transfer from utility power to Battery Power, inverter output.
- This transfer can take as **25 ms,** which may be too long for some Electronics loads.
- An Offline UPS will transfer to battery backup during Power cut condition.

- Off-line systems are generally equipped with spike suppressors, aimed to protect the hardware from high voltages on the utility grid.

Advantage:

- Cheaper than other type of UPS.
- Small size.
- High efficiency.
- More economical
- More energy efficient.
- Lower operating temperature (Due to Fewer parts)
- Simple Internal control Circuit.
- Lower initial cost (fewer parts) and lower operating cost (Supplies power is charge only Charger).

Disadvantage:

- No isolation between main supply and load
- No Power Conditioning.
- Slower Transfer Time.
- Harmonic distortion is high.
- UPS output is Quasi square wave.
- The output contains voltage spikes, brownouts, blackouts.
- Output is not perfectly reliable.
- A more serious problem of offline systems is that the load is continuously exposed to spikes, transients and any other abnormalities coming from the power line. This creates a risk of loss or damage to sensitive equipment and data. However in many systems this risk is mitigated but does not eliminated, by spike suppression and radio frequency filtering
- Most of the short term spikes surges and high frequency harmonics are decayed by means of special filters but transient of mains power existence, like over voltages can harm protected data.

Applications:

- small offices, personal home computers and other less critical application
- Computers, printers, scanners etc.
- Emergency power supplies, EPABX.

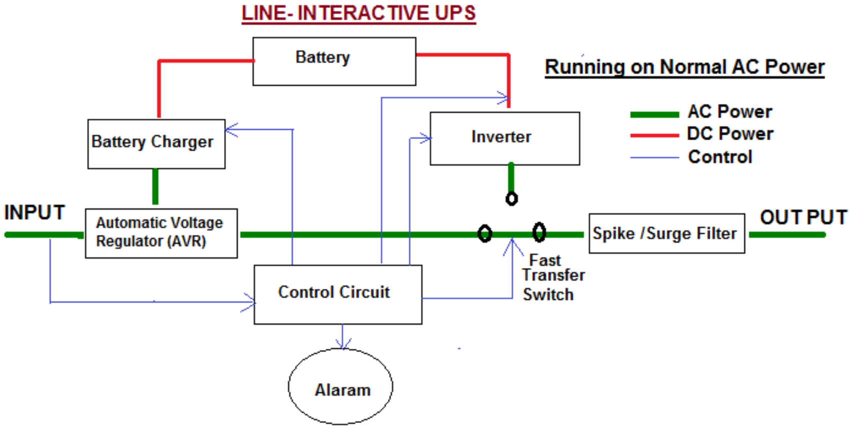
Capacity:

- Up to 800VA.

(II) Line-Inter active UPS:

- Working Principle of Line Interactive UPS is same as OFF Line/ stand UPS. It connected directly from mains, switching to battery (via the inverter) in mains Power cut condition.
- The designing of line interactive UPS is same as OFF Line UPS in addition the design Line Interactive generally includes an automatic voltage regulator (AVR) or a tap-changing transformer. This enhances the regulation of voltage by regulating transformer taps as the input voltage differs.
- The main difference between an off-line and a line-interactive UPS is that a line-interactive UPS in the stand-by mode has active voltage regulation.
- Voltage regulation is a significant feature when the conditions of a low voltage exist, otherwise the UPS would transfer to battery and then finally to the load. The usage of more common battery can cause early battery failure.
- It typically uses either a Ferro resonant transformer or a buck-boost transformer. Both helps to reduce the frequency of transfers to battery, slightly improving efficiency and reducing battery wear.
- Ferro resonant designs also offer power conditioning and tight voltage regulation, as well as an energy store that can maintain uninterrupted power supply output while the inverter switches on.

Circuit Diagram:



Working Function:

- **Normal Condition:**
- In Normal Power Condition, power supply will continuously provide to Load with some filtering and voltage regulation circuit.
- During normal operation, the Line Interactive UPS takes utility power and passes it through a transformer with various tap selections on the output. When utility power is high, the Line Interactive UPS selects a tap to lower (buck) the output voltage. Similarly, when the utility voltage is low, the UPS selects a tap to increase (boost) the output voltage.
- In Normal Condition Battery is charged continuous charge through Battery Charger
- Battery charger convert AC power to DC Power and this DC Power charged Battery.
- **Power outage Condition:**
- When utility power fails, the device will start its internal inverter Circuit by Mechanical Switch.
- Mechanically transfer Switch Transfer from utility power to Battery Power, inverter output.
- This transfer can take as **2 to 4 ms.**

Advantage:

- small Size
- Low cost
- High Efficiency (because less power conversion is when AC input is present).
- Sine Way Output.
- Battery life is good compared to OFF Line UPS.
- Voltage regulation is fair (more than OFF Line UPS but Less than ON Line UPS)
- EMI/RFI/Noise Rejection is good.
- Change over Time is 2 to 4 Milliseconds.
- Lower electricity consumption (less costly to operate).
- Higher reliability (Lower component count and lower operating temperatures).

Disadvantage:

- No isolation between main supply and load
- Higher Heat Output
- More Expensive
- Problematic with power factor corrected loads.

Applications:

- For small business.
- IT Racks, Network Switches, Medical Instrument System where data loss is a serious problem.
- The line interactive UPS may not be the appropriate choice for installations where AC power is unstable or highly distorted, because battery power will be used too often to keep the UPS output within specifications.

Capacity:

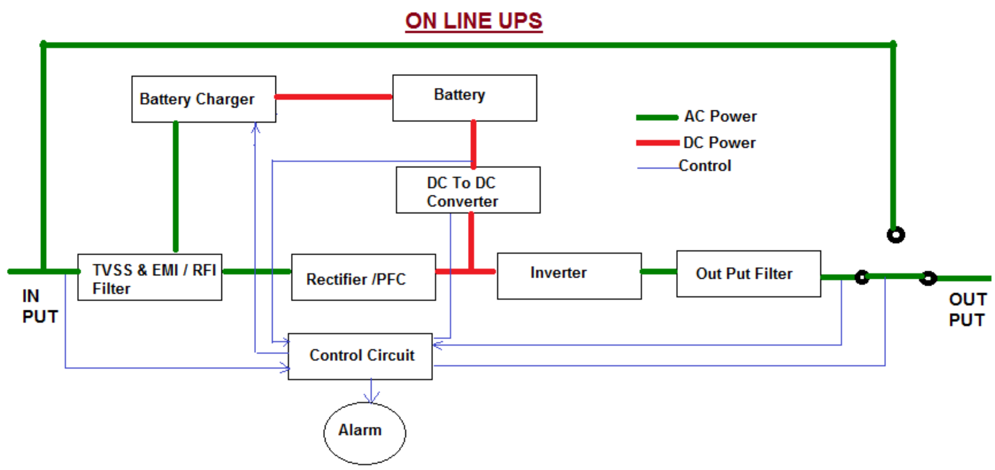
- UPS in the range of 500VA to 5kVA power.

(III) ONLINE UPS/ Double Conversion UPS

- It is truly uninterrupted power system (UPS) provide continuous power to load in any condition.

- Online UPS sometimes called “double conversion” UPS.
- Today most users with highly-critical loads are choose online UPS .It is used to protect sensitive equipment and data from mains problems at all times with any extra cost.
- This UPS have no power transfer switches and therefore no transfer time is existed under the mains power failure. Thus this is truly an uninterrupted system.
- In Online UPS to maintain the charge of the battery, a battery charging unit is continuously powered from the AC mains.
- Online UPSs are often called ‘double conversion’ types because incoming power is Firstly converted once AC to DC for the battery and then back Secondly Converter DC to AC before reaching the load which is therefore well-insulated from the mains like an electrical firewall between the incoming power and sensitive electronic equipments. It also control of the output voltage and frequency regardless of the input voltage and frequency.
- The online UPS continuously filters power through the battery before sending it to your computer.
- By contrast, online UPS systems draw power through the power conditioning and charging components during normal operation, so the load always receives conditioned power rather than raw mains.

Circuit Diagram:



Working Function:

- The designing of this UPS is similar to the Standby UPS, excluding that the primary power source is the inverter instead of the AC main.
- In this UPS design, any cutoff of input AC Supply does not cause triggering of the transfer switch, because the input AC Supply is charging the backup battery source which delivers power to the o/p inverter. So, during failure of input AC Supply, this UPS operation results in no transfer time.
- The Transfer switch will automatically transfer the load to mains in case of overload or UPS failure.
- **Normal Condition or Power outage Condition:**
- In Normal Power Condition, power supply will continuously feed from the Inverter, providing conditioned, stabilized sinusoidal voltage.
- Input Power is filter and regularized by RFI Filter circuit then it is feed to Battery charger which is convert AC Power to DC Power. This DC Power is charged Battery continuously.
- Battery DC power is converted to AC power by Inverter Circuit.

Advantage:

- The cost is high compare to other type of UPS.
- It provides isolation between main supply and load.
- The output is pure Sign wave.
- 100% Power Conditioning
- Constant voltage output.
- Correction of Input Power Factor
- Zero transfer time
- The output voltage is free from distortion due to inverter is always ON.
- It offers the best power protection, covering any and all types of mains disturbances of supply such as blackout, brownouts, spikes etc are absent in the output.
- Voltage regulation is better

- Transfer time is practically zero since inverter is always ON.
- High Reliability, Units can be connected in parallel redundant configuration.
- This is the best choice, considering such issues as modularity, ability to work from generator, power factor correction, maintenance, hot swapping, fault clearing, supervising, and communicating.

Disadvantages:

- More Expensive
- Lower Efficiency (Due to inverter is always ON).
- Higher Heat Output
- Higher battery TCO
- Higher operating cost (Supplies power is charge Battery Charger and Inverter both).
- The wattage of the rectifier is increased since it has to supply power to inverter as well as charge battery

Applications:

- It the preferred choice for most business applications.
- Induction motor drives and similar other motor control applications.
- Medical equipments and Intensive care units.
- Electronics manufacturers.
- Data and call centers.
- Banks.
- TV stations
- Production-based manufacturers.
- Telecommunications.

Capacity:

- From 1 KVA up to 5 MVA.

Comparison of all types of UPS:

Comparison of all types of UPS			
Features	**OFFLINE**	**Line-Interactive**	**ON Line**
Size of UPS	Compact	Moderate	Big
Cost	Cheap	Cheaper	expensive
Circuit Simplicity	Simple	Simple	Complicated
Transfer Time	4 to 10 millisecond	2 to 4 millisecond	0
Efficiency	High	Moderate	Low
Power Consumption	Less	Less	High
Battery Charging Time	More	More	Less
Battery Life	Less	Less	More
Backup Time	Short	Short	More
Surge Protection			
Voltage Regulation	Low	Better	Best
Load Protection	Low	Better	Best
Size	Up to 2KVA	Up to 5KVA	5 to 500KVA
Reliability	Low	Better	Best
Isolation from Mains	Not Available	Not Available	Available
Noise Reduction	Good	Good	Best
Frequency Stability	Not Stable	Not Stable	Always Stable
Voltage Conditioning	Low	Better	Best
Cost/KVA	Low	Medium	High
Inverter always Operating	Yes	Yes	Yes
Application	For Domestic Desktops	IT Racks ,Switches ,Distributed Server	Data Center, Hospital, Banks
Capacity	Up to 800VA	800VA to 1500VA	1000VA to 5000VA

Selection of UPS:

(1) Size of the UPS (VA & Watts)

- To decide Power Capacity of the required UPS, we should decide which should be protected and its power consumption in Amps, VA, or Watt.

(2) Back-up time

- Battery Backup time is the time that batteries are able to back-up operation and feed the load upon failure of utility power. Load consumption and size of UPS batteries decide the back-up time.

(3) Type of the UPS you need

- UPS's are divided to three main classes.
- The Off Line (Stand-by) UPS is the simplest and the least expensive.
- The Line Interactive type, which overcomes the major disadvantages of the off-line unit
- The On-Line UPS, which provides the best power protection.

(4) Cost:

- For applications where low cost is critical and it does not matter if backup times are short, an OFF Line UPS is proper solution. However it will not provide adequate protection against spikes or sags from the grid.
- For applications that require complete isolation from any changes in grid power, such as many medical applications then On Line UPS is the best solution.
- For applications where power losses due to inefficiencies are less of a concern and eliminating the delay from grid power available to back power is paramount, online UPS is the only solution.
- For typical applications where conditioning Power is required and very short transfer times from grid to backup power are acceptable and daily energy consumption is a concern, Line Interactive is the preferred solution

(5) Non-Essential or Critical Load

- For small office where PC loads is less and small network data protection is required, a small single-phase UPS is often an adequate solution.
- Most single-phase UPSs use off-line or line-interactive topologies.
- If the equipment to be protected is critical, an online UPS is the best choice.
- For loads above 10kVA, the most practical solution is a three-phase UPS, which is most normally with true-online topology. Three-phase online UPSs offer the advantage of providing centralized protection using a single UPS.

(6) Efficiency:

- Efficiency is mainly affected on UPS design or operating mode.
- standby and line-interactive UPSs are more energy efficient than ON Line UPSs because there is no power conversion from AC to DC and then back to AC
- Efficiency is a factor of UPS size. Larger UPS modules typically have higher energy efficiency than smaller ones, because the support power required for control electronics and auxiliary components becomes a smaller portion of the total capacity of the UPS system.
- For example, a 500 kW UPS module of a given design would typically be more efficient than a 5 kW UPS module of the same design.

Efficiency of UPS			
Capacity	**Size Standby UPS**	**Line-interactive UPS**	**On Line UPS**
5 kW	95 %	96 %	91 %
100 kW	98 %	97 %	98 %
500 kW	99%	98 %	99%

(7) Form Factor:

- Form factor refers to the the outer-shape of the unit. The Form Factor refers outer shape of UPS.
- **Tower:** This is smaller and a stand-alone unit, and It is primarily designed for simple home/office setups.
- **Rack mounted:** is larger, designed for a standard rack shelf, and is primarily used for more complex commercial operations.

(8) Noise

- UPS fan noise may or may not be an issue as per your requirement.
- Smaller UPS does not normally require a fan for cooling, but larger ones often will.
- If r work requires perfect silence, make sure your UPS is fan-free.

Resolve Power Quality problem by Type of UPS:

Power Quality Problems & solution by UPS			
Power Quality Problem	**Description**	**Effect**	**Solved by UPS**
Temporary Interruption	Accidental total loss of utility power (Seconds to minutes)	Equipment shutdown, loss of data, file , hard disk and operating system Corruption	Off-line - Yes Line-interactive - Yes On-line - Yes
Long-Term Interruption	Accidental total loss of utility power (minutes to Hour)	Equipment shutdown, loss of data, file , hard disk and operating system Corruption	Off-line - No Line-interactive –No On-line - Yes
Momentary Interruption	Very short planned or Accidental power loss. (Milliseconds to seconds)	Computer and network equipment reboots or hangs, loss of work and data, file	Off-line - Maybe Line-interactive - Maybe On-line - Yes
Sag or Under-Voltage	A decrease in utility voltage Sags (Milliseconds to a few seconds)	Shrinking display screens, Computer hangs or reset, equipment power supply damage, loss of data, file	Off-line - No Line-interactive - Yes On-line - Yes
Swell or Over-Voltage	An increase in Utility Voltage (Milliseconds to a few seconds)	Permanent equipment damage, Computer and network equipment reboots or hangs, loss of data	Off-line - No Line-interactive - Yes On-line - Yes
Transient, Impulse or Spike	A sudden change in voltage up to several hundreds to thousands of volts (Microseconds)	Network Errors, Burned or damaged equipment, computer and network equipment reboots or hangs, loss of work and data, file	Off-line - Yes Line-interactive - Yes On-line – Yes, Higher level of protection.
Noise	An unwanted electrical signal of high frequency from other equipment	Slow LAN, audible noise in Telephone and audio equipment.	Off-line - No Line-interactive - No On-line - Yes
Harmonic Distortion	An alteration of the pure sine wave, due to nonlinear loads	Causes motors, transformers and wiring to overheat, lowers operating efficiency	Off-line - No Line-interactive - No On-line - Yes

Chapter: 77 Method for Installation of HVAC System

Purpose:

- This method explains the Procedures or sequence of activity for safely and efficiently installation and Testing of Refrigerant Pipes, Drain Pipes ,Indoor and Out Door Unit of HVAC System as per standard Practice and Code.

General Equipment & Tools:

- The equipment that will be engaged for Installation of Cable works will be
- Lifting crane , Transportation vehicle, Fork Lift
- Winches, Pulling Rope , Welding machine
- Lubricant (Soap based, wax based), Cleaning agent (CRP)
- Copper pipe Flaring tools
- Vacuum Pump,
- Brazing Torch , Brazing Rod , Oxy-Acetylene Brazing Kit ,Wire Brush
- Nitrogen Cylinders , Soldering Tools
- Crimping tool, Drilling Machine with various Bits , Grinding Machine , Cutting Machine
- Electrical Tool Box, Cable Cutter, Screwdriver, Pliers, Spanner.
- Ladder , Scaffolding / Mobile scaffold
- Nylon rope, Marker , Leveling device , Tape measure
- Removable Barricades , Portable Lights
- **Testing Equipment for System**
- Multi meter ,Clamp Meter
- Refrigerant / Nitrogen cylinder,
- Vacuum Gauge

Storage & Material Handling:

- The storage area must be free from dust and Water leakages / seepages.
- **Manufacturer recommendation shall always be followed in loading/unloading and storing of Material.**
- Material and its accessories shall be unloaded handle with care in designated area of the Store (Do not directly drop to Ground) to avoid any damages.
- Materials shall be stored in a dry place which is free from water or from weather effects and protection should be given to the material by means of covering the material with Tarpaulin sheet.
- The Material will be stacked / unload in the site store on a proper stand on wooden loft on a flat surface at a sufficient height from Ground.
- The A/C Units should be kept on the wooden platform and covering with polythene to protected from any dust or mechanical damages
- **For storing the copper pipes:**
- If pipes will be used soon, nozzle should be sealed by plastic bag or tape.
- If pipes will be stored for a long time, the pipes should be charged into 0.2 to 0.5MPa Nitrogen and the nozzle should be sealed by welding.

Inspection of Materials:

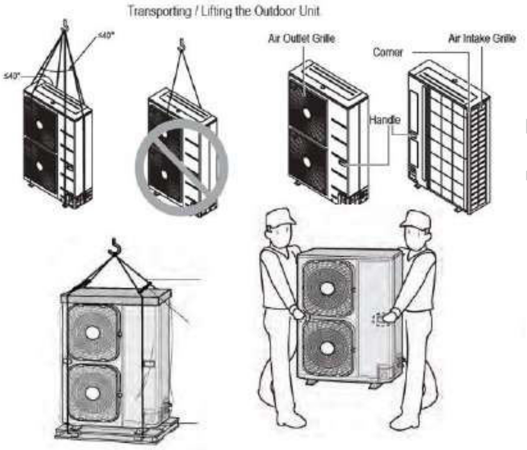
- Check The Material according to its Type, Size, Make
- **Physical Damages Inspection:**
- Damage on Pipes and Units.
- Damage on insulation of Cable

- In case of any damages observed during inspection, the Material shall be returned to the supplier for replacement.

Installation of Outdoor Units :

a) Transporting / Lifting the Outdoor Unit

- Use appropriate moving equipment to transport outdoor Unit, ensure the equipment is capable of supporting the weights. When lifting the unit, use lifting straps and place around the unit.
- Always lift the unit using appropriate size of lifting straps rated to carry the unit weight and long enough to maintain a maximum of a 40° angle as shown.
- When moving / adjusting the placement of the outdoor unit, always hold the unit by the corners. Moving the outdoor unit using the side intake holes on the frame may damage the frame.
- Consider the unit's center of gravity before lifting. Hoist the unit with the center of gravity centered among the lifting straps. There is a risk of the product falling and causing physical injury.
- Lift the outdoor unit from the base at specified locations. Support the outdoor unit at a **minimum of six points to avoid slippage** from the rigging apparatus.
- Do not lay the unit on its side and do not slant the unit more than **30 degrees.**



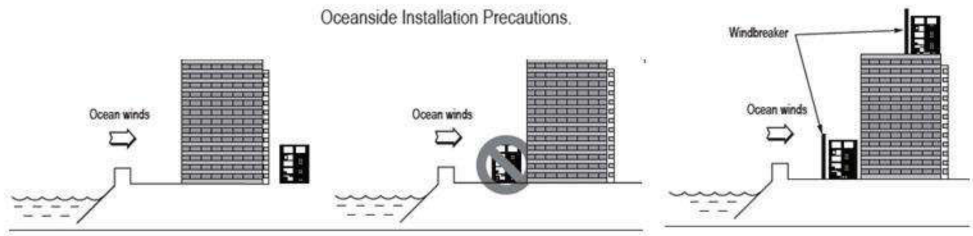
- On a supporting structure that can bear the weight of the outdoor unit. The supporting structure can be a base on the ground, on a waterproof roof, or in a pit. With sufficient clearances around the unit for service and repairs. In a well-ventilated location. Away from strong wind.
- Away from direct exposure to rain or snow. Where there is no risk of flammable vapor leakage. Where there is no exposure to salt, machine oil, sulfide gas, or corrosive environmental conditions.

b) Selecting the Best Location for the Outdoor Unit(s)

- **Don'ts:**
- Do not install the unit in an area where combustible gas may generate, flow, stagnate, or leak. These conditions can cause a fire.
- Do not install the unit in a location where acidic solution and spray (sulfur) are often used or in environments where oil, steam, or sulfuric gas are present.
- A location that allows for optimum air flow and is easily accessible for inspection, maintenance, and service. Where piping between the outdoor unit and indoor unit(s) / heat recovery units are within allowable Limits.
- Avoid placing the outdoor unit in a low-lying area where water could accumulate.
- If the outdoor unit is installed in a highly humid environment (near an ocean, lake, etc.), ensure that the site is well-ventilated and has a lot of natural light (Example: Install on a rooftop).
- Where operating sound from the unit will disturb inhabitants of surrounding buildings.
- Where the unit will be exposed to direct, strong winds.
- **Where the discharge of one outdoor unit will blow into the inlet side of an adjacent unit (when installing multiple outdoor units).**

- If the outdoor unit is not placed on a roof, place it on the leeward side of the building or in a location where the unit will not be exposed to constant wind.
- If placement exposes the unit to constant wind activity, construct a wind break in front of the unit. Follow the placement guidelines set

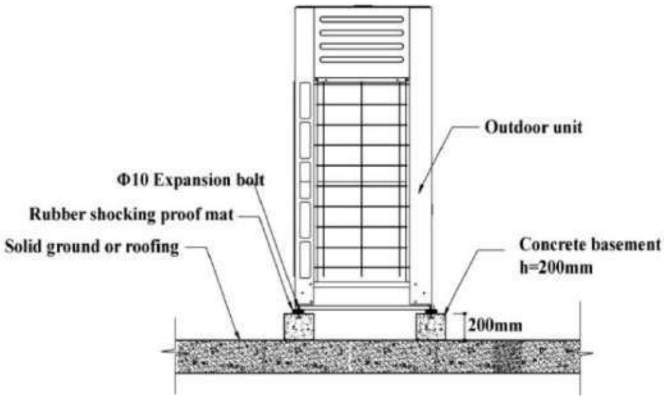
- Avoid installing the outdoor unit where it would be directly exposed to ocean winds.
- Install the outdoor unit on the side of the building opposite from direct ocean winds.
- Select a location with good drainage and periodically clean dust or salt particles off of the heat exchanger with water.
- Ocean winds may cause corrosion, particularly on the condenser and evaporator fins, which, in turn could cause product malfunction or inefficient performance.
- If the outdoor unit must be placed in a location where it would be subjected to direct ocean winds, install a concrete windbreaker strong enough to block any winds. **Windbreaker height and width must be more than 150% of the outdoor unit,** and be installed at least 27.5 inches away from the outdoor unit to allow for airflow.



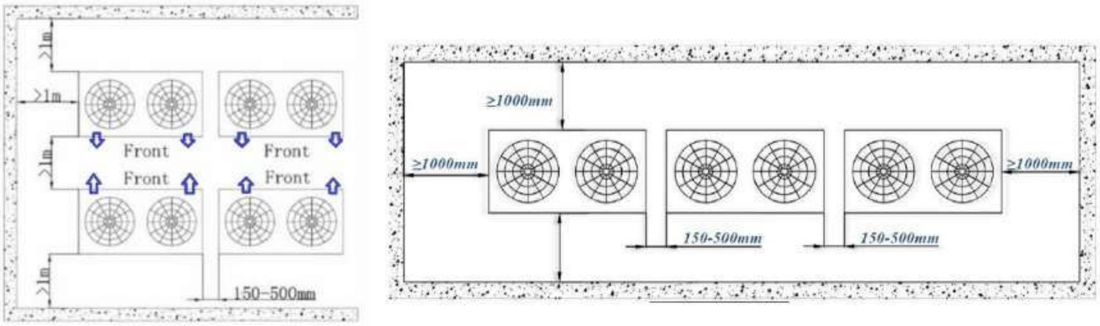
- Rubber anti-vibration pads are necessary to avoid vibration.

Rubber Pad

- Foundation can be made of channel steel or concrete.



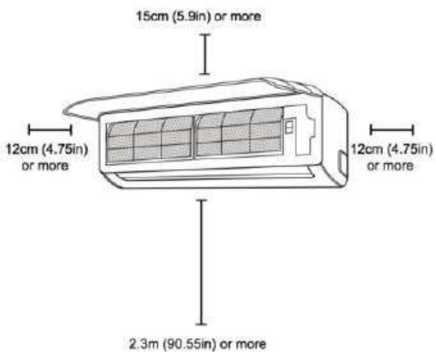
- Reserve the space for discharging condensate water from outdoor units.
- The outdoor unit should be placed neatly, and reserve enough space for maintenance.
- The outdoor unit should be installed in the place that is dry, well-ventilation and close to the indoor units.



Indoor Unit Installation:.

a) High Wall Unit:

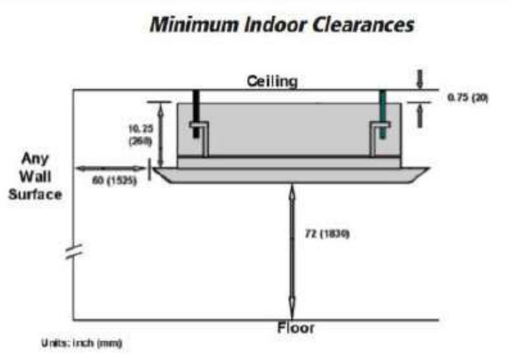
- The installation of the split air conditioners is a crucial job. If the installation is done accurately air conditioner will give optimum cooling, but if it is not done properly we won't get the desired cooling effect. A poor installations also leads to frequent maintenance problems.
- Several factors have to consider during the installation of split air conditioner.
- **Strength of wall to hold the AC**
- The indoor unit of split AC must be installed on a wall strong enough to hold the unit's weight.
- Proper spacing between wall and AC unit
- The indoor unit of split AC requires at least **15 cm of** open space surrounding its top and sides for proper air flow.
- **Appropriate installation height from ground**
- Mount the indoor unit of split AC at a height of **7 to 8 feet** above the ground for adequate cooling inside the room
- **Correct tilt angle of indoor unit**
- While fixing the aluminum bracket on wall make sure that the bracket is given a slight tilt angle, so that the indoor unit of split AC, when fitted is also at a slight angle to enable unrestricted flow of the condensed water from the drain pipe.



b) Cassate Type:

- Air inlet and outlet should be clear of obstructions, ensuring proper airflow throughout the room.

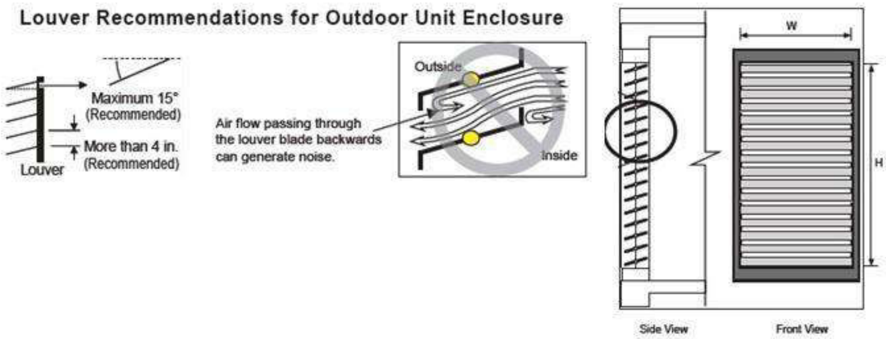
- Condensate can be easily and safely drained.
- A structure strong enough to withstand four **4 times the full weight and vibration of the unit.**
- Filter can be easily accessed for cleaning.
- Leave enough free space to allow access for routine maintenance.
- Do not install in a laundry room or by a swimming pool due to chemical sorrowing cassette coil.



- Indoor Unit Hanger Mounting Depending on the type of ceiling, attach the threaded hanger bolts securely to the support stud. Before lifting the indoor unit to the installation location, insert the upper nuts, flat washers (with insulation), flat washers (without insulation), lower nuts and double locking nuts on the threaded hanger bolts.
- Lift the Ceiling Cassette main body to the threaded hanger bolts. Insert the unit mounting brackets between washers and then fasten it securely.
- Pack the indoor unit with plastic bag after hoisting to protect them from dust entering.

Louvers:

- Allow for ventilation intake and exhaust air based on maximum outdoor unit fan capacity.
- Select the size, type and orientation of architectural louvers with adequate "net free area" face velocity to ensure the total external static pressure from the outdoor unit fan does not exceed design limitations.
- No obstructions must be placed in front of the louver that could hamper the free flow (throw) of air.
- Roof top openings and / or discharge and supply louvers must be equipped with screens to prevent bird and insect infiltration.
- Louver Angle is not more than **15 Deg Horizontally**
- **Space between Louvers is not more than 4 inch**
- If louver open rate is too small it will create noise from louver blade vibrations. Insufficient air flow exchange creates drop in outdoor unit performance and may create air conditioner stop operating.

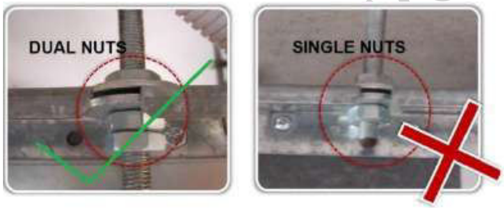


Refrigerant & Drain Pipe Installation Work:

a) Pipe Support:

- A properly installed pipe system will have sufficient supports to avoid pipes from sagging during the life of the system.
- **Sagging pipes become oil traps that lead to equipment malfunction.**
- Pipe supports must never touch the pipe wall; supports shall be installed outside (around) the primary pipe insulation jacket. Insulate the pipe first because pipe supports shall be installed outside (around) the primary pipe insulation jacket.
- Field provided pipe supports must be designed to meet local codes. If allowed by code, use fiber straps or split-ring hangers suspended from the ceiling on all-thread rods (fiber straps or split ring hangers can be used as long as they do not compress the pipe insulation). Place a second layer of insulation over the pipe insulation jacket to prevent chafing and compression of the primary insulation in the confines of the support clamp.
- As necessary, place supports closer for segments where potential sagging could occur. Maximum spacing of pipe supports shall meet local codes. If local codes do not specify pipe support spacing, pipe shall be supported:
- Wherever the pipe changes direction, place a hanger within twelve **12 inches on one side and within twelve 12 to 19 inches** of the bend on the other side. Support piping at indoor units, Y-branch, and Header fittings
- **Supports must be strong enough. The supports should be full thread booms, and their diameters should be ≥ 10mm.**
- Dual nuts should be adopted to fix the indoor unit under the ceiling.

The distance between the supports of the copper pipes.	
Diameter	**Distance (m)**
≤ 20 mm	1 Meter
20 To 40 mm	1.5 Meter
≥ 40 mm	2 Meter

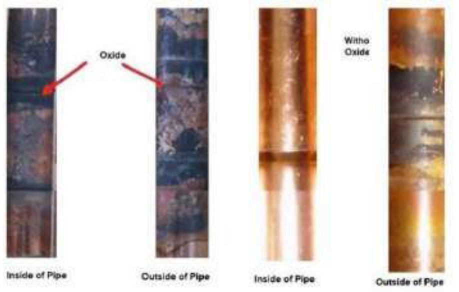


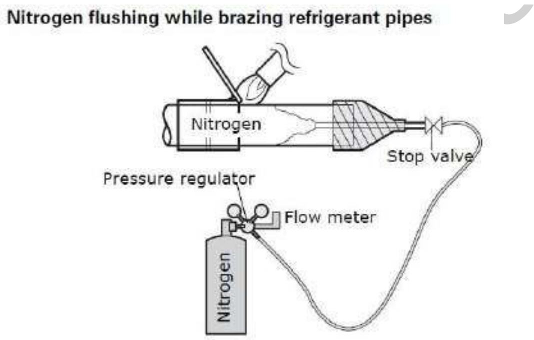
b) Cutting & Welding of Refrigerant Pipe:

- Install piping to be as short and direct as possible, with a minimum number of joints, elbows and fittings. Piping must be installed parallel to the building lines..
- Pipes must be cut accurately to measurements established on site and must be worked into place without springing or forcing.
- Pipes must be installed as permit free expansion and contraction without damage to joins or hangers.
- All piping shall be installed in accordance with the mechanical design. Any deviation shall be submitted for prior approval to the mechanical engineer prior to installation.
- Refrigerant piping diameter, thickness, and temper is selected according to length, as specified in this section.
- Cut or extend field-supplied piping as needed. To extend pipes, braze or using flared pipe connections Refer to "Pipe Cutting," "Nitrogen Flushing While Brazing," and "Flared Pipe Connections,"
- Make sure that pipes are free of dirt, debris, and moisture, and do not leak.
- Braze or use flared pipe connections to install piping. Refer to "Connecting Piping to the Single- Phase Outdoor Unit,"
- **Pipe Cutting**
- Using a pipe cutter, cut the pipe so that the cut edge is at 90° to the side of the pipe.
- Use a reamer to remove all burrs at the cut edge. Examples of correctly and incorrectly cut pipes.

- Selected copper tube must be of suitable wall thickness for higher operation pressures.
- Use a tubing cutter, do not use a saw to cut pipe. De-bur and clean all cuts before assembly

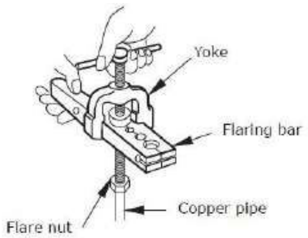
- **Brazing:**
- While brazing refrigerant pipes, flush them with nitrogen gas. Use a pressure regulator to maintain a flow rate of 1.76 ft3/h (0.05 m3/h) or more.
- **Dry Nitrogen:** Dry nitrogen must be used during all brazing (pressure regulated to 3 PSI) to prevent copper plate or oxidation formation.
- Always use a non-oxidizing material for brazing. Do not use flux, soft solder, or anti-oxidant agents. If the proper material is not used, oxidized film may accumulate and clog or damage the compressors. Flux can harm the copper piping or refrigerant oil.
- **Requirement of welding:**
- When welding the copper pipe, nitrogen is necessary to protect the copper pipe.The pressure of the nitrogen is 0.02 MPa
- Charge the nitrogen to the copper pipe at the beginning of welding and only.when the copper is fully cooled down, the nitrogen can be removed
- If Nitrogen is not used, Welding will create Oxide on copper pipe inside and outside, which cannot be removed and it jams the refrigerant flow and damage the Compressor.





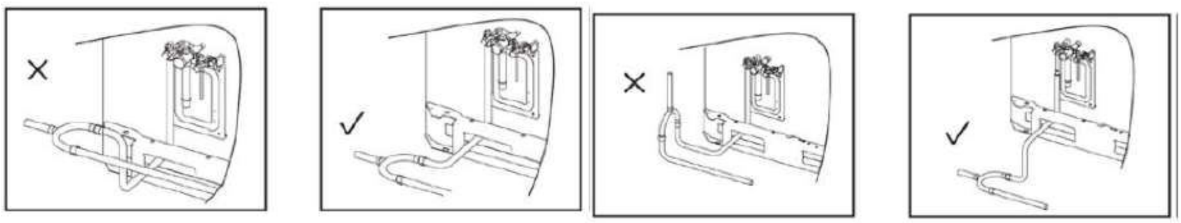
Warning:

- Do not braze in an enclosed location. Do not allow the refrigerant to leak during brazing. Always test for gas leaks before and after brazing.
- Do not allow the refrigerant to leak during brazing; if the refrigerant combusts, it generates a toxic gas. There is risk of fire, explosion, and physical injury or death.
- **Flaring:** Flared tube ends should have a smooth, even round flare of sufficient length to fully engage the mating surface of the flare nut, without protruding into the threads.
- Use a flaring tool specifically designed for flare joints in R-410A systems, which creates deeper flares than those by made by traditional flaring tools. This flaring tool has an eccentric mandrel and clutch type handle. Follow the flare tool manufacturer's directions for using the tool.
- Slide the flare nut over the pipe to be flared. Slide the end of the pipe into the hole on the flaring bar that fits the pipe, leaving a length of pipe, determined by tool type (see table), extending above the flaring bar. Clamp it down.
- Remove the pipe. The end of the pipe that you flared should look like the end of a trumpet. See examples of correctly and incorrectly flared pipes.

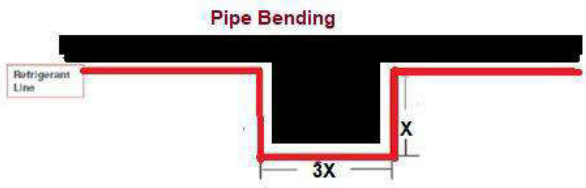


c) Y Joints

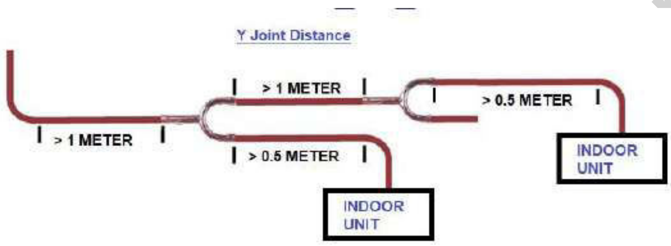
- Confirm the Y branching piping matches allowable designs from the Installation Manual



- Installed with single end of Y Joints always towards outdoor unit.
- The branch joint of outdoor side must be installed horizontally.
- The branch joint of indoor side can be installed horizontally or vertically.
- Y Joints are supported before and after.
- "Y" joints are the correct size and match the locations as shown on the Selection Report.
- **Maintain a minimum distance of 20" between branching joints,** headers, elbows and equipment.
- **Recommend horizontal runs to be 3 times that of the vertical when traps cannot be avoided**

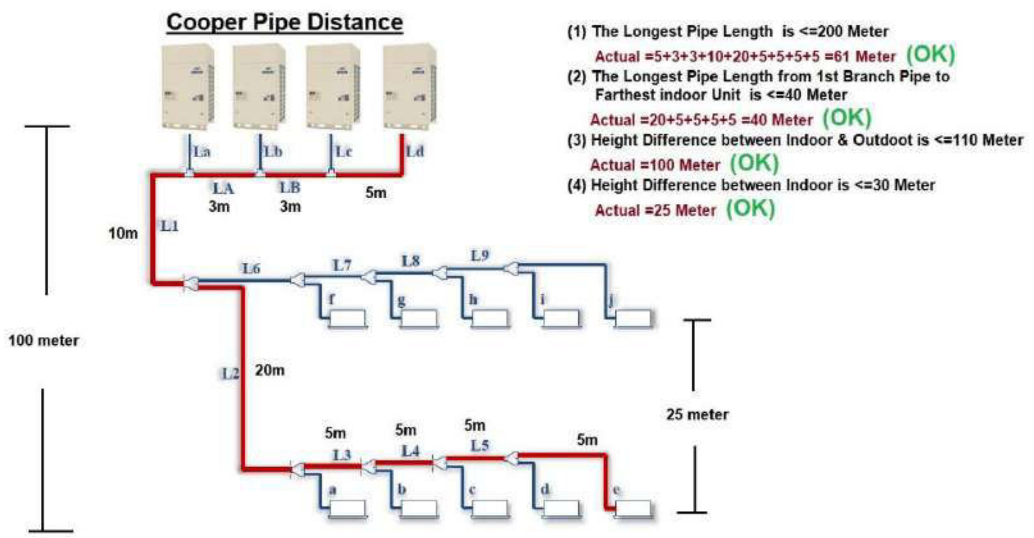


- Between two branch joints ≥1m
- Between branch joints and indoor unit ≥0.5m
- 3. From the inlet or outlet of branch joint, there should be straight pipe with length at least 0.5m



d) Copper Pipe Length:

The permitted length and drop difference		
Pipe length	Max. pipe length	<= 240 Meter
	Equivalent length from the first branch to the farthest indoor unit	<= 40 Meter
Drop height	Drop height between indoor unit and outdoor unit	<= 110 Meter
	Drop height between indoor units	<= 30 Meter



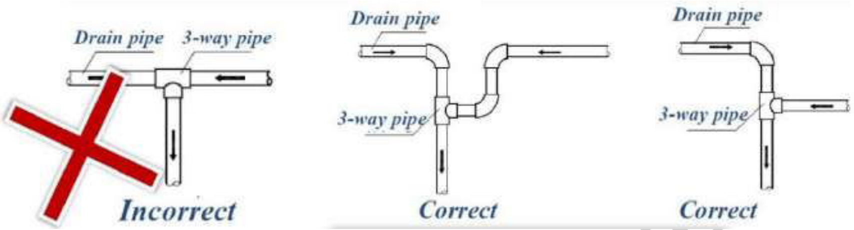
- Record the actual liquid pipe length for future reference when charging additional refrigerant.

Split AC Copper Pipe Length		
A.C Capacity	**Maximum Pipe Length**	**Maximum Indoor & Outdoor Height Difference**
0.5 Ton	15 Meter	5 Meter
0.6 Ton	15 Meter	5 Meter

0.75 Ton	15 Meter	5 Meter
1 Ton	20 Meter	10 Meter
1.5 Ton	25 Meter	10 Meter
2 Ton	25 Meter	10 Meter
2.5 Ton	30 Meter	10 Meter
3 Ton	30 Meter	20 Meter
3.5 Ton	30 Meter	20 Meter
4 Ton	30 Meter	20 Meter

e) Drain Pipe

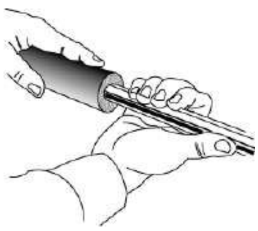
- Water leakage test
- Check leakage of water pipe After finished installation of drainage pipe, filled the pipe with water,
- **Waiting for 24 hours to check whether there's any leakage.**
- Check leakage from the indoor unit
- Charge water from the check hole of indoor unit to check whether the water can be exhausted smoothly or not



Size of Drain Pipe		
Condensate water volume : V (L/h)=Indoor Unit (HP)x2	**I.D (mm)**	**Thickness (mm)**
V ≤ 14	Φ 25	3
14 < V ≤ 88	Φ 30	3.5
88 < V ≤ 175	Φ 40	4
175 < V ≤ 334	Φ 50	4.5
334 < V	Φ 80	6
*If Slop is <1% than select next higher Size of Drain Pipe		

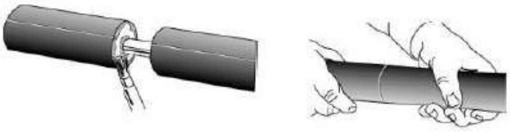
f) Insulation of Refrigerant Pipe & Drain Pipe

- The slip-on method of installation is used for insulation on new refrigeration piping
- The inside of the insulation is coated with a powdered lubricant, making it easy to slip the insulation over the pipe.
- Small amounts of powdered lubricant may enter the open ends of pipe or tubing. This dust must be kept out of refrigeration systems. Plug the open ends of pipe before slipping on the insulation.
- Apply insulation only when the pipes are clean, dry, and unheated or uncooled. The surface to be insulated must be free of rust.
- Never stretch insulation when sealing the joints. It is better to compress it slightly. Use pieces of insulation that are at least as long as the section of pipe to be insulated.
- Always use the insulation that is properly sized for the pipe it is to cover. Do not stretch it over the pipe.
- Do not crowd insulation-covered pipes. Space pipes far enough apart to allow for the free circulation of air. Air movement is an extra safeguard against surface condensation of cold pipes, especially under hot, humid conditions.

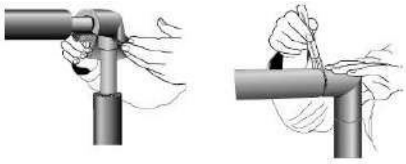


- All piping insulation must be properly sealed to minimize heat loss and control condensation. On cold lines, open pipe insulation joints may allow the formation of condensation, increasing the potential for or contributing to possible pipe or tubing corrosion. Seal insulation joints

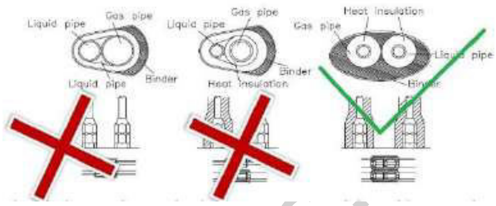
- Do not compress piping insulation at joists, studs, columns, ducts, hangers, etc. This is important because the insulation will lose thermal efficiency where it is compressed. On cold systems, surface condensation may occur where insulation is compressed
- Apply a coating of an approved contact-type adhesive to both butt ends to be joined.



- Before butting the ends together, allow the adhesive to set until it is dry to the touch but still tacky under slight pressure. Join the surfaces.
- Cut open the inside wall of the elbow, taking care not to damage the opposite wall. The slit-open elbow should slip over the fitting. Apply adhesive to the seam (not to the butt ends), allow to tack dry, and fit over the fitting. Press the seams together working from the ends toward the center of the elbow.



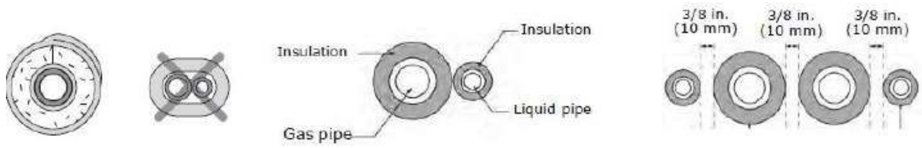
- Finally, wet seal the butt ends to the incoming lengths of insulation. Cut the incoming lengths so that the butt joints are in slight compression.



- Do not wrap the gas and liquid refrigerant pipes together.
- Avoid compressing the insulation as much as possible
- Be sure there are no cracks or deformities in the insulation at bends in pipes.
- If necessary double the insulation to prevent condensation from forming in warm or humid areas.
- Cut off excess insulation

Referent Pipe Insulation			
Pipe	**Pipe size**	**Insulation Type (EPDM or NBR)**	
		Standard conditions 86°F (30°C), < 85%	**High humidity conditions(a) 86°F (30°C), >85%**
Liquid Pipe	1/4" (6.35 mm) To 3/8" (9.52 mm)	3/8" (9 mm)	3/8" (9 mm)
	1/2" (12.70 mm) To 2" (50.80 mm)	1/2" (13 mm)	1/2" (13 mm)
Vapor Pipe	1/4" (6.35 mm) To 7/8" (22.23)	1/2" (13 mm)	3/4" (19 mm)

- Wrap insulation around the entire surface of each pipe, including the refrigerant pipes from the indoor unit to the service valves inside the outdoor unit, the branch joints, distribution header, and connection points on each pipe.



- Do not wrap the vapor and liquid refrigerant pipes together.
- If vapor and liquid pipes are in contact with one another, use thicker insulation and make sure the pipes are not pressing tightly against one another.
- Pipe connections between the indoor unit and EEV kit: Leave 3/8 in. (10 mm) of space between vapor and liquid pipes.
- Be sure there are no cracks or deformities in the insulation at bends in pipes or where hangers are attached to pipes.
- If necessary, double the insulation to prevent condensation from forming in warm or humid areas.

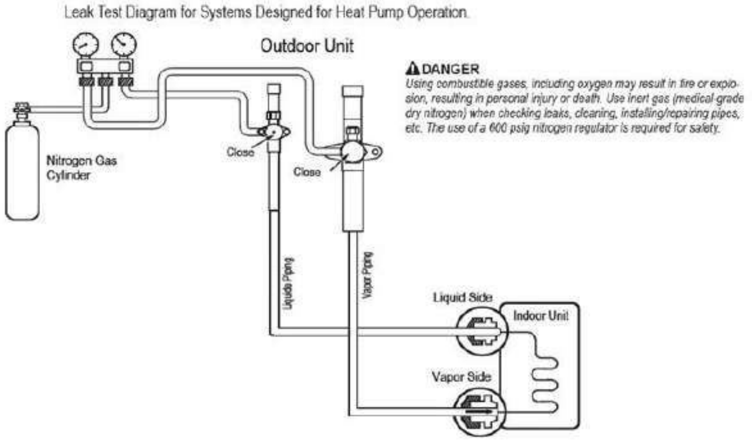
Insulation Thickness

Refrigerant Pipe	Insulation	Drain Pipe	Insulation
22.22mm To 28.58mm	19mm	**25mm / 32mm /40mm**	6mm
12.7mm To 19.05mm	13mm / 19mm		
6.35mm To 9.2mm	9mm / 13mm		

HVAC Refrigerant Pipe Testing:

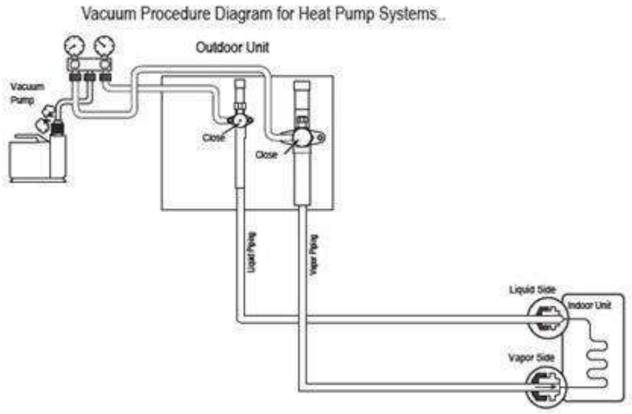
a) Refrigerant Piping (Leak Check) by Pressure Testing:

- Pressure testing helps ensure a leak free system, a critical component to a successful installation.
- Max PSI and duration of pressure tests can vary between manufacturers and should be reviewed in the installation manual.
- **All VRV systems should be pressure tested to 550 PSIG and held for 24 hours.**
- **Pressure testing process:** Tighten down stop valves before any pressure testing to prevent nitrogen
- From leaking back through condenser and contaminating refrigerant.
- Pressure testing shall be done in three (3) steps.
- Step 1 – Leak check 3 minutes at 150 PSI
- Step 2 – Leak check after 5 minutes at 325 PSI
- Step 3 – Leak check after 24 hours at 550 PSI (450 psi for systems with vertical Air Handlers)
- After the gauge reading reaches 550 psig, isolate the system by first closing the gauge manifold, then close the nitrogen cylinder valve.
- Check the flared and brazed connections for leaks by applying a bubble solution to all joints.
- The bubble solution must be a solution designed for refrigerant leak testing. Common soap solution must never be used on refrigerant piping as those contain chemicals that could corrode copper and brass, and cause product malfunction.
- If the pressure does NOT drop for 24 hours, the system passes the test.
- In this case, the pressure drop of 9.5 psig was due to temperature differences, therefore, there is no leak in the refrigerant piping system.
- If the pressure drops and it is not due to ambient conditions, there is a leak and it must be found. Remove the bubble solution with a clean cloth, repair the leak(s), and perform the leak / pressure check again.
- After the system has been thoroughly tested and no leaks are found, depressurize by loosening the charging hose connector at the nitrogen cylinder regulator. When system pressure returns to normal, completely disconnect the charging hose from the cylinder, and release the nitrogen charge from all refrigerant piping. Wipe off any remaining bubble solution with a clean cloth.
- **Ambient Conditions and the Leak / Pressure Check**
- If the ambient temperature changed between the times when pressure was applied and when the pressure drop was checked, adjust results by factoring in approximately 0.79 psi for each 1°F / 1°C of temperature difference.
- Correction formula: (°F / °C Temperature when pressure was applied - °F / °C Temperature when pressure drop was checked) x 0.79.
- Example: When pressure (550 psig) was applied, temperature was 80°F / °C; 24 hours later when pressure drop (540 psig) was checked, temperature was 68°F / °C.
- Thus, (80°F / °C - 68°F / °C) x 0.79 = 9.5 psig.



b) Triple Evacuation (Vacuum)

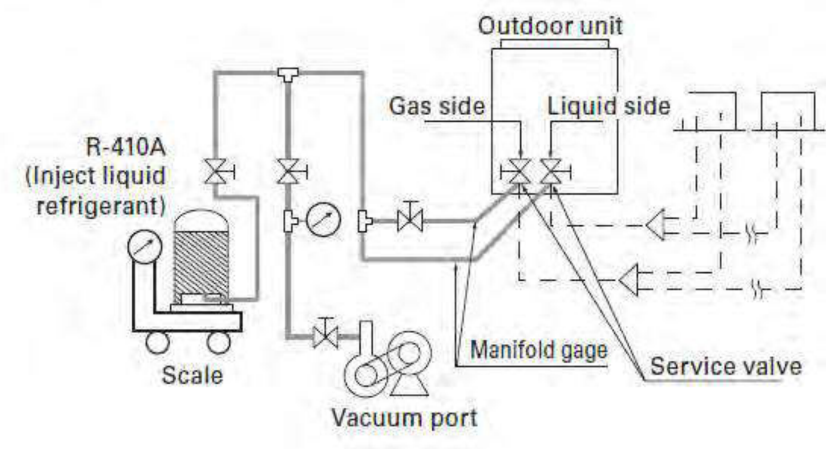
- Why is a triple evacuation so important instead of a deep vacuum? Because the relationship between pressure and temperature with water.
- When the first vacuum is pulled, some of the moisture in the lines boils and evaporates.
- However, once it reaches a certain pressure the water will actually freeze and leave small ice crystals in the system. This is why a single deep vacuum is insufficient.
- A triple evacuation of all piping should be performed to eliminate moisture in the system:
- **Do NOT open service valves until the deep vacuum of 500 microns or below has been achieved and the additional charge has been added**
- If Heat Recovery System connect to all three main refrigeration stop valves at outdoor unit.
- Verify that the micron gauge is connected at a point where it can read the system's pressure at all times during this process, even when the vacuum pump is not running during the hold test.
- **Evacuation procedures:** Evacuation procedures shall be performed as follows:
- **Step 1- Operate the vacuum pump and evacuate the system to the 2,000 micron level.**
- Isolate the pump by closing the manifold gauges and the vacuum pump valve, and then watch the micron level. Micron level may rise a bit, but MUST eventually stop rising for fifteen (15) minutes.
- If the micron level DOES NOT stop rising, there is a leak, and the leak test must be performed again. If the micron level DOES rise above 2,000 micron, re-open the manifold gauges and the vacuum pump valve and continue evacuation back down to 2,000 micron level.
- If the micron level holds at 2,000 micron, Break the vacuum with dry nitrogen to a pressure of 2-3 PSI and hold for 15 minutes (this is to "sweep" moisture from piping).
- **Step 2- Evacuate to 1,000 micron level.**
- Isolate the pump by closing the manifold gauges and the vacuum pump valve, and then watch the micron level. Micron level may rise a bit, but MUST eventually stop rising for fifteen (15) minutes.
- If the micron level DOES NOT stop rising, there is a leak, and the leak test must be performed again.
- If the micron level DOES rise above 1,000 micron, re-open the manifold gauges and the vacuum pump valve, and continue evacuation back down to 1,000 micron level. If the micron level holds at 1,000 micron, Break the vacuum with dry nitrogen to a pressure of 2-3 PSI and hold for 15 minutes (this is to "sweep" moisture from piping).
- **Step3- Evacuate to static micron level ≤500.**
- Micron level must remain ≤500 for 24 hours. If the vacuum gauge rises and stops, the system may contain moisture, therefore, it will be necessary to repeat the steps of vacuum break and drying.
- After maintaining the system in vacuum for 24 hours, check if the vacuum gauge rises or not. If it doesn't rise, then the system is properly evacuated.
- Close manifold gauges.
- Shut the valve before turning off the vacuum pump.



Refrigerant Charging:

- Weigh in additional refrigerant with digital scales. Calculate charge based on total line length plus lb/ft of diameter. Check with each unit model for correct multiplier.
- After the amount of refrigerant to be added is determined write it down on the label on the back side of the front cover. After the vacuum/drying is complete, charge the additional refrigerant in its liquid state through the liquid stop valve service port.

- Make sure to use installation tools you exclusively use on R410A installations to withstand the pressure and to prevent foreign material from mixing into the system.



Gas Pressure For any Ton Capacity			
Refrigerant	Suction Pressure (PSI)	Discharge Pressure (PSI)	Standing Pressure (PSI)
	M/C ON	M/C ON	M/C OFF
R 22	60 To 70	250To 300	156
R 32	120	490	260
R 134A	35	158 To 199	95
R 290	65	275 To 300	125
R 404A	87	270 To 356	190
R 407C	63	247 To 307	153
R 410A	110 To 120	400 To 500	250
R 417A	65	261	140

Refrigerant Piping –Additional Refrigerant Charge:

- Do NOT open unit service valves until additional refrigerant charge has been calculated, added and recorded.
- Calculates the additional refrigerant charge based on the refrigerant piping layout. If at any time there is a change in the actual piping installation from the design layout, it must be reported back to the designer for verification.
- Enter additional refrigerant charge amount -R410A.Lbs.
- Record additional charge amount inside the outdoor unit using a permanent marker.

Additional Refrigerant Charged Volume	
Liquid pipe Size	R410A (kg/m)
6.4 mm	0.022
9.5 mm	0.057
12.7 mm	0.11
15.9 mm	0.18
19.1 mm	0.26
22.2 mm	0.37
25.4 mm	0.45

Split AC Copper Pipe Additional Refrigerant Charge			
Total Pipe Length	50 Meter	60 Meter	70 Meter
Additional Refrigerant	None	250 gm (25gm/Meter)	500 gm (25gm/Meter)

Electrical Connections:

- Make all electrical connections in accordance with electrical codes and ordinances.
- Multi-pole circuit breaker or disconnect is required to fully isolate the unit from all power.
- Install circuit breakers/disconnects in accordance with local and national codes.
- Select the power cable in accordance with relevant local and national regulations.

- **Unbalanced power must be maintained within 10% of supply rating** among all indoor units or the unit will stop and an error code will be generated. (Significantly unbalanced power may shorten the life of the system.)
- Ground the unit at an exclusive grounding terminal, at the electrical panel
- The communication cable between single-phase outdoor units and between indoor and outdoor units has no polarity.

Correct

Not Acceptable

Testing of the System:

a) Indoor Unit Cooling Measurent:

- Measure Indoor unit Return Air Temperature or Room Temperature.
- Measure Indoor Unit Grill Temperature.
- Grill Temperature should be 10^{0}C to 13^{0}C less than Room Temperature in 10 to 15 min.

b) Outdoor Unit Hot Air Measurent:

- Measure Outdoor Atmosphere Air Temperature near Out Door Unit (Fan inlet Temperature).
- Measure Outdoor Unit Fan Discharge Temperature.
- Outdoor Unit Fan Discharge Temperature should be 11^{0}C to 14^{0}C higher Out Door Unit Fan inlet Temperature.

c) Measure Suction Pressure and Discharge Press of System

- Suction and Discharge Pressure should be according to Refrigerant Type.

d) Measure Cuurent drawn by Compressor.

- Ampere drawn by should be as per Manufacture recommended Current Rating.

e) Fell Cooling of Discharge Line (Liquid Line)

- Discharge line should be cool enough after starting of Compressor.

f) System Cooling Problems

a) Less or No cooling even though No Leakage in Refrigerant Pipe & Suction Pressure is OK.

- Low Discharge Pressure
- Weak Compressor.

b) Ice accumulation on Discharge Line (Liquid Line / Small Line)

- Less Gas Pressure
- Capillary Problem.

c) Ice accumulation on Suction Line (Gas Line / Big Line)

- Less Gas Pressure
- Indoor Air Filter chock up, Blower Not running, indoor unit cooling coil problem.
- Outdoor unit Fan speed is too low, Capacitor Discharge, Refrigerant Pipe Bend or punch

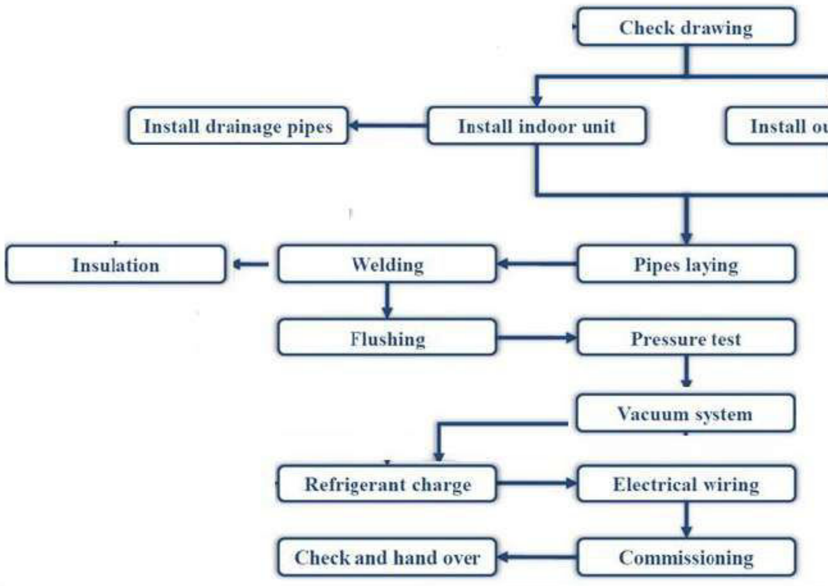
d) Ice accumulation on both Suction & Discharge Line

- Not Cut Off Compressor,
- Electrical Contactor stuck , Electrical Contactor coil not working
- Problem in Sensor, Thermostats.
- Machine is continuous working

System Problems				
System Problem	**Discharge Line Pressure**	**Suction Line Pressure**	**Suction Line Temperature**	**Compressor Amp**
Over Gas Charge	**High ↑**	**High ↑**	**Low ↓ (Ice on Suction Pipe)**	**High ↑**
Under Gas Charge	**Low ↓**	**Low ↓**	**High ↑**	**Low ↓**

Capillary Block	Low ↓	Low ↓	High ↑	Low ↓
Less Air Flow on Evaporator (Indoor Unit)	Low ↓	Low ↓	Low ↓	Low ↓
Less Air Flow on Condenser (Outdoor Unit)	High ↑	High ↑	High ↑	High ↑
Dirty Condenser (Outdoor Unit)	High ↑	High ↑	High ↑	High ↑
Low Ambient Temperature	Low ↓	Low ↓	Low ↓	Low ↓
High Ambient Temperature	High ↑	High ↑	High ↑	High ↑
In sufficient Compressor	Low ↓	High ↑	High ↑	Low ↓

HVAC System installation & Testing Flow Chart



Chapter: 78 Method of Statement for Fire Fighting Works

Purpose:

- This method describes the detailed procedure for installation and Testing of Wet Raiser Fire Protection System, Pipes, Sprinkler, Fire Pumps, Valves and Fire Fighting Accessories as per the standard Practice and Codes.

General Equipment & Tools:

- The equipment that will be engaged for Installation of Fire Fighting works will be
- Tool Box
- Welding Machine
- Drilling Machine with various Bits
- Grinding Machine
- Cutting Machine
- Threading Machine
- Chain Block
- Pipe Wrench
- Hand Tools-gloves.
- Hammer
- Portable Lights
- Manual Excavation Tools
- Removable Barricades
- Scaffolding / Mobile scaffold
- Ladder
- Spirit Level
- Screwdriver, Pliers, Spanner.
- Marker
- Pressure gauge
- Level gauge / Spirit level.
- Measuring tape
- Pressure test pump.

Storage & Material Handling:

- The storage area must be free from dust and the materials should be stacked in proper manner to avoid any damages.
- The Material shall be stored in designated area of the Store to protect the M.S Pipe and Other Fire Fighting Accessories against effects of weather and environment.
- The material shall be transported in their original packing to Site location.
- The pipes will be stacked in the site store on a proper stand on wooden loft on a flat surface at a height not exceeding 1.7m. From the bottom layer.
- All open ends of pipes will be covered to protect from foreign matter, dirt/debris
- Fittings will be separately packed and stored as per the sizes required for the project.
- Chemicals must be stored in well ventilated location and away from direct sunlight.

Inspection of Materials:

- **Inspection of Pipe / Valve / Flanges:**
- Check Type of Material ,Size of Material , Make of Material.
- Chemicals such as paints, primer and thinner, check their expiration date before receiving.
- **Physical Damages Inspection:**
- In case of any damages observed during inspection, the concern report will be issued and Material shall be returned to the supplier for replacement.

Installation Procedure:

1) Pipe Hanger / Support Installations

- Piping Route will be the as per most advantageous manner possible with respect to headroom, valve access, opening and equipment clearance, and clearance for other work.
- **The Line layout should be verified from Site in charge**.
- After marking the pipe routes, the anchoring points will be drilled according to the required support spacing as shown on the approved shop drawings.

Pipe Diameter (mm)	Maximum Hanger Spacing (mm)	Rod Size (mm)
25	2000	8
32	2500	8
40	2500	8
50	2500	8
65	2500	10
80	2500	10
100 *	2500 *	12 *
150 *	3000 *	16 *
200 *	3000 *	16 *
* As per Site Requirement Fabrication Support may be used.		

- Mark out the location of hanger thread rods for pipe installation as per the approved construction drawing.
- Fasteners and fully threaded rods shall be used for installing the pipe supports. The sizes of pipe supports and installation shall be in accordance with manufacturer's recommendations.
- For Single pipes of size 100 mm and above, with the prior approval **50xx50xx6 mm MS Angle iron** and for Double Pipe **75x75x6mm with U Clamp** with Fastener may be used for Supporting horizontal Pipe from ceiling.
- Drill the marked position for hangers and supports by using the drill bit of appropriate size.
- Fix the unfix anchor at drilled position by gentle and uniformly hammering.
- Fix the threaded rod of appropriate diameter and size & length in the anchor by twisting by turning.
- After fixing the threaded rod, insert a washer of appropriate size in to the rod.
- Finally fix the washer near to the slab by tightening a nut over it, this will improve the strength and load bearing capacity of threaded rod.
- For installing pipes vertically or horizontally inside the building standard pipe supports of reputed make shall be used. Following supports shall be used.

1) Clevis Hangers or MS Chanel for horizontal supports to adjust varying heights.

- The Pipe route should be min **500mm** away from wall.
- Supports will be arranged as near as possible to pipe joints and any change in direction.
- **Vertical Riser Support:**
- Risers shall be supported by pipe clamps or by hangers located on the horizontal connections within **24 inches (0.6 Meter)** of the centerline of the riser.

2) Pipe Welding / Fabrication:

- **Welding Machine:**
- Welding machines shall be in good working condition and shall have proper control for regulating current.
- Location of welding machines and the distribution boards to be connected with them shall be verified by site electrical Team to avoid overloading of the distribution boards, cables and electrical power sources.
- All welding Machine ,other Electrical Tools, the electric cables, distribution boards and connections for machines shall be carefully checked once a Month to maintained it in a good working condition.
- Welding cables used shall have proper insulation throughout the length. The cables sh
- all be carefully examined and repaired as necessary every day.
- **Welding Electrodes:**
- Electrodes used for welding should comply with IS:814, 1991.
- Generally all welding shall be performed using Shielded metal arc welding (SMAW) process using cellulosed-coated electrode (**E6013 type**) for root run and subsequent passes
- **Storing of Welding Electrodes:**
- Welding electrodes shall be stored in indoors free from moisture.
- Qualified and certified welders only shall do welding.
- No welding shall be done if there is impingement of any rain, or high winds
- **Fabrication of Pipe (But Welding):**
- The welding of pipes in the field should comply with IS:816, 1969.

- All pipes and fittings shall be cleaned of Dust, Mud from inside and outside before Welding.
- All pipe, fittings shall be smooth, clean and free from blisters, loose mill scale, sand and dirt prior to the installation.

a) **Edge Preparation**: Before welding, the ends shall be cleaned by wire brush, filing or grinding and making "V" on edge of both pipe.

b) **Welding of Root Run:** Primary Welding shall be done by **E6013, 2.5mm** Welding Rod **(90 to 90A, 18 to 25V)** of approved make.

c) **Chipping and Cleaning of Root Run:** Each weld- Root run shall be thoroughly cleaned to remove the slag, irregularities and any defects, before the next run is deposited.

d) **Final Welding Run:** Final Welding shall be done by **E6013, 3.5mm** Welding Rod **(80 to 140A, 20 to 25V)** of approved make.

e) Chipping and Cleaning of Final Run: Each Final weld shall be thoroughly cleaned to remove the slag, irregularities and any defects

3) Pipe Installation:

- Installation of pipe shall be co-ordinate with architectural, structural and MEP work for a fit for purpose installation. Any deviation shall be intimated to the engineer for approval.
- Cut all pipes accurately to measurement determined at the site. After cutting the pipe, ream it and remove all burrs.
- Run all piping as direct as possible, avoiding unnecessary offsets and conceal piping in finished rooms.
- Install all piping close to walls, ceilings and columns so piping will occupy the minimum space but Proper space will be provided for covering and removal of pipe, special clearance, and for offsets and fittings.
- Pipe work will be installed not closer than **200 mm** to electrical conduits, lighting, and power cables.
- Pipes will be spaced in ducts, ceilings, voids and plant areas, such as adequate access is permitted to any pipe for maintenance or removal without disturbance to the remaining pipe work and other services.
- **Pipes will not be solidly built into walls or plaster.** Pipe joints will not be positioned within the thickness of walls, floors or in any other inaccessible position. Pipes passing through walls and floors will be sleeved.
- Couplers, unions and fittings will be screwed up to the reduced depth of the thread, such that no more three-turns are showing when pulled up tight.
- All pipes, valves and fittings and connected equipment will be thoroughly cleaned of rust, sand and dust, scale and other foreign matter before erection and before any initial fill water for hydraulic testing.
- After completion of pipe end connection, fix / tight the support clamps properly to make the pipe straight and level as per the layout.
- Check the levels of pipe work with spirit levels and measuring tape.
- The Spacing of fire pipe supports for sprinkler / clevis hanger shall not be more than that specified below

Pipe Support Details			
Nominal Pipes Diameter	**Spacing between supports**	**Hanger rod diameter**	**Hanging Strip Size(thickxwidh)**
Up to 25 mm	2.00 meter	8 mm	1.5mmx25mm
32 to 50 mm	2.50 meter	8 mm	1.5mmx25mm
65 to 80 mm	2.50 meter	10 mm	2mmx30mm
100 mm *	2.50 meter *	12 mm *	2mmx30mm *
150 mm *	3.00 meter *	16 mm *	3mmx30mm *
200 mm & above *	3.00 meter *	16 mm *	3mmx30mm *
* As per Site Requirement Fabrication Support may be used.			

- All lines shall be suitably supported so as to provide rigidity and avoid vibrations.
- Proper lines and levels shall be maintained while installing exposed pipes.
- All lines less than 50 mm NB size can be socket welded to matching rating fittings.
- All lines above 50mm NB size shall be butts welded with full penetration welds.
- **All bolts, nuts and washers used shall be of GI.**
- Extra supports shall be provided at the bends and at heavy fittings like valves to avoid undue stress on the pipes.
- Open ends of piping shall be blocked as soon as the pipe is installed to avoid entrance of foreign matter.
- Pipes must be of Heavy grade M.S. pipe conforming to IS 1239. The pipes, fittings and installation shall be hydraulically tested to a pressure of 15 Kg/Sq.cm. or 1.5 times the working pressure whichever is higher.

4) Flanges:

- Mild steel flanges shall be in accordance with Table - 17 of IS : 6392 i.e. "Plate Flanges for Welding" and flange thickness shall be as under. **Gasket thickness shall not be less than 3 mm.**
- Check the flange size and specification according to pump size and valve size,

Flange Details		
Pipe Dia	**Flange Thickness**	**No. of holes**
200 mm.	24 mm.	12
150 mm and 125 mm	22 mm.	8
100 mm and 80 mm	20 mm.	8
65 mm.	18mm	4
40 mm and below.	16mm	4

- All hardware items such as Nuts, Bolts, and Washers shall be of appropriate size.
- **Washers shall be used on both sides of the bolt.**

5) Vertical risers

- Vertical risers shall be parallel to walls and column lines and shall be straight and in plumb. Risers passing from floor to floor shall be supported at each floor by MS angle with clamp as per specification of pipe support.
- The space in the floor cut outs around the pipes work may be closed using cement concrete (1:2:4 mix) or steel sheet, from the fire safety considerations, taking care to see that a small annular space is left around the pipes to prevent transmission of vibration to the structure.
- Riser shall have suitable supports at the lowest point.

6) Sprinkler Heads & Accessories

- Installation of sprinkler heads will be done after pipe work flushing is completed.
- Apply the PTFE tape only to the male portion of the sprinkler and install the upright sprinkler head using the wrench provided by the manufacturer, and in such a way that the arms are parallel to the branch pipe. Maintain a clearance of 1" between the deflector of upright sprinkler and ceiling. Ensure that sprinkler heads have the correct finish and temperature rating.
- For fixing sprinkler heads, 15 mm. dia. M.S. Socket is to be screwed to range pipes at the locations as' per drawings. Dead plug shall be fixed in the socket.
- If sprinkler head is to be provided away from range pipe, M.S. Pipe nipple of suitable size be used to extend the sprinkler head and socket is welded at desired location.
- During occupation of the building, sprinkler heads shall be provided in place of dead plugs. Teflon tape shall be used on threaded portion.

7) Fire Hose Reel / Fire Hose Cabinets

- Check cabinets are approved size and dimension. Inspect for signs of damage.
- Locate exact location of these Cabinets as per approved shop drawings and with careful measure of elevation and plumb.
- Fix cabinet using recommended anchor and bolts. Proceed with installation of accessories, lock shield valve, landing valves, etc. taking in consideration of approval for these devices.
- Prior to the installation Foreman will read, understand and strictly follow the manufacturer's instructions.
- Examine the location of the hose reel cabinets and ensure that opening is sufficient for fixing all equipment and the mounting height of the hose valve and hose racks is as per the approved shop drawings and to the requirements. Hose reel, hose valves and fire extinguishers are of approved type and have the correct rating.
- The cabinet (without the equipment) will be installed where applicable. Branches to the hose rack (reel) / hose valve will be installed on site to ensure actual entry point to the cabinet. Location of Pipe sleeves shall be as per approved drawings.
- Hose reel & valve will be installed as per the manufacturer's instructions at the correct mounting height.
- Keep fire extinguisher inside the cabinet along with the hose rack. Ensure that the top of the wall mounted extinguisher do not exceed from the levels as per approved drawing and specification.

8) Drain Piping of the System:

- Fittings will be of the eccentric pattern to ensure proper drainage and the elimination of air pockets wherever necessary.
- **In Sprinkler Network at far end Drain Pipe shall be provided on last Sprinkler to remove Air from Sprinkler Network.**

9) Sleeves

- The branch lines will be hanged to the proper level and will be connected to the cross main. Where piping is embedded or passing through masonry or concrete, sleeves will be provided as per specification mostly of MS or GI material.
- Pipe sleeves of diameter larger than the pipe by least **50 mm** shall be provided wherever pipes pass through walls and the annular spaces shall be filled with felt and finished with retaining rings.

10)Sealant

- After the removal of the concrete forms and installation of the pipeline, the annular space between the sleeve and the pipe shall be filled with caulking material leaving enough space at both ends of the sleeve for sealing.

11)Under Ground Pipe

- Where mild steel pipes are to be buried under ground the same shall be treated anti corrosion treatment. The top of the pipes shall be not less than 100 cm below the ground level.
- Where this is not practicable, permission of the Engineer-in-charge shall be obtained for burying the pipes at lesser depth.
- After the pipes have been laid, the trench shall be refilled with the excavated soil and rammed and any extra soil shall be removed from the site of work by the contractor.
- Underground pipe shall be laid at least 1 meter away from the face of the building preferably along the roads and foot paths.
- As far as possible lying of pipes under road, pavement and large open spaces shall be avoided.
- To facilitate detection of leak and isolation of defective portion of pipe, valves shall be provided in underground pipe at suitable locations.
- As far as possible such valves shall be provided over ground or at Basement. If the valves are to be provided below ground, suitable masonry chamber with cover plate shall be provided.
- Locations where vehicles can pass shall be avoided for provision of valve below ground

12)Anti-Corrosive Protection on Under Ground Pipe

- Corrosion protection tape shall be wrapped on M. S. Pipes to be buried in ground.
- 2 No's of corrosion protection tape minimum **4 mm thick** shall comprise of coal tar/asphalt component supported on fabric of organic or inorganic fiber and conform to requirement of **IS 10221** Code of practice for coating and wrapping of underground mild steel pipe line.
- Before application of corrosion protection tape all foreign matter on pipe shall be removed with the help of wire brush and suitable primer shall be applied over the pipe thereafter.
- The primer shall be allowed to dry until the solvent evaporates and the surface becomes tacky.
- Both primer and tape shall be furnished by the same manufacturer. Corrosion protection tape shall then be wound around the pipe in spiral fashion and bounded completely to the pipe.
- There shall be no air pocket or bubble beneath the tape. The overlaps shall be **15 mm** and **250 mm shall be left uncoated on either end of pipe** to permit installation and welding.
- This area shall be coated after the pipe line is installed. The tapes shall be wrapped in accordance with the manufacturer's recommendations.
- If application is done in cold weather, the surface of the pipe shall be pre- heated until it is warm to touch and traces of moisture are removed and then primer shall be applied and allowed to dry.

Flushing, Cleaning of Piping and Equipment:

- After piping is erected, all piping systems including main header line and branch line will be cleaned to remove all mill, welding scale, oil, corrosion, and other construction debris.
- Prior to hydraulic testing, all pipe work systems including valves, strainers and fittings will be washed thoroughly. Any washing of the piping systems will be carefully carried out where there are isolation valves or equipment are employing.
- Any stoppage due to foreign matter or air lock which is found to impede the flow of fluid will be removed, either before or after the systems are in operation.
- Do not operate pumps or equipment until debris has been removed from the respective system has been flushed out.
- Flushing of the system can be done from a pumping source with minimum flow rate to provide a velocity of **3 m/ sec.**
- Flush the piping system until all debris is removed and clean water comes out.

- Automatic devices which can become clogged during the cleaning process will be disconnected and will not be connected permanently until the cleaning process is complete.
- Enough draining points will be left for this purpose. These points will be the lowest point of the area/zone and the water supply point.

Painting:

- All pipes & fittings above ground and in exposed locations shall be painted with two coat of zinc chromate primer and two or more coats of synthetic enamel of fire red color paint.

  1) Clean the MS / GI Pipe
- Clean the black pipe with cotton rag to remove any dust or grease on the pipes before painting.

  2) Fabrication of Pipe:
- After Cleaning, fabrication work of Sprinkler network shall be completed on ground level.

  3) Paint the Pipe with 1st Coat Red Oxide (Before Fabrication)
- After Fabrication of MS Pipe, paint the black pipes with one coat of approved Red-oxide Primer will be applied as per Manufacture's film thickness **or Microns measured as per Sample paint**.
- Please ensure both sides (top & bottom) are painted evenly.
- Put the painted pipes in a good ventilation condition for 24 hours for the paint dry.

  4) Paint the Pipe with 2nd Coat Red Oxide
- After completion of 1st Coat apply, 2nd coat of Red oxide shall be applied of as per Manufacture's film thickness **or Microns measured as per Sample paint**.
- Put the painted pipes in a good ventilation condition for 24 hours for the paint dry.

  5) Paint the Pipe with 1st Coat of Enamel Paint:
- After drying, red oxide, 1st Coat of Enamel Paint will be applied on Pipe with as per Manufacture's film thickness **or Microns measured as per Sample paint**.
- Please ensure both sides (top & bottom) are painted evenly.
- Put the painted pipes in a good ventilation condition for 24 hours for the paint dry.

  6) Install the Pipe
- After the 1st Coat of Enamel Paint dry, install the pipes.

  7) Paint the Pipe with 2nd Coat of Enamel Paint:
- After Completion of Hydro Test, 2nd Coat of Enamel Paint of Approved make of as per Manufacture's film thickness **or Microns measured as per Sample paint**.
- Please ensure both sides (top & bottom) are painted evenly.

Testing of the System:

1. Initial Pressure Testing (24 Hour Test)

- After completion of the work, all valves/ fittings shall be installed in position and entire system shall be tested for 24 hours at a pressure of **10 Kg/cm2 to 15 kg/ cm2.**
- Plug all the openings
- Close all the drain valves.
- Fill complete pipeline with water avoiding any air column. (For this purpose keep the drain valve at the highest elevation slightly open, while filling water when line is completely filled with water close the valve)
- By a pressure pump pressurize the line to an intermediate pressure of 10 Kg/cm2 to 15 kg/ cm2. Wait for 24 Hours.
- Check all major joints for any visible leak.
- The drop of pressure up to 0.5 kg/cm2 shall be accepted.

2. Hydrostatic Testing of Pipe Work

- Make available a highlighted drawing of area intended for hydrostatic pressure testing. Indicate on the drawing the location of vent/drain valve, plugged connections and water pressure pump connection.
- Make sure the test witness timing and pressure duration are agreed by the client/consultant.
- Place safety warnings at all points where personnel may pass through within the vicinity of testing.
- **Make sure that all equipment item such as sprinklers; valves etc. are subjected to the pressure test.**
- Attach the pressure pump to the desired location through an isolation valve, by pass valve and calibrated pressure gauge to indicate the pressure on the pipe work.

- **The entire pipe work shall be hydrostatically tested for not less than 2 hours at 15 bars (or 1.5 times the working) pressure without leak.**
- Physically check and ensure that all pipes undergoing test is strongly supported and addition of pipe work will not introduce undue stress on any support.
- Make sure that all pipe works are suitably plugged.
- Connect a calibrated and approved pressure gauge and fix an isolation valve just below the pressure gauge.
- Apply pressure gradually until it reaches the test pressure. The test pressure will be as per agreed terms and as per requirements.
- **All piping shall be tested to hydrostatic test pressure of at least the 1.5 times of operating pressure, but not less than 15 kg./sq.cm. For a period not less than 24 hours.** All leaks and defects in joints revealed during the testing shall be rectified to the satisfaction of the Engineer-in-Charge.
- Piping repaired subsequent to the above pressure test shall be re-tested in the same manner.

3. Final Testing (Automation of the System)

- After completion of Hydro Test, all operation checks shall be carried out for automatic operation of the systems. For this purpose, landing valves may be opens at different locations. The exercise shall be repeated couple of times to ensure trouble free operation of the system.
- Flow Test: The design flow of pumps shall be checked. The pump shall be operated after opening a number of landing valves at different locations. Design pressure is be maintained in the pump house. Water discharge is to be
- Measured by drop in level in UG tank for a certain period. All pumps shall be tested one by one. The flow rate shall be not less than as specified while maintaining the design pressure in pump house.

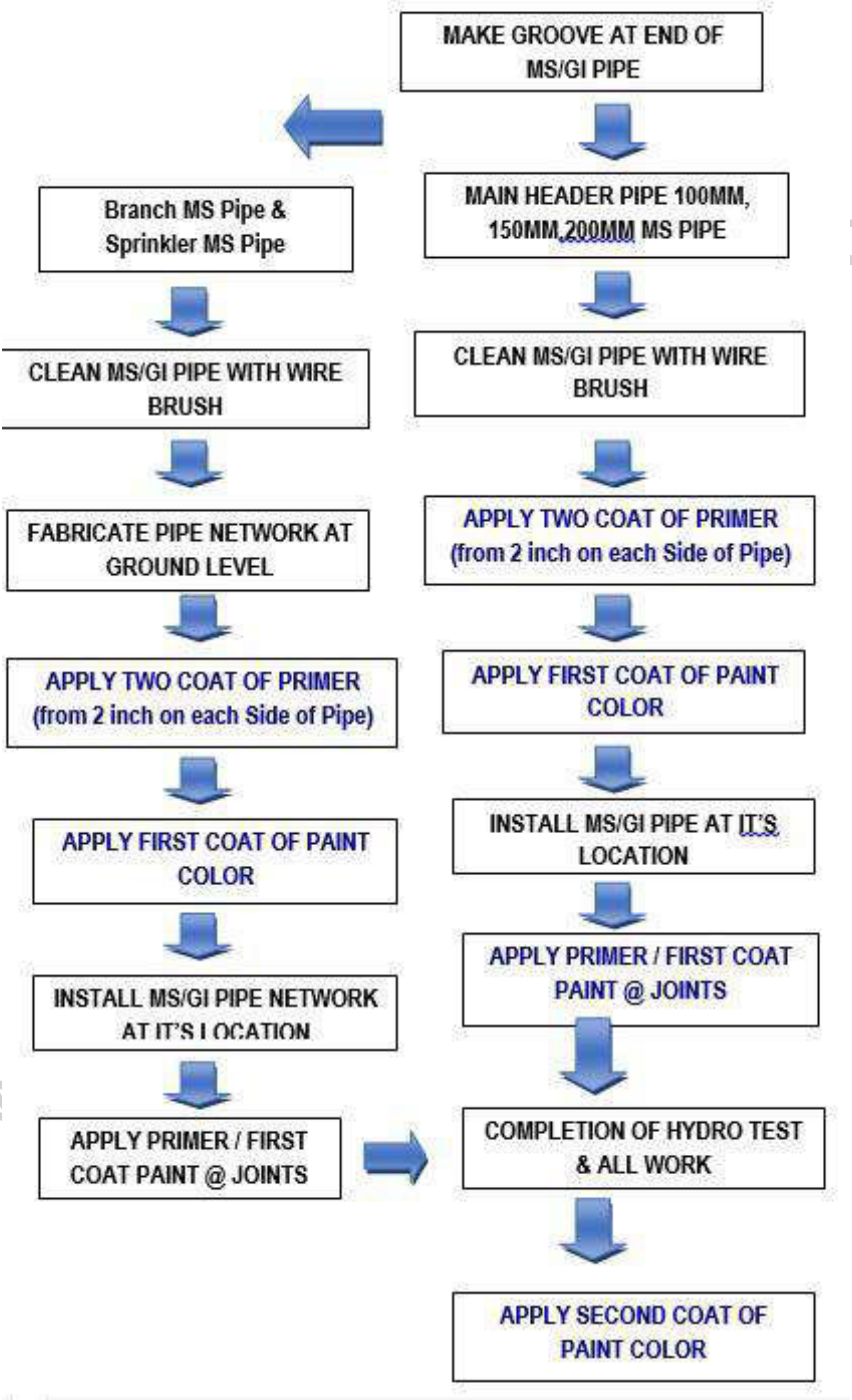
Pipe Identification Installation:

- After the pipe layout hydrostatically tested and finally painted, install pipe identification as per Site Requirements.
- Background Color –Red.
- Letter Color –White.
- Lettering Size –as per Size of Pipe or Equipment.
- Flow –Direction Arrows –integral with piping-system

References:

- Project Specification.
- Indian Standard.
- BS Code.
- Local Fire Authority Regulations.
- NFPA (National Fire Protection Association) Code.
- NBC Code.

Flow Chart of Fabrication & Painting:



Chapter: 79 Method for Wrapping Coating & Holiday Test for Fire Fighting Pipe

Purpose:

- This method describes the detailed procedure for installation & Testing of Wrapping Coating and Holiday Test for Fire Pipes as per the standard Practice and Codes.

General Equipment & Tools:

- The equipment that will be engaged for Installation of Fire Pipe works will be
- Tool Box
- Welding Machine
- Grinding Machine
- Cutting Machine
- Chain Block
- Pipe Wrench
- Hand Tools-gloves.
- Hammer
- Portable Lights
- Manual Excavation Tools
- Removable Barricades
- Scaffolding / Mobile scaffold
- Ladder
- Spirit Level
- Marker
- Holiday Test Machine

Storage & Material Handling:

- The storage area must be free from dust and the materials should be stacked in proper manner to avoid any damages.
- The material shall be transported in their original packing to Site location.
- All materials shall be stored in a covered warehouse in a location as cool as possible and protected from the ingress of dirt, dust, moisture, etc.
- Any coating materials show evidence of deterioration due to weathering or damage due to mishandling while are in the custody contractor, shall be replaced by the contractor.
- Chemicals must be stored in well ventilated location and away from direct sunlight.

Inspection of Materials

- **Inspection of Wrapping Coating:**
- Check the reference of delivered material against approved submittal.
- Check the material against the purchase order.
- Check Type of Material ,Size of Material , Make of Material
- Chemicals such as paints, primer and thinner, check their expiration date before receiving.
- **Physical Damages Inspection:**
- In case of any damages observed during inspection, the Material shall be returned to the supplier for replacement.

Sequences of Wrapping Works:

- wrapping system shall comprise the followings sequences:

a) Surface Preprations:

- Prior to brush cleaning, all oil, grease on the pipe surface shall be thoroughly removed by flushing with suitable solvent and wiping with clean tags.
- Rusted materials surface shall be adequate scrubbed manually with stiff wire brush where ever surface get rusted, prior to application of primer.

- Surface shall be completely free from rust, mill scale, grease, weld spatter, weld slag, dirt, dust, oil and any other foreign matter and to be dry at time of application.
- Oil and grease shall be removed using an approved solvent. White spirit and paint thinners are suitable solvents. Kerosene shall not be used.
- Mechanical cleaning machines shall not employ knives or other tools, which may produce notches or gauges on the pipe surface.
- Blast cleaning machines shall be maintained in correct adjustment and replacement tools shall be available throughout the cleaning process.
- All weld joints shall be cleaned manually with stiff wire brush/buffing
- The coat of primer shall be given as soon as practicable and before detrimental corrosion or recontamination occurs. The cleaned surface shall never be left unprotected overnight.
- The cleaning method employed shall not result in thinning of the pipe wall beyond the limits of the pipe specification. Cleaning shall be carried out immediately before application of the priming coat and shall be to the satisfaction of OWNER. If the outside of the pipe becomes contaminated with any foreign matter.

b) Application of Primer:

- Immediately after cleaning the surface shall be applied with one coat of primer before application of coal tar wrapping. The entire surface of pipe should be primed.
- The primer shall be applied in a thin layer without runs, sags, drips, holidays (gaps or voids) or other defects.
- If any defects may be found in the primed surface, the pipe shall be re-cleaned and primed to the required standard and to the satisfaction of principal/engineer.
- No specific time gap between two coats needs to be maintained but after the coat of primer, the coating should before the primer is completely hardened.
- The primer shall be suitable for brush or spray application and still form at thin uniform coating with an approximate 40 micrometer dry film thickness according to vendor's instruction.
- Freshly primed pipe shall be properly supported on racks, and allowed to be uncontaminated by moisture, dirt or other foreign matter.
- If application is done in cold weather, the surface of the pipe shall be pre- heated until it is warm to touch and traces of moisture are removed and then primer shall be applied and allowed to dry.
- Coating and wrapping shall not be started until that section of line has been tested and accepted.
- The primer shall be suitable for brush or spray application and still form at thin uniform coating with an approximate 40 micrometer dry film thickness according to vendor's instruction.
- Primer shall be applied at an average rate 0.12 liter per square meter.

c) Application of Coating (Wrapping):

- The pipe shall be kept on a suitable platform with ease of rolling so that the enamel can be applied manually with brush/spray so that it will spread uniformly on the metal surface.
- Immediately, wrap of coal tar as per approved specification shall be applied over the coal tar enamel.
- The total, clean, dry prepared surface shall be spirally wrapped with the laminated tape with min 15 MM or as per Specification overlapped using sufficient tension to ensure complete conformability. Any bulges formed at covers may be removed by splicing the tape in site and repress ring.
- The inside of the coal tar is heated with burner and is pressed against the metal with hands so that there is no air gap and with required overlap (i.e. 15mm).The coating shall be continuous for the full length of the pipe except 200 mm at both ends of the pipes.
- The tape shall be applied with tension controlled provide a uniform, tightly adhesive coating free from wrinkles, puckers, void, or break.
- When the wrapping shall be performed "AT SHOP" or "AT SITE" (when it is necessary to stock the wrapped pipes), an outer wrap shall be spirally wound over a clean dry Primer with 15 mm minimum overlap using sufficient tension to ensure complete conformity. No bulges shall be permitted.
- End laps between adjoining rolls of the wrap or between pipe sections shall be a minimum of 150 cm
- There after the pipes are lifted by suitable methods and allowed to dry on wooden sleeper/Sand bags. It is done at 2meter distance from digging area.

d) Handling of Coated Pipe:

- All coated pipes shall be handled in such a way that the coating does not suffer damage.
- Coated pipe shall be handled at all times with wide non-abrading slings or belts, or other equipment designed to prevent damage to the coating. All skids used to support coated pipe shall be padded.

- Bar cables, chains, hooks etc. shall not permitted to come in contact with coatings. Coated pipes shall be supported at two bare ends cleared from ground either on kids or sand bags.
- If the pipeline protective coating suffers damage between the coating and laying operations, the Contractor shall replace or repair the coating to the satisfaction of the OWNER
- Pipe shall normally be lowered into the trench immediately after the coating and wrapping has been approved. Where coated and wrapped pipe is supported on padded skids, their number shall be sufficient to ensure that no damage will be caused to the coating and wrapping.
- All coated and wrapped pipes which have been supported in any manner on padded skids, or lowering devices, shall be subjected to closed inspection to see that the coating is undamaged before the pipe reaches the bottom of the trench.
- Backfilling shall be carried out immediately after the pipeline is lowered into the trench but Contractor shall first obtain the approval by OWNER. If any backfilling is carried out without this approval, OWNER will have the right to require the Contractor to remove the backfill for examination of the coating and wrapping.

e) Inspection of Wrapping Pipe:

- After application of tape coating, visual inspection shall be carried out for uniformity without any wrinkle, irregularities and over lapping width.
- Visual inspection shall ensure that the coating is continuous, that the overlap is correctly maintained and that there are no wrinkles in the tape.
- All coating shall be subjected to 100% visual inspection and 100% inspection with an electrical holiday detector before being lowered into the trench.
- Thickness of the coal tar enamel coating shall be measured with the digital thickness gauge. Minimal acceptable thickness shall be 4mm or as per Specifications.

Testing of Wrapping by Holiday Test:

- The holiday detector shall be used to check that there is a continuous coating over the pipe surface, particular attention being given to bends and to areas where the tape has been spliced or repaired.
- Holiday detection shall be carried out only in dry weather conditions.
- Inspection for holidays are carried out on all buried field and shop components prior to backfilling. All field joint coated areas to be tested & free from contaminants such as sand, grease and moisture. It shall be performed on completely finished coatings.
- Prior to back filling, all wrapped pipe shall be holiday tested using an approved holiday tester set at 5KV per mm of tape thickness to a maximum of 15KV.
- The holiday detector shall be of an approved type and the operating voltage and setting shall be determined by a method approved by OWNER.
- The holiday detector settings shall be checked at least twice per day, while it is in use.
- The calibration report for the Holiday detector will be submitted for review before carrying out Holiday detector testing.
- **Testing Voltage:**
- The applied output voltage of the holiday detector shall have a spark discharge of thickness **equal to at least twice the thickness of the coating** to assure adequate inspection voltage and compensate for any variation in coating thickness. The electrode shall be passed over the coated surface at approximately half the spark discharge distance from the coated surface only one time at the rate of approximately 10 to 20 nd min.
- The edge effects shall be ignored. Excessive voltage shall be avoided as it tends to induce holidays in the coated surface thereby giving erroneous readings.

Test Voltage (IS 15337)	
Thickness of Coating	**Test Voltage, Max**
2 mm	10KV
3 mm	12KV
4 mm	15KV

- The electrical equipment used to test tape wrapping shall be a portable, low amperage, adjustable voltage, pulse type holiday detector. It shall be furnished with a coil spring electrode or, a suitable brush type electrode. The primary input wattage shall not be higher than 20 W and the minimum pulse at crest voltage shall be 20 per second.

- The wrapping machine shall be equipped with an overlap control device properly adjusted to provide the following minimum overlap under all conditions
- **Testing Method:**
- The Visual inspection of the wrapped and coated is carried out to see that the overlap is correctly maintained and there are no wrinkles, voids, blisters, pinholes, open seams, entrapped air or any other defects likely to cause failure of the coating.The electrode of the holiday detector, which is in the form of a coil spring, is put on the surface of the coated pipe.
- The voltage of the holiday detector is set by the operator using the adjustable knob.
- At no point of time the voltage will be allowed to go beyond 15000V. To ensure proper inspection voltage the equipment shall be grounded properly and the voltage adjusted in accordance with the instructions of the equipment manufacturer.
- After the voltage adjustment the electrode shall be passed over the taped surface one time only at the rate of approximate 15 m /min. If the electrode shall be passed over the coated surface, the current to the electrode should be immediately cut off to avoid damaging the coating.
- The location of the holiday should be marked using chalk/crayon. That 3" on either side of defective portion of the tape is to be cut opened and removed and fresh tape of that size or slightly larger than that is to be applied using the same application procedure.
- The repaired area shall then be retested once again with the holiday detector.
- The report for the above test will be documented as per approved format.
- **Precaution:**
- It is not intended that the holiday detector should be used to reveal pin holes and minor faults in the inner tape wrap. Such defects would not normally show up on the holiday detector with the specified coating system, unless the voltage was set at a level, so high, that it would be likely to damage the coating.
- At no time, shall the holiday detector be permitted to remain stationary around a coated pipeline with the operating voltage switched on.
- All defects, whether discovered visually or by means of the holiday detector, shall be clearly and indelibly marked.
- To ensure continuity between the brushes or rings, a short circuit test shall be carried out at regular intervals to determine the efficiency. If brushes are used, these must be cleaned every day.

Repair of Wrapping Coating:

- All defects in the coating shall be made good immediately after their detection.
- In the time of holiday test if any defective work is found, remove the wrapping and coating to the required extend from those areas by using a sharp knife. Then heated enamel shall be applied manually over the area following the procedure described above and inner and outer wrap applied.
- The Contractor shall be responsible for the complete cost, including cost of materials, of making good all defects caused by incorrect storage, handling, application, erection and testing of the protective coating or caused by incorrect construction of the pipeline.
- In the event of numerous defects in the coating, OWNER shall have the right to order the whole coating to be stripped, the pipe cleaned and another coating provided, applied and tested in accordance with this specification at the Contractor's expense.
- Holiday or localized defects in the inner tape wrap shall be repaired by the following procedure:
- (a) Strip off outer wrap from affected area, after ensuring that completed coating on either side is properly secured to prevent the outer wrap from unraveling.
- (b) Strip off inner wrap and primer from the affected area and thoroughly clean the pipe surface.
- (c) Re prime in accordance with this specification.
- (d) Apply patch of inner wrap not smaller than 150 mm x 150 mm (6" x 6").
- (e) Test for continuity of repaired inner wrap with holiday detector before replacing outer wrap.
- (f) Replace outer wrap and secure firmly.

References:

- Project Specification.
- IS 10221 / IS 15337 / NFPA (National Fire Protection Association) Code. / NBC Code.

Chapter: 80 Basic of External Lightning Protection System (LPS)

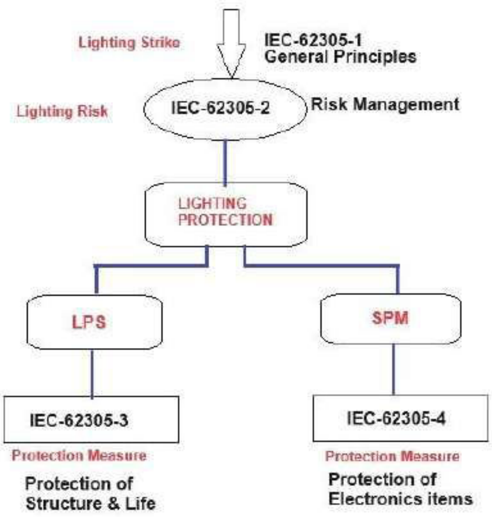
Introduction:

- A lightning protection system does not attract or prevent a lightning strike. but the lightning protection system provides a low impedance path to lightning currents to flow from Lightning striking Point to the ground to prevent dangerous flashovers and lightning-caused fires.
- Lightning protection systems are designed to protect structures, equipment or people from the damaging effects of lightning strikes. These systems create pathways for lightning strikes to travel safely from the top of a structure to the ground with a lightning conductor. They protect the internal electrical components of a building by preventing fires or electrocution for that all metallic installations in the building must be made at equal potential.
- The basic goal of LPS is to prevent thermal, mechanical, and electrical effects that can cause damage to the protected structure or to humans via touch or step voltages within the structure.

Lighting Protection Standards:

- There are various lighting protection standards. Widely use are
- IEC 62305
- IS 2309
- NFPA 780
- NBC-2016

IEC:62305 -Part 1 to 5:



COMPARISON BETWEEN IEC AND IS STANDARD FOR LPS:

Comparison between IEC and IS standard for External LPS			
Description	**LPS as per IEC 62305**	**LPS as per IS 2309**	**ESE (Early Streamer Emission)**
Coverage area	Real, Calculated and approved design as per building type complying to IEC 62305-3.	Real, Calculated and approved design as per building type complying to IEC 62305-3.	Imaginary - no proof available, Not complying and national or international standard.
Approvals / Applicability of latest standard	IEC 62305-3 - International standard, Released in 2010	IS 2309 & IS 3043 - National standard, Released in 1989	Approved only in France which is their local standard

Insurance cover	Yes.	Yes.	No. Not approved by IS & CEA
Height limitation	No height limitation as the LPS is based on horizontal air terminal	No height limitation as the LPS is based on horizontal air terminal	Height restriction is applicable surrounding the airport area as ESE is based on Vertical air terminal.
Air Termination Design	Rolling sphere method	Protective Angle method & Mesh method	Not as per any international method.
LPS for Type of Building	Any type of complex building.	Simple and Flat /Slopped Building	
Material for Air terminal & down conductor.	8mm Aluminum round, which is easier to install, bend & needs less conductor holder.	25X3 GI is used which is difficult to install, bend & needs twice the amount of conductor holder.	Not as per any international method.
Material compatibility	Taken care using bi-metal connector	No specific mention in the standard.	Not taken care.
Expansion /contraction of metal in summer/winter	Taken care of using Expansion pieces.	Not taken care	Not applicable as it is based on vertical air terminal.
No of Down Conductor.	More than one down conductor to dissipate the Lightning current to the ground (Multiple Dissipation)	Less number of down conductors when compared to IEC 62305	In most of the sites, only one down conductor is installed.
Current sharing Path	Many Parallel paths. LEMP has minimal effects	Few parallel paths	Maximum 2 Parallel paths. High LEMP can damage electronic equipment.
Design of LPS	based on LPL 1 to 4 backed up by IEC 62305	Based on Experience & old IEC, BS standards.	Not as per any international method.
Experience	Used for many decades without any problem.	Used for many decades without any problem.	Approximately 15 years old. In Some country many buildings with ESE were damaged.
Grounding	Type B as per IEC 62305-1	Ring earthing as per IS 3043	Recommended only for small residences (not even apartments) where electronic equipment is not available.
Installation	time consuming but effective	time consuming but effective	less time consuming but ineffective

Lighting Protection Levels:

- Lighting Protection Level are divided into four categories. For each category, a set of maximum and minimum lightning current parameters is fixed (LPL I to IV).
- The maximum values of lightning current parameters are used to design lightning protection components (e.g. Cross section of conductors, thickness of metal sheets, current capability of SPDs and Separation distance against dangerous sparking).
- The minimum values of lightning current amplitude for the different LPL are used to derive the Rolling Sphere Radius to define the Lightning Protection Zone (LPZ0B) which cannot be reached by direct strike.

RELATION BETWEEN LPL AND CLASS OF LPS

Table-7, IEC- 62305-3		
LPL	**RISK LEVEL**	**CLASS OF LPS**
CLASS I	Very High Risk	I
CLASS II	High Risk	II
CLASS III	Moderate Risk	III
CLASS IV	Low Risk	IV

CLASSIFICATION OF LPS		
Table-4, IEC- 62305-1		
CLASSIFICATION OF LPL	**Maximum Current (KA)**	**Minimum Current (KA)**
CLASS I- (Very High Risk)	200 KA	3 KA
CLASS II-(High Risk)	150 KA	5 KA
CLASS III-(Moderate Risk)	100 KA	10 KA
CLASS IV-(Low Risk)	100 KA	16 KA

Types of Lighting Protection System (LPS):

- There are two types of Lightning Protection System
  (1) External Lighting Protection
  (2) Internal Lighting Protection.
- **External lightning protection**
- External lightning protection protects buildings in case of a direct lightning strike. It basically intercepts direct lightning flashes to the structure and conduct the lightning current from the point of strike to the ground and creates a protective sheath around the building which prevents it from catching fire and protects the people within.
- The External LPS also disperses this current into the earth without causing damage to the structures or causing unsafe potential rise / sparking.

- **Internal Lighting Protection:**
- An Internal LPS protects equipment against transient voltages and currents.
- Internal Lighting Protection / Surge protection provides safety within the building. It keeps surges which might enter the house via power supply cables / Power Line and protect electrical /electronic devices of house (which would otherwise be at risk via these routes).

Types of External LPS System

- There are two types of External LPS System

(a) Non-Conventional System / Early Streamer Emission (Isolated System)
(b) Conventional System (Non-Isolated System)

(a) Non-Conventional / Early Streamer Emission (Isolated System):

- Non-Conventional System / Isolated System does not mean that the system is electrically isolated from earth (a common misconception). It just means of physical distance achieved between the lightning current and the item being protected.
- In Non-Conventional / Isolated System, Lightning conductor does not directly attach to the structure or asset being protected. There is little or more separation between Structure and Lightning system.
- This can be achieved with free-standing masts (or poles) which stand someway off the item being covered at highest Point. Or, in some cases, separation can be achieved by using non-sparking conductors.
- Lightning Rods are installed at the highest point of protected building with sufficient separation distance to each other electrically and physically. Separate (Isolated) Lighting Rod provides conductive path to lighting current to the earth.

(b) Conventional (Non-Isolated System):

- In Conventional / Non-isolated System is typically attached conductor arrangements directly to the structure or asset being protected with little or no separation.

Components of External Lighting Protection System:

- An external Lightning Protection System has following parts

(1) **Air terminal system**= Intercept a lightning flash to a structure

(2) **The down conductor system** =provides the safest path to the lightning current towards the earth.

(3) **Earthing system** =Disperse the lightning current into the earth.

- These individual elements of an LPS should be connected using appropriate lightning protection components. This will ensure that in the event of a lightning current discharge to the structure, any potential damage to the structure protected will be minimized.
- In most cases, the external LPS may be attached to the structure to be protected. An isolated LPS is preferred for areas at risk of explosion and fire.

(1) Air Termination System:

- The role of an air termination system is to capture the lightning discharge current and dissipate harmlessly to earth via down conductor and earth termination system. Therefore, it is very important to use a correctly designed Air-termination system.
- Air Termination System can be composed of any combination of the following elements.
- (i) Rods (including free standing masts)
- (ii) Catenary wires (suspended wires)
- (iii) Meshed conductors that may lie in direct contact with the roof or be suspended above it.

AIR TERMINATION SYSTEM DESIGN

- As per considering Class of Lighting Protection System, the air-termination system shall be design by following methods.
- All methods should be used, independently or in any combination to ensure that the protection zones by different parts of the air-termination overlap and ensure that the structure is entirely protected.
- Methods for the air-termination for Lighting Protection System is

(A) Protection Angle Method

(B) Rolling Sphere Method and

(C) Mesh Method

- All three methods may be used for the design of an LPS. The choice of the method depends on a practical evaluation of its suitability and the vulnerability of the structure to be protected.
- The major difference in Air Termination methods is as below.
- (i) The protection angle method is suitable for simple structures or for small parts of bigger structures. It also has limitations on the height of the air terminal. This method is not suitable for structures higher than the radius of the rolling sphere relevant to the protection level of the LPS.
- (ii) The rolling sphere method is suitable for complex shaped structures. This method is mostly used in all the cases.
- (iii) The mesh method is for general purposes, and it is particularly suitable for the protection of plane surface.

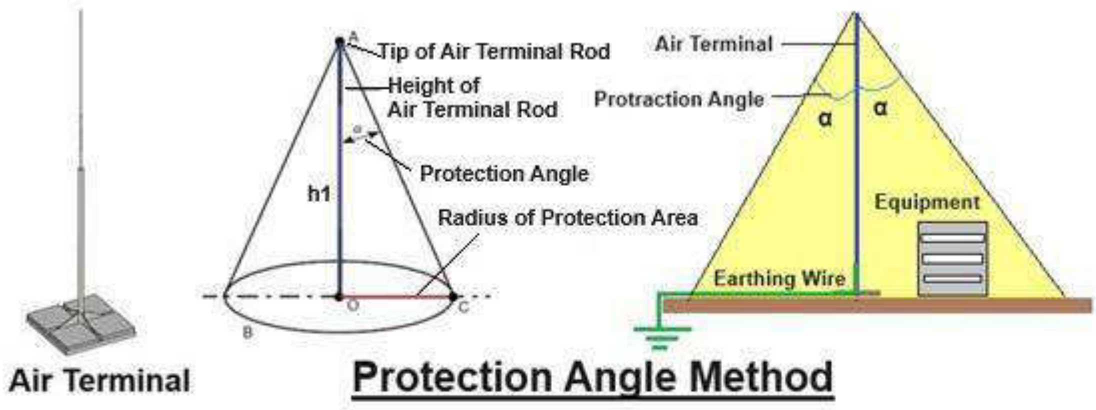
(A). PROTECTION ANGLE METHOD (Suitable for Simple-Shaped building)

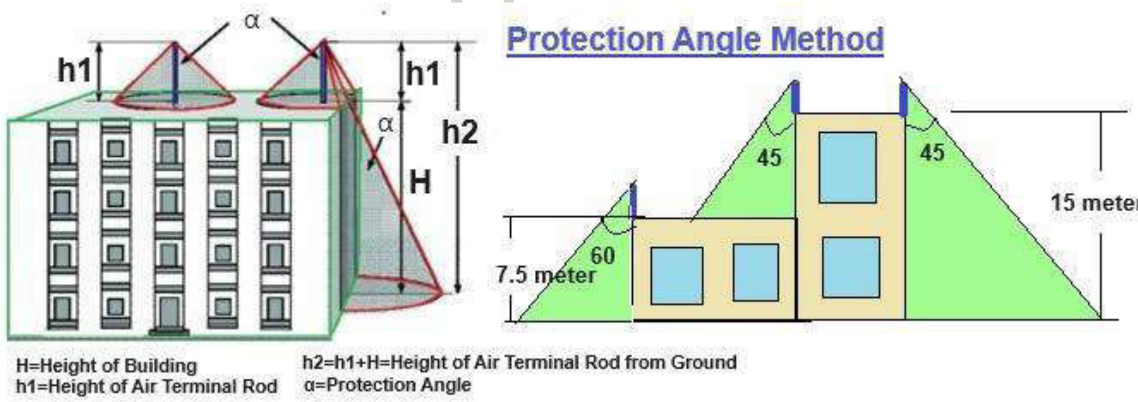
- The Protection Angle method is wider used compared to mesh method, because it can be installed at simple structure, on not smooth/not flat surface, on protruding metallic structure.
- This method is used for structures that do not exceed 15 Meter in height.
- For structures less than 7.5 Meter in height, a Protection angle shall be 60 degrees, or 1:2, angle is permitted.
- For structures over 7.5 Meter but not in excess of 7.5 Meter a Protection angle shall be 45 degrees, or 1:1, angle is used. This is illustrated in Figure
-
- The Protective Angle Method is generally used as a supplement to the Mesh Method.
- Air-termination rods should be positioned so that all the parts of the structure, including metallic equipment installed on the roof like HVAC units, PV panels to be protected inside the envelope generated by the air-termination rods.
- In this method several air terminals are placed at the highest points on top of buildings/structures at different locations. Each air terminal covers a certain angle of protection.
- The degree of protection can be selected based on the height of terminal from base to tip. For example, if class I is selected, this means that the angle of protection is 70 degrees, considering 2 meters height of the terminal.

- In the case of installing metallic equipment's, like HVAC Unit, PV panels at roof, sufficient distance among the equipment and air terminals shall be considered to avoid sparking, as well as selecting the appropriate protection angle.
- The real physical dimension of metal Air-termination shall be considered to calculate area protected by Lighting terminal. Typically, if the air rod is 5 meters tall, then the zone of protection offered by this air terminal rod would be based on 5 meters and the relevant class of LPS.
- If the building height is less than 30 meters, 45-degree cone of protection can be used. For building height more than 30 Meters, 30-degree cone of protection shall be considered

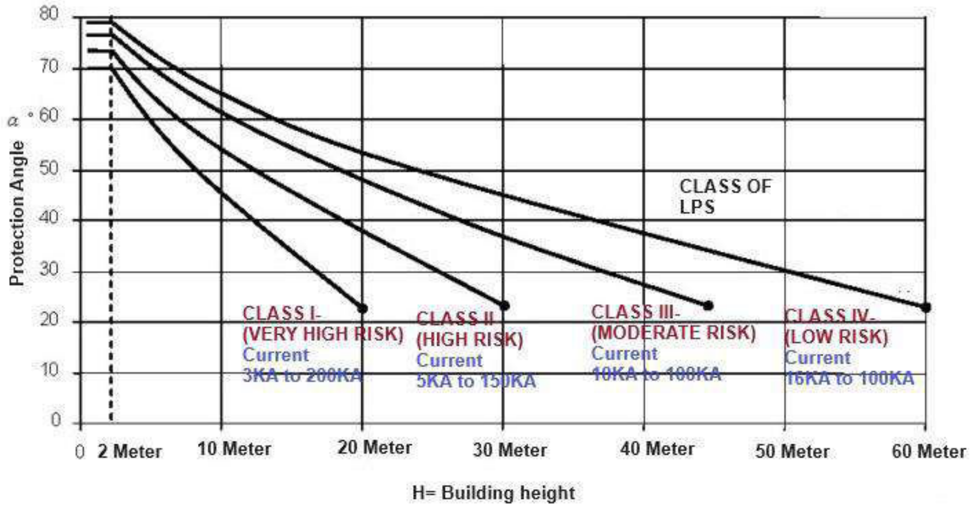
Volume protected by a vertical rod air-termination system

- Air-termination conductors, rods, masts and wires should be positioned so that all parts of the structure to be protected are inside the envelope surface generated by projecting points on the air-termination conductors to the reference plane, at an angle α to the vertical in all directions.
- The volume protected by a vertical rod is assumed to have the shape of a right circular cone with the vertex placed on the air-termination axis, semi-apex angle α, depending on the class of LPS, and on the height of the air-termination system as given in Table.





- The protection angle should confirm to the table mentioned below, with h being the height of the air-termination above the surface to be protected.



Height of Air Termination Rod-Protection Angle & Protection Distance								
Height of Air termination rod in meter	LPS-CLASS-I		LPS-CLASS-II		LPS-CLASS-III		LPS-CLASS-IV	
	Angle	Protection Distance in Meter	Angle	Protection Distance in Meter	Angle	Protection Distance in Meter	Angle	Protection Distance in Meter
1	71	2.9	74	3.49	77	4.33	79	5.14
2	**71**	**5.81**	**74**	**6.97**	**77**	**8.66**	**79**	**10.29**
3	**66**	**6.74**	**71**	**8.7**	**74**	**10.46**	**76**	**12.03**
4	62	7.52	68	9.9	72	12.31	74	13.95
5	59	8.32	65	10.72	70	13.74	72	15.39
6	56	8.9	60	11.28	68	14.85	71	17.43
7	53	9.29	58	12.12	66	15.72	69	18.24
8	50	9.53	56	12.8	64	16.4	68	19.8
9	48	10	54	13.34	62	16.93	66	20.21
10	45	10	52	13.76	61	18.04	65	21.45
11	43	10.26	50	14.08	59	18.31	64	22.55
12	40	10.07	49	14.3	58	19.2	62	22.57
13	38	10.16	47	14.95	57	20.02	61	23.45
14	36	10.17	45	15.01	55	19.99	60	24.25
15	34	10.17	44	15	54	20.65	59	24.96
16	32	10	42	15.45	53	21.23	58	25.61
17	30	9.81	40	15.31	51	20.99	57	26.18
18	27	9.17	39	15.1	50	21.45	56	26.69
19	25	8.26	37	15.39	49	21.86	55	27.13
20	23	8.49	36	15.07	48	22.21	54	27.53
21			35	15.26	47	22.52	53	27.87
22			36	16.71	46	22.78	52	28.16
23			32	15	47	24.66	53	30.52
24			30	14.43	44	23.18	50	28.6
25			29	14.41	43	23.31	49	28.76
26			27	13.76	41	22.6	49	29.91
27			26	13.66	40	22.66	48	29.99
28			25	13.52	39	22.67	47	30.03
29			23	12.73	38	22.66	46	30.03

30					37	22.61	45	30
31					36	22.52	44	29.94
32					35	22.41	44	30.9
33					35	23.11	43	30.77
34					34	22.93	42	30.61
35					33	22.73	41	30.43
36					32	22.5	40	30.21
37					31	22.23	40	31.5
38					30	21.94	39	30.77
39					29	21.62	38	30.47
40					28	21.27	37	30.14
41					27	20.89	37	30.9
42					26	20.48	36	30.51
43					25	20.05	35	30.11
44					24	19.59	35	30.81
45					23	19.1	34	30.35
46							33	29.87
47							32	29.37
48							32	29.99
49							31	29.44
50							30	28.87
51							30	29.44
52							29	28.82
53							28	28.18
54							27	27.51
55							27	28.02
56							26	27.31
57							25	26.58
58							25	27.05
59							24	26.27
60							23	25.47

- Air termination conductors and down conductors should be inter-connected by means of conductors at the roof level to provide sufficient current distribution over the down conductors.
- Conductors on roof and the connections of air termination rods may be fixed to the roof using both conductive or non-conductive spacers and fixtures. The conductors may also be positioned on the surface of a wall if the wall is made of non-combustible material. The fixing centers shall be minimum 1 meter apart.
- **For each non-isolated LPS, the number of down conductors shall be not less than two.**
- A down conductor should be installed at each exposed corner of the structure, where this is possible.

Limitation:

- The protection angle method has geometrical limits and cannot be applied if Building height (H) is larger than the rolling sphere radius (r).
- The angle will not change for values of Building height (H) below 2 meters.

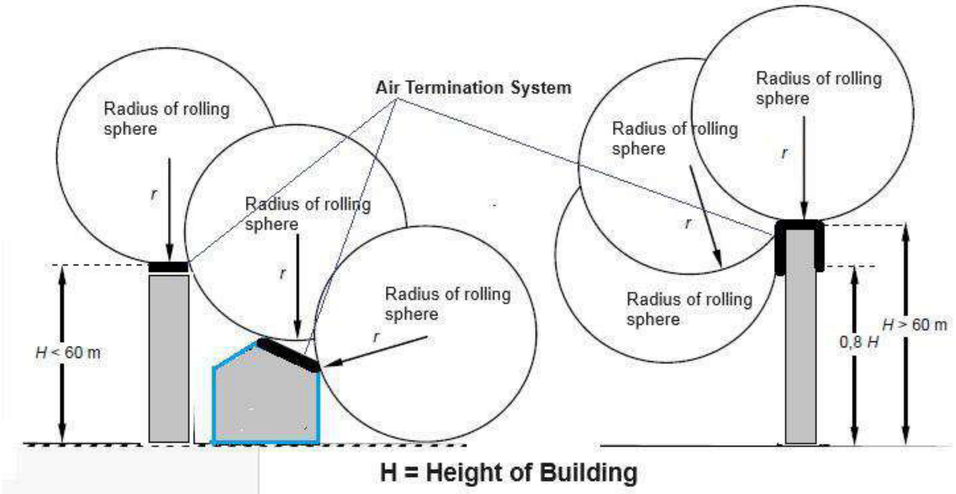
(B). ROLLING SPHERE METHOD: (Suitable for all complex shaped building)

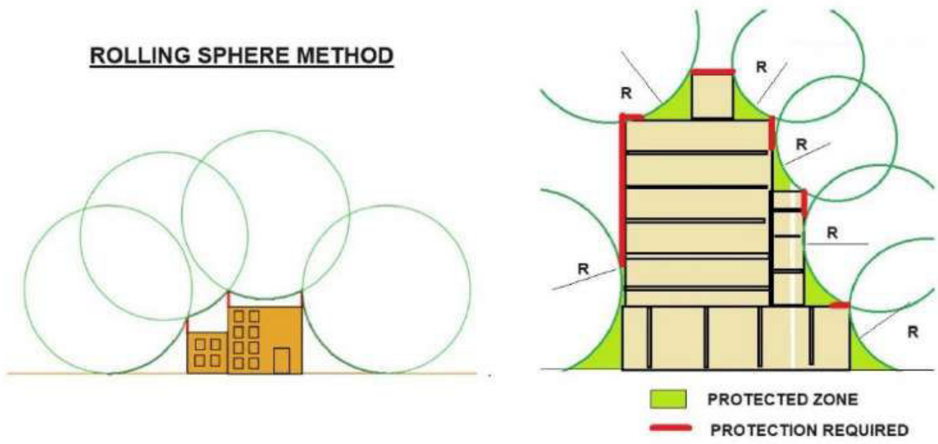
- The rolling sphere method should be used to protect the areas of a structure when there is design limitation to use the protection angle method.
- The rolling sphere method is recommended as the main method to be used in the design of lightning protection system with location of air terminals for structures with complex shapes.
- This method is more accurate, and complex compared to other lightning protection schemes, because it specifies the exact number of spikes needed for each building and considers the worst-case scenarios, in which a lightning strike hits the side of the building.
- **Position of Air Termination Rod:**

- In this method, the positioning of the Air-Termination system is adequate so that no point of the structure to be protected comes in to contact with a sphere with radius ‘r’ depending on the class of LPS (see table) rolling around on top of the structure in all possible directions. In this way, the sphere only touches the air termination system (see figure).
- **Radius of Sphere:**
- The rolling sphere lightning protection method assumes the electrically charged field that produces a lightning strike has a radius “r” and the sphere with that radius rolling over the surface of the building. Any place the sphere touches the building is a location where lightning can strike the building. By installing air terminals, the sphere cannot touch the building because electrical charges flow through the lightning protection system into the ground.
- The radius of the rolling sphere is correlated with the peak value of the current in the lightning that strikes the structure: **r = 10xIx0.65** where I define as kA.
- In the rolling sphere method, the radius of the sphere is selected in such a way that its radius is equal to the striking distance. Since the striking distance is a function of the prospective return stroke current, the radius of the sphere “r” is defined as a function of the probable return stroke current according to the relationship between the lightning striking distance and the peak return stroke current.
- The lightning stroke depends on the degree of risk considered. So, for a high-risk facility, the sphere radius is at its smallest, e.g. 20meter or a 40meter diameter ball. The smallest size ball means the amount of protection installed will be at its highest. Thus, lowering the risk profile and increasing the protection afforded.
- For a low-risk scenario method, the sphere radius is at its largest distance, 60 meters (120-meter diameter ball), which means a lot less hardware to install.
- The radius r of the rolling sphere depends on the class of LPS as per given Table.

RADIUS OF THE ROLLING SPHERE	
Class of LPS	**Rolling sphere radius, r (m)**
CLASS I- (Very High Risk)	20 Meter
CLASS II- (High Risk)	30 Meter
CLASS III- (Moderate Risk)	45 Meter
CLASS IV- (Low Risk)	60 Meter

- Figure shows the application of the rolling sphere method to different types of structures. The sphere of radius r is rolled around and over all the structure until it meets the ground plane or any permanent structure or object in contact with the ground plane which can act as a conductor of lightning.
- A striking point could occur where the rolling sphere touches the structure and at such points protection by an air-termination conductor is required.
- Any part of the structure that is in contact with the sphere is considered to be vulnerable to a direct lightning strike; the untouched volume defines a lightning protected zone.

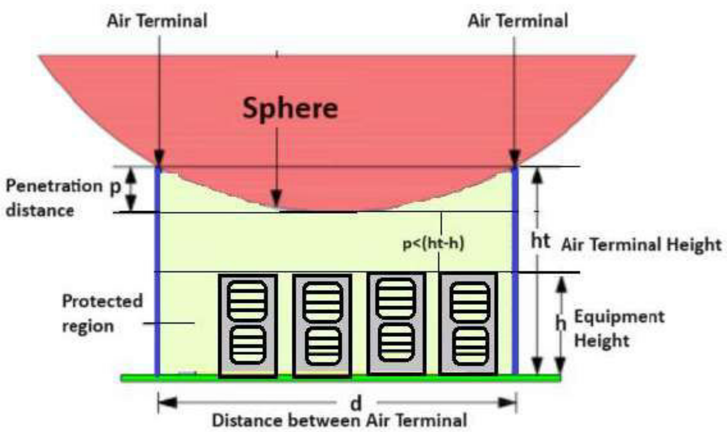




- When the rolling sphere method is applied to the structure, the structure should be considered from all directions to ensure that no part protrudes into an unprotected zone a point which might be overlooked if only front, side and plan views on drawings are considered.

PENETRATION DISTANCE:

- The distance between the two air terminals should be chosen in such a way that protection is provided for all the objects placed on the surface to be protected.
- The protection of the objects placed on the surface can be ensured by calculating the penetration distance of the rolling sphere.
- The distance between the level of air terminals and the least point of sphere in the space between the air terminals is called **penetration distance.**



- Let us consider an object of height 'h' placed on the surface to be protected. Let 'ht' be the height of the air terminal, 'p' be the penetration distance and 'd' be the distance between the two terminals.
- In this case, the penetration distance 'p' should be less than the physical height of the air-termination rods above the reference plane minus the height of the objects to be protected.
- **P<(ht-h)**

DISTANCE BETWEEN TWO AIR TERMINALS:

- The penetration distance of the rolling sphere below the level of conductors in the space between the conductors can be calculated by using the below formula (IS 62305-3).
- **p=r-√(r^2-(d/2)^2)**
- Were,
- p : penetration distance
- r : radius of rolling sphere
- d: distance between the air terminals
- For attaining a particular penetration distance, we can derive the required distance between the air terminals from the above equation.
- **d=2x√(2 x p x r-p^2)**
- If there are no objects protruding from the structure to be protected, then the penetration distance can be increased up to the height of the air terminal to provide maximum protection. At this condition, the distance can be calculated by substituting the value of height of air terminal (ht) in place of penetration distance (p).

- **d=2x√(2 x ht x r-ht^2)**
- The distance between the air terminals(d) in rolling sphere method depends on two factors.
  1) Height of the air terminal and
  2) Radius of the rolling sphere
- Among these two factors, the radius of rolling sphere is a constant value which depends on the class of LPS as specified by IS/IEC 62305-3. Hence for particular class of LPS, the distance between the air terminals purely depends on the height of air terminal.

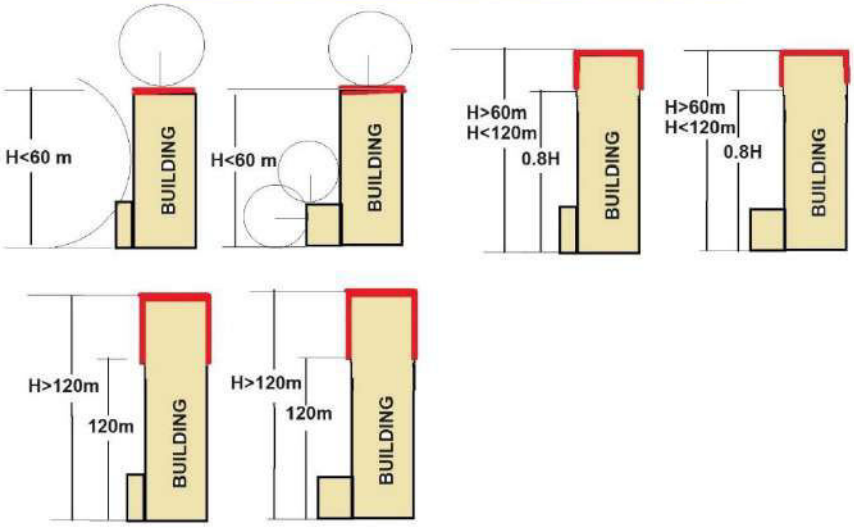
Distance between Air Terminals (Meter)				
Height of Air Terminal (ht)	Radius of Rolling Sphere(r)			
	LPS-I	LPS-II	LPS-III	LPS-IV
	r=20 Meter	r=30 Meter	r=45 Meter	r=60 Meter
0.5 Meter	8.8	10.9	13.37	15.45
1 Meter	12.48	15.36	18.86	21.81
1.5 Meter	15.2	18.7	23	26.66
2 Meter	17.43	21.5	26.53	30.72
3 Meter	21.07	26.15	32.31	34.36
4 Meter	24	29.9	37	43
6 Meter	28.56	36	44	52.3

- **Example:**
- Conclude the equipment installed on Terrace is whether protected by LPS System or not by LPS system installed on Building (Calculate penetration height) having following details.
- LPS Level is -IV (Low Risk).
- The maximum height of equipment is 1 meter from Terrace Floor.
- The distance between the two Air terminals is 10 meters.
- Height of Air Terminal is 2 Meter.
- **Calculation:**
- First, we calculate the maximum distance between two Air terminal according to LPS level.
- Here Height of Air terminal (ht)= 2Meter.
- Height of equipment (h)=1 Meter
- According to LPS-IV Radius of rolling sphere (r) = 60 meter
- **Distance between two Air terminals (d) =2√(2*ht*r-ht^2)**
- Distance between two Air terminals (d) =2√(2x2x60-2^2)
- Distance between two Air terminals (d) =30.72 Meter
- Distance between actual installed Air terminals is 10 meter which is less than maximum calculated distance between two Air terminals.
- Now to calculate penetration height.
- penetration height (p)=r-√(r^2-(d/2)^2)
- penetration height (p)=60-√(60^2-(10/2)^2)
- penetration height (p)=0.20 Meter.
- Now Height of Air terminal (ht)-Height of equipment(h) = 2-1 =1Meter.
- Check condition of P< (ht-h)
- Here 0.2 <1 meter
- Hence equipment installed on terrace which height is 1 meter is protected from installed LPS System.

SIDE FLASHES IN TALL STRUCTURE

- On all structures higher than the rolling sphere radius "r", flashes to the side of structure may occur. Each lateral point of the structure touched by the rolling sphere is a possible point of strike. However, the probability for flashes to the sides is generally negligible for structures lower than 60 meters.
- For taller structures, a major part of all flashes will hit the top, horizontal leading edges and corners of the structure. Only a few percentages of all flashes will be to the side of the structure.
- The probability of flashes to the sides decreases rapidly as the height of the point of strike on tall structures when measured from the ground.
- Therefore, consideration should be given to install a lateral air-termination system on the upper part of tall structures (typically the top 20 % of the height of the structure). In this case the rolling sphere method will be applied only to the positioning of the air-termination system of the upper part of the structure.

ROLLING SPHERE METHOD FOR TALL STRUCTURE



1) **Buildings Taller Than 120-meter High**

- For structures taller than 120 meters, the standard recommends that all parts above 120 meters be protected. It is expected that due to the height and nature of such a structure, it would require a design to LPL I or II (99% or 97% protection level).
- For tall buildings, the actual risk of flashes to the side are estimated by the industry to be less than 2%, and typically these would be the smaller lightning flashes, e.g., from branches of the downward leader. Therefore, this recommendation would only be appropriate for high-risk locations or structures.

2) **Buildings Above 60-meter High**

- In the IEC standards, for buildings above 60-meter, protection is required to the sides of the upper 20% of height. The same placement rules used for roofs should apply to the sides of the building.
- While the mesh method is preferable, particularly if using natural components, protection is permitted using horizontal rods and rolling sphere method. However, horizontal rods on most structures are impractical due to window washing access equipment, etc.

3) **Buildings Less Than 60-meter High**

- Note that for structures less than 60 meters high the risk of flashes to the sides of the building is low, and therefore protection is not required for the vertical sides directly below protected areas.

4) **Buildings Taller Than 30 meters:**

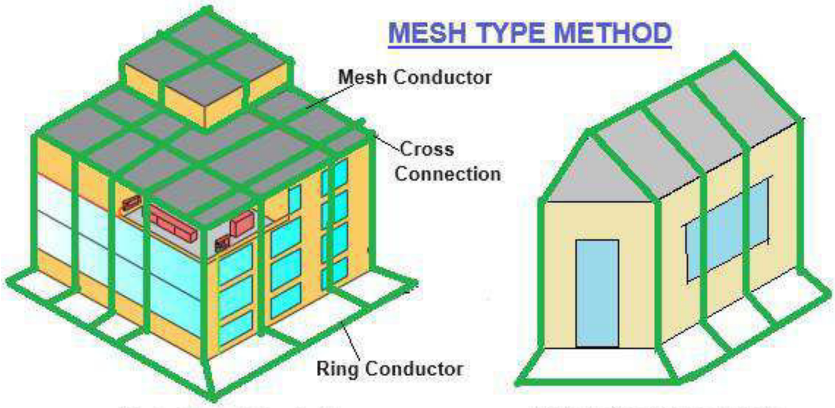
- For buildings taller than 30 m, additional equipotential bonding of internal conductive parts should occur at a height of 20 m and every further 20 m of height. Live circuits should be bonded via SPDs.

(C). THE MESH METHOD (Suitable for all flat surface building)

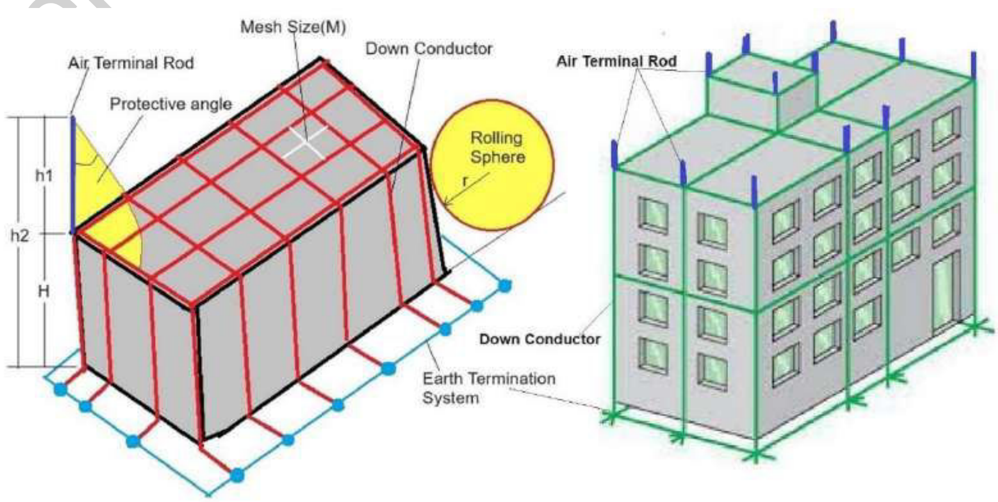
- The mesh method is the simplest and most flexible method for LPS because it does not depend on the height of the structure. However, it requires flat but non curved surfaces. The Flat surface may be horizontal or vertical surfaces.
- It is mostly used for simple Building like domestic households, mainly for perfectly square or rectangular buildings.
- In the mesh method, a mesh is created by a flat conductor and placed on the structure. The separation distance of the conductors is based upon the class of protection determined during the risk assessment.
- **Mesh Size:**
- According to IEC 62305, mesh conductor size is based on the selected class of LPS and that is totally dependable on user requirements.
- In the Mesh method, a conducting mesh with a cell size determined by the minimum return stroke current that is allowed to strike the protected structure.
- In order to avoid a direct strike, the mesh has to be located at a critical distance above the flat surface to be protected. This procedure is called “protective mesh method”.
- The maximum mesh size should be in accordance with the table below.

Class of LPS	Mesh Size (M)
CLASS I-(VERY HIGH RISK)	5 X 5 METER
CLASS II-(HIGH RISK)	10X 10 METER
CLASS III-(MODERATE RISK)	15 X 15 METER
CLASS IV-(LOW RISK)	20 X 20 METER

- The following conditions shall be considered while selecting the Mesh Method.
- (a) Air-termination conductors are positioned, on roof edge lines, on roof overhangs, on roof ridge lines, if the slope of the roof exceeds 1/10.
- (b) The mesh dimensions of the air-termination network are not greater than the values given in Table.
- (c) The network of the air-termination system is constructed in such a way that the lightning current will always encounter at least two distinct metal routes to earth-termination.
- (d) No metal installation protrudes outside the volume protected by air-termination systems.
- (e) The air-termination conductors follow, as far as possible, the shortest and most direct route.
- **Location of Mesh**
- The corners and edges of roofs are most susceptible to damage due to lightning. Therefore, designers and installers should place the conductors as close to the edge of the roof as possible.
- IEC 62305 allows for the use of conductors under the roof of a structure. Thus, the natural components of a structure can be used as part of the mesh grid, or even the whole grid. These components may be the rebar structure underneath the roof or dedicated lightning protection conductors, but they must be connected to the air termination rods that are mounted above the roof.
- For structures, with a protruding metallic structure, the Protective Angle Method is generally used as a supplement to the Mesh Method



- **Mesh Method with combination of other Methods:**
- For Medium to large scale buildings mesh can be implemented, but due to its limitations, it does not come alone. It must be merged with other types of LPS, either protection angle or rolling sphere, subject to the suitable class number of each type.
- Air termination conductors and down conductors should be inter-connected by means of conductors at the roof level to provide sufficient current distribution over the down conductors.
- Conductors on roof and the connections of air termination rods may be fixed to the roof using both conductive or non-conductive spacers and fixtures. The conductors may also be positioned on the surface of a wall if the wall is made of non-combustible material. The fixing centers shall be minimum 1 meter apart.
- For each non-isolated LPS, the number of down conductors shall be not less than two. A down conductor should be installed at each exposed corner of the structure, where this is possible.



Mesh Method combination with Protective Angle Method & Sphere Ball Method

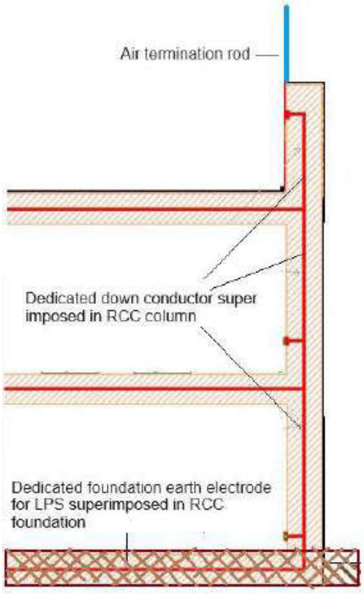
- **Limitations:**
- The mesh method is suitable for horizontal and inclined roofs with no curvature.
- The mesh method is suitable for flat lateral surfaces to protect against side flashes.
- If the slope of the roof exceeds 1/10, parallel air-termination conductors, instead of a mesh, may be used provided the distance between the conductors is not greater than the required mesh width.

COMPARISION OF VARIOUS PROTECTION METHOD

COMPARISION OF VARIOUS PROTECTION METHOD			
Protection Method	Type of Structure		
	Simple structure	Complex shaped structure	Plane Structure
Protection Angle	(*) YES	NO	NO
Mesh Method	NO	YES	YES
Rolling sphere Method	YES	YES	YES
(*) This method is not suitable for structure height more than radius of the rolling sphere relevant to the selected protection level of LPS			

(2) Down Conductor system:

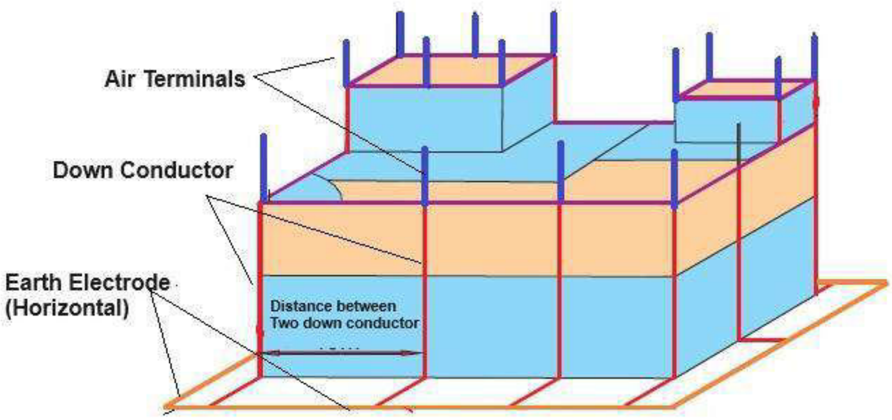
- In Air-termination systems, down-conductor systems and earth-termination systems should be harmonized to produce the shortest possible path for the lightning current.
- Down-conductors should preferably be connected to junctions of the air-termination system network and routed vertically to the junctions of the earth-termination system network.
- The function of a down conductor system is to conduct the lightning impulse from air-termination system to the earthing system. The down conductor system should be installed in such a way that the following points are ensured.
- (i) Several parallel current paths exist
- (ii) Length of current path is kept to minimum.
- (iii) Equipotential bonding to conducting parts is performed.
- Selection and installation of down conductors plays a major role in protecting electrical and electronic installations in a building. The number of down conductors to a typical building depends upon the class of LPS.
- A down conductor should be installed at each exposed corner of the structure and form a direct continuation of the air-termination conductors. Drown conductors are installed in such a way that they provide the shortest and most direct route to earth. Avoiding the formation of bends and loops is required.
- To reduce damage caused by lightning current, the down conductors are arranged so that the current path around the building's perimeter is parallel and at equal distances.
- Even if the down conductor encased in insulating material, down conductors must not be installed in service shafts, gutters, or downspouts, as doing so invites severe damage during a lightning strike.
- Electrical insulation between LPS components and other metallic installation in the building are necessary to avoid flashover between different metal parts.
- **Integration of down conductor with Building Natural Components:**
- External down-conductors should be installed between the air-termination system and the earth-termination system. Wherever natural components (Steel reinforcement, metal framework structure) are available, they can be used as down-conductors.
- Down conductors are also integrated into structural steel reinforcement, metal framework of structure, steel roof, metal façade, handrails etc. is the best and practical solution for new and upcoming high raise buildings. In this integrated approach high safety is offered with no maintenance, long life, no influence on aesthetics. Separation distance need not be considered in this case.
- Down conductors can be embedded in RCC columns. In this case, bonding different metallic installations in the building is simple, thereby eliminating potential differences. This integrated method is not only cost-effective but has no negative effect on the building's aesthetics. It also reduces the failure of electronic equipment inside the building from radiated lightning effects.
- Test joints are not required, and earth resistance measurements are not necessary in the location where the natural down conductors are terminated to foundation earthing.



- **Number & distance between each Down Conductor:**
- For each non-isolated LPS, the number of down conductors shall be not less than two and should be distributed around the perimeter of the structure to be protected. An equal spacing of the down conductors is preferred around the perimeter. The typical values of the distance between the conductors are shown below.

DISTANCE BETWEEN DOWN CONDUCTORS	
(IEC/BS EN 62305-3 Table 4)	
Class of LPS	**Distance between conductors**
CLASS I- (Very High Risk)	10 Meter
CLASS II- (High Risk)	10 Meter
CLASS III- (Moderate Risk)	15 Meter
CLASS IV- (Low Risk)	20 Meter

- If the distance between down-conductors is too large with the reference to the Table, the number of down-conductors should be increased to meet the required separation distance.
- As stated, a down-conductor should be installed at each exposed corner of the structure, where this is possible. However, an exposed each corner does not need a down conductor if the distance between this exposed corner to the nearest down-conductors complies with the following conditions:
- (i)the distance to both adjacent down-conductors is half the distance according to Tables or smaller.
- (ii) the distance to one adjacent down-conductor is one-quarter of the distance according to Tables or smaller.



- The number and position of down-conductors is important because if the lightning current is shared in several down-conductors, the risk of side flash and electromagnetic disturbances inside the structure is reduced. It follows that, as far as possible, the down-conductors should be uniformly placed along the perimeter of the structure and with a symmetrical configuration.
- The current sharing is improved not only by increasing the number of down-conductors but also by equipotential interconnecting rings.
- Down-conductors should be placed as far as possible away from internal circuits and metallic parts in order to avoid the need for equipotential bonding with the LPS., In cantilevered structures the separation distance should also be evaluated with reference to the risk of side-flashing to persons.

- If it is not possible to place down-conductors at a side, or part of a side, of the building because of practical or architectural constraints, the down-conductors that ought to be on that side should be placed as extra compensating down-conductors at the other sides. The distances between these down-conductors should not be less than one-third of the distances in Table.
- A variation in spacing of the down-conductors of ±20 % is acceptable as long as the mean spacing conforms to Table.
- In closed courtyards with more than 30-meter perimeter, down-conductors have to be installed.
- **Insulation / Separation of LPS parts**
- If it is not possible to make a straight connection because of large roof overhangs, etc. the connection of the air-termination system and the down-conductor should be a dedicated one and not through natural components like rain gutters, etc.
- It is permitted, where aesthetic consideration needs to be taken into account, to use a thin coating of protective paint or PVC covering over the external down-conductors.
- Down conductors, even if covered in insulating material, shall not be installed in gutters or waterspouts. The effects of moisture in the gutters lead to intensive corrosion of the down conductor.

Minimum Size of Down conductor		
Protection level	**Material**	**Section**
I-IV	Steel	50 mm2
I-IV	Aluminum	25 mm2
I-IV	Copper	16 mm2

- For non-isolated LPS, down conductors are mounted directly onto the building (without separation distance) if the wall is made of flame resistant or normally inflammable material, the down conductors may be installed directly on or in the wall.
- Metal framework of a steel structure or the interconnected reinforcing steel of the structure can be used as a down conductor. Reinforcement of existing structure cannot be used as natural down conductor unless the reinforcement is safely interconnected. Separate external down conductors must be installed.
- Conductors on roofs and the connections of air-termination rods may be fixed to the roof using both conductive or non-conductive spacers and fixtures. The conductors may also be positioned on the surface of a wall if the wall is made of non-combustible material.
- Recommended fixing centers for these conductors are shown in the Table.

Suggested fixing centers		
Table E.1 IEC- 62305-3		
Arrangement	Fixing centers for tape and stranded conductors (mm)	Fixing centers for round solid conductors (mm)
Horizontal conductors on horizontal surfaces	500 mm	1000 mm
Horizontal conductors on vertical surfaces	500 mm	1000 mm
Vertical conductors from the ground to 20 m	1000 mm	1000 mm
Vertical conductors from 20 m and thereafter	500 mm	1000 mm
NOTE: Assessment of environmental conditions (i.e. expected wind load) should be undertaken and fixing centers different from those recommended may be found to be necessary.		

(3) Earth Termination:

- The purpose of the earth termination system is to provide a safe low-impedance path to high frequency lightning current into the ground.
- To minimize dangerous over voltage due to lightning, The shape and the dimension of the earth termination system are important.
- The earth termination system should be designed to have a resistance to earth of less than 10 ohms, as per the IEC/BS EN 62305 standards.
- There are two basic types of earth electrode arrangements are recommended in IS/IEC 62305 and NBC-2016 such as vertical /horizontal
  - (a) **Type A arrangement:** Horizontal earth electrodes or vertical earth electrodes installed **outside the structure** and connected to down conductors.
  - (b) **Type B arrangement:** Ring earth electrodes installed around the **perimeter of the structure.**

- **POINTS NEED TO BE CONSIDER:**
- **Step Voltage:** If earthing termination network is used in public access area, then the selection of suitable types of earth electrodes and safe distances from structure and from the external conductive parts in the soil (cables,

metal ducts, etc.) are important. Hence special steps need to be taken for the protection against dangerous step voltages in the vicinity of the earth-termination networks.

- **Earth resistance value:** The recommended value of the overall earth resistance of 10 Ω is fairly conservative in the case of structures in which direct equipotential bonding is applied. The resistance value should be as low as possible in every case but especially in the case of structures endangered by explosive material. Still the most important measure is equipotential bonding.
- **Depth of Electrode:** The embedded depth and the type of earth electrodes should be such as to minimize the effects of corrosion, soil drying and freezing and thereby stabilize the equivalent earth resistance.
- It is recommended that the first half meter of a vertical earth electrode should not be regarded as being effective under frost conditions. Deep-driven earth electrodes can be effective in special cases where soil resistivity decreases with depth and where substrata of low resistivity occur at depths greater than those to which rod electrodes are normally driven.
- **Mechanical Splitting / Stressing:** When the metallic reinforcement of concrete is used as an earth electrode, special care should be exercised at the interconnections to prevent mechanical splitting of the concrete.
- If the metal reinforcement is also used for the protective earth, the most severe measure in respect of thickness of the rods and the connection should be chosen. In this case, larger sizes of reinforcement bars could be considered. The need for short and straight connections for the lightning protection earthing should be always recognized.
- In the case of pre-stressed concrete, consideration should be given to the consequences of the passage of lightning discharge currents, which may produce unacceptable mechanical stresses.

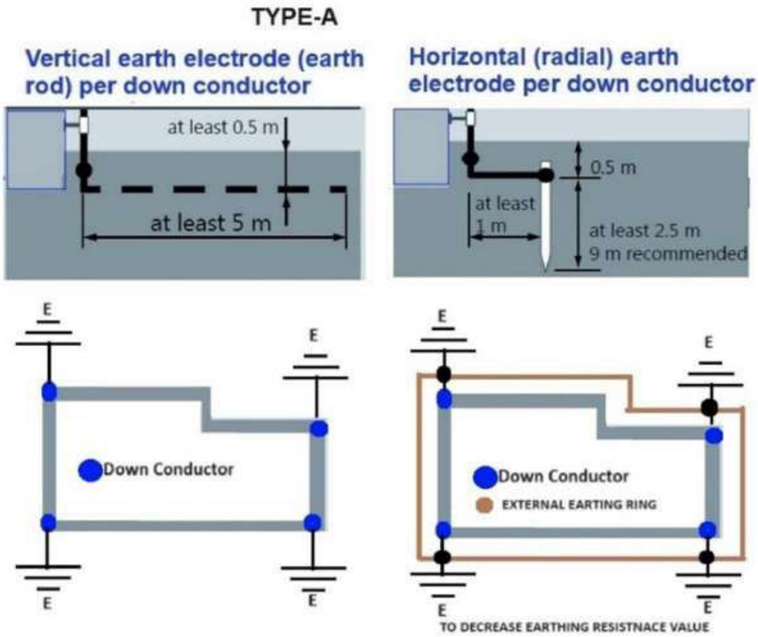
(A). Type-A Earthing (Embedded Earth Electrode)

- This is the conventional type of LPS Earthing System where **earthing rods** are used to form the earth electrode and connected each down conductor to an earth rod. The earth electrodes installed **outside the structure.**
- The type A earth-termination system is suitable for low structures (family houses ,Low rise building).
- This type of arrangement comprises horizontal or vertical earth electrodes connected to each down-conductor.
- Where there is a ring conductor, which interconnects the down-conductors, in contact with the soil, the earth electrode arrangement is still classified as type A, if the ring conductor is in contact with the soil for less than 80 % of its length.
- The total number of earth electrodes in Type A arrangement shall not be less than two.
- **Type-A earthing suitable for:**
  (1) The type A earth termination arrangement is suitable for low structures (Houses), (below 20 meters in height)
  (2) existing structures or an LPS with rods or stretched wires or for an isolated LPS.
  (3) It is suitable for locations with low fault currents and provides safety and functional grounding.
  (4) commonly used in residential and commercial settings.
- Type A earthing system depends upon the soil resistivity and class of LPS.
- Each down conductor shall have a vertical earth electrode with a minimum length as per the table. In case of horizontal electrode, the length shall be double.
- The earth electrodes shall be installed at a depth of upper end at least 0.5 m in soil if an earth chamber is not used.
- In general, a low earthing resistance (if possible lower than 10 Ω when measured at low frequency) is recommended for type A earthing if the specific length cannot be ensured.
- The minimum length of each earth electrode at the base of each down-conductor is specified in BS EN 62305 and the table below.

Horizontal & Vertical electrode Length for Type A & Type-B earth electrode (based on soil resistivity)								
IEC- 62305-3								
Class of LPS	**<500 Ωm**		**<1000 Ωm**		**<2000 Ωm**		**<3000 Ωm**	
	Horizontal electrodes (l1)	**Vertical electrodes 0.5 x I1**	**Horizontal electrodes (l1)**	**Vertical electrodes 0.5 x I1**	**Horizontal electrodes (l1)**	**Vertical electrodes 0.5 x I1**	**Horizontal electrodes (l1)**	**Vertical electrodes 0.5 x I1**
I	5 Meter	2.5 Meter	20 Meter	10 Meter	50 Meter	25 Meter	80 Meter	40 Meter
II	5 Meter	2.5 Meter	10 Meter	5 Meter	30 Meter	15 Meter	45 Meter	22 Meter
III	5 Meter	2.5 Meter	5 Meter	2.5 Meter	5 Meter	2.5 Meter	5 Meter	2.5 Meter
IV	5 Meter	2.5 Meter	5 Meter	2.5 Meter	5 Meter	2.5 Meter	5 Meter	2.5 Meter

Note 1 For LPS Class III and IV l1 is independent of soil resistivity
Note 2 For LPS Class II l1 is fixed for soil resistivity below 8000m
Note 3 For LPS Class I l1 is fixed for soil resistivity below 5000m

- The minimum length of each earth electrode at the base of each down-conductor is l1 for horizontal electrodes, or 0.5 x l1 for vertical (or inclined) electrodes,
- where l1 is the minimum length of horizontal electrodes. For combined (vertical or horizontal) electrodes, the total length shall be considered.
- Reduction of earthing resistance by the extension of earth electrodes is practically convenient up to
- 60 m. In soil with resistivity higher than 3000 Ωm, the use of type B earth electrodes or earthing enhancing compounds is recommended.



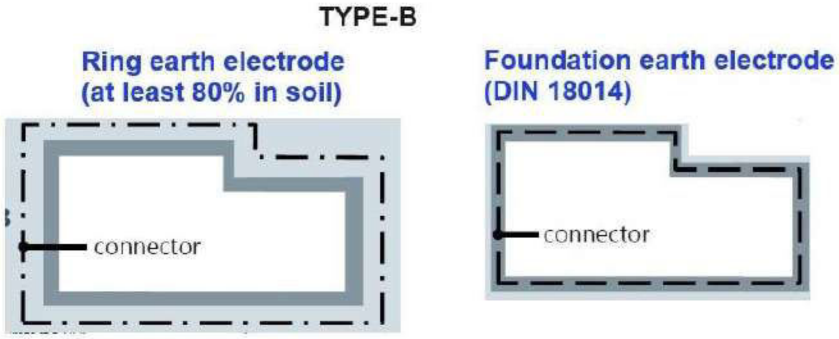
- **Radial and vertical earth electrodes**
- Each down-conductor should be provided with an earth electrode.
- Radial earth electrodes should be connected to the lower ends of the down-conductors by using test joints.
- During installation it is necessary to measure the earthing resistance regularly. Additional electrodes can then be installed in more suitable locations.
- The earth electrode should have sufficient separation from existing cables and metal pipes in the earth. The separation distance depends on the electrical impulse strength and resistivity of the soil and the current in the electrode.
- In the type A arrangement, vertical earth electrodes are more cost-effective and give more stable earthing resistances in most soils than horizontal electrodes.
- In some cases, it may be necessary to install the earth electrodes inside the structure, for example in a basement or cellar.

- **Advantages:**
- If there is a danger of an increase in resistance near to the surface, it is often necessary to employ deep-driven earth electrodes of greater length. Radial earth electrodes should be installed at a depth of 0,5 m or deeper. A deeper electrode ensures that in countries in which low temperatures occur during the winter, the earth electrode is not situated in frozen soil (which exhibits extremely low conductivity).
- An additional benefit is that deeper earth electrodes give a reduction of the potential differences at the earth surface and thus lower step voltages reducing the danger to living creatures on the earth surface. Vertical electrodes are preferred to achieve a seasonally stable earthing resistance.
- **Limitation:**
- When the type A earthing arrangement is provided, it is necessary to all electrodes are at equal equalization. This can be achieved by bonding all conductors by bonding bars. Special care also needs to be cared to control step voltage.

(B). Type-B Earthing (Foundation /Ring Earthing)

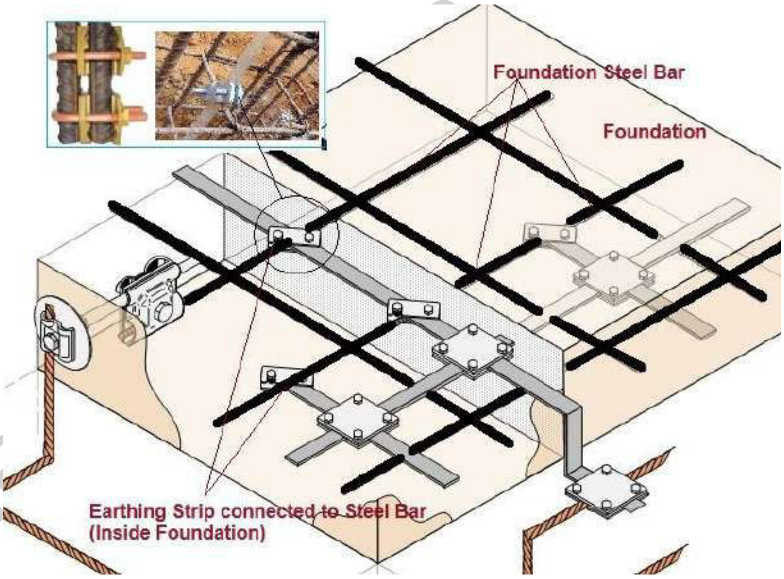
- Type B Earthing consists of either a Ring conductor external to the structure to be protected (in contact with the soil for at least 80% of its total length) or a Foundation earth electrode forming closed loop.
- Type-B Earthing is also done by combination of both Ring earthing and Foundation earthing.
- Foundation earthing is done using conductors embedded in foundation of the building.
- Foundation earthing also serves as protective and functional earthing. This is the most efficient earthing system to protect electronic equipment. Materials used and construction techniques availed must fulfil various mechanical, electrical and chemical requirements to provide long life for the installation.
- Connection of a Lightning Protection System to the steel in the concrete foundation can be done for all new constructions since this steel is usually good for equipotential bonding. A dedicated Earth Rod can also be installed in the foundation but then these Earth Electrodes would need to be bonded to the steel in the concrete.
- Earth-termination systems should serve the following three purposes.
  1. conduction of the lightning current into the earth.
  2. equipotential bonding between the down-conductors.
  3. potential control in the vicinity of conductive building walls.
- The foundation earth electrodes and the type B ring-type earth electrodes meet all these requirements.
- Type A radial earth electrodes or deep-driven vertical earth electrodes do not meet these requirements with respect to equipotential bonding and potential control.
- The structure foundations of interconnected steel-reinforced concrete should be used as foundation earth electrodes. They exhibit very low earthing resistance and perform an excellent equipotentialization reference. When this is not possible, an earth-termination system, preferably a type B ring earth electrode, should be installed around the structure.
- **Type-B Earthing Suitable for:**
  (1) Structures built on rocky ground
  (2) Structures housing sensitive electronics/equipment
  (3) Large structures
  (4) It is used in areas with high fault currents, such as critical infrastructure and industrial facilities, to provide enhanced protection against surges and transients, often resulting from lightning or equipment malfunctions.
  (5) The type B earth-termination system is preferred for meshed air-termination systems and for LPS with several down-conductors.
  (6) Type B is recommended for buildings with electrical and electronic installations and buildings in high soil resistivity.
- Type B earth electrodes also perform the function of potential equalization between the down conductors at ground level, since the various down-conductors give different potentials due to the unequal distribution of lightning currents due to variations in the earth resistance and different lengths in the above ground conductor current paths. The different potentials result in a flow of equalizing currents through the ring earth electrode, so that the maximum rise in potential is reduced and the equipotential bonding systems connected to it within the structure are brought to approximately the same potential.
- In some Area it is not possible to install a ring earth electrode that will fully surround the structure Where structures belonging to different owners are built closely to each other or common for both. In this case the efficiency of the earth-termination system is somewhat reduced, since the conductor ring acts partly as a type B electrode, partly as foundation earth and partly as an equipotential bonding conductor.
- Where large numbers of people frequently assemble in an area adjacent to the structure to be protected, further potential control for such areas should be provided. More ring earth electrodes should be installed at distances of approximately 3 m from the first and subsequent ring conductors. Ring electrodes further from the structure should be installed more deeply below the surface i.e. those at 4 m from the structure at a depth of 1 m, those at 7 m from the structure at a depth of 1,5 m and those at 10 m from the structure at a depth of 2 m. These ring earth electrodes should be connected to the first ring conductor by means of radial conductors.
- **POINTS NEED TO BE CONSIDER:**

- If it is not possible to close the ring, a connection must be made inside the building using conductive metallic equipment such as pipes.
- Ring shall be at least 0.5meter below the surface
- Ring shall be maintained at least 1 meter from the structure / from the external walls.
- It is recommended that 80% of the length of the ring shall be in contact with natural soil. Thus, no more than 20% of the total length may be in the basement of the structure instead of in direct contact with the soil.
- If the radius of the ring electrode is less than the length of vertical or horizontal earth electrodes required for Earthing, then additional horizontal or vertical earth electrodes can be connected to the ring.
- Bonding of different metallic installations in the building avoid dangerous potential differences and flashover
- **Ring earth electrode Radius length:** For the ring earth electrode (or foundation earth electrode), the mean radius (re) of the area enclosed by the ring earth electrode (or foundation earth electrode) shall be not less than the horizontal electrodes value (l1)
- **re ≥ l1**
- When the required value of l1 is larger than the convenient value of re, additional horizontal or vertical (or inclined) electrodes shall be added with individual lengths lr (horizontal) and lv (vertical) given by the following equations:
- **lr = l1 – re (2) and lv = (l1 – re) / 2**
- It is recommended that the number of electrodes should be not less than the number of down-conductors, with a minimum of two.
- The additional electrodes should be connected to the ring earth electrode at points where the down-conductors are connected and, for as many as possible, equidistantly.
- **EARTH TERMINATION SYSTEM IN LARGE AREAS:**
- An industrial plant typically comprises a number of associated structures, between which a large number of power and signal cables are installed. The earth-termination systems of such structures are very important for the protection of the electrical system. A low impedance earth system reduces the potential difference between the structures and so reduces the interference injected into the electrical links.
- A low earth impedance can be achieved by providing the structure with foundation earth electrodes and additional type B and type A earth arrangements.
- Interconnections between the earth electrodes, the foundation earth electrodes and the down conductors should be installed at the test joints. Some of the test joints should also be connected to the equipotential bars of the internal LPS.
- Internal down-conductors, or internal structural parts used as down–conductors, should be connected to an earth electrode and the reinforcement steel of the floor to avoid step and touch voltages. If internal down-conductors are near expansion joints in the concrete, these joints should be bridged as near to the internal down-conductor as possible.
- The lower part of an exposed down-conductor should be insulated by PVC tubing with a thickness of at least 3 mm or with equivalent insulation.
- When the area adjacent to the structure is covered with a 50 mm thick slab of asphalt of low conductivity, sufficient protection is provided for people making use of the area.



- Foundation Earth Electrodes are simply concrete reinforced foundations – they are considered to be Type B Earthing. For these Foundation Earth Electrodes, there should be at 50mm of concrete covering the electrode to minimize corrosion.
- The type B earthing is recommended as either a ring conductor outside the perimeter of the structure which it's recommended should be in contact with the soil for at least 80% of its total length.
- The alternative is to use a foundation earth electrode which can be in a mesh form.
- The reinforced concrete floor slab can be used around the structure.
- If the required resistance cannot be achieved by this method the vertical or radial earthing electrodes can be added to the network.

- For ease of testing after installation an inspection pit with an earth bar should be installed where the legs of the ring and conductor routing onto the ring from each test clamps join
- **FOUNDATION EARTHING / NATURAL CONDUCTORS AS PART OF THE LPS**
- The building's natural components, metal roof, rebar, steelwork etc. can be considered as part of the LPS
- The reinforcing bars within the concrete structure can be used as a natural component of the LPS provided they are electrically continuous by either welding or clamping the joints.
- The re-bars are considered as electrically continuous provided that a major part of interconnections of vertical and horizontal bars are welded or otherwise securely connected by clamps conforming to BS EN 50164 standards.
- **Forming:**
- Foundation grounding is one of the most healthy grounding methods. Foundation grounding of buildings must be started at the beginning of construction, i.e. foundation stage. It is performed by installing a galvanized conductor between the reinforcing bars in the foundation. This conductor is connected to reinforcing bars at certain distances. The ends of the grounding conductor are taken out from some specified points and left as the connection bud. Once these ends are connected to the equipotential grounding bus bars, the grounding is completed by connecting all systems to be grounded to these buses.
- Foundation grounding must be performed in the form of a closed ring and placed in the foundation of the external walls of the building, or the foundation platform. In buildings with a large perimeter, foundation grounding rods must be divided into sections of 20x20m. Connection must be established with reinforcing bars every few meters.
- Foundation earthing can be accomplished in various ways, such as by using cable or flat conductor, connected to earth rods or by surrounding the foundation with conductor that enters the foundation through an earth terminal. Grounding standards, such as IEEE 80 Standard, provide guidelines for the design and installation of earthing systems, including those for foundations.
- For the foundation earthing's connection with a lightning rod, a conductor is placed inside the pillars before the concrete placement, ending on the building's rooftop.
- Circumferentially on the rooftop, an aluminum or copper conductor is placed on braces, in spots that include chimneys, solar water heaters, etc. Then spikes are placed, and the construction of the lightning rod is complete



- The connecting rebar must overlap and be clamped using rebar clamps or welded to a minimum of 20 times the diameter of the rebar a (Welding to be done on either side of the rebars.)
- The concrete used for the foundations of buildings has a certain conductivity (relative comparison) and, in general, "a large contact area" with the ground. It is highly recommended to use bare metal electrodes completely embedded in concrete (to a minimum depth of 5 cm) for grounding purposes, as they are highly protected against corrosion, usually for the entire life of the building according to IEC 60364
- It is recommended to use a foundation earth electrode embedded in concrete during the construction of the building (itself) to obtain a lower earth resistance value.
- **Materials for Earth-Termination Systems**
- The foundation earth electrode has to be made of
- Round steel (min. diameter 10 mm) or
- Strip steel (min. dimension 30 mm x 3.5 mm) which has to be galvanized (or black) for laying in concrete, or for laying in soil.

- **Advantages:**
- Does not require additional excavation work.
- Provides good contact with the ground.
- It extends over virtually the entire surface of the building foundation and results in minimum ground electrode impedance that can best be achieved with this surface.
- It also provides an optimal grounding arrangement for the lightning protection system.
- It is erected at a depth that is normally free from negative influences resulting from seasonal weather conditions.
- Step voltage elimination
- Equipotential connections
- Corrosion resistant

Material Combinations and Dimensions

- Required to use galvanically compatible metals in lightning protection system components and surface materials on which the components are mounted. For example, do not connect copper to aluminum.
- Do not use together metals that are not galvanically compatible. Bad matching accelerates their corrosion in the presence of moisture.
- With aluminum conductors, use only connection devices designed for aluminum. Make sure to use the right fastening torque.

Different Contact Material

Material	Suitable Contact Material
Copper	Nickel /Brass / Tin / Lead / Stainless steel / Monel (nickel–copper alloy)
Aluminum	Magnesium / Zinc / Galvanized steel / Stainless steel / Lead / Wrought iron / Galvalume (an aluminum-coated sheet steel product)

LPS Material

LPS Materials and Conditions of Use

Table-5 (IEC 62305-3)

Material	Use			Corrosion		
	In Open Air	In Earth	In Concrete	Resistance	Increased by	May be destroyed by Galvanic Coupling with
Copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	–
	Stranded	Stranded	Stranded	–	Organic materials	–
	–	As coating	As coating	–	–	–
Hot galvanized steel[1,2,3]	Solid	Solid	Solid	Acceptable in air, in concrete, and in benign soil	High chlorides content	Copper
	Stranded [4]	–	Stranded [4]	–	–	–
Steel with electro-deposited copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	–
Stainless steel	Solid	Solid	Solid	Good in many environments	High chlorides content	
	Stranded	Stranded	Stranded	–	–	–
Aluminum	Solid	Unsuitable	Unsuitable	Good in atmospheres containing low concentration of Sulphur and chloride	Alkaline solutions	Copper
	Stranded	–	–	–	–	–
Lead [5]	Solid	Solid	Unsuitable	Good in atmospheres with high concentration of sulphates	Acid soils	Copper
	As coating	As coating	–	–	–	Stainless steel

Material Dimensions

- Several lightning protection system codes and standards define minimum dimensions for the components of a grounding system. These standards are designed to protect buildings and other inhabited or otherwise critical facilities.
- Practical minimums are based on field experience and indicate what is needed to protect the installed equipment in a cost-effective way during the foreseeable technical lifetime, typically a few decades, taking into account local regulations. To ensure proper operation of the grounding system, periodic inspection and maintenance is needed

Minimum Dimensions of Earth Electrode as per IEC 623053

- Table 1 and Table 2 are based on standard IEC 62305-3 Ed 2. The tables list minimum dimensions for the lightning protection system equipment.
- The following table lists the different materials and shapes that are used in air terminals, down conductors, and ground electrodes, including the cross-sectional area.

Minimum Dimensions of Earth Electrodes				
Table-7, IEC-62305-3				
Material	Configuration	Dimensions		
		Earth Rod Diameter	Earth Conductor	Earth Plate
Copper, Tin-plated copper	Stranded	–	50 Sq.mm (8 mm)	–
	Solid round	15 mm	50 Sq.mm (8 mm)	–
	Solid tape	–	50 Sq.mm (8 mm)	–
	Pipe	20 mm	–	–
	Solid plate	–	–	500 × 500 mm
	Lattice plate	–	–	600 × 600 mm
Hot-dipped galvanized steel	Solid round	14 mm	78 Sq.mm (9.96 mm)	–
	Pipe	25 mm	–	–
	Solid tape	–	90 Sq.mm (10.7 mm)	–
	Solid plate	–	–	500 × 500 mm
	Lattice plate	–	–	600 × 600 mm
	Profile	*	–	–
Bare steel (Shall be embedded in concrete for a minimum depth of 50 mm.)	Stranded	–	70 Sq.mm (9.4 mm)	–
	Solid round	–	78 Sq.mm (9.96 mm)	–
	Solid tape		75 Sq.mm (9.72 mm)	
Copper coated steel	Solid round	14 mm	50 Sq.mm (8 mm)	
	Solid tape		90 Sq.mm (10.7 mm)	
Stainless steel	Solid round	15 mm	78 Sq.mm (9.96 mm)	
	Solid tape		100 Sq.mm (11.28 mm)	
Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements of the future IEC 62561 series.				
In case of a type B arrangement foundation earthing system, the earth electrode shall be correctly connected at least every 5 m with the reinforcement steel.				
* Different profiles are permitted with a cross-section of 290 mm2 and a minimum thickness of 3 mm, e.g. cross profile.				

Minimum Cross-sectional Area of Air-termination Conductors

Minimum Cross-sectional Area of Air-termination Conductors			
Table 6 (IEC 62305-3)			
Material	Configuration	Cross-sectional Area	Comments
Copper, tin-plated copper	Solid tape	50 Sq.mm / 8mm *	2 mm min. thickness
	Solid round[1]	50 Sq.mm / 8mm *	8 mm diameter
	Stranded [1]	50 Sq.mm / 8mm *	1.7 mm min. dia of each strand
	Solid round***	176 Sq.mm /15mm	16 mm diameter
Aluminum	Solid tape	70 Sq.mm*	3 mm min. thickness
	Solid round	50 Sq.mm / 8mm *	8 mm diameter
	Stranded	50 Sq.mm / 8mm *	1.7 mm min. dia of each strand
Aluminum alloy	Solid tape	50 Sq.mm / 8mm *	2.5 mm min. thickness
	Solid round	50 Sq.mm / 8mm *	8 mm diameter
	Stranded	50 Sq.mm / 8mm *	1.7 mm min. dia of each strand
	Solid round***	176 Sq.mm /15mm	16 mm diameter
Copper-coated aluminum alloy	Solid round	50 Sq.mm / 8mm *	

Hot-dipped galvanized steel **	Solid tape	50 Sq.mm / 8mm *	2.5 mm min. thickness
	Solid round	50 Sq.mm / 8mm *	8 mm diameter
	Stranded	50 Sq.mm / 8mm *	1.7 mm min. dia of each strand
	Solid round***	176 Sq.mm /15mm	16 mm diameter
Copper-coated steel	Solid round	50 Sq.mm / 8mm *	
	Solid tape	50 Sq.mm / 8mm *	
Stainless steel	Solid tape	50 Sq.mm / 8mm *	2 mm min. thickness
	Solid round***	50 Sq.mm / 8mm *	8 mm diameter
	Stranded	70 Sq.mm / 9.5mm*	1.7 mm min. dia of each strand
	Solid round ***	176 Sq.mm /15mm*	16 mm diameter
* If thermal and mechanical considerations are important, these dimensions can be increased to 60 mm2 for solid tape and to 78 mm2 for solid round.			
** The coating should be smooth, continuous and free from flux stains with a minimum thickness coating of 50 µm.			
***Applicable for air-termination rods only. For applications where mechanical stress such as wind loading is not critical, a 10 mm diameter, 1 m long maximum air-termination rod with an additional fixing may be used.			

Minimum values of the cross-section of the bonding conductors with different bonding bars

Minimum dimensions of conductors connecting internal metal installations to the bonding bar		
Table-8 (IEC-62305-3)		
Class of LPS	**Material**	**Cross-section (mm2)**
I to IV	Copper	16 Sq.mm
	Aluminum	25 Sq.mm
	Steel	50 Sq.mm

Minimum dimensions of conductors connecting internal metal installations to the bonding bar		
Table-9 (IEC-62305-3)		
Class of LPS	**Material**	**Cross-section (mm2)**
I to IV	Copper	6 Sq.mm
	Aluminum	10 Sq.mm
	Steel	16 Sq.mm

Table 10: Minimum thickness of metal sheets or metal pipes in air termination systems			
(IEC/BS EN 62305-3 Table 3)			
Class of LPS	**Material**	**Thickness (1) t**	**Thickness (2) t'**
I to IV	Lead	-	2 MM
	Steel (stainless, galvanized)	4 MM	0.5 MM
	Titanium	4 MM	0.5 MM
	Copper 5 mm 0.5 mm	5 MM	0.5 MM
	Aluminum 7 mm 0.65 mm	7 MM	0.65 MM
	Zinc – 0.7 mm	-	0.70 MM
Thickness t prevents puncture, hot spot or ignition			
Thickness t' only for metal sheets if it is not important to prevent puncture, hot spot or ignition problems			

Minimum Dimensions

Air Terminal Minimum Dimensions	
Material	**Dimension**
Copper, aluminum	Tube with a 16 mm diameter, minimum wall thickness of 2 mm
	8 mm (0.31 in) solid round

Steel	10 mm

Down Conductor Minimum Dimensions	
Material	**Dimension**
Copper	25 mm2 solid or stranded wire or solid tape
Aluminum	35 mm2 in solid or stranded aluminum
Steel	35 mm2 solid steel or stranded wires

Minimum Thickness of Tapes	
Material	**Thickness**
Copper	1 mm
Aluminum	2 mm
Galvanized steel	2 mm
Stainless steel	2 mm

Minimum Thickness of Strand Diameters in Stranded Cables	
Material	**Thickness**
Copper	1 mm
Aluminum	1.6 mm
Steel	1.6 mm

Ground Rod Minimum Dimensions	
Material	**Thickness**
Copper	Solid round 15 mm
	Pipe 20 mm diameter with a minimum wall thickness of 2 mm
Copper clad solid steel	14 mm
Galvanized steel	16 mm
Galvanized steel, pipe	25 mm diameter with a minimum wall thickness of 2 mm

Horizontal Ground Electrode Minimum Dimensions	
Material	**Thickness**
Copper	25 mm2 solid/strand/tape with a minimum 2 mm thickness
Galvanized steel, round wire	50 mm2 with a minimum 8 mm diameter
Galvanized steel, stranded	50 mm2 with a minimum strand diameter of 1.7 mm
Galvanized steel, tape	50 mm2 with a minimum thickness of 2 mm

Installation Depth of Ground Electrode	
Ground Electrode Type	**Installation Depth**
Ground rod	3 meter
Horizontal ground electrode	0.6 meter

Typical Ground Electrode Length and Spacing		
Minimum values	**Ground rod**	**Horizontal ground electrode**
Length	Typically, 3 Meter	10 Meter to 30 Meter as per soil type dependent
Loop diameter	–	5 Meter to 6 Meter
Spacing	Min. 2 × rod length	–

Guideline for LPS System:

- The following design guidelines need to be adhered to ensure safer installation of the external LPS.
- **Air Terminal:**
- Air terminal should be selected and provided only based on the protection angle or rolling sphere method
- Proper safety distance between the air terminal and any metallic object needs to be maintained as per the calculation mentioned earlier to avoid dangerous spark-overs.
- **Different Material Jointing & Insulations:**

- Wherever incompatible materials to be joined (Ex. Copper with Aluminum), suitable bi-metal connectors should be used.
- Suitable expansion joints must be provided on the horizontal conductors on top to take care of thermal effects.
- Special conductor holders of insulating type need to be provided on top of the terrace floor for routing the conductor to ensure electrocution impact does not happen in case of water stagnation.
- **Equi potential Bonding:**
- Required measures to ensure shielding, bonding / equipotential bonding techniques are handled properly to avoid LEMPs.
- Establishing connection for equipotential bonding with nearby metallic components need to be taken care of.
- Joints should be mechanically and electrically effective, should be protected against corrosion or erosion from the elements or the environment and should present an adequate contact area.
- **Reinforcement Structure:**
- In the case of using reinforcement in concrete structures as lightning down conductor details should be decided at the design stage, before building construction begins.
- Good contact between reinforcing bars to be ensured only by using connection clamps tested as per the requirement of IEC 62561-1
- **Down Conductor:**
- A down-conductor should be installed at each exposed corner of the structure where it is possible.
- The Down conductor should run as straight and vertical as possible so that they provide the shortest and most direct path of a low impedance from the air termination to the earth electrode so that the lightning current can be safely conducted to earth.
- The formation of loops in bring the down conductor shall be avoided, but where this is not possible the distance shall be maintained
- There should be a test joint arrangement to have separation between down conductor and earth termination for safety and for measurement of earth resistance.
- At least two down conductors are mandatory for any size of Building.
- The termination of the down conductor to an earth electrode should be done minimum of 1 meter away from the structure and minimum of 0.5m depth inside the ground.
- Earth electrodes for each down conductor shall be provided.
- Connection of down conductors to gutters or down-spouts even if they are covered by insulating materials.
- Usage of multiple connections with different materials should not be permitted.
- Insufficient conductor dimensions (non-complying material as mentioned in IEC 62305-3 Table – 5) should be strictly avoided.
- When the distance from down conductors to combustible materials cannot be assured, the cross section of the down conductor shall not be less than 100 mm^2