Confederation of Indian Industry

Identification, Prevention and Mitigation of Electrical Hazards

Workshop on Managing Electrical Safety Risks – April 2018, Kolkata

Mudit Maheshwari

Corporate EHS, **ITC Limited, Kolkata**

Electrical safety & risks

THE HINDU

Home Today's Paper All Sections News National International Opinion Bus

Cities Bengaluru Chennai Coimbatore Delhi Hyderabad Kochi Kozhikode Kolkata

CITIES » BENGALURU

Updated: February 2, 2014 00:36 IST

Electrical accidents kill 94

SPECIAL CORRESPONDENT

COMMENT

During the past five years 959 people died in electrical accidents of which 60 were permanent staff of the KSEB while 57 were contract employees.

In these years, 689 people were injured in electrical mishaps of which 165 were permanent staff of the KSEB while 146 were contract employees.

Two die of electrocution

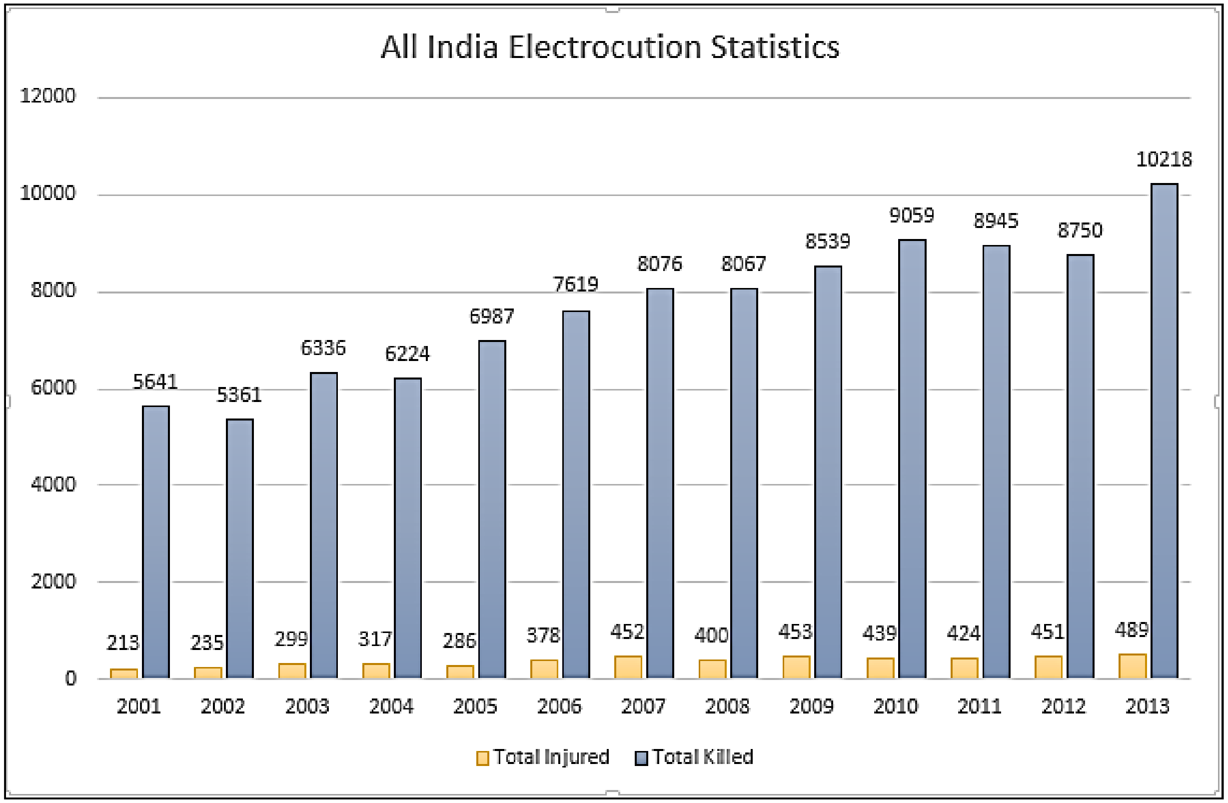
Worker electrocution triggers mob attack

Buildings constructed close to high tension lines in violation of building bylaws have been blamed for a majority of deaths.

Electrical accidents assume alarming proportions

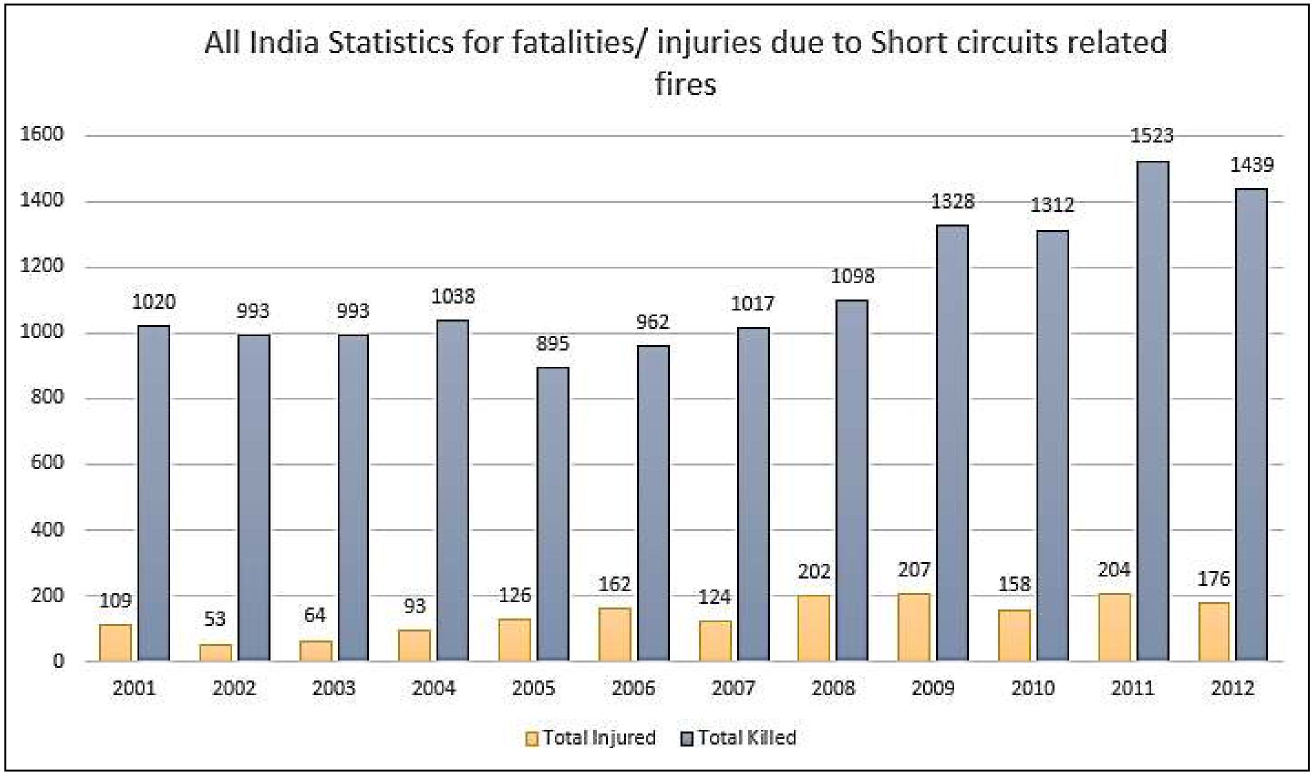
200 ट्रांसफार्मर के गोदाम में आग, धमाके से पहले काबू

All India accident statistics



Source: *https://data.gov.in/*

All India accident statistics



Source: *https://data.gov.in/*

Major Incidents

- ✓ DESU transformer fire leads to death of 19 people in Khari Baoli area.
- ✓ 1996 fire in departure terminal of Delhi airport.
- ✓ Explosion in a CESC transformer near Dumdum.

The CESC unit caught fire around 11.30am after one of the two transformers on the premises had exploded. Firemen fought for three hours to control the flames.

Fire department officials are yet to ascertain the reason behind the explosion.

Two tenders reached the spot from the fire station at the nearby Gun and Shell Factory but the capacity of their water-tanks was not adequate. Both turned back.

Major Incidents

Fire at Kolaghat power plant, supply not affected

Suman Mondal TNN | Updated: Apr 17, 2018, 07:46 IST

A- A+

The Monday evening blaze at Kolaghat Thermal Power Station

KOLAGHAT: A fire broke out on Monday evening at Kolaghat Thermal Power Station (KTPS) that supplies nearly a sixth of the state's power requirement and a third of state utility WBPDCL's generation. Though three transformers were gutted, power generation was not affected as firemen managed to insulate the six generating units. According to officials, the flames were first spotted around 6pm in one of the seven transformers of Unit No. 4. Soon, the fire spread to two more transformers in the same unit.

Fire Hazard at Auto Transformer-II, KTPS on 12/05/2014

At around 16:40 Hrs on 12th May 2014, Auto Transformer-II (220/132/33 KV), KTPS failed with the initiation of Differential Relay (87). The trouble was accompanied by huge fire hazard & bursting of bushings. The fire was so heavy that it created panic all round. However, KTPS Engineers took prompt action by diverting the reserve sources of Stage-1 to SAT (33/6.9 KV Transformer) of Stage-2. This action totally saved KTPS Stage-1 units from being collapse due to non-availability of reserve source. The fire not only caused damage to Auto Tranformer-II but also created severe damage to nearby reserve-2 cable.

And the recent one - What does it tell ?

Electrical Hazards

- ✓ Main safety hazards – Electrocution & Fire
- ✓ More importantly – Mitigation and prevention at different stages
- ✓ Then what should be the approach?
  - ✓ Design as per codes & standards
  - ✓ Procurement as per codes & standards
  - ✓ Installation as per codes & standards
  - ✓ Operation & Maintenance as per codes & standards

This is the process followed in ITC

Electrical Hazards

- ✓ Examples of the mitigation and prevention strategies at different stages for different equipment.

  - ✓ Design - example of Lightning & Earthing
  - ✓ Procurement – example of Transformer
  - ✓ Installation – example of cable
  - ✓ O & M – example of Switchgear panels

Electrical Hazards

- ✓ ITC's Approach
- ✓ ***Electrical safety starts at the drawing board.***
  - ✓ Designs of all projects is done as per national and international codes & standards, e.g., BIS, IEC, NFPA, IEEE etc.
  - ✓ Power system designs undergo a check at Corporate level - verification vis-à-vis codes, standards, best practices, etc.
  - ✓ Existing systems maintained as per BIS and international codes & standards and undergo periodic verification from Corporate

Electrocution hazard

- ✓ IEC 61140 & IS 3043 provides guidance for protection against electric shock.
- ✓ Under normal conditions – <u>hazardous live parts shall not be accessible</u>.
- ✓ Under fault conditions – <u>accessible conductive parts shall not be hazardous</u>.

- ✓ Measures adopted to protect against this hazard, include;
- ✓ Automatic disconnection of power supply.
- ✓ Or special arrangements such as
  - ✓ Shrouding
  - ✓ Use of class II equipment
  - ✓ Equipotential bonding
  - ✓ Use of isolation transformers and SELV supply

Electrical Hazards

- Let us start with the minimum basic safety requirement for automatic disconnection of power supply system.

- EARTHING
  - Interventions in earthing system design
  - Maintenance for earthing system

Earthing

- ✓ Basic data for designing an earthing system are *soil resistivity* and *fault level* of the system for sizing of earthing conductors
- ✓ From safety point of view attaining minimum earth resistance is not the only criteria
- ✓ Earthed equipotential bonding and automatic disconnection of supply is <u>operating principle</u>

Earthing

Earthing Strip Sizing Basis

As per IS:3043 - 1987 Clause 12.2.2.1

Issc/S	=	k/√t
S	=	(Issc *√t)/k
where		
S	=	Cross-sectional Area (sq.mm)
Issc	=	Value (ac, rms) of fault current (Amp)
t	=	Operating time of disconnection device (sec)
k	=	Factor dependent on the material of the protective conductor, the insulation & initial & final Temepratures

Available Parameters

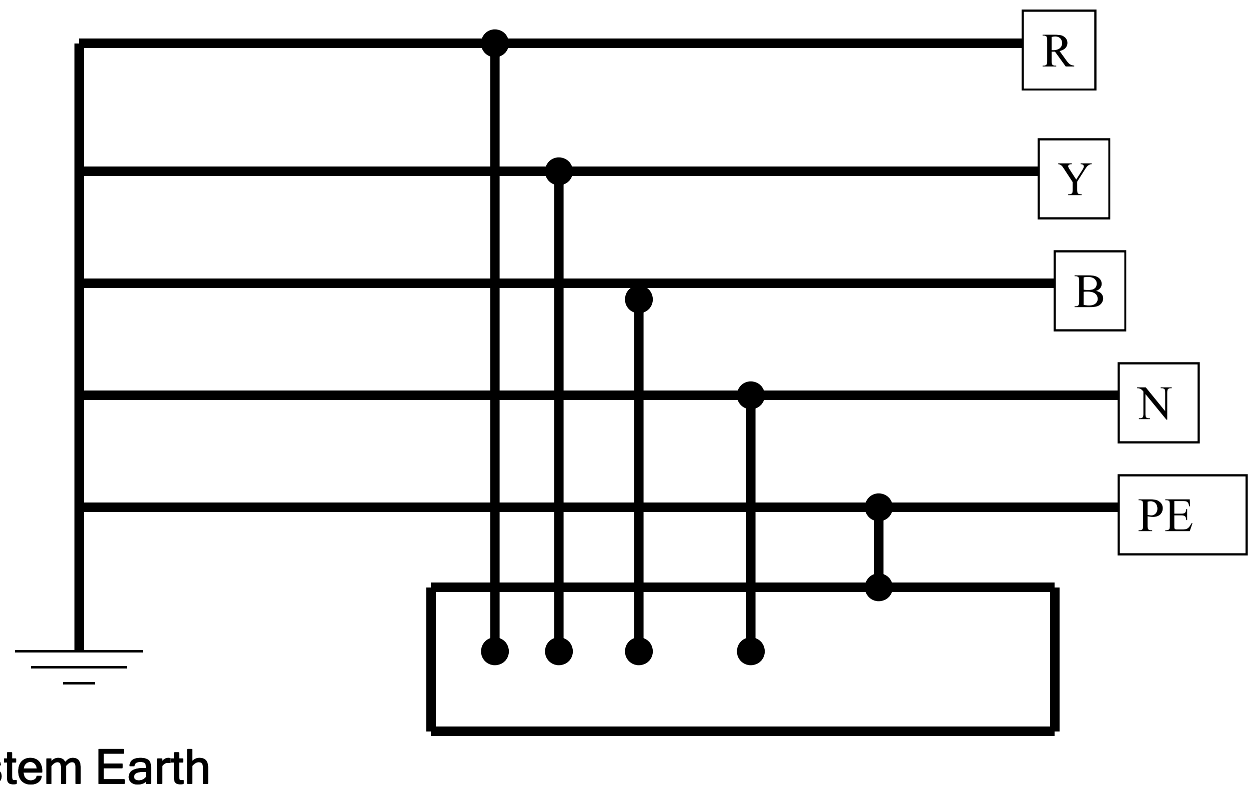
t	=	1	sec (max)
k	=	80	(for Steel with initial temp 40 deg C & final temp 500 deg C)
	=	205	(for Copper with initial temp 40 deg C & final temp 395 deg C)

Earthing Strip Area Calculations (GI)

Issc (Amp)	t (sec)	k (for bare Steel)	Earthing Strip Area (sq. mm)	Corrosion Allowance	Final Earthing Strip Area Requirement (sq.mm)	GI Earthing Strip Size (sq. mm)
10,000	1	80	125	15%	144	25 x 6
18,000	1	80	225	15%	259	50 x 6
25,000	1	80	313	15%	359	50 x 10
35,000	1	80	438	15%	503	50 x 10
42,000	1	80	525	15%	604	75 x 10
50,000	1	80	625	15%	719	75 x 10
65,000	1	80	813	15%	934	2 x 50 x 10

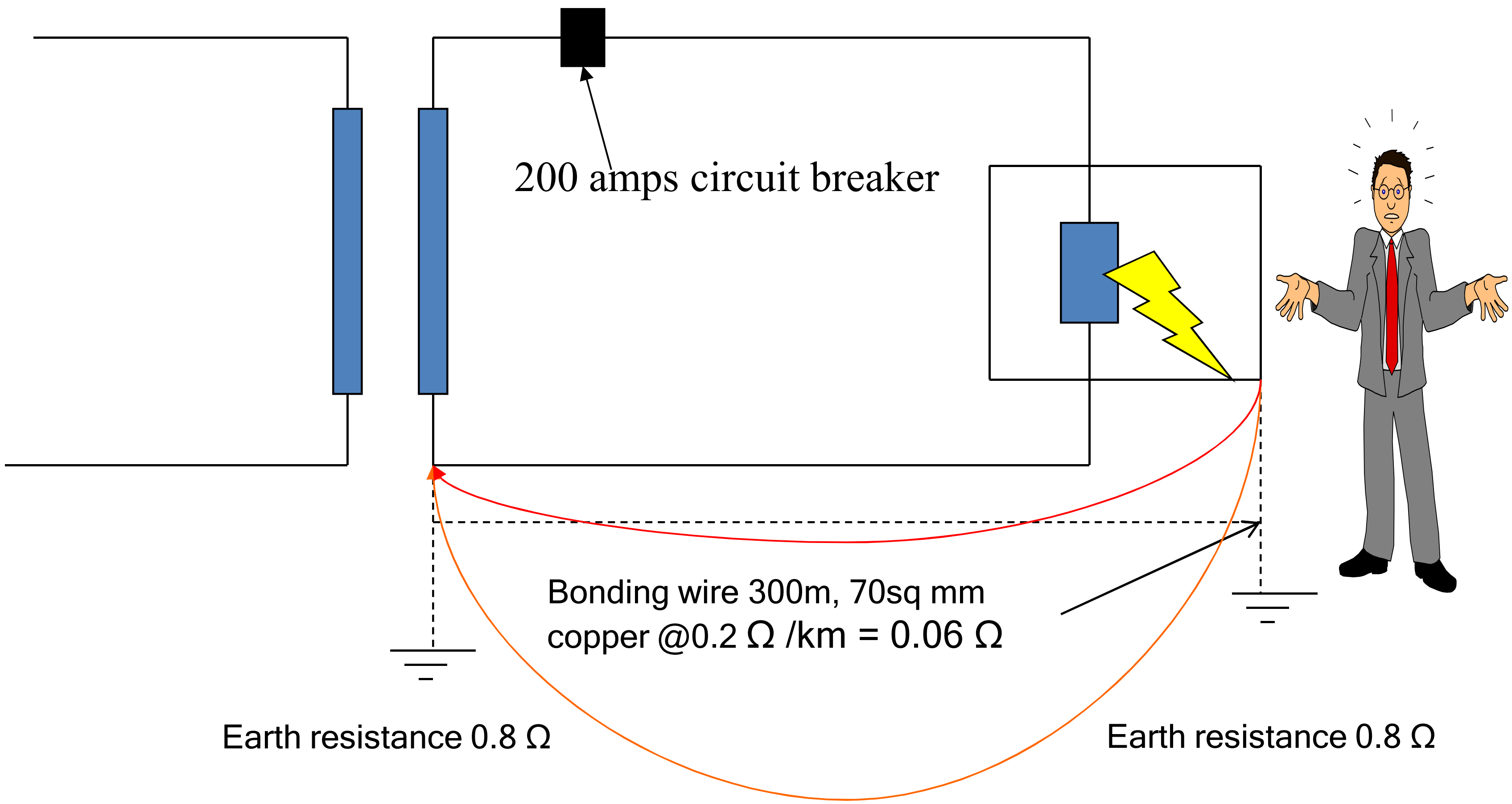
Earthing

✓ Terra-Neutral Separate



(<u>Followed in ITC</u>)

Earthing



Without bonding fault current = 240 / 1.6 = 150 amps (<u>circuit breaker will not trip</u>)

With bonding fault current = 240 / 0.06 = 4000 amps (<u>circuit breaker trips instantly</u>)

Earthing

- ✓ Without bonding, voltage between body of equipment and earth = (240 / 1.6) X 0.8 = 120 volts
- ✓ Assuming dry conditions, average resistance of human body will be around 1300 Ω

Therefore current through body = 120 / 1300 = 92mA

- ✓ Criterion is to ensure earth continuity resistance is within limits such that
  - ✓ Touch potential is within limits
  - ✓ Protective circuit breakers operate effectively when earth fault currents flow

Earthing

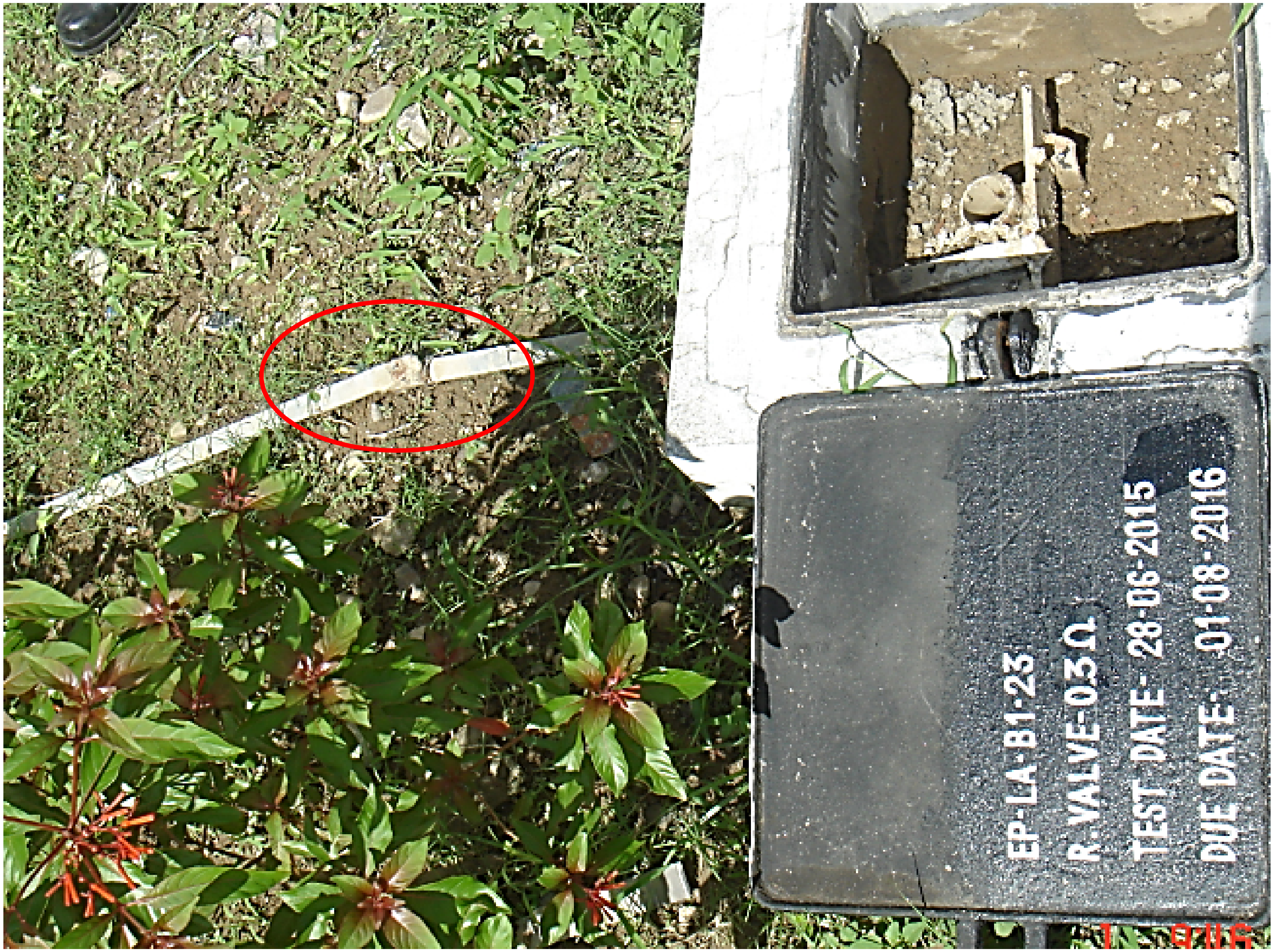
✓ **Maintenance**

- Earthing system resistance should be tested at all earth pits on a dry day once in two years. (Refer IS 3043 CL 34).
- Records of the tests made and the results thereof should be maintained and available for past 3 years.
- Overall system earth resistance should be less than 1 Ω.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

- where $R1$, $R2$, etc., are individual independent earth electrode resistance (when disconnected from the earth grid)

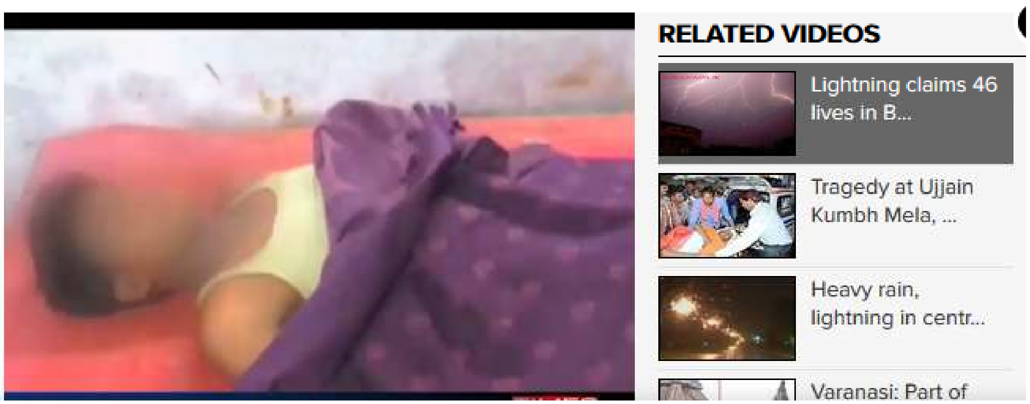
Prevention of Electrical Hazards



Lightning protection

At least 55 killed, 8 injured in lightning strikes in Bihar

TNN & Agencies | Jun 22, 2016, 11.47 AM IST



20 Killed in Lightning Strikes as Heavy Rain Lashes Andhra Pradesh

Lightning protection

Table-1(C)

Number, Share and Rate of Accidental Deaths by Causes Attributable to Nature, Un-natural and Other Causes of Accidents during 2014 & 2015

Sl. No.	Cause	2014 No.	2014 % Share (w.r.t. All India)	2014 Rate	2015 No.	2015 % Share (w.r.t. All India)	2015 Rate	% Variation during 2015 over 2014
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. CAUSES ATTRIBUTABLE TO NATURE								
1	Avalanche	23	0.1	0.0	38	0.4	0.0	65.2
2	Exposure to Cold	913	4.5	0.1	1149	10.9	0.1	25.8
3	Cyclone	62	0.3	0.0	15	0.1	0.0	-75.8
4	Tornado	42	0.2	0.0	13	0.1	0.0	-69.0
5	Tsunami	0	0.0	0.0	0	0.0	0.0	-
6	Starvation Due to Natural Calamity	50	0.2	0.0	30	0.3	0.0	-40.0
7	Earthquake	2	0.0	0.0	92	0.9	0.0	4500.0
8	Epidemic	48	0.2	0.0	218	2.1	0.0	354.2
9	Flood	541	2.7	0.0	846	8.0	0.1	56.4
10	Heat/Sun Stroke	1248	6.2	0.1	1908	18.2	0.2	52.9
11	Landslide	499	2.5	0.0	232	2.2	0.0	-53.5
12	Lightning	2582	12.8	0.2	2641	25.1	0.2	2.3
13	Torrential Rain	156	0.8	0.0	195	1.9	0.0	25.0
14	Forest Fire	11	0.1	0.0	19	0.2	0.0	72.7
15	Other Natural Causes	14024	69.4	1.1	3114	29.6	0.2	-77.8
16	**Total (A)**	**20201**	**100.0**	**1.6**	**10510**	**100.0**	**0.8**	**-48.0**

Source: *https://NCRB.gov.in*

Lightning protection

How Did Lightning Kill More Than 300 Reindeer?

Trilobites

By NICHOLAS ST. FLEUR AUG. 30, 2016

He added that this case is unusual because of the large number of reindeer that were killed, but that it isn't uncommon for livestock to be felled by lightning. The most cattle ever killed by lightning is 68 according to the Guinness World Record. There are also reports of lightning apparently striking many types of animals, including 53 pigs and 143 goats in China, 16 bulls in Scotland, a giraffe at Disney World, and even one historical account of two bolts killing 654 sheep in Utah.

Lightning is dangerous to people as well, and in June of this year more than 70 people in India were killed by lightning.

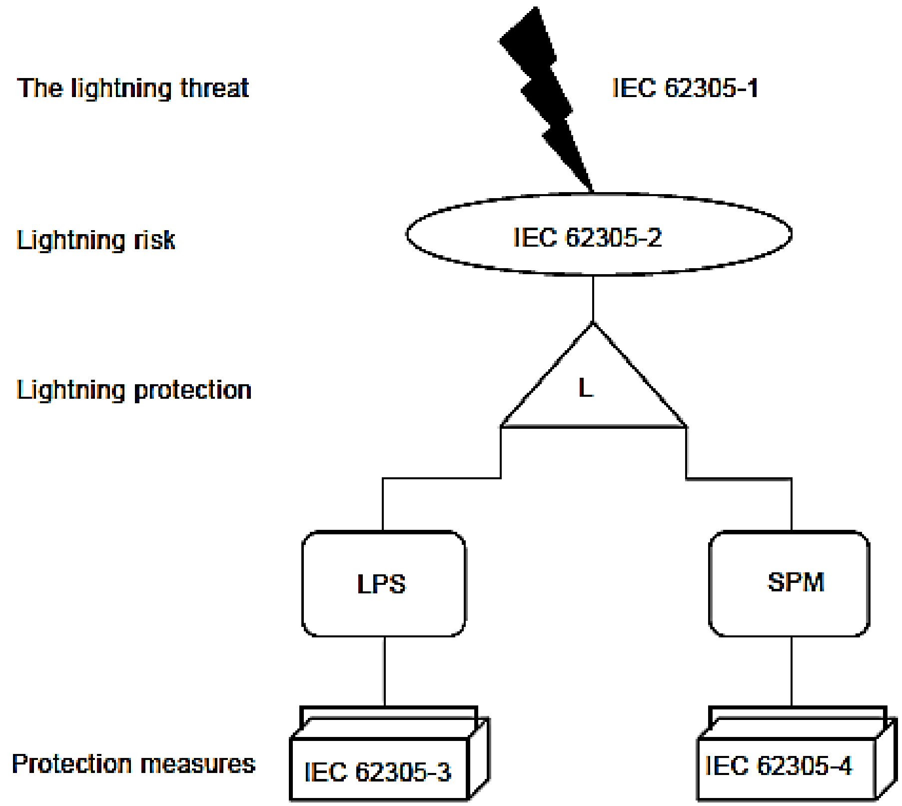
Mr. Jensenius said that we can learn from the reindeer's misfortune.

Electrical current from a lightning strike killed more than 300 reindeer in Norway. Ntb Scanpix/Reuters

Lightning protection

- ✓ How to prevent hazards arising from lightning strikes ?
- ✓ IS/ IEC 62305 replaces the old standard IS 2309.
- ✓ Primary factors which influence lightning threat includes;
  - ✓ Probable number of lightning strikes
  - ✓ Use of structure
  - ✓ Nature of construction
  - ✓ Location
  - ✓ Height of the building etc.

LPS – Lightning protection system
SPM – Surge protection measures

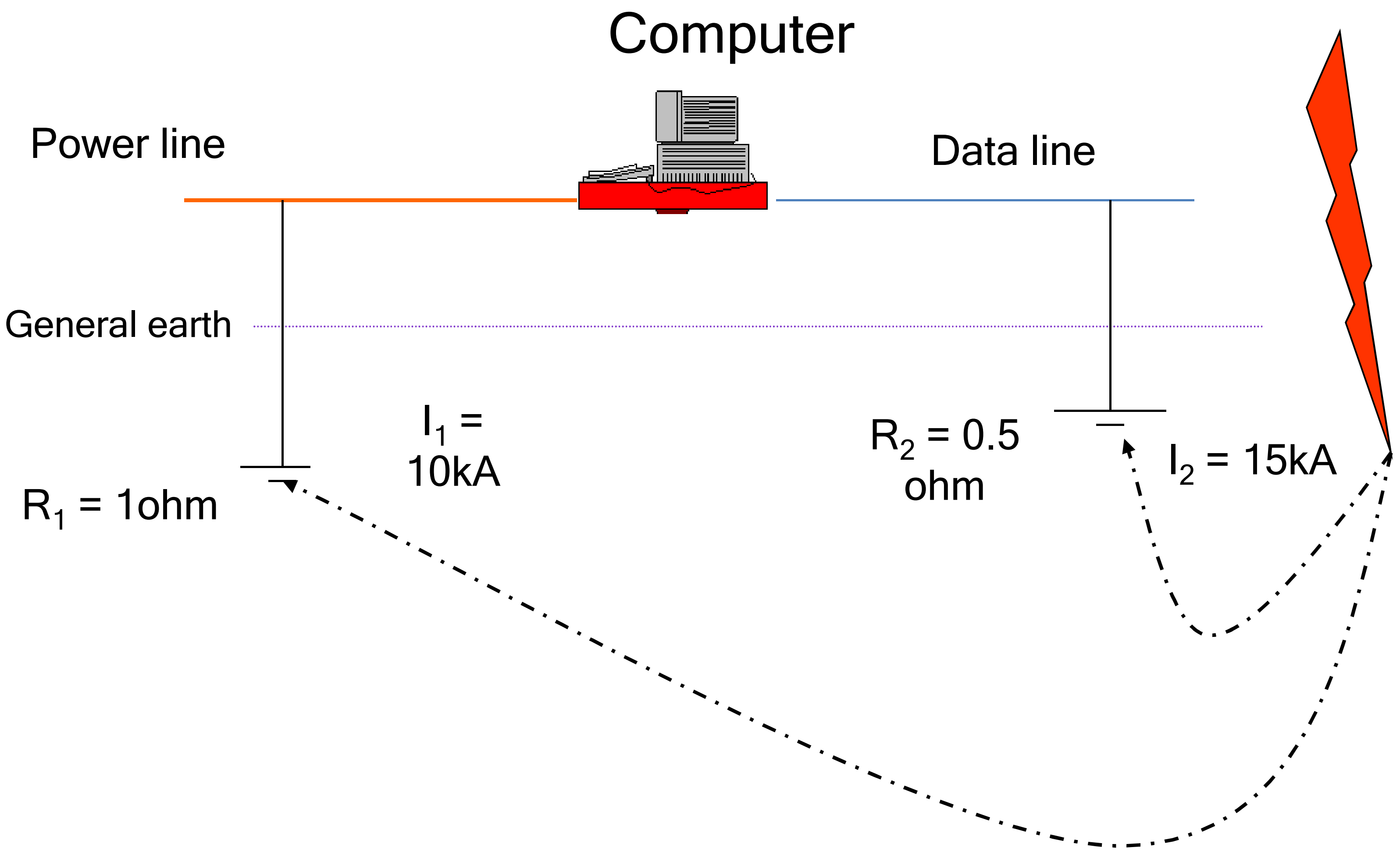


Lightning protection

- ✓ Air termination calculations – Angle method or Rolling sphere method
- ✓ An equal spacing of downconductor is preferred around the perimeter of the building/ structure. Typical preferred values of distance between the

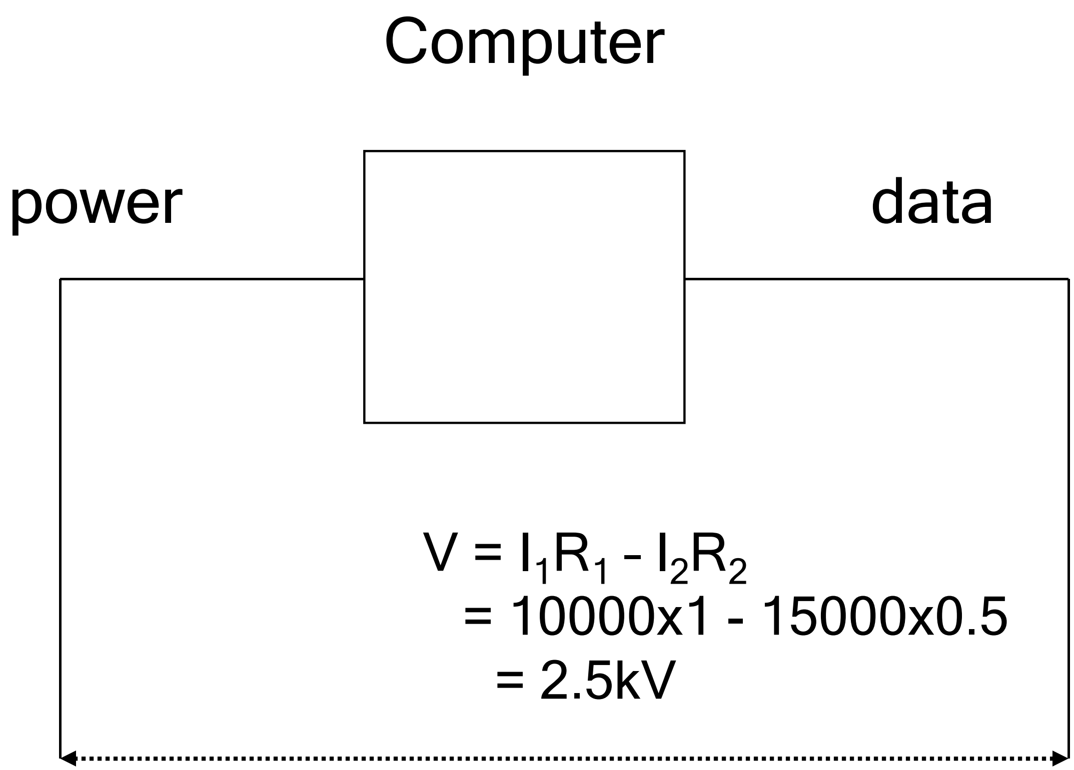
Class of LPS	Typical distances m
I	10
II	10
III	15
IV	20

Single reference earthing



Single earthing grid for TNS, lightning and electronic system earth pits - IEEE 1100

Single reference earthing

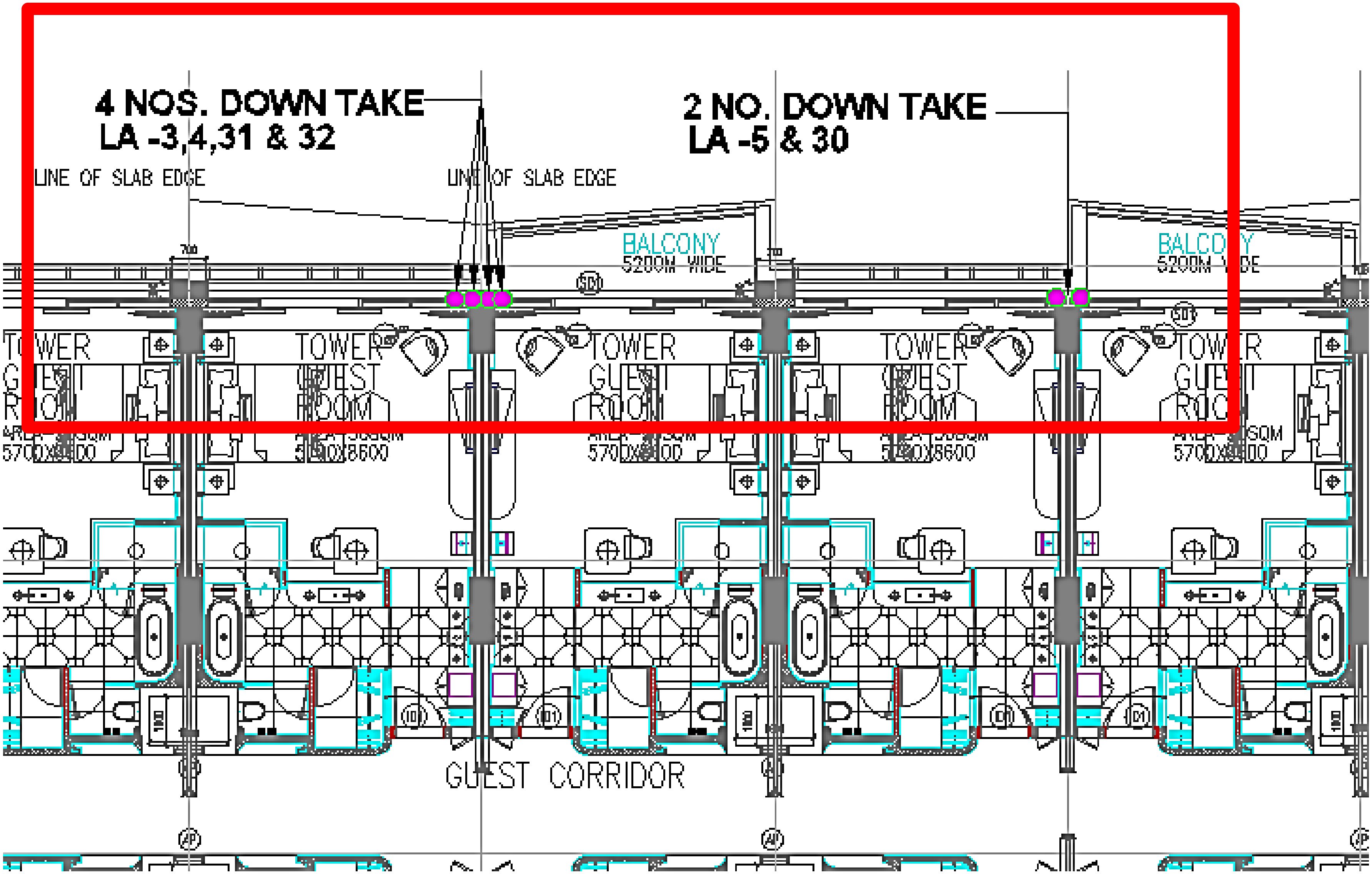


$$
\begin{aligned}
V &= I_1R_1 - I_2R_2 \\
&= 10000\text{x}1 - 15000\text{x}0.5 \\
&= 2.5\text{kV}
\end{aligned}
$$

Single reference earthing is a must – IEEE 1100

Lightning protection

Lightning protection



Checking during procurement

- Equipment – transformer / motor / switchgear / cable / UPS etc., conforms to relevant standards.

- How to verify ?
  - Check the type test report and verify it as per relevant standard.

  - Check the routine test report and verify it as per relevant standard.

  - Let us see the same for a power transformer ..

Checking during procurement

Checking during procurement

- ✓ Reference standards
  - ✓ IS 1180 — for outdoor oil immersed distribution transformer (up to 11 kV)
  - ✓ IS 2026 or IEC 60076 — for oil filled Power Transformer
  - ✓ IS 11171 or IEC60726 — for dry type Transformer
  - ✓ CBIP Manual on Transformer

Checking during procurement

- Tests on a power transformer (Refer IS 2026 & IEC 60076)
- Type tests
  - Temperature rise test as per IS 2026-2
  - Lightning Impulse test as per IS 2026-3
- Routine tests
  - Winding resistance
  - Voltage ratio and phase displacement
  - Short circuit impedance and load loss
  - No-load loss and current
  - Dielectric routine tests
  - Tests on OLTCs.

✓ Most common failures for oil filled transformers

  ✓ OLTCs

  ✓ Bushing failure

ELECTRICAL RESEARCH AND DEVELOPMENT ASSOCIATION

TEST REPORT

SHEET : 1 of 2

NAME & ADDRESS OF CUSTOMER	REPORT NO. : HCCT/03/128 DATE : 02.05.2010	
TELAWNE POWER EQUIPMENTS PRIVATE LIMITED. R-457, M.I.D.C.,RABALE, THANE BELAPUR ROAD, NAVI MUMBAI -400 701 INDIA.	CUSTOMER REF. NO.	DATE
	NIL	25.03.2010
	DATE OF SAMPLE RECEIPT	DATE OF TESTING
	27.03.2010	27.03.2010
SAMPLE DESCRIPTION	SAMPLE IDENTIFICATION	
DISTRIBUTION TRANSFORMER MFG.BY : TELAWNE POWER EQUIPMENTS PRIVATE LTD. RATING : 1000 KVA VOLTS : 11000/433 V (at no-load) CURRENT : 52.48/1333.37 Amps. PHASES : 3/3 FREQUENCY : 50 Hz WINDING : Copper % IMPEDANCE : 5.0 % VECTOR GROUP : Dyn 11 GUAR. MAX. TEMP. RISE IN OIL/WINDING: - 40/50 °C	ERDA ID NO. : HCCTWO00712285 MFG.SR NO. : TPE-899 COOLING : ONAN CUSTOMER : Esdel Paints Ltd.	
TEST DETAILS	TEST SPECIFICATION	
1.Measurement of impedance voltage and Load loss. 2. Measurement of no load loss and current.	As per customer's requirement ,testing procedure followed 1.cl.no.16.4 of IS:2026-1977,Part-1. 2.cl.no.16.5 of IS:2026-1977,Part-1.	

TEST RESULTS : As per sheet 2 of 2.

REMARKS : Transformer **conforms** to the guaranteed requirement as per above mentioned test specification for above mentioned tests.

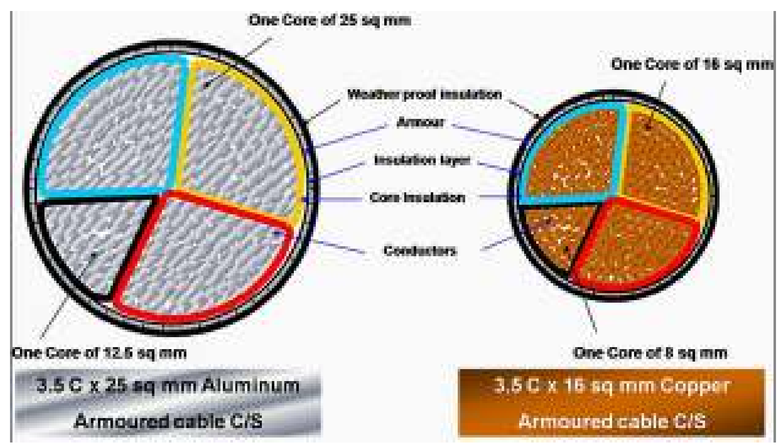
PREPARED BY CHECKED BY APPROVED BY

Note : 1. This report relates only to the particular sample received in good condition for testing at E.R.D.A.
2. This report cannot be reproduced in part under any circumstances.
3. Publication of this report requires prior permission in writing from Director , E.R.D.A.
4. Only the tests asked for by the customer have been carried out.

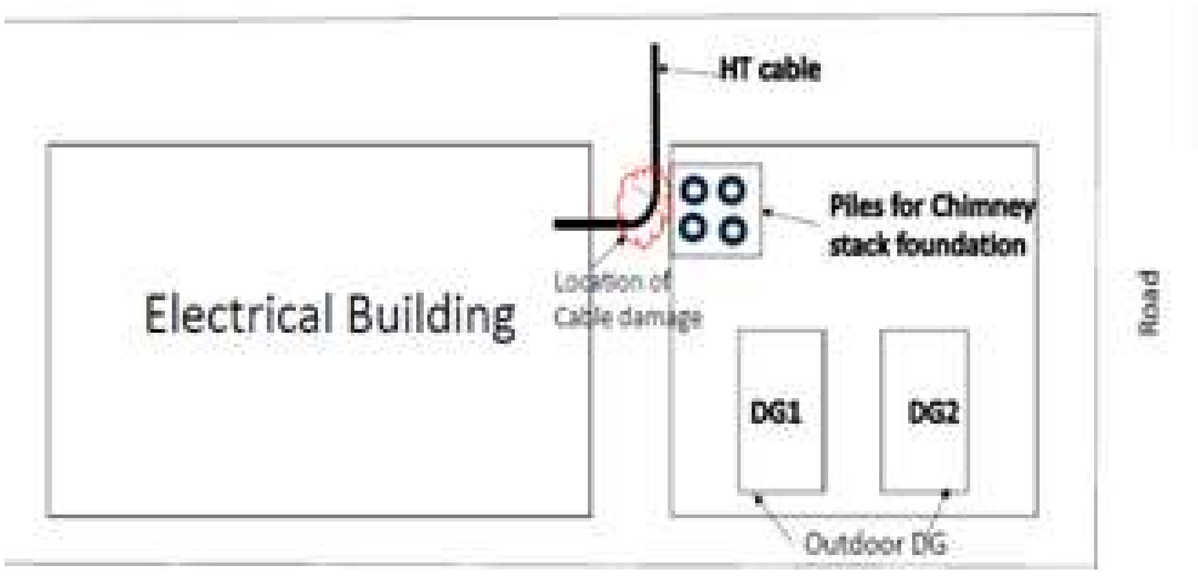
TE 0458342

Checking during installation

- Applicable standards for **Cables**
  - ✓IS 7098 : XLPE insulated PVC sheathed cables up to 1100 V.
  - ✓IS 1554 : PVC insulated heavy duty electric cables.
  - ✓IS 14927 : Cable trunking & ducting systems
  - ✓IS 1255 : Installation & maintenance of power cable
  - ✓IS 12459 : Fire safety in cable runs
  - ✓IS 10810 : Tests on cables
  - ✓IS 8623 : Requirements for busbar trunking systems
  - ✓IS 61196 : Coaxial communication cables
  - ✓IEC 60189: Instrumentation cables



Checking during installation



Checking during installation

✓ Mode of power cable laying

Switchyard & outlying areas	Cable trenches or directly buried if no contaminants present in soil
Indoor switchgear rooms located in ground floor	Cable trenches
Process plants & utility	Cable trays with conduit for branch off connections. Cable trenches may also be used.
Conveyor belts	Cable trays run along conveyor structures
Road/ rail crossings & oil/ gas/ water sewage pipes crossing	Through buried hume pipes or overhead cable rack
Hotels	Above false ceiling, laid in cable trays supported from roof slab or directly cleated on the ceiling.

Checking during installation

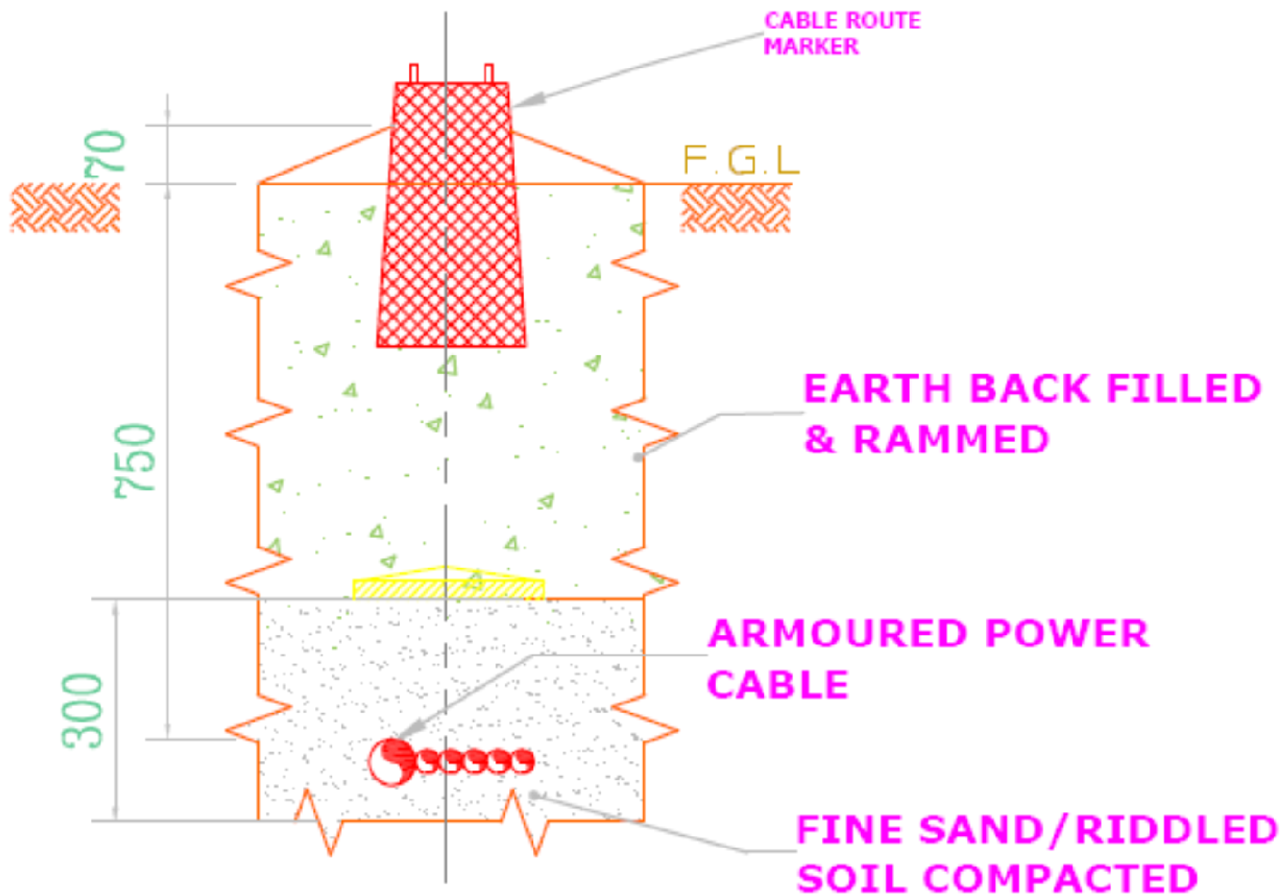
- ✓ Mode of power cable laying
  - ✓ On ground, bedding of loose sand 75 mm depth, cover again with 75m loose sand + bricks or tiles.
- ✓ Depth of burial

✓ Low Voltage & Control cables	0.75 m
✓ 3.3 to 11kV	0.9 m
✓ 22 – 33 kV	1.05 m
✓ At road crossings	1.00 m minimum

- ✓ Steel, cast iron, hume pipe (cement ducts) to be used for road crossings

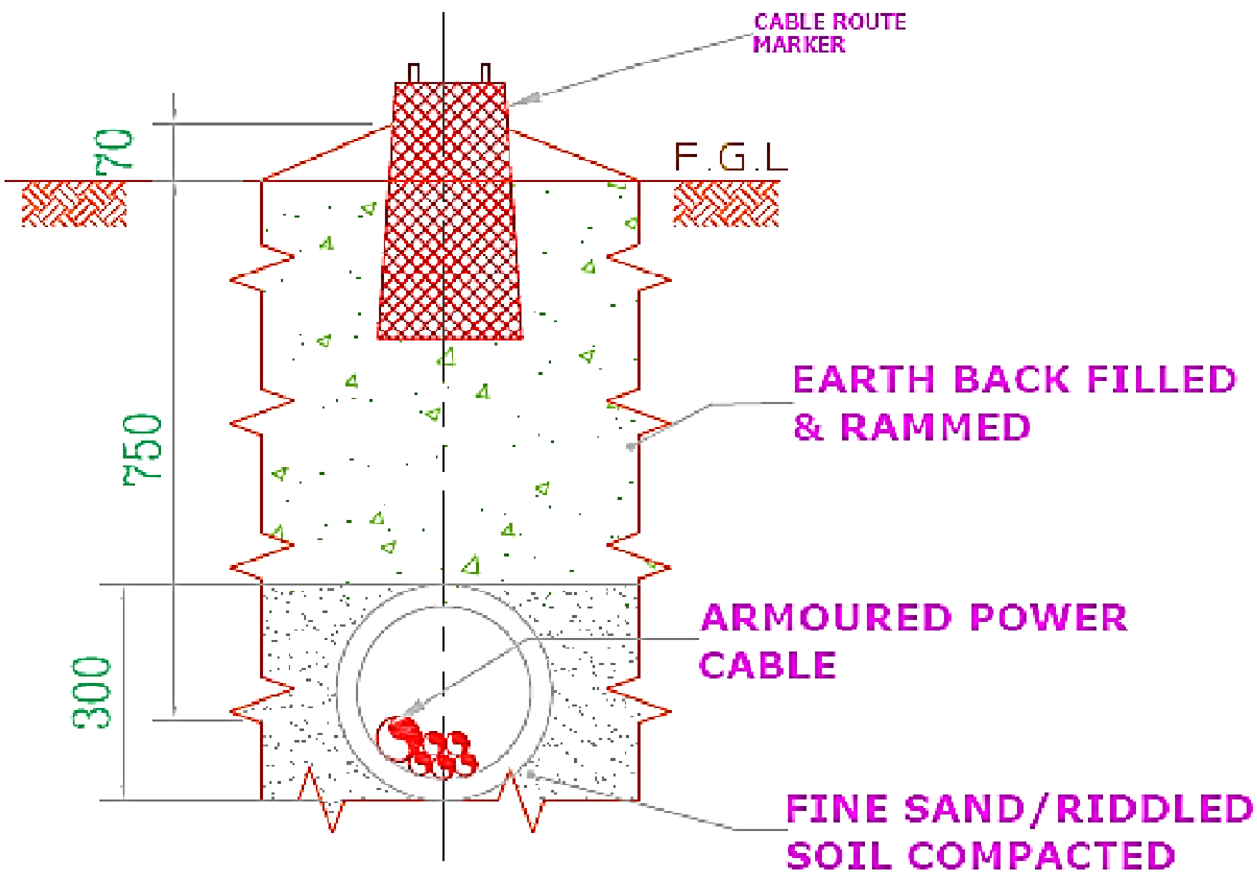
Checking during installation

- ✓ Mode of power cable laying
  - ✓MV power cables directly buried



Checking during installation

- ✓ Mode of power cable laying
  - ✓MV power cables in hume pipe



Checking during installation

5.3 Minimum Permissible Bending Radii — The cable should not be bent to a sharp radius. Minimum recommended bending radii are given in Table 5 (*see* Fig 1). Wherever possible, larger bending radii should be used.

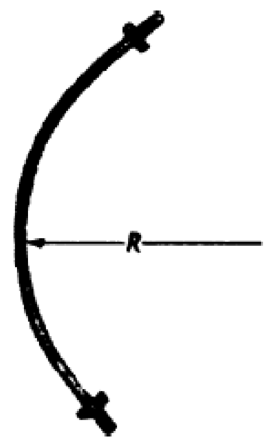


FIG. 1 PERMISSIBLE BENDING RADII

Reference IS 1255

TABLE 5 MINIMUM PERMISSIBLE BENDING RADII FOR CABLES

VOLTAGE RATING	PILC CABLES		PVC and XLPE CABLES	
	Single-Core	Multi-Core	Single-Core	Multi-Core
(1) kV	(2)	(3)	(4)	(5)
Up to 1.1	20 *D*	15 *D*	15 *D*	12 *D*
Above 1.1 to 11	20 *D*	15 *D*	15 *D*	15 *D*
Above 11	25 *D*	20 *D*	20 *D*	15 *D*

NOTE — *D* is outer diameter of cable.

Checking during O & M

- ✓ Applicable Standards for **Switchgears**:

✓ IEC 62271-100	HV AC Breakers
✓ IEC 62271-102	AC Isolators & Earthing Switches.
✓ IEC 62271-200	AC Metal Enclosed Switchgear up to 52kV.
✓ IEC 62271-201	AC insulation-enclosed switchgear and controlgear up to 52kV
✓ IEC 62271-106	HV AC Contactors
✓ IEC 61439	LV switchgear assemblies
✓ IS 13947 / IEC 60947	LV switchgear / Control gear
✓ IS 8828 / IEC 60898	Miniature Circuit Breakers
✓ IS 12640 / IEC 61008	Residual Current Circuit Breakers

Checking during O & M

Checking during O & M

Checking during O & M

✓Relevant codes of practice to be followed. For LV switchgear assemblies:

- Annual mV drop test across terminations or thermography tests.

$$T_{full\ load} = T_{measured} \left(I_{full\ load} / I_{measured} \right)^2$$

Refer IS 16168

Thermography inspection assessment

Sr. no.	Temperature rise above ambient (at full load current)	Recommendations
1	>50 °C	Investigate the root cause & repair immediately
2	25-50 °C	Investigate the root cause & repair at the earliest opportunity
3	10-25 °C	Investigate during next scheduled maintenance activity
4	<10 °C	Record & continue to monitor

Checking during O & M

Refer NFPA 70E

- ✓ Standard for Arc flash suits.

Standard Performance Specification for Flame Resistant and Arc Rated Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards	ASTM F1506
Standard Test Method for Determining the Arc Rating and Standard Specification for Eye or Face Protective Products	ASTM F2178

- ✓ Arc flash suits are not required for work on control circuits (with exposed energized electrical conductors) voltages < 120 V. (Refer NFPA 70E Table 130.7(C)(15)(A).

Checking during O & M

- ✓ Arc flash suit not required if any task needs to be performed outside the arc flash boundary. (Refer NFPA 70E for further details)

Table 130.7(C)(15)(A)(b) Arc-Flash Hazard PPE Categories for Alternating Current (ac) Systems

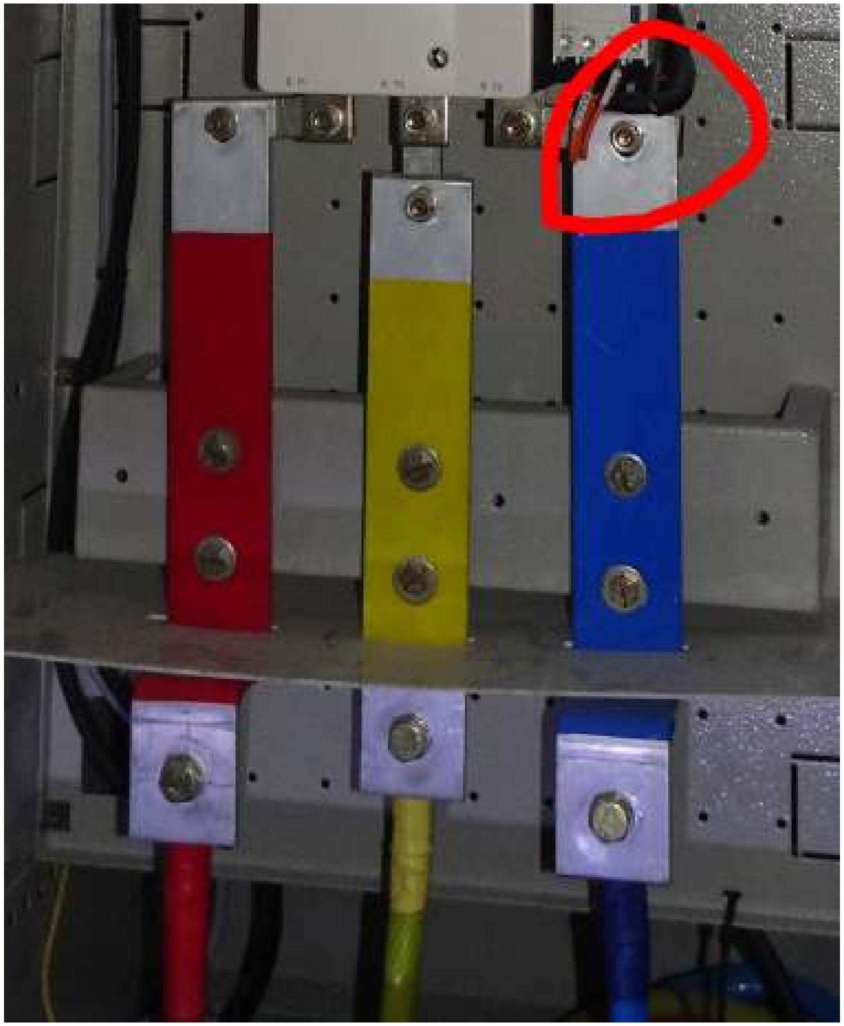
Equipment	Arc Flash PPE Category	Arc-Flash Boundary
Panelboards or other equipment rated 240 V and below Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 455 mm (18 in.)	1	485 mm (19 in.)
Panelboards or other equipment rated >240 V and up to 600 V Parameters: Maximum of 25 kA short-circuit current available; maximum of 0.03 sec (2 cycles) fault clearing time; working distance 455 mm (18 in.)	2	900 mm (3 ft)
Metal-clad switchgear, 1 kV through 15 kV Parameters: Maximum of 35 kA short-circuit current available; maximum of up to 0.24 sec (15 cycles) fault clearing time; working distance 910 mm (36 in.)	4	12 m (40 ft)

PPE Category	Arc flash suit rating
1	4 cal/cm^2
2	8 cal/cm^2
3	25 cal/cm^2
4	40 cal/cm^2

Checking during O & M

- ✓ Relevant codes of practice to be followed. For switchgear assemblies:
- ✓ <u>Half yearly checks</u>
  - ➢ Check for healthiness of relay & control circuits.
  - ➢ Clean & tighten busbar joints
  - ➢ Inspect shape of jaw contacts
  - ➢ Checks on charging motor & trip coil/ closing coil etc.
- ✓ <u>Yearly checks for circuit breakers</u>
  - ➢ Clean the close and trip coils and main contacts with white petroleum
  - ➢ Replace charging motor brushes, if required
  - ➢ Check plug contact alignment
  - ➢ Remove and clean arc chutes. Replace arc chutes, if necessary.
  - ➢ Grease the bearing, gear, auxiliary shaft joint
  - ➢ Test protection relays for proper operation.
  - ➢ Annual mV drop test across terminations or thermography tests

Checking during O & M



Harmonics Control

What is Harmonic rich environment

- ✓ Non-linear Loads generate current harmonics
- ✓ Harmonic currents finds least resistance path through capacitors
- ✓ The flow of harmonic currents cause voltage harmonics.
- ✓ Harmonics injected into the network flow towards other users connected to the Network.
- ✓ A harmonic rich environment is said to exist when the percentage of non linear loads in an installation becomes greater than 20% of connected load.

Harmonics Control

Loads generating Harmonics

- ✓ Equipment using Switched Mode Power Supply, i.e.,
  - ✓ Television
  - ✓ Computers, other IT Loads
- ✓ Equipment using Power Electronic Devices
  - ✓ AC & DC Drives
  - ✓ Frequency Converters
  - ✓ Rectifiers
  - ✓ Arc & Induction furnaces
  - ✓ UPS
  - ✓ Compact Fluorescent & other discharge Lamps, LED driver

Harmonic levels as per IEEE 519

Current Distortion Limits for General Distribution Systems (120 V Through 69 000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_L	<11	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

* All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where
I_{sc} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at PCC.

PCC - Point of Common Coupling i.e., Grid metering point

Harmonic rich environment

Type of Equipment	Effect of Harmonics
✓ Rotating Machines	✓ Increased losses, over heating due to Skin Effect. ✓ Pulsating Torque
✓ Transformer, Switch-Gear, Power Cables	✓ Over heating - fire, Increased Power consumption
✓ Protective Relays	✓ Mal-operation, Nuisance tripping
✓ Power Electronics	✓ Mal-operation, Failure
✓ Control & Automation	✓ Erratic Operation
✓ Power Capacitors	✓ High currents & failure due to overload

Capacitors in harmonic rich environment

- ✓ Power factor correction by the use of capacitors, in harmonic rich environment, must be carried out with certain precautions.
- ✓ $X_c = \dfrac{1}{(2 \times 3.14 \times f_n \times C)}$
- ✓ Capacitors drawing higher current i.e., more than the rated current at normal operating voltages is a typical indication of presence of harmonics.
- ✓ The increase results in Capacitors being overloaded leading to premature failure and increased voltage distortion.

Harmonic filters – selection criteria

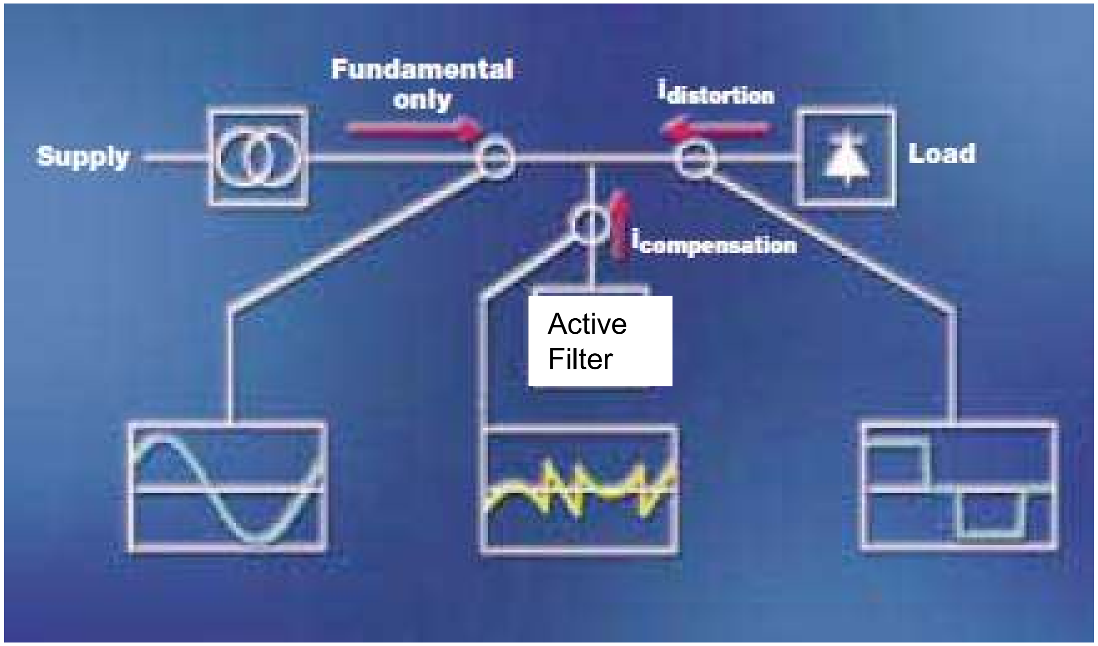
- ✓ Detuned Filters
  - ✓ Power Factor correction is of paramount importance
  - ✓ Reduction of THD(V) not relevant
  - ✓ To prevent capacitors from harmonic overload
- ✓ Tuned Filters
  - ✓ Power Factor correction & reduction of THD(V) are of paramount importance
  - ✓ Specifically designed for each location
  - ✓ More bulky, since it carries large amount of harmonic currents. Hence expensive.

Harmonic filters – selection criteria

- ✓ Detuned Filters
  - ✓ Standard 7% detuned filters are suitable for use in majority of installations where the dominant harmonics are higher than 189 Hz like 5th and higher.
  - ✓ 7% detuned filters should not be used in installations where predominant 3rd harmonics are present like "IT based" industries.
  - ✓ For "IT based" industries 14% detuned filters should be used.

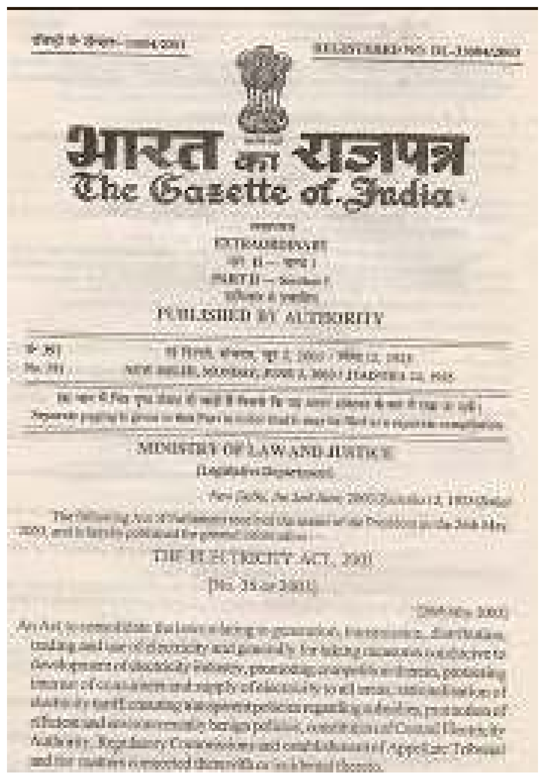
Harmonic filters – selection criteria

- ✓ Active Filters
  - ✓ High level of harmonics with almost unity power factor
  - ✓ Concerns on power quality due to high level of harmonics
  - ✓ Multiple harmonic contents (e.g., 3rd, 5th, 7th etc.) needs to be filtered.
- ✓ Principle of active filtering



Indian Law – Acts & Rules

- ✓ Indian Electricity Act 2003 (last amended)
- ✓ CEA Regulations, 2010 (last amended) - Measures relating to Safety and Electric supply [*this supersedes IE Rule 1956*]
- ✓ Factories Act, 1948 & applicable state factory rules



भारत का राजपत्र
The Gazette of India
EXTRAORDINARY
PUBLISHED BY AUTHORITY
MINISTRY OF LAW AND JUSTICE
THE ELECTRICITY ACT, 2003

Overview of Standards & Codes of Practice

- ✓ Electrical standards followed in ITC
  - ✓ BIS
  - ✓ IEC
  - ✓ IEEE
  - ✓ BS EN
  - ✓ NFPA NEC

Thank You