Important Instruction to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance.(Not applicable for subject English and Communication Skills)
4) While assessing figures, examiner may give credit for principle components indicated in a figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case some questions credit may be given by judgment on part of examiner of relevant answer based on candidate understands.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1. A) Attempt any Six of the following **12 Marks**

i) Classify the transmission line based on length and operating voltage.

(1- Mark for length level & 1- Mark for voltage level)

Note: Student may write any one of the following answer both are correct

Classification:-

1) According to Length of Transmission line:

a) Short Distance Transmission Line - (up to 50 KM)

b) Medium Distance Transmission Line - (up to 50 to 150 KM)

c) Long Distance Transmission Line - (above 150 KM)

2) According to Voltage level:

a) High voltage Transmission Line (HV)

b) Extra High Voltage Transmission Line (EHV)

c) Ultra High voltage Transmission Line (UHV)

OR

1) **Short Transmission Line: -** The length of Short transmission Line is up to **50KM** and its line voltage is less than **20 KV**
2) **Medium Transmission Line: -** The length of Medium transmission Line is up to **50KM-150KM** and its line voltage is between **20KV to** 100 **KV**
3) **Long Transmission Line: -** The length of Long transmission Line is above **150KM** and its line voltage is above **100KV**

ii) State the application of suspension type and pin type insulator **(1 Mark for each insulator)**

Application of suspension type insulator:

1. Here one disc is designed for 11 KV so by connecting number of discs in a string of suspension insulators it can be used for 66/110/132/220/400/765 KV & even more voltages.
2. When transmission line is running straight.

Application of Pin type insulator:

1. Used for voltage level up to 33KV maximum.
2. When transmission line is running straight.

iii) List the types of conductors with their brand/trade names.

List of types of conductors: (Any Two types are expected)

(List -1 Mark & Brand/Trade-1 Mark)

1. **Copper conductor:**
   - i) Hard drawn copper conductor
   - ii) Medium drawn conductor
   - iii) Soft (annealed) copper conductor
   - iv) Cadmium copper conductor
   - v) Copper clade conductor
   - vi) Phosphor bronze conductor
2. **Aluminum conductor :**
   - i) All aluminum conductor (AAC)
   - ii) All aluminum Alloy conductor (AAAC)
   - iii) ACSR conductor (Aluminum conductor steel Re-inforce)

iv) Bundle conductor

v) Steel conductor

Brand/trade names: (Any two of the following expected)

i) All aluminum conductor (AAC) (Any two of the following)

S.No	Brand/Trade name
1	Ladybird
2	Ant
3	Spider
4	Cockroach
5	Butterfly
6	Rose
7	Gnat
8	Fly
9	Bluebottle
10	Earwing
11	Cleg
12	Wasp
13	Chafer
14	Moth

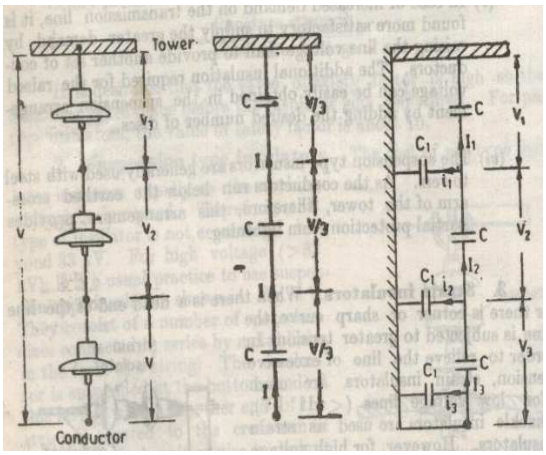
ii) ACSR Conductor (Aluminum conductor steel Re-inforce) (Any two of the following)

S.No	Brand/Trade name
1	Squirrel
2	Rabbit
3	Raccoon
4	Cat
5	Tiger
6	Lion
7	Goat
8	Mole
9	Gopher
10	Weasel
11	Ferret
12	Mink
13	Horse
14	Beaver
15	Otter
16	Dog
17	Leopard

18	Coyote
19	Wolf
20	Lynx
21	Panther
22	Bear
23	Sheep
24	Koo Doo
25	Deer
26	Zebra
27	Elk
28	Camel
29	Moose

iv) Draw the string of three suspension insulators and show the voltage distribution. Write expression for string efficiency. **(Figure-1 Mark & expression -1 Mark)**

String of three suspension insulator & the voltage distribution:-



Or equivalent diagram

String Efficiency:-

$$\text{String \% } \eta = \frac{votage\ across\ whole\ string\ (Vph = V_L/\sqrt{3}\ )}{n \times voltage\ across\ disc\ nearer\ \ to\ conductor} \times 100$$

OR

$$\text{String } \eta\% = \frac{Vph\,(V_L/\sqrt{3})}{n \times V_n} \times 100$$

Where, n = Number of Disc insulators

v) "In A.C transmission lines, more current passes through the outer surface of the conductor" state with reasons if the above statement is true or false.

The statement is true. Because, **(2 Marks)**

The inductive reactance (X_L) at the centre of the conductor is more than surface of conductor, so inductive reactance (X_L) opposes hence more current passes through the outer surface of the conductor.

OR

The electric current flows mainly at the "skin" of the conductor, between the outer surface and a level called the **skin depth**.

An alternating current in a conductor produces an alternating magnetic field in and around the conductor. When the intensity of current in a conductor changes, the magnetic field also changes. The change in the magnetic field, in turn, creates an electric field which opposes the change in current intensity. This opposing electric field is called **"counter-electromotive force" (**counter EMF). The counter EMF is strongest at the center of the conductor, and forces the conducting electrons to the outside of the conductor.

vi) Why 3-Ph AC system is preferred for power transmission.

Advantages of 3-phase system: - **(Any Two points each point 1 Mark)**

1. **More output:-** for the same size output of poly-phase machines is always higher than single phase machines.
2. **Smaller size:-**for producing same output the size of three phase machines is always smaller than that of single phase machines.

3. **More power is transmitted-** it is possible to transmit more power using a three phase system than single system.

4. **Smaller cross-sectional area of conductors-** if the same amount of power is transmitted then the cross-sectional area of the conductors used for three phase system is small as compared to that of single phase system.

5. Better power factor-power factor of three phase machines is better than that of single phase machines.

6. Three phase motors are self starting-three phase ac supply is capable of producing a rotating magnetic field when applied to stationary windings, the three phase ac motors are self starting. While single phase induction motor needs to use additional starter windings

7. Horse power rating of three phase motors is greater than that of single phase motor.

8. Power delivered by a single phase system fluctuates whereas for three phase system power delivered to the load is the same at any instant.

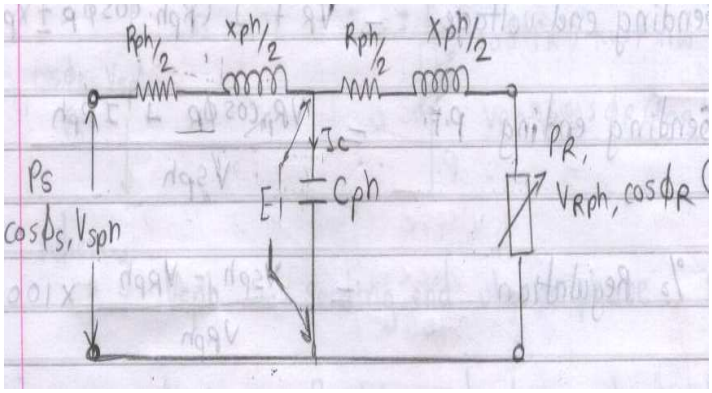
vii) Compare H.V.D.C transmission with EHV AC transmission.

(Any four point expected 1/2 mark each)

S.No	Points	H.V.D.C	EHV A.C
1	Number of conductor required for single circuit	1 conductor. Ground is used as a return path	3 conductor (R.Y.B)
2	For double circuit	2 conductors. Ground is used as a return path	6 (R,Y,B & R,Y,B)
3	Design of Tower	Light	Heavy
4	Intermediate substation	Not required	Required at very 250 Km
5	Capital cost of S/S	More	Less
6	Transmission line cost/km	Less	More
7	Ground return	Possible	Not possible
8	Frequency	Absent	Present
9	Skin effect	Absent	Present
10	Proximity effect	Absent	Present
11	Ferranti effect	Absent	Present
12	Corona losses	Less	More

13	Radio interference	Absent	Present
14	Effect of L &C	Absent	Present
15	Value of resistance	Less	More 1.6 times than DC
16	Copper loss	Less	More
17	Eiffiency	More	Less
18	Voltage drop in transmission line	Less	More
19	% Regulation	Better than EHVAC	Good
20	Limitation on length of cable	Charging current is absent so no limitation on length	Due to charging current there is able limitation on length of cable
21	String efficiency	100 %	Less than 100 %
22	Losses in S/s	More	Less
23	Maintenance cost of S/S	More	Less
24	Asynchronous tie	Possible	Not possible
25	Reliability & availability	One bipolar line is sufficient	Two AC circuit are necessary
26	Control system	Difficult, costly	Simpler cheaper
27	Power handling capacity	No limit	There is limit due to power angle & inductance
28	Voltage control	Easier as L&C are not effective	Difficult for long distance lines due to L &C
29	Stability limit	No limit due to power angle	EHVAC limits due to power angle & inductance
30	Power flow control	Power can be quickly controlled, fast	Power flow cannot be easily controlled, slow
31	Power transfer ability	High	Lower
32	Transient performance	Excellent	Poor
33	Back to Back conversion stations	Possible	Not Possible
34	Short ckt current level	Less	More
35	Reliable circuit breaker	Not available	Available
36	Fault levels	Remains unchanged	Get added after interconnection
37	Frequency conversion	Possible	Not possible
38	Cascade tripping of circuit	Avoided	Likely
39	Spinning reserve	Reduced	Not much reduced
40	Frequency of fault	Less	More

viii) Draw neat circuit diagram for nominal 'T' method. State for which type of transmission line it is used. **(figure 1.5 Marks & where it is used 1/2 mark)**



or equivalent diagram

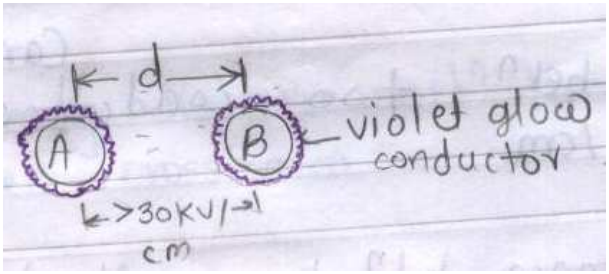
State for which type of transmission line it is used:-

Medium Transmission line system

Q.1. B) Attempt any Two of the following **08 Marks**

i) What is meant by corona? State any two advantages of corona.

Corona:- **(Meaning-2 Marks & Advanatges-2 Marks)**



or equivalent fig.

When AC Voltage given across two conductors separated by distance 'd' as shown figure is increased greater than breakdown voltage of air i.e. 30KV/cm, then air around the conductor gets ionized and ionized his conducting under this condition corona is form .

During corona following observations are observations are noted:

- Luminous violet glow is occurs around the conductor.
- Hissing sound is produced.
- Ozone gas is produced.

This phenomenon is known as "corona" effect.

Advantages of Corona:- (Any two advantages expected)

i) Due to formation of corona air around the conductor gets ionized. Hence effective diameter of conductor increases. So its resistance decreases. ($Since\ R = \rho\frac{l}{A}$)

ii) It reduces electrostatic stresses as cross section of conductor's increases.

iii) It provides safety valve against over voltage due to lighting stroke.

iv) It reduces effect of transient produced by surge.

ii) What are the reasons of failure of insulator and explain any one of them briefly.

(Reason- 3 Marks & Explanation-1 Marks)

The Reasons for the Failure of Insulators: - (Any Six points expected)

a) Manufacturing Defect

b) Uneven expansion and contraction

c) Mechanical stress

d) Porous

e) Flash over due to lighting stroke

f) Flash over due to large birds or other similar objects

g) Flash over caused due to dust deposition

h) Wrong Selection

i) Rough Handling

j) Ageing effect

Explanation:- (Any one explanation expected)

a) Manufacturing Defect:-

Insulator may fail due to manufacturing defect. So, it must be tested before use.

b) Uneven Expansion and Contraction:-

Insulator is manufacturing by using combination of material. For.eg: porcelain, glass, cements and also attachment steel is used.

Co-efficient of expansion and contraction of each material is different. So, there is possibility of cracking of insulator.so.it may fail.

c) Mechanical Stress:-

Due to mechanical stress of wind insulator may fail.

d) Porous:-

Procelin is porous material. So, if insulator is not glazed properly then direct dust will accumulate on insulator and It will absorb moisture from air, so reduces resistance of insulation.

Hence leakage current increase which increases temperature of insulator. It may cause failure of insulator.

e) Flashover due to lightning stroke:-

If lightning stroke directly attacks on insulator than there is flash over and causes failure of insulator**.**

f) Flash over due to large birds or similar objects:-

Large birds or similar objects causes short circuit resulting in flash over and causes of failure insulator.

g) Flash over caused due to dust deposition:-

Transmission line running over dusty area for eg: coal mine, large stone crusher, cement factory.

Dust will deposit on insulator which reduces clearance between two conductor. So, there is possibility of flash over and causes failure of insulator.

i) Wrong Selection:-

If 11 KV insulators is used for 22 KV, then it causes failure of insulator.

j) Rough Handing:-

Due to rough handling of insulator during transportation, construction of line work etc causes failure of insulator.

k) Ageing Effect:-

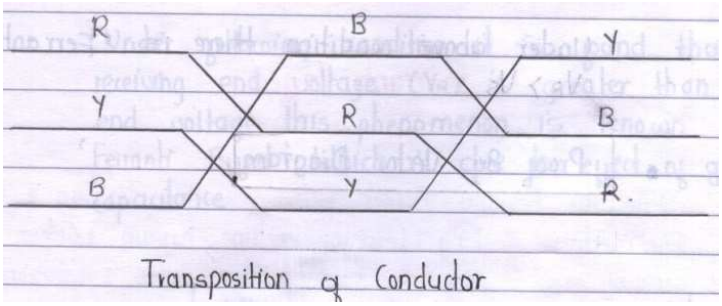
Due to continuous use of insulator for a long period, its dielectric strength reduces. So, it may be causes of failure insulator.

iii) What is meant by transmission of conductors? Why it is necessary?

(Meaning-1, Figure – 2 Marks & Necessity- 1 Marks)

Transposition of conductor means exchanging the position of 3 phases (R-Y-B) at regular interval.

Each phase occupies 3 different positions consequently on line support (Tower) as shown in fig.



or Equivalent fig.

Necessity (Reason):-

- Due transposition of conductor inductance of each line is same due to transposition $L_A = L_b = L_c$, So drop due to inductive reactance in each line is same so voltage at receiving end between any two line become same.
- So to obtain same voltage in any two line at receiving end ($V_{RY} = V_{YB} = V_{RB}$) transposition is necessary.
- Radio interferences is less due to transposition.

Q.2 Attempt any Four of the following **16 Marks**

a) What are the limitations of EHVAC transmission?

Following are the Limitations of EHVAC Transmission: (Any four expected- 1 Mark each)

a) In case of EHVAC transmission at every 250km distance additional substation (Switch S/s) is required on the way of transmission line to improve the performance of transmission line which increases transmission cost

b) Voltage control is difficult for long distance EHVAC transmission line.

c) Stability of EHVAC is very low because of presence of inductance.

d) There is limitation on power transfer ability due to presence of inductance of transmission line & power angle.

e) If power is to be transmitted of EHVAC through underground cable then there is limitation on the length of cable due to charging current. e.g. for 400 KV line limitation on length of cable is 25 Km

f) Ground return not possible

g) Economical only for bulk amount of power is to be transmitted over long distance.

h) Asynchronous tie not possible.

i) Back to back conversion station not possible.

j) Power flow cannot be easily controlled, slow.

k) Transient performance is poor.

l) Short circuit current level is more

m) Insulation cost increases as voltage increases

n) Skin effect is more

o) Proximity effect is more.

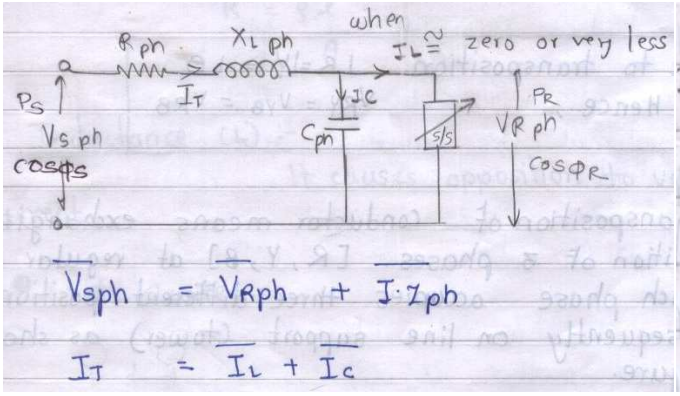
p) Radio interference increases.

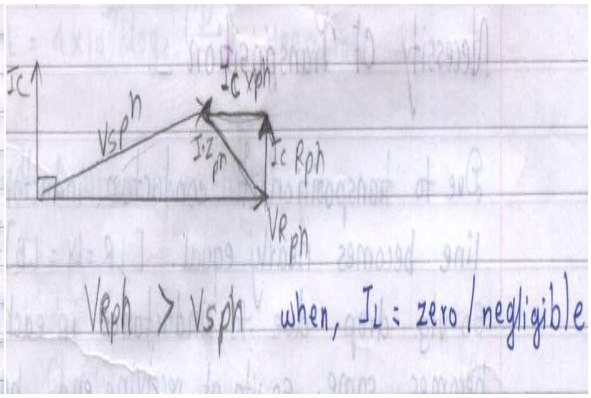
q) Corona loss increases.

r) To improve the performance of transmission line additional equipments such as series & shunt reactor & capacitor are required which increases cost of substation.

b) Why receiving end voltage is higher than sending end voltage under no load condition? What this phenomenon is called? (Figure (reason)-2 Marks, Phenomenon-2 Marks)

From vector diagram it is clear that receiving end voltage is higher than sending end voltage under no load condition





or equivalent diagram

This phenomenon is known as Ferranti effect.

OR

From this vector diagram is clear that receiving end voltage is higher than sending end voltage due to capacitive current this **phenomenon is known as Ferranti effect.**

c) Given Data:

P_R = 3MW = 3000KW V_R = 11KV p.f = 0.80 lag R = 0.3 ohm/km

X = 0.5/km ohm

L = 15 km

Note: In this example given R & X are not specified whether its value is total or each conductor, so this example is solved by two ways accept any one

Assuming Given values of R & X are of each conductor

R = 0.3 ohm /km X 15 = 4.5 ohm, X = 0.5 ohm / km X 15 = 7.5 ohm

Total resistance RT = 2R = 2 X 4.5 = 9 ohm

Total Reactance XT = 2 X = 2 X 7.5 = 15 ohm

Power P = $VI\cos\phi$ ---------- **(1/2Marks)**

Power P = $KVA \times P.f$

Power P = 500×0.8

Power P = 400 KW---------- **(1Mark)**

$$I \equiv \frac{P}{V\cos\phi}$$ ---------- **(1/2Marks)**

$$I \equiv \frac{500\times10^3}{11\times10^3}$$

$I \equiv 45.45\ amp$ _____ **(1/2Marks)**

1. Transmission efficiency: (If value of resistance each conductor is assume))

$$\%\,\eta_T = \frac{output}{output + Total\ losses\ I^2\ R_T}\times100$$ ---------- **(1/2Marks)**

$$\%\,\eta_T = \frac{400\times10^3}{400\times10^3 + (45.45)^2\times9}\times100$$

$\%\,\eta_T = 95.56\,\%$---------- **(1Marks)**

OR (Student may write following answer)

2. Assuming given values of R & X are total:- (If value of total assume)

$$\%\,\eta_T = \frac{output}{output + Total\ losses\ I^2\ R_T} \times 100$$

$$\%\,\eta_T = \frac{output}{400\times10^3 + (45.45)^2 \times 4.5} \times 100$$

$$\%\,\eta_T = 97.72\,\%$$

d) Classify a.c distribution system. Which type of distribution system is used for short distances? **(Classificatin-3 Marks & reason-1 Mark)**

Classify a.c distribution system

1) Primary distribution system:

a) 3-Ph, 3 Wire voltage level 11/22/33KV.

2) Secondary distribution system:

a) 3-Ph, 4 Wire, voltage level-3-ph, 440 Volt & 1-ph, 2-Wire voltage-230V

3) According to Method of construction: -

a) Overhead distribution system

b) Underground distribution system

4) According to scheme of connection: -

a) Radial (Tree) distribution system

b) Ring mains distribution system

c) Grid (interconnected) distribution system

Which type of distribution system is used for short distances:-

Radial (Tree) distribution system is used for short distances

e) Which are the design considerations of A.C distribution system? Explain briefly any one consideration.

NOTE :There are Two answer select any one

(Marks Allotted – 4 Marks, Any four points - 1 Mark each from part I or II)

Design considerations for A.C. distribution system:-

1) **Design:** layout should be simple in design.
2) **Initial Cost:** It should be less.
3) **Maintenance:** It should be low & less time consuming.
4) **Reliability:** It should have high reliability.
5) **Voltage fluctuation:** It should be less and within permissible limit.
6) **Availability of power :-** It should be available whenever needed
7) **Stability:** Fault on nearest distribution system should not affect stability of existing distribution system.

OR (Student may write following answer)

Part –I following factors are to be considered while designing the Feeder:-

1) **Current carrying capacity of conductor:-** Conductor should have high current carrying capacity
2) **Maintenance:** It should be low & less time consuming.
3) **Availability of power:** It should be available whenever needed
4) **Reliability:** Depending upon application distribution system should be selected. e.g.
   1) Radial distribution system in rural area
   2) Ring main distribution system in urban area
   3) Grid distribution system where continuity of supply is important. e.g telephone exchange, T.V center

Part –II Following factors are to be considered while designing the distributor.

1) **Voltage drop limit:** It should be within permissible limit

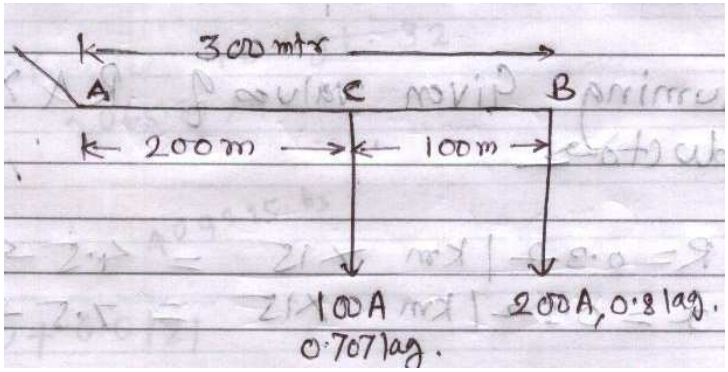
2) **Length of distributor:** There is limit to length of distributor due to voltage drop permissible limit.

3) **Size (cross-section) of conductor: -** Sufficient cross section of conductor

4) **Availability of power: -** It should be available whenever needed

5) **Maintenance:** It should be low & less time consuming.

f) Given data:



R = 0.2 ohm/km X = 0.1 ohm/km $\therefore Z = (0.2 + j0.1)\Omega/km$

Section Impedance:-

$$Z_{AC} = \frac{200}{1000}(0.2 + j0.1)$$ ---------- **(1/2Marks)**

$$Z_{AC} = 0.04 + j0.02$$

$$Z_{AC} = 0.0447 \angle 26.57^0 \ ohm$$ ---------- **(1/2Marks)**

$$Z_{CB} = \frac{100}{1000}(0.2 + j0.1)$$

$$Z_{CB} = 0.02 + j0.01$$

$$Z_{CB} = 0.022 \angle 26.57^0 \ ohm$$ ---------- **(1/2Marks)**

Section Current:

Given, I_C = 100A, 0.707 lag

$$100 \angle -45^0$$

$$70.71 - j\,70.71 \ Amp$$ ---------- **(1/2Marks)**

Given, I_B = 200A, 0.8 lag

$200\angle -36.87^0$

$160 - j120$ *Amp* ---------- **(1/2Marks)**

Section Current: $I_{CB} = I_B$

Section Current: $I_{AC} = I_C + I_B$

= (70.71-j70.71) + (160-j120)

= 230.71-j190.71

= 299.3282 $\angle -39.5778$ *Amp* ---------- **(1/2Marks)**

Voltage drop in section CB:-

= I_{CB} X Z_{CB} ---------- **(1/2Marks)**

= $(299.3282\angle -39.5778)(0.02236\angle 26.565)$

= $6.69\angle -13.01$ *Volts*

= $6.5182 - j1.5060$ *Volts* ---------- **(1/2Marks)**

Q.3 Attempt any Two of the following **16 Marks**

a) Given data:

m= 0.11KV **(Give stepwise Marks as mention below)**

i) Line to neutral voltage:-

$V_3 = V_1 (m^2 + 3m + 1)$ ---------- **(1Mark)**

$15 = V_1 (0.11^2 + 3x0.11 + 1)$

$$V_1 = \frac{15}{(0.11^2 + 3 \times 0.11 + 1)}$$

V_1 = 11.1765 KV ----------**(1Mark)**

$V_2 = V_1 (1 + m)$ ---------- **(1Mark)**

$V_2 = 11.1765\ (1 + 0.11)$

$V2 = 12.4059\ KV$ ---------- **(1Mark)**

∴ Voltage across string = $V_{ph} = V_1 + V_2 + V_3$ ---------- **(1Mark)**

= 11.1765 + 12.4059 + 15

V_{ph} = 38.5824 KV ---------- **(1Mark)**

ii) String efficiency:-

$$\text{String } \eta\% \equiv \frac{Vph}{n \times V_3} \times 100$$ ---------- **(1Mark)**

$$\text{String } \eta\% \equiv \frac{38.5824}{3 \times 15} \times 100$$

$$\text{String } \eta\% \equiv 85.73\%$$ ---------- **(1 Mark)**

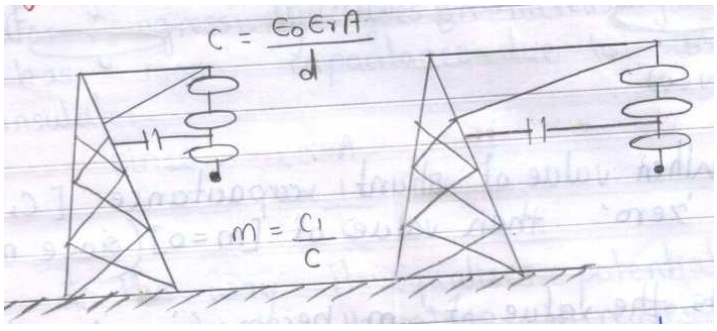
b) State the methods of improving string efficiency and explain briefly all the methods with neat sketches. (Method- 4 Marks & each explanation - 1Marks)

The Methods of Improving String Efficiency:-

1) By reducing value of 'm' or ('k') by using longer cross arm.
2) By Making of 'm' or ('k') equal to zero
3) By grading Insulator.
4) By Using guard ring.

Explanation:-

1) By reducing value of 'm' or ('k') by using longer cross arm:-

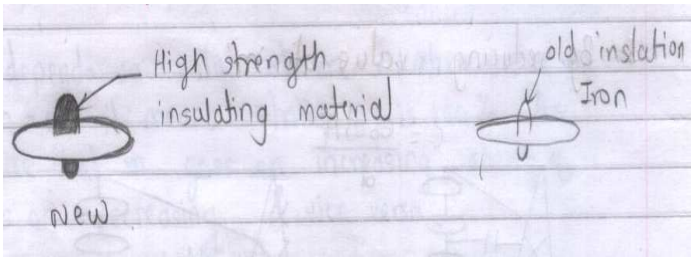


or equivalent diagram

The value of 'm' can be decreased by reducing value of shunt capacitance (C_1) since $m = C_1/C$.

In order to reduce value shunt capacitance (C_1) distance of string of insulator from tower must be increased. i.e by using longer cross arm. Due to this value of shunt capacitance (C_1) reduces.

2) By Making of 'm' or ('k') equal to zero:-

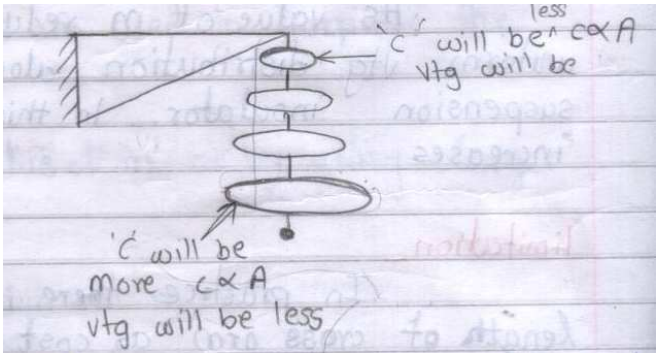


or equivalent diagram

If an insulating material or any non conducting material of high strength is used for connection between two disc insulators in a string instead of using steel part.

Than value of Shunt Capacitance (C1) becomes Zero, therefore value of 'm' becomes zero (since m = C_1/C) So string efficiency becomes 100%.

3) By grading Insulator :-

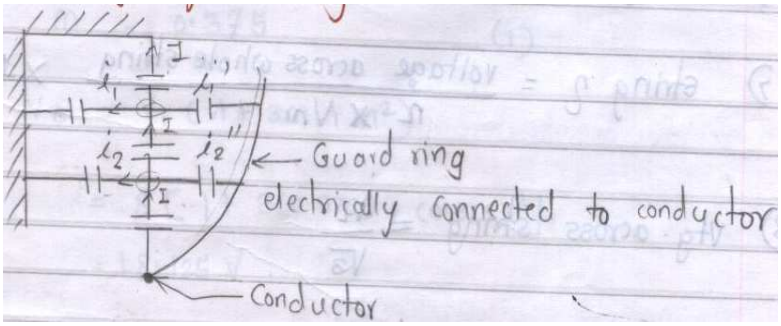


or equivalent diagram

In this method, disc insulators of different dimensions are so selected that each disc has different capacitance. The assembly in the string of suspension insulator is made in such a way that the top unit insulator has less dimensions. (Less capacitance) ($C \propto A$) and dimensions of insulators progressively goes on increasing i.e bottom unit has maximum capacitance due to large dimensions of insulators.

In this way it equalizer potential distribution across the string and therefore increases string efficiency.

4) By Using guard ring :-



or equivalent diagram

Guard ring is a metal ring electrically connected to conductor and surrounding the bottom insulator.

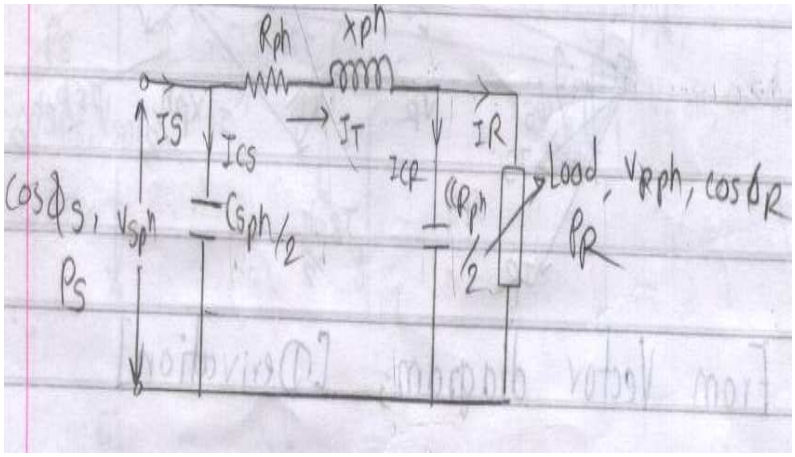
Due to guard ring leakage current through all discs in a string is same.

So, we will get uniform voltage distribution along the string of suspension insulator, In this way string efficiency increases.

c) Draw the neat circuit diagram of medium transmission line with π method. Draw the vector diagram. What is the difference between nominal T and nominal π method?

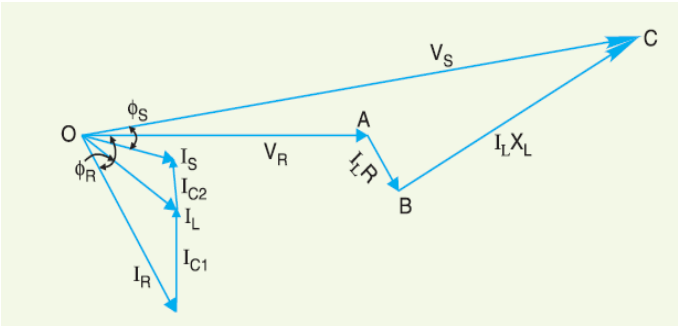
(Figure-3 Marks, Vector diagram-3 Marks & difference for any two point- 2 Marks)

Circuit Diagram Nominal π (pi) Network: - ---------- (3Marks)



or equivalent diagram

Vector diagram of π network for: ---------- (3Marks)



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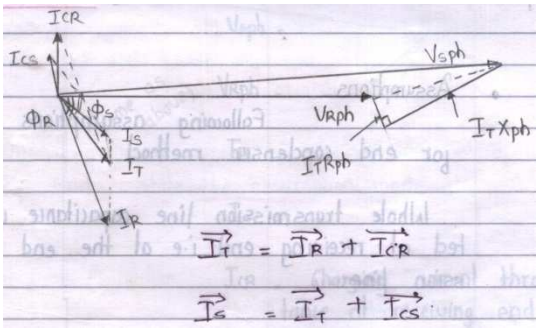
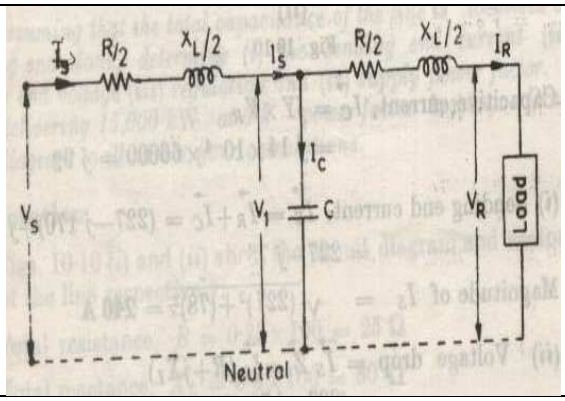
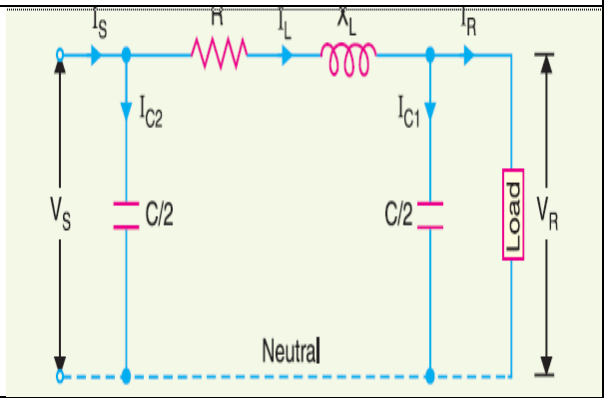


or equivalent vector diagram

Difference :(Any Two points are expected):

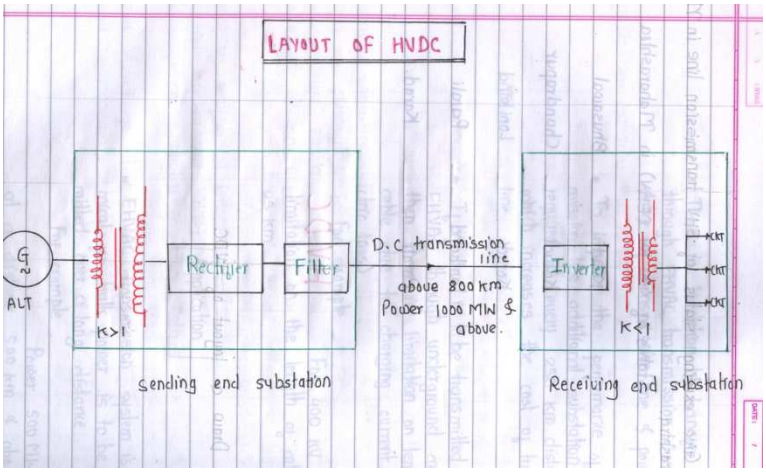
S.No	Nominal T Method	Nominal π Method
1	It is assume that line capacitance is connected at centre of transmission line	It is assumed that capacitance of transmission line is divided into half of the line capacitance is connected at receiving end & half of capacitance is connected at sending end.
2	It is assume that half of the resistance & reactance per phase are divided in either side of capacitance.	It is assumed that transmission line resistance & reactance per phase is connected in between two half transmission line capacitance
3	Shape of equivalent circuit is like letter 'T' hence its name is nominal 'T' method	Shape of equivalent circuit is like letter 'π' hence its name is nominal 'π' method
4		

Q.4. Attempt any Two of the following **16 Marks**

a) Draw the neat sketch of H.V.D.C transmission system. State its three important advantages and limitations

(Diagram- 5 Marks, Advantages-1/2 Marks & Limitations-1/2 Marks for each point)

Neat sketch of H.V.D.C transmission system:



or equivalent diagram

Advantages of HVDC Transmission System :- (Any three expected)

1) The basic D.C transmission line requires only 2 Conductor. (+ ve & - Ve) and if ground is used as a return path, then only one conductor is sufficient.
2) If ground is used as return path, then only 2 conductors are sufficient for double circuit.
3) As number of conductor required are less, so load on tower is less. This make Tower design simple and lighter.
4) No intermediate substation is required like HVAC transmission line.
5) Due to above advantages, Cost of transmission line per KM is less.
6) Skin effect is absent.
7) No proximity effect.
8) Less radio interference.
9) No Ferranti effect.
10) Low corona loss.
11) Copper loss is less.

12) As effect of L & C is absent and value of DC resistance of conductor is less, so voltage drop in transmission line is less.
13) Voltage regulation is better than HVAC transmission line.
14) There is no need of reactive power compensation.
15) Voltage control easy for long distance HVDC transmission line.
16) HVDC line has more stability than HVAC.
17) There is no limit for transmission of power.

Limitations of HVDC transmission Line :- (Any three expected)

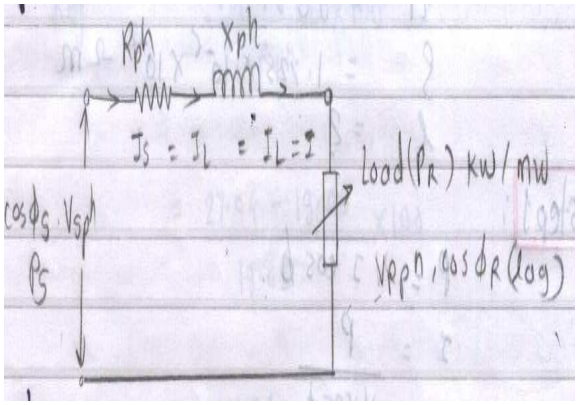
1) It is difficult to step up and step down DC voltage like AC voltage.
2) Special cooling arrangements are necessary for converter, so it increases cost of substation.
3) Converter has little over load capacity.
4) Reliable DC circuit breakers are not available like AC circuit breakers.
5) If ground is used as the return path, then it leads corrosion of underground metallic structure of buildings, pipes, etc. Also causes disturbance in underground communication cable.
6) Cost of DC substation is more than AC substation, due to additional equipment required like rectifier, inverter etc.
7) Maintenance cost of DC substation is more due to additional equipment.
8) Losses in DC substation are more due to additional equipment.

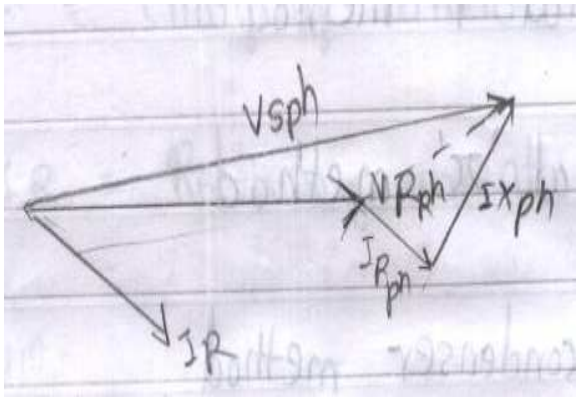
b) Derive an expression for efficiency and regulation of short transmission line for lagging power factor. (Give stepwise marks as per below)

Assumption:

While calculating the performance of short transmission line, effect of the capacitance is not considered because distance & voltage of transmission line is less, so effect of capacitance is negligible.

(Figure-3 Marks)





or equivalent vector diagram

Where, ---------- **(1 Mark)**

V_{Sph} = Sending end voltage per phase, V_{Rph} = receiving end voltage per phase

Cos $Ø_S$ = sending end power factor, Cos $Ø_R$ = receiving end power factor (lagging)

$I_S = I_T = I_L = I$ = Load current,

R_{ph} = Resistance per phase transmission line,

X_{ph} = Reactance per phase transmission line, P_R= Receiving end power

Calculation: (Derivation from phasor diagram)

Sending end voltage = VR +I (R_{Ph} Cos $Ø_R$ + X_{Ph} Sin $Ø_R$)

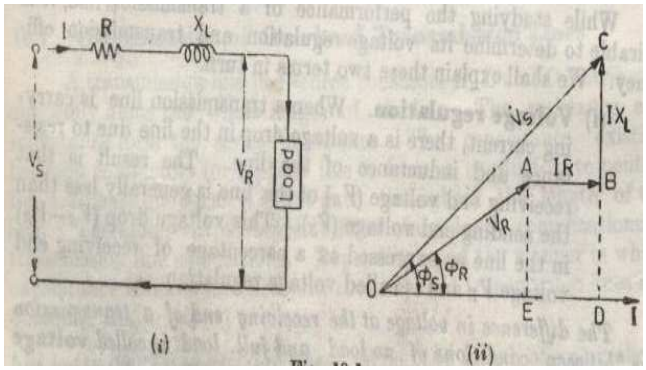
Sending end Power factor = $\frac{V_{R\,Ph}Cos\phi R + IR_{Ph}}{V_{S\,Ph}}$

% Regulation = $\frac{V_{S\,Ph} - V_{R\,Ph}}{V_{R\,Ph}} \times 100$ ---------- **(2 Marks)**

% Efficiency = $\frac{P_R}{P_R + 3I^2R_{Ph}} \times 100$ *for* $3-Phase$ **OR**---------- **(2 Marks)**

% Efficiency = $\frac{P_R}{P_R + I^2R_T} \times 100$ *for* $1-Phase$

OR



or equivalent diagram ----- **(3 Marks)**

Let, I = Load current, R= Loop resistance i.e resistance of both conductors---- **(1 Mark)**

X_L = Loop reactance, V_R = receiving end voltage

Cos $Ø_R$ = receiving end power factor (lagging) V_S = Sending end voltage

Cos $Ø_S$ = sending end power factor

The vector diagram of the line for lagging load power factor is shown in figure.

From the right angled triangle ODC, we get,

$$(OC)^2 = (OD)^2 + (DC)^2 \text{ or}$$

$$V_S^2 = (OE+ED)^2 + (DB+BC)^2$$

$$= (V_R Cos\phi_R + I\,R)^2 + ((V_R Sin\phi_R + I\,X_L)^2$$

$$V_S = \sqrt{(V_R Cos\phi_R + I\,R)^2 + ((V_R Sin\phi_R + I\,X_L)^2}$$

$$\% \text{ age Voltage Regulation} = \frac{V_S - V_R}{V_R} \times 100$$ ---------- **(2 Marks)**

Transmission efficiency:-

$$Transmission\ \ Efficency = \frac{Output}{Input}$$

$$\eta_T\,\% = \frac{Output\ (P_R)\ (Load(power)\ at\ reciving\ end)}{Output\ (P_R) + Total\ losses} \times 100$$ -------- **(2 Marks)**

OR

$$\textbf{\% Efficiency} = \frac{output\ \ power}{output\ \ power + total\ copper\ losses} \times 100$$

c) Given Data: **(Give stepwise marks as per below)**

$$Z = 0.02\,\Omega + j0.04\,\Omega$$

To find section impedance:

$$Z_{AB} = \frac{200}{600}(0.02 + j0.04)$$ ---------- -------- **(1/2Marks)**

$$Z_{AB} = 6.6666 \times 10^{-3} + j\ 0.013333\ \Omega \quad = 0.0149\ \angle 63.4346\ \Omega$$ ---- **(1/2Marks)**

Calculate Section Current:

$$I_D = 50A \; at \; 0.6 \; lag$$

$$I_D = 50 \angle -53.1301^0$$ ---------- **(1/2Marks)**

$$I_D = 30 - j\,40\; A$$

Given $I_C = 50\; A \; at \; 0.8 \; lag.$

$$= 50\angle -36.87^0$$ ---------- **(1/2Marks)**

$$I_C = 40 - j\,30\; A$$

Given $I_B = 50\; A \; at \; unity$

$$= 50\angle 0^0$$ ---------- **(1/2Marks)**

$$I_B = 50 - j\,0\; A$$

To calculate the section current:

$$I_{CD} = I_D$$

$$I_{BC} = I_C + I_D$$ ---------- **(1/2Marks)**

$$I_{BC} = (40 - j30) + (30 - j40)$$

$$I_{BC} = 70 - j\,70\; A$$

$$I_{BC} = 98.9949 \angle -45^0\; A$$ ---------- **(1/2Marks)**

$$I_{AB} = I_B + I_C + I_D$$

$$I_{AB} = I_B + I_{BC}$$

$$I_{AB} = (50 - j0) + (70 - j70)$$

$$I_{AB} = 120 - j70$$

$$I_{AB} = 138.9244 \angle -30.256^0$$ ---------- **(1/2Marks)**

Calculate Voltage drop: $CD\,(V_{CD})$

$$V_{CD} = I_{CD} \times Z_{CD}$$ ---------- **(1/2Marks)**

$$= (50\angle -53.130^0)\,(0.0149\angle 63.4349^0)$$

$$= 0.645\angle 10.2474$$

$$V_{CD} = 0.6347 + j0.1147$$ ---------- **(1/2Marks)**

Calculate Voltage drop Section A_B:

$$V_{AB} = I_{AB} \times Z_{AB}$$

$$= (138.9244 \angle -30.256^0) \times (0.0149 \angle 63.4346^0)$$

$$= 2.0699 \angle 33.1786$$

$$V_{BC} = 1.7324 + j1.1327 \quad volt$$ ---------- **(1/2Marks)**

Voltage drops in section BC (V_{BC}):

$$V_{BC} = I_{BC} \times Z_{BC}$$

$$= (98.9949 \angle -45^0)\ (0.0149 \angle 63.4349^0)$$

$$= 1.475 \angle 18.4349$$

$$V_{BC} = 1.3993 + j0.4664 \ volt$$ ---------- **(1/2Marks)**

Total Voltage Drop:-

$$= V_{BC} + V_{CD} + V_{AB}$$ ---------- ---------- **(1/2Marks)**

$$= (0.6347 + j0.1147) + (1.3993 + j0.4664) + (1.7324 + j1.1327)$$

$$= 3.7664 + j1.7138\ V$$

$$= 4.1379 \angle 24.46^0\ V$$ ---------- **(1/2Marks)**

Voltage at far end (V_D) = V_A – Total voltage drop

= (250+j 0) – (3.7664+ j1.7138)

= 246.2336- j 1.7138

= 246.2395 $\angle$ -0.3987^0 volt---------- **(1Mark)**

Q.5. Attempt any Four of the following **16 Marks**

a) Compare outdoor and indoor substation on the basis of: i) Space required ii) fault location iii) Capital cost iv) Operation and maintenance **(Each point -1 Mark)**

S.No	Outdoor Sub-station	Indoor sub-station
i	**Space Required :**	
	Space required is more	Space required is less.
ii	**Fault location**	
	Fault location locates easy.	Fault location locate difficult.
iii	**Capital cost**	
	Capital cost is less.	Capital cost is high.

iv	Operation and Maintenance	
	Operation is not safe in rainy season and Maintenance is more.	Operation is easy/safe in rainy season and Maintenance is less.

b) State four factors that are to be considered while designing a feeder for distribution

(Each factor -1 Marks)

Following factors are to be considered while designing the Feeder. (Any four point expected)

1) **Current carrying capacity of conductor:-** Conductor should have high current carrying capacity
2) **Need:** Depending upon application distribution system should be selected. e.g.
   1) Radial distribution system in rural area
   2) Ring main distribution system in urban area
   3) Grid distribution system where continuity of supply is important. e.g telephone exchange, T.V center
3) **Availability of power:** It should be available whenever needed
4) **Maintenance:** It should be low & less time consuming.

c) Why the load power factor should be considered while designing the A.C distributor?

State the importance of load power factor (Reason-2 Marks & Importance-2 Marks)

Note: In this questions credit may be given by judgment on part of examiner of relevant answer based on candidate understands.

Reason:-

The load power factor should be considered while designing the A.C distributor **because** Cross section of conductor (distributor) increases since cross section of conductor (distributor) $\alpha\, I\, \alpha 1/(pf)$ **OR** As power factor reduces current increases, cross section of conductor (distributor) increases. Hence its cost increases.

Important of power factor for electric supply company: (Any Two points expected 1 Mark each)

i) P.F. increases current reduce so, cross section of conductor decreases hence its cost is reduces.

ii) P.F. increases current reduce so, cross section of conductor decreases hence weight decreases. So design of supporting structure becomes lighter.

iii) Copper losses Decreases, Hence transmission efficiency increases.

iv) Voltage drop reduces, hence voltage regulation becomes better

v) Handling capacity (KW) of each equipment increases as p.f. increases.

vi) Less capacity (KVA) rating of equipment required so capital cost decreases.

vii) Cost per unit (KWH) decreases.

d) State the requirements of a distribution system.

Following are the different Requirements of good distribution system :- (Any Four requirement expected-1 Mark each)

a) Design layout: - It should be simple in design.

b) Initial Cost: - It should be less and also time required for completion of work should be less.

c) Time require for completion : Should be less

d) Maintenance: - In should be easy, less costly and time required for maintenance should be less.

e) Reliability: - It should have high reliability to maintain supply.

f) Voltage fluctuation: - It should be less and should be within permissible limit.

g) Availability of power: - Power must be available to all consumers on demand that they may require from time to time.

h) Stability: - Fault on nearest distribution system should not affect stability of existing distribution system.

e) Which are the cable laying methods? Explain any one method in brief.

(Methods of laying-2 Marks & Explanation-2 Marks)

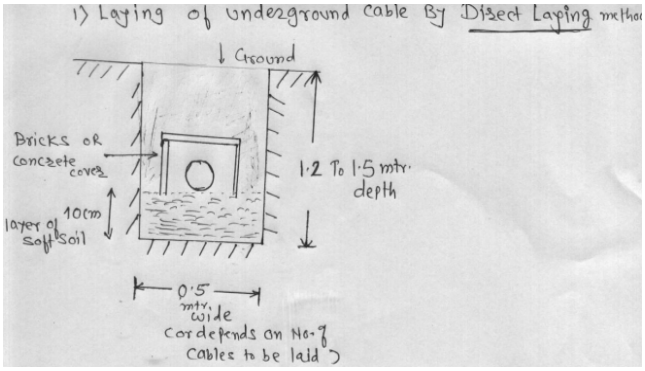
Following are the different methods of Laying of under- ground cable:- (Any two expected)

1. Direct laying cable
2. Draw- in system

3. Solid System
4. Cable laid in tray

Explanation: - (Any one expected) (Explanation-1 Mark & figure-1 Mark)

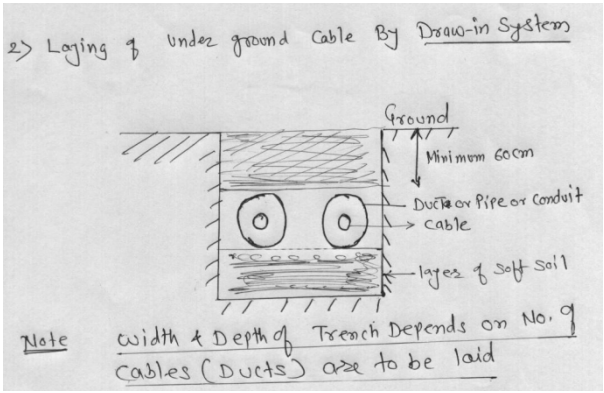
1) Direct laying Cable:



or equivalent diagram

1. For laying of a cable trench about 1.5m deep and 0.5m wide is made along the cable route.
2. A layer of 10 cm thickness of soft soil is spread throughout the cable route in trench.
3. The cable is laid on this soft soil (bed)
4. A wall of bricks (concrete cover) is provided on either side or top of cable along the length of cable for better mechanical protection.
5. Another layer of soft sand, about 10 cm thickness is spread throughout its cable length.
6. Refill the remaining trench with the help of remaining soil up to ground level.
7. While crossing roads (public-crossing) cable is laid through cement pipe or DWC pipe, instead of bricks for better mechanical protection.
8. When more than 1 cable is to be laid in the same trench, then minimum 30 cm spacing is provided between 2 cables and gap is filled by sand.
9. The spacing is kept between 2 cables to reduce the effect of mutual heating and also fault occurring on one cable does not damage the adjacent cable.
10. Only armored cables are used in this method.

2) Draw in cable laying System:



or equivalent diagram

1. A trench of minimum 60cm deep is made along with cable route.
2. Width of trench depends on number of conduits to be laid.
3. Separate pipes are provided for each cable.
4. Spacing between 2 cables (conduit) is between 25 cm to 75 cm.
5. Diameter of pipe is 2 to 3 cm, greater than cable diameter for easy handling of cable.
6. Pipe used may be cement pipe, DWC pipe or ducts of glad stone are used.
7. For Maintenance and other cable work, man-holes are provided at suitable distance.
8. Size of man-holes should be large enough to allow a person to enter into duct without difficulty.
9. Unarmored cables are used in this type.

f) List various causes of cable failures. State which is most generally observed cause of cable failure. **(Any three Causes- 3 Marks & Reason- 1 Marks)**

List & explain the causes of cable failures:- (Any three causes expected-1 Mark Each)

1. Cable may fail due to continuous over loading.
2. Cable insulation may fail due to rise in temperature.
3. Cable may fail if it is used for high voltage instead of voltage for which it is designed. e.g. 11 KV cable if used for 22 KV then cable insulation will fail.
4. Cable may fail due to continuous water just near the cable.
5. Cable may fail due chemical action in soil.

6. Due to continuous vibrations layer of metallic (lead) sheath may crock due to these there are chances of failure of cable.
7. Due to rough handling of cable during laying of cable there will be mechanical through insulation if may causes failure.
8. If raw material used for manufacturing of cable if poor quality was then cable it was poor quantity then cable may failed.
9. Cable may fail due to aging effect.

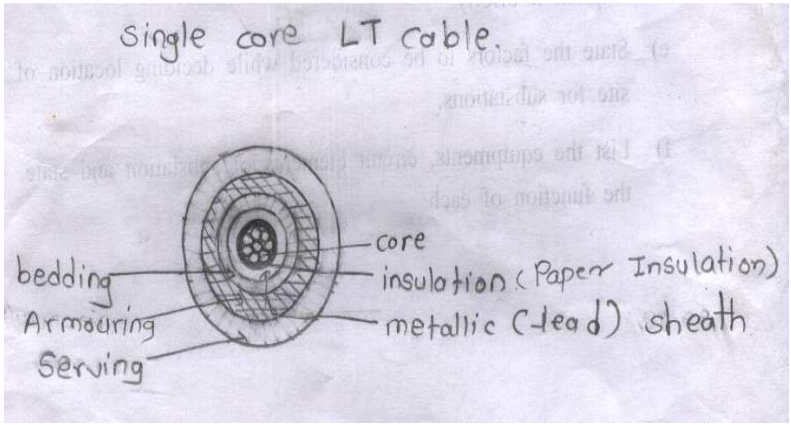
Most generally observed cause of cable failure. (Any two are expected)

1. Cable may fail due to continuous over loading.
2. Cable insulation may fail due to rise in temperature.
3. Cable may fail due to continuous water just near the cable.
4. Due to continuous vibrations layer of metallic (lead) sheath may crock due to these there are chances of failure of cable.
5. Due to rough handling of cable during laying of cable there will be mechanical through insulation if may causes failure.

Q.6 Attempt any Four of the following **16 Marks**

a) Draw the neat sketch of single core low tension cable and label the various parts.

Neat sketch of single core low tension cable:- **(Sketch-2 Marks & label-2 Marks)**



or Equivalent fig.

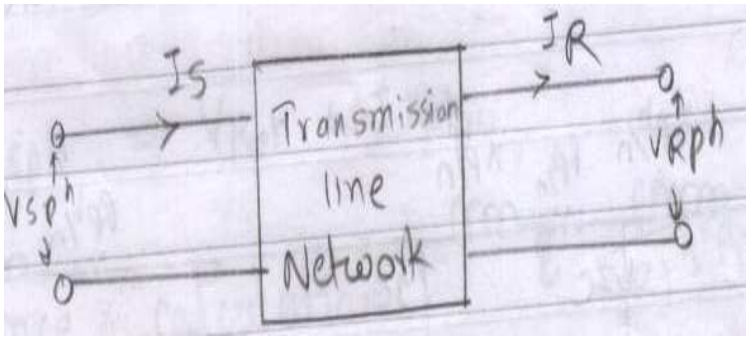
b) Compare underground cable with overhead line. (Any four point expected-1 Mark Each)

S.No	Points	Underground cable	Overhead line
1	Capital cost	More	Less
2	Erecting cost	More	Less
3	Time require for completion of work	More	Less
4	Flexibility	No flexibility	More flexibility
5	Future expansion in voltage level	System voltage cannot be increased	System voltage can be increased easily
6	Overload capacity	Less	More
7	Chances of fault	Less	More
8	Fault finding	Difficult	Easy
9	Reliability	More	Less
10	Chances of accident	No chances of accident	More
11	Safety	More	Less
12	Radio interference	Not produces radio interferences	Produces radio interferences
13	Short cute route	possible	Difficult
14	Theft Of energy	Less possibility	More possibility
15	Voltage drop	less	More
16	Power factor	More	Less
17	Appearance	Very good	Not good
18	Application	Short distance transmission & distribution, urban areas, thickly populated area, taking supply in water (ocean) with help of marine cable.	For Long distance transmission, For distribution rural and sub urban area.

c) Write down sending end voltage, sending end current by using generalized circuit constants of a transmission line. Mention two important points about it.

(Voltage equation--1 mark, Current equation-1 Mark & Each point of important-1 Mark)

A transmission line is two port networks. Two input terminals where power enters the network & two output terminals where power leaves the network.



or equivalent diagram

The input voltage, sending end voltage (V_S) & sending end current of a 3-ph transmission line can be expressed as

$$\vec{V}_{SPh} = \vec{A}\,\vec{V}_{Rph} + \vec{B}\,\vec{I}_R$$ ----------sending end voltage

$$\vec{I}_S = \vec{C}\,\vec{V}_{Rph} + \vec{D}\,\vec{I}_R$$ ----------sending end current

$$A = \frac{V_{S\,ph}}{V_{R\,ph}}$$ ---------- Voltage Ratio

$$B = \frac{V_{S\,ph}}{I_R}$$ ---------- Impedance in ohm

$$C = \frac{I_S}{V_{R\,ph}}$$ ---------- Conductance

$$D = \frac{I_S}{I_R}$$ ---------- Current Ratio

Two important points:-

For a Given transmission line:

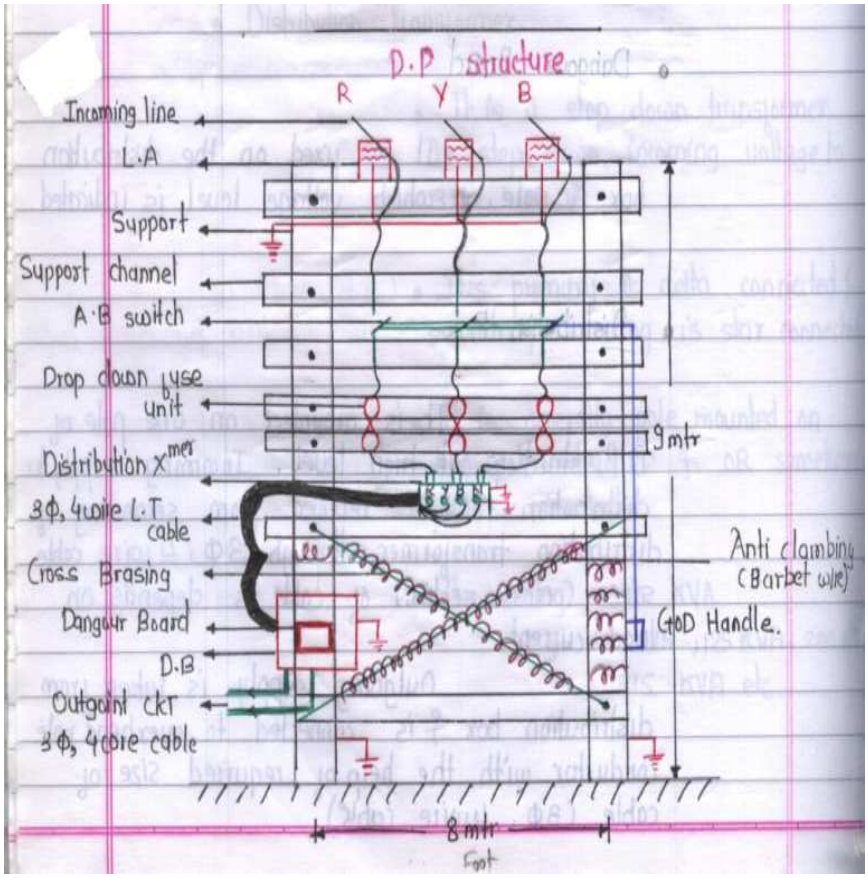
$$\vec{A} = \vec{D}$$

$$\vec{A}\,\vec{D} - \vec{B}\,\vec{C} = \vec{1}$$

d) Draw neat connection diagram of a pole mounted substation. Explain it briefly.

(Figure- 3 Marks & Explanation-1 Marks)

Connection Diagram of Pole Mounted Substation:



or equivalent diagram

Explanation:-

1. **Incoming Line (feeder):**

   Incoming line voltage is 11/22/33KV which depends on load on distribution transformer.

2. **Lighting Arrester:**

   Its function is to protect substation against lighting stroke. It is connected in between line and ground at the starting of DTC.

3. **Gang operated vertical air breaker switch or AB Switch/GOD :**

   Its function is to make or break incoming line from distribution transformer whenever required. (e.g at the time of maintenance) It is operated manually from ground level by GOD handle.

4. **Drop Down Fuse:**

It is a fuse wire covered with pipe. Its function is to protect distribution transformer from over current. It is on H.T side. It's name is drop down fuse because when fuse element melts due to over current that time one end of covering pipe drop down & other end of pipe remains hanging, so we can judge that fuse is blow out from ground level.

5. **Distribution transformer:**

Its function is to step down incoming voltage to distribution voltage (3-ph, 440 V). It's primary winding is delta connected and secondary is star connected. It is oil cooled and rating is in KVA e.g 63KVA, 100KVA, 163/200 KVA and 315 KVA etc

It is either pole mounted/plinth mounted now a day's dry types transformer are used when DTC is in load.

6. **Cross brassing:**

It is used to support D.P structure..

7. **Anticlambing device:**

Barbed wire is wound around the pole upto 1.4 m height from ground level & along the cross brassing to prevent easy climbing & to protect DP structure from animals.

8. **Danger Board:**

It is fixed on pole & distribution box. It is board which indicates danger signal. Incoming voltage level is indicated on danger board. e.g. 11KV, 22KV and 33KV danger board

9. **Distribution Box:**

It is fixed on pole. Output from secondary of transformer is given to distribution box through cable. It is consists of bus bar & HRC fuses for various outgoings circuits

10. **Earthing:**

Following points of DP structure are well earthed with the help of 8 SWG GI wire to pass the leakage current towards ground. (L.A, transformer body, transformer neutral, distribution box, both pole and all fabrication supporting channels)

e) State the factors to be considered while deciding location of site for substation.

Following factors should be considered while deciding location of site for sub-station:-

(Any four factor are expected- 1 Mark each factor)

1. **Near load centre :**
   Sub-station should be located near load centre to reduce cost of Transmission and distribution lines and to reduce losses**.**
2. **Easy access for transmission Line :**
   There should be easy access for incoming and outgoing line.
3. **Easy access towards sub-station :-**
   There should be easy access towards sub-station for transportation of equipments and manpower etc.
4. **Space available :**
   Sufficient land should be available for installation of sub-station and future expansion.
5. **Atmospheric conditions :**
   Atmospheric condition in the area of sub-station should be clean and dry.
6. **Cost of land :**
   Cost of land should be less to reduce capital cost of sub-station.
7. **Municipal restriction :**
   Where municipal restriction will not take any objection for required type building of sub-station
8. **Staff amenities :**
   The site should be such that there essential amenities must be available to staff like quarters, drinking water, schools, hospital, public transportation, communication etc.
9. **Hard land :**
   To reduce construction cost of building and for better foundation equipments land should be hard**.**
10. **Area free from earthquake :**
    To avoid damage to sub-station area should be free earth quake.

f) List the equipments, circuit elements of substation and state the function of each.

List the equipments, circuit elements of substation & their function: (Any four expected-1 Mark each)

i) Busbar: - Bus bar is common conductor to which incoming & outgoing lines are connected. It is generally made from ACSR conductor. Cross section of conductor depends on current. In Substation, there are three bus bar:

1) Incoming bus bar (33KV/66KV)

2) Station bus bar (11 KV) 3) Outgoing bus bar (11KV)

ii) Power Transformer:- Its function is to step down the incoming voltage to outgoing voltage without change in frequency.

iii) Auxiliary Transformer: - Its function is to step down the input voltage (11 KV) to distribution voltage (3-ph, 4wire, 440V) to give supply to control room, area lighting, staff quarters etc,

iv) Lighting Arrester: - It is provided for protection of substation, transformer against lighting stroke

v) Earth switch: - It is used for safety purpose. It is closed during maintenance to discharge capacitor.

vi) Isolator: - Its function is to isolate the circuit whenever required. e.g at the time of maintenance.

vii) Circuit Breaker: - It is protective device. It open or break the circuit whenever there is fault & protect the equipment.

viii) Relay: It sense that faults & gives signal to clipping c circuit of C.B to open.

ix) Instrumental Transformer (CT & PT):- C.T & P.T are used for measurement of electrical quantities also C.T. is used for protection purpose.

x) Horn Gap Fuse: - It is provided to primary side of transformer for protection against over current

xi) Control Room: - It is construction near switchyard in which control panel is installed from which various circuits are controlled by operator.

xii) Control Panel: - Control panel consists of different types of relays to detect different types of faults.

xii) PLCC (Power Line carrier communication):- It is used for direct communication between substations to generating station also between two major substations. For this purpose same transmission line carries communication signal.

xiii) Series Reactor: - To limit the short circuit current

xiv) Shunt Reactor: - It supplies lagging KVAR to control voltage of transmission line.

xv) Series Capacitor: - It supplies leading KVAR

xvi) Shunt Capacitor: - For power factor improvement.

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