Important suggestions 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 Attempt any TEN of the following: ----------20 Marks

a) State the standard voltages for following in India. i) Secondary Distribution voltage ii) Primary Distribution System

Answer:-

i) Secondary Distribution voltage: **(1 Mark)**

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

ii) Primary Distribution System: **(1 Mark)**

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

b) State any two reasons, why three phase A.C system is preferred for power transmission.

Answer:-

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

1. There is considerable saving in conductor material (volume of conductor material)
2. This system is convenient & efficient.
3. Power delivered by a single phase system fluctuates whereas for three phase system power delivered to the load is the same at any instant.

c) State any eight components of transmission line.

Answer:- Following are the some components of transmission Line:

(Any Eight components are expected points each point 1/4 Mark)

1. Overhead conductor
2. Supporting structure (pole)
3. Line insulator
4. Stay set (Stay wire of 7/8 or 7/10 SWG)
5. Two Pin Cross arm
6. Four pin cross arm
7. 'V' Cross arm
8. Top pin support
9. Different types of Clamp (A-type, B-Type)
10. Guarding wires
11. Bird guards
12. Continuous earth wire
13. Vibration damper
14. Jumpers
15. Lighting arrestors
16. Cables
17. Fuses and Isolating switches

d) State any four insulating material used for cable.

Answer:- Following are the some insulating material used for cable.

(Any Four material are expected each point 1/2Mark)

1. Butyle Rubber
2. Silicon Rubber
3. VIR (Vulcanized Indian Rubber)
4. Styrene Rubber
5. Gutta-Percha (It is similar to rubber)
6. Silk and Cotton
7. Enamel insulation
8. Impregnated Paper
9. Varnished cambric (Empire tape)
10. PVC (Polyvinyl Chloride)
11. Polyethene
12. XLPE (Cross- linked polyethelene)
13. Neoprene

e) State any two points, how proximity effect can be reduced?

Answer: - Proximity effect can be reduced:- (Any Two points are expected each point 1 Mark)

1. By increasing the distance between two conductors i.e. by using longer cross arm
2. By using overhead transmission system instead of underground. Because in cable distance between two conductor is less. So proximity effect is more
3. Effects are negligible for small size, small current carrying conductor
4. Use DC transmission system instead of AC transmission system to avoid proximity effect, Since frequency of DC supply is Zero

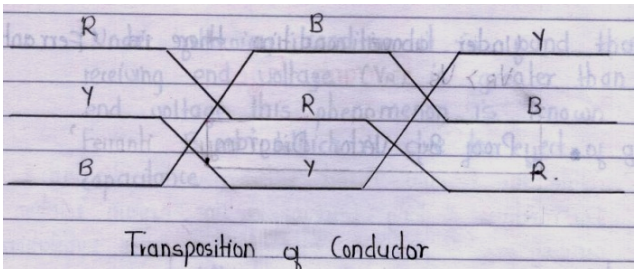
f) What is the meaning of transposition of conductor draw figure?

(Meaning-1, Figure – 1 Mark)

Answer: -

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.

g) State the effect of low P.F. on i) Efficiency of transmission line ii) Regulation of transmission line.

Answer:-

Effect of poor power factor on efficiency :----------(1-Mark)

- When power factor of load reduces current drawn by transmission line increases so copper losses in transmission line increases, hence transmission efficiency reduces.

Effect of poor power factor on voltage Regulation:- ----------(1-Mark)

- When power factor of load reduces current through transmission line increases, so voltage drop in transmission line (due to resistance & inductive reactance) increases so regulation increases. (Become Poor)

h) State two assumptions made while drawing equivalent circuit of nominal 'T' network of medium transmission line.

Answer: - Assumptions: ---------- (1-Mark each assumption)

1. It is assume that line capacitance is connected at centre of transmission line.
2. It is assume that half of the resistance & reactance per phase are divided in either side of capacitance.

i) State any two applications of HVDC transmission system.

(Any Two applications are expected each point 1 Mark)

Answer: - Following are the different applications of HVDC transmission system:-

1) HVDC is economical to transmit bulk amount of power (1000 MW) & above. Over a long distance (800 Km & above)
2) HVDC is preferred for underground cable transmission as incoming line in megacities.
3) HVDC is preferred for underground cable transmission for crossing long lake, ocean etc.
4) HVDC is preferred for underground cable transmission where atmospheric conditions are too bad for overhead transmission line, e.g. High wind pressure, rainfall etc.

5) Interconnection of two transmission lines having different frequencies is possible through HVDC link.

j) State four components of distribution system.

Answer: -

Following are the different components of distribution system:-

(Any four components are expected each point 1/2 Mark)

1. Feeder (Primary distribution

2. Distribution Transformer (DTC)

3. Distributor (Secondary distribution System)

4. Service mains

k) State four points to be considered while designing the distributor.

Answer:-

Following factors are to be considered while designing the distributor.

(Any four points are expected each point 1/2 Mark)

1) **Voltage drop limit:** It should be within permissible limit (± 6%)

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

3) **Size (cross-section) of conductor: -** Cross section of conductor should be of sufficient current carrying capacity.

4) **Availability of power: -** Power should be available whenever needed (Power must be available to all consumers on demand that they may require from time to time.)

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

l) Write sequence of operation of isolator and circuit breaker while opening and closing.

Answer:-

Sequence of operation of Isolator, C.B. while opening & closing is as below:

- **While Opening:** **(1 Mark)**
  1. Open circuit breaker
  2. Open Isolator
  3. Close earthing switch

- **While Closing:** **(1 Mark)**
  1. Ensure circuit breaker is open
  2. Open earthing switch
  3. Close isolator
  4. Close circuit breaker

Q.2 Attempt any FOUR of the following: ----------16 Marks

a) Study the figure No.1 and answer following questions: i) What is the meaning of part 1? State its voltage level ii) What is the meaning of part 2? iii) What is the meaning of part 3? State its voltage level

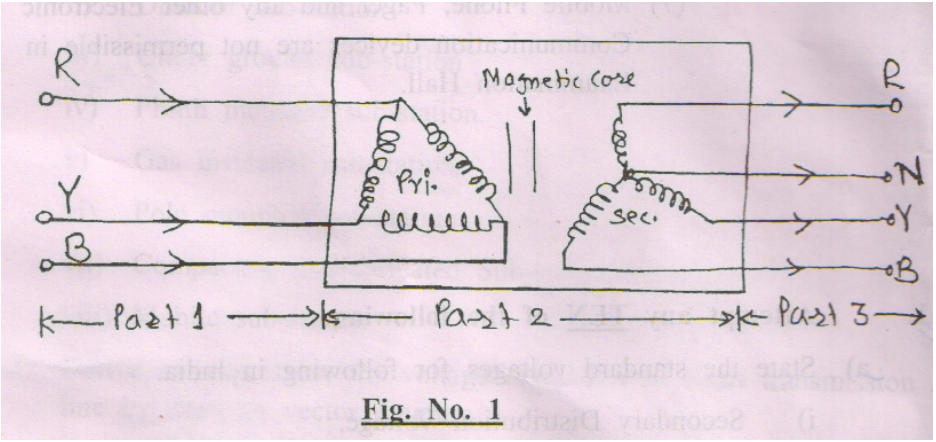


Fig. No. 1

Answer:-

i) The meaning of part 1 = Primary Distribution System **(1.5 Mark)**

State its voltage level = 11 KV or 22 KV or 33 KV

ii) The meaning of part 2 = Distribution Transformer **(1 Mark)**

iii) The meaning of part 3 = Secondary Distribution voltage **(1.5 Mark)**

State its voltage level:

= 3-Ph, 4 Wire, voltage level-3-ph 400V **OR** 440 Volt & 1-ph, 2-Wire voltage-230V

b) Discuss any four disadvantages of bundle conductors.

Answer:-

Disadvantages of Bundle Conductors:

(Any four points are expected each point 1 Mark)

1. It requires additional supporting insulator so cost of supporting insulator increases.
2. Design of supporting structure (tower) becomes heavier when bundle conductors are used so cost of tower increase.
3. It increases ice loading.
4. To connect two sub conductors spacers are required.

c) State eight points, why underground cable is preferred for transmission and distribution in metro Politian cities.

Answer:-

Due to following advantages underground system is preferred in metro Politian cities.-

(Any Eight points are expected each point 1/2 Mark)

1. As cable is underground, there are less chances of faults.
2. As cable is laid underground, there are no chances of accidents.

3. In the urban areas, distance between 2 buildings is very less & mostly all buildings are multi-stored so from safety point of view underground system is preferred.
4. No radio-interference.
5. Short cut roots are possible.
6. Less possibility of theft of energy.
7. Voltage drop is less.
8. More reliability to maintain supply as chances of faults is less.
9. Availability of space is less. so no space is consumed in underground system as against overhead system.
10. Life of insulation is more.
11. Its appearance is good, so it will not spoil the beauty of city due to overhead structure.

d) Compare single circuit and double circuit on following points: i) Number of conductors ii) Reliability to maintain supply iii) Height of supporting structure iv) Design of supporting structure v) Inductance vi) voltage drop vii) Power factor viii) Economics

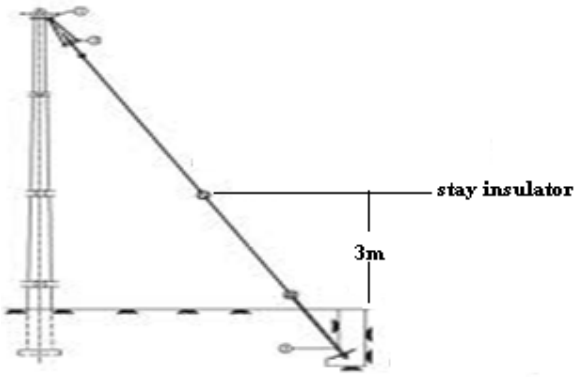
Answer:- **(Each point: 1/2 Mark)**

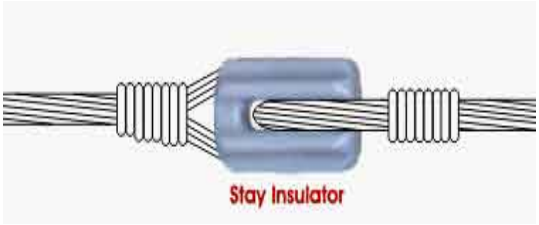
Sr.No	Points	Single circuit	Double circuit
1	**Number of conductors:**	Three Conductors (R-Y-B)	Six Conductors (R-Y-B & R-Y-B)
2	**Reliability to maintain Supply:**	Less	More
3	**Height of Supporting Structure:**	As compare to double circuit it is less. E.g. 220KV-25 meters	As compare to single circuit it is More. E.g. 220KV-double circuit-28 meters
4	**Design of supporting structure:**	Light	Heavy
5	**Inductance :**	More as distance between two conductor is more	Less as distance between two conductor is Less
6	**Voltage Drop:**	More	Less
7	**Power Factor:**	Less	More
8	**Economics:**	It is more expensive	It is most economical & cheaper

e) Draw a neat labeled diagram of stay insulator used in T and D network. State its two functions. **(Neat Diagram: 2 Mark & Function: 2 Mark)**

OR

OR





- **Function of stay insulator:-**

  1) To protect animals, human against shock due to leakage current

  2) It increases strength of stay wire.

f) A string of three unit suspension insulator observed to have voltage distribution on top disc 9 KV, middle disc 12 KV. Find : i) Line voltage ii) String efficiency

V_1= 9KV, V_2= 12KV **(Give stepwise Marks as mention below)**

Answer: - **Ratio of capacitance 'k':-**

$V_2 = V_1 (1+ m)$

$\therefore$ $12 = 9 (1+ m)$

$\therefore$ $12 = 9+ 9m$

$12- 9 = 9m \therefore 3 = 9m$

k = m = 0.333---------- **(1/2 Mark)**

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

$= 9 [(0.333)^2 + (3 \times 0.333) +1]$

V_3 = 18.981 KV ---------- **(1/2 Mark)**

$\therefore$ **Voltage across string =** $Vph = V_1 + V_2 + V_3$

$= 9+12+18.981$

$= 39.981$ KV ---------- **(1/2 Mark)**

i) The line voltage: $V_L = \sqrt{3}\, V_{ph}$

$V_L = \sqrt{3} \times 39.981$

V_L = 69.249 KV---------- **(1 Mark)**

ii) String efficiency:-

String $\eta\% \equiv \frac{Vph}{\eta \times V_3} \times 100$ ---------- **(1/2 Mark)**

String $\eta\% \equiv \frac{39.981}{3 \times 18.981} \times 100$

String $\eta\%$ **= 70.21%.** ---------- **(1 Mark)**

Q.3 Attempt any FOUR of the following: ----------16 Marks

a) State any eight important reasons for adoption of EHVAC transmission.

Answer:-

Following are the important reasons for adoption of EHVAC transmission:

(Any eight point expected- 1/2 Mark each)

Following are the advantages Hence EHVAC Transmission is adopted:

1. As Transmission voltage increases, current decreases**. (as** $\mathbf{I} \alpha \frac{1}{V}$)
2. As current decreases, cross section of conductor decreases. **[as c/s of conductor** α **I]**
3. As cross section of conductor decreases, its weight decreases.
4. As weight of the conductor decreases, design of tower becomes lighter in weight.
5. As current decreases, cross section of bus bar and size of switch gear contact etc. reduces.
6. Due to above advantages, Transmission cost per KM decreases
7. As transmission voltage increases. A current decreases, so copper losses in transmission line reduces**.(as** $Cu.losses \ \alpha \ I^2$ **)**
8. As copper losses reduces, transmission efficiency increases **[as Tr.** $\eta_T \alpha \frac{1}{Cu.loss}$ **]**
9. As current reduces, voltage drop in transmission line reduces. **[As Voltage drop** α $\mathbf{I} \alpha \frac{1}{V}$ **]**
10. As voltage drop in transmission reduces, voltage regulation becomes better (improved).
11. As efficiency and regulation of transmission line gets improved, so performance of transmission line increases
12. As transmission voltage increases power handling capacity of transmission line increases (as P α V^2)
13. Due to high voltage transmission line, successful interconnection of transmission line is possible than low voltage.
14. Generating Stations are generally located away from load centre.

b) State any four electrical properties of insulating material. State the four name of insulating material used for manufacturing T and D line insulator.

(Any four properties: 1/2 Mark each & any four name of insulating material: 1/2 Mark each)

Answer:-

Insulating material should possess following ling properties:

Electrical Properties of insulating material:-

1) It should have high resistance.

2) It should have high breakdown voltage.

3) It should have high dielectric strength.

4) It should have low dielectric constant.

5) It should have low dielectric loss.

6) It should have high relative permittivity.

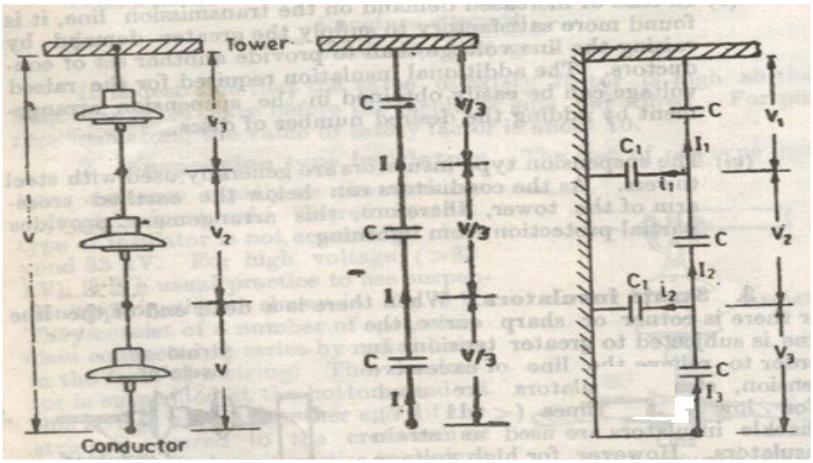
Following are some insulating material:

1. Porcelain
2. Glass
3. Steatite
4. Polymer

c) Derive the mathematic expression of sting efficiency of three phase transmission line having three disc insulators.

Answer:-

String of three suspension insulator & the voltage distribution :- **(1 Mark)**



Or equivalent diagram

Mathematical proof:

Where, C_1 = Shunt capacitance C = Self capacitance

$$m = K = \frac{C_1}{C} \qquad C_1 = mc$$ ---------- **(1/2 Mark)**

Step- I: Applying KCL to node 'A' ---------- **(1 Mark)**

$$I_2 = I_1 + i_1$$

$$V_2\,\omega\,C = V_1\,\omega\,C + V_1\,\omega\,C_1 \qquad But\ ,\ C_1 = mc$$

$$V_2\,\omega\,C = V_1\,\omega\,C + V_1\,\omega\,mc \qquad \therefore\ V_2 = V_1 + V_1\,m$$

$$\therefore\ V_2 = V_1\ (1+m) \text{ ----------} equation - I$$

Step- II: Applying KCL to node 'B' ---------- **(1 Mark)**

$$I_3 = I_2 + i_2$$

$$V_3\,\omega\,C = V_2\,\omega\,C + (V_1 + V_2)\,\omega\,C_1 \qquad But\ ,\ C_1 = mc \quad \& V_2 = (m+1)\,V_1\omega$$

$$V_3\,\omega\,C = V_1\ (1+m)\,\omega C + V_1\,\omega\,mc + V_1\,(1+m)\,\omega\,C$$

$$V_3 = V_1\ (1+m)\ + V_1\ m + V_1\ (1+m)\ m$$

$$V_3 = V_1\ (1+m+m+m+m^2\ )$$

$$V_3 = V_1\ (1+3m+m^2\ ) \quad \text{-----------------------} \quad equation - II$$

$$\therefore\ Volatge\ \ between\ conductor\ and\ earth\ \ (Tower)\ (V_{ph}) = V_1 + V_2 + V_3$$

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

String $\eta\% = \dfrac{Vph}{n \times V_n} \times 100$

Where, n = Number of Disc insulators, Vn = Voltage across disc nearer to conductor

$$\eta\% = \frac{Vph}{3 \times V_3} \times 100$$ ---------- **(1/2 Mark)**

d) State three parameters of transmission line. What is the effect of line parameters on performance of transmission line.? **(Types -2 Mark & Effect-2 Mark)**

Answer:- Following are the of Line parameters of transmission line:

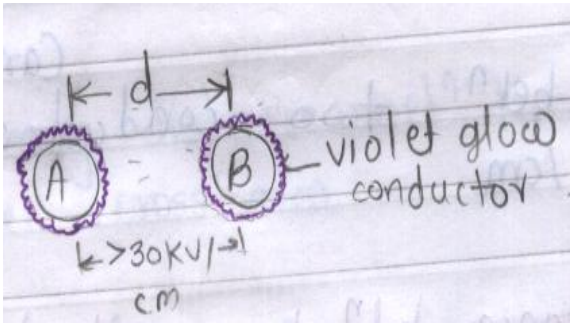
1. Resistance (R)
2. Inductance (L)
3. Capacitance (C)

Following effect on performance of transmission line:

1. Due to resistance (R), voltage drop in transmission line & copper losses in transmission line depends or produces.
2. Due to inductance voltage drop in transmission line depends/ produces.
3. Capacitor draws charging current through transmission line. This charging current produces additional copper losses & voltage drop on transmission line.
4. Due to above reasons, transmission line efficiency & voltage regulation gets affected also power factor of transmission line gets affected.

e) Explain the phenomenon of corona. How corona effect can be reduced. (State any two points). **(Meaning-2 Marks & effect-2 Marks)**

Answer:- **Corona:-**



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

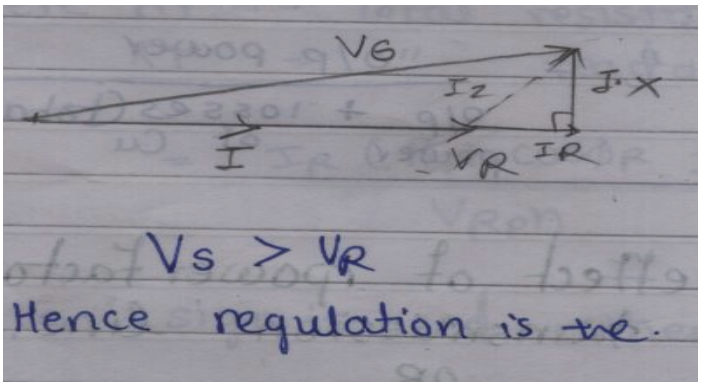
Corona effect can be reduced: (Any two points expected)

1. By increasing distance between two conductor i.e by using longer cross arm.
2. By using larger size(diameter) of conductor e.g./ using ACSR, bundled conductor
3. By using smooth body conductor and hardware.

f) Draw vector diagram for unity. Lagging and leading P.F in transmission line? State its effect on voltage regulation. **(Each Vector Diagram -1Mark & All Effect -1 Mark)**

Answer:-

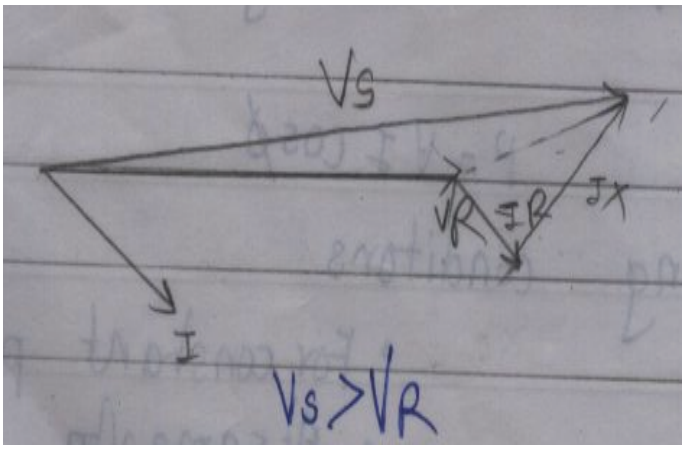
i) Vector Diagram for Unity Power Factor: ---------- **(1 Mark)**



Effect on voltage regulation:

At UPF receiving voltage is less than Sending end hence regulation is positive.

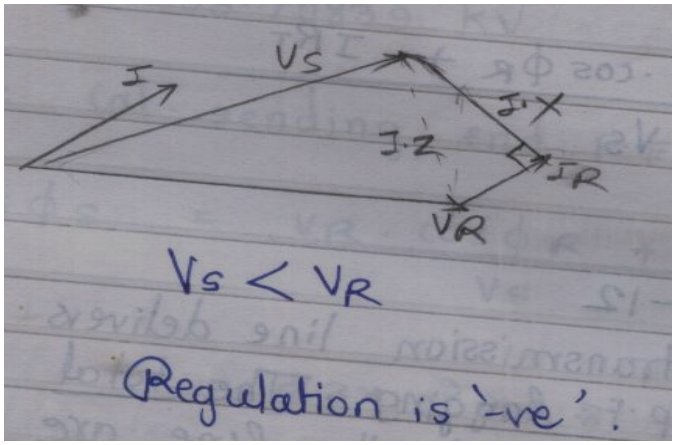
ii)Vector Diagram for Lagging Power Factor: ---------- **(1 Mark)**



Effect on voltage regulation:

At Lagging PF Receiving voltage is less than Sending end hence regulation is positive

iii) Vector Diagram for Leading Power Factor: ---------- (1 Mark)



Effect on voltage regulation:

At Leading PF Receiving voltage is more than Sending end hence regulation is negative.

Q.4 Attempt any FOUR of the following: ----------16 Marks

a) Explain any four factors affecting corona. (Any four factor expected: 1 Mark each)

Answer:-

The Factors affecting corona:-

i) **Magnitude of Voltage :**

If voltage across two conductors is greater than 30 KV/cm, i.e. breakdown voltage of air than corona formation starts. Corona will not start if voltage is below 30 KV/cm

ii) **Distance between two conductor:**

If spacing between two conductors is very large as compare to their diameter than there is no possibility of corona formation. Because value of voltage at which corona occurs increases.

iii) **Size of conductor:**

If size (Cross section) of conductor is more, than magnitude of voltage required to occur the corona increases.

iv) **Condition of conductor & Hardware:**

Rough and irregular surface of conductor and hardware will give more corona than solid, smooth body conductor & hardware.

v) **Atmospheric Condition:**

As corona takes place due to ionization of air so it depends on condition of air so for dry air formation of corona occurs late than in wet air (damp atmosphere condition/ rainy season/thunderstorms/fog air becomes more conductivity)

vi) **Effect of supply Frequency**: Corona loss varies directly as the supply frequency

vii) **Effect of density of air**: Corona loss increases with the decrease in the density of air (The corona loss of transmission line passing through hilly area is higher than that of a similar line in plain due to reduced value of air density at high level /altitude)

b) State the values of generalized circuit constant of A,B, C and D in case of i) 'T' equivalent circuit ii) 'π' equivalent circuit of medium transmission line.

Answer:-

- **Values of ABCD constants T-equivalent circuits of are as bellows: ---------- (2-Marks)**

$$\therefore \mathbf{A} = \mathbf{D} = 1 + \frac{YZ}{2}$$

$$\therefore \mathbf{B} = \mathbf{Z}\left[1 + \frac{YZ}{4}\right]$$

$$\therefore \mathbf{C} = \mathbf{Y} \text{ ohm}$$

- **Values of ABCD constants π equivalent circuits of are as bellows: ---------- (2-Marks)**

$$\therefore \mathbf{A} = \mathbf{D} = 1 + \frac{YZ}{2}$$

$$\therefore \mathbf{B} = \mathbf{Z}$$

$$\therefore \mathbf{C} = \mathbf{Y}\left[1 + \frac{YZ}{4}\right] mho$$

c) A single phase overhead transmission line delivers 5000 kW at 11 KV, 0.8 P.f. lagging. If resistance and reactance per conductor is 0.45 ohm and 0.08 ohm respectively calculate: i) Sending end voltage ii) Transmission efficiency.

Given Data:-

P_R = 5000KW, V_R = 11KV, P.F. = 0.8 lag, R Per conductor =0.45 ohm, X Per conductor = 0.08

Step 1: To calculate current:

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

$I = \dfrac{P}{V\cos\phi}$, $I = \dfrac{5000}{11\times 0.8}$

$I \equiv 568.18\ amp$ **(1/2 Mark)**

Step 2: To calculate value of sin : (1/2 Mark)

$\therefore Cos\phi_R = 0.8 \ \therefore \ \sin\phi_R = 0.6$

To Calculate Total /loop values of R & X

Total resistance R_T = 2R= 0.45× 2=0.90 ohm

Total Reactance X_T = 2X =0.08×2=0.16 ohm

Step 3: To calculate Sending end voltage:

Vs = $V_R + I(R_T\cos\phi_R + X_T\sin\phi_R)$ **(1/2 Mark)**

= $11\times10^3 + 568.18(0.90\times0.8 + 0.16\times0.6)$

= 11463.635 volt **(1 /2Mark)**

Vs = 11.463635 KV

Step 4: To calculate Total Line Losses: (1/2 Mark)

Total Line Losses = $I^2 R_T$

= $(568.18)^2 \times 0.9$

= 290545.66Watt

= 290.54566 KW

Step 5: To calculate Total Transmission efficiency

$\%\eta_T = \dfrac{P_R}{P_R + I^2R_T}\times100$ **(1/2 Mark)**

$\%\eta_T = \dfrac{5000\times10^3}{5000\times10^3 + 290545.66}\times100$

$\%\eta_T = 94.51\%$ **(1/2 Mark)**

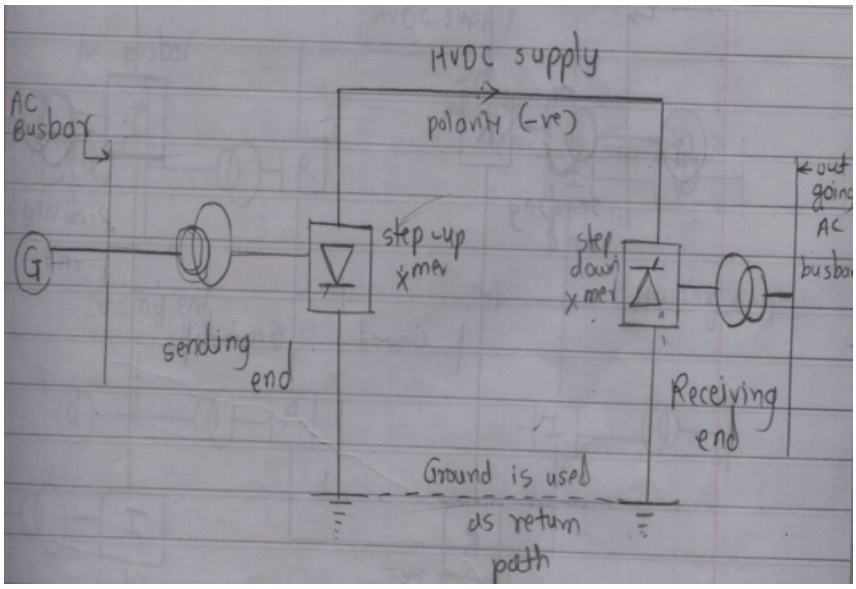
d) Give the classification of HVDC transmission system. Draw layout of monopolar HVDC transmission system.

Answer:-

The different types of HVDC transmission system: **(Any two expected: 1 Mark each)**

1. Monopolar HVDC transmission line (System).
2. Bipolar HVDC transmission line (System).
3. Homopolar HVDC transmission line (System).
4. Back to Back HVDC coupling System
5. Multi-terminal HVDC System

Draw layout of Monopolar HVDC transmission system: **(2 Mark)**



OR equivalent figure

e) Compare HVDC and EHVAC transmission system on the basis of : i) No.of conductors required for double circuit ii) capital cost of substation iii) Ground return iv) Skin effect v) Proximity effect vi) Ferranti effect vii) corona loss viii) String efficiency

Answer: - **(Each point 1/2 mark)**

S.No	Points	H.V.D.C	EHV A.C
1	**Number of conductor required for double circuit**	2 conductors. Ground is used as a return path	6 (R,Y,B & R,Y,B)
2	**Capital cost of S/S**	More	Less
3	**Ground return**	Possible	Not possible
4	**Skin effect**	Absent	Present
5	**Proximity effect**	Absent	Present
6	**Ferranti effect**	Absent	Present
7	**Corona loss**	Less	More
8	**String efficiency**	100 %	Less than 100 %

f) Compare Primary and secondary distribution system on any eight points.

Answer: - **(Any eight points expected: 1/2 mark)**

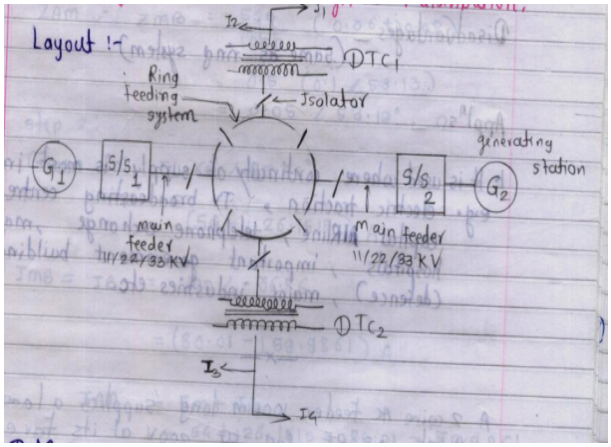
SR.No.	Primary distribution system	Secondary distribution system
1	It is link between receiving substation & distribution transformer	It is link between distribution transformer substation & consumer
2	It is also called as Feeder	It is also called as Distributor
3	It is also called as a High Tension Line	It is also called as a low Tension Line
4	It is a 3-Ph, 3 wire system.(R-Y-B)	It is a 3-Ph, 4 wires system. (R-Y-B-N)
5	Feeder voltage is 11KV/22KV/33KV depending upon load	Distributor voltage is for 3-ph consumer-400V and 1-Ph consumer- 230V
6	Feeder is high capacity conductors.	Distributors are low capacity conductors
7	Feeder is not tapped along its length	Distributors are tapped throughout its length.
8	Its loading point is at substation only	Distributors loading point is throughout its length.
9	Feeder forms the primary distribution system	Distributors forms secondary distributor system.
10	While designing feeder its current carrying capacity is important	While designing distributor its voltage drop calculation is important.

Q.5 Attempt any FOUR of the following: ----------16 Marks

a) Draw layout of grid or interconnected distribution system. State its two advantages and two applications.

Answer:-

Grid or interconnected system of distribution: - (2 Mark)



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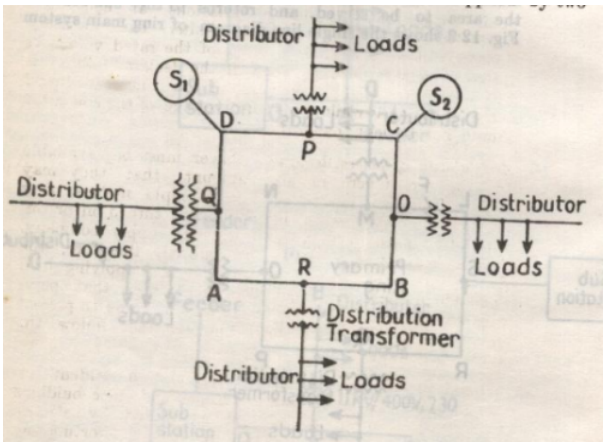


or equivalent

In this system, when the feeder of loop or ring is charged (energized) by two or more than two substations from two generating stations then it is known as "Grid distribution system. In this system only one feeder is utilized at a time.

Advantages: **(Two advantages expected: 1/2 Mark each)**

1. Supply to distribution transformer centre is given through two different generating stations or major generating stations
2. It has highest reliability to maintain supply even when there is a fault on any one feeder
3. It has highest reliability to maintain supply even when there was maintenance on any one feeder.

Applications: **(Any two applications expected: 1/2 Mark each)**

- It is used where continuity of supply is most important. e.g. electric traction, TV broadcasting centre, capital airline, telephone exchange, major hospitals, important government buildings and major industries etc.

b) A single phase distributor one kilometer long and is loaded as shown in figure No.2 has a resistance and reactance per conductor is 0.1 ohm and 0.15 ohm for one kilometer. At far end voltage is 200 volt the P.f. of load is referred to voltage of receiving end . Draw vector diagram and calculate voltage at sending end.

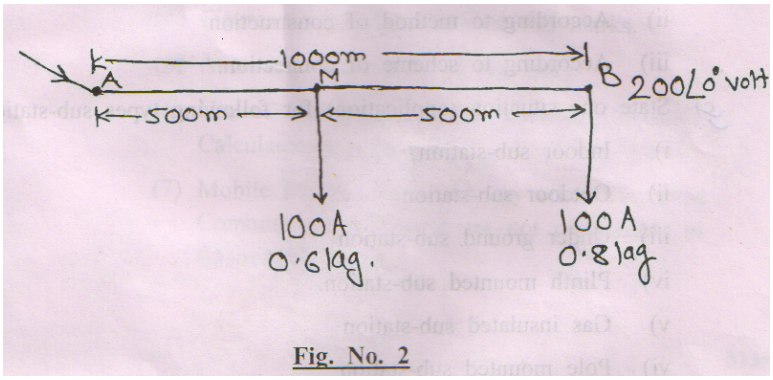


Fig. No. 2

Answer:- $\therefore Z = (0.1 + j\,0.15)\Omega/1\,km$

Step I: To find section impedance: **(1/2 Mark)**

Impedance per each conductor:-

$$Z_T = 2 \times impedance\ per\ each\ \ conductor$$

$$Z_T = 2 \times (0.1 + j\,0.15\,\Omega)$$

$$Z_T = (0.2 + j\,0.30\,\Omega)\ \ per\ KM$$

$$Z_{AM} = Z_{MB} = \frac{500}{1000}(0.2 + j\,0.3)$$

$$Z_{AM} = (0.1 + j\,0.15)$$

$$Z_{AB} = 0.18027\ \angle\ 56.30^0\ ohm$$

Step II: To calculate Section Current: **(1/2 Mark)**

$$I_M = 100\,A,\ at\ \ P.f.\,0.6\ lag$$

$$= 100\ \angle -53.13\ A$$

$$I_M = 60 - j\,80\ \ A$$

$$I_B = I_{MB} = 100\,A,\ at\ \ p.f. = 0.8\ lag$$

$$= 100\ \angle -36.86$$

$$= 80 - j\,60\ \ A$$

$$I_B = I_{MB} = 80 - j\,60\ A$$

Total Current $I_{AM} = I_M + I_B$

$I_{AM} = (60 - j\,80) + (80 - j\,60)$

$I_{AM} = 140 - j\,140\ A$

$I_{AM} = 197.9899 \angle -45^0\ A$

Step III : Calculate Voltage drop : **(1/2 Mark)**

Voltage drop in section AM:-

$V_{AM} = I_{AM}\ X\ Z_{AM}$

$= (197.9899 \angle -45) \times (0.18027 \angle 56.30^0)$

$= 35.6916 \angle 11.30^0$ *Volts*

$V_{AM} = 34.999 + j\,6.9936$ *Volts*

Voltage drop in section MB:-

$V_{MB} = I_{MB}\ X\ Z_{MB}$

$= (100 \angle -36.86) \times (0.18027 \angle 56.30^0)$

$= 18.027 \angle 19.44^0$ *Volts*

$V_{MB} = 16.99 - j\,5.99$ *Volts*

Step IV: Total Voltage drop:- **(1/2 Mark)**

Total voltage drop = Voltage drop in section AM + Voltage drop in section MB

$= V_{AM} + V_{MB}$

$= (34.999 + j\,6.9936) + (16.99 - j\,5.99)$

$= 51.989 + j\,12.9836$ *Volts*

$= 53.5857 \angle 14.022^0$ *Volts*

Step V: Calculate sending end voltage at point 'A': **(1 Mark)**

Reference voltage = Receiving end voltage

$V_{ref} = 200 \angle 0^0$

$V_{ref} = 200 + j\,0^0\ V$

$V_A = V_B + V\ total\ voltage\ drop$

$$= (200 + j\,0) + (51.989 + j\,12.9836) \quad Volts$$

$$= 251.989 + j\,12.9836 \quad Volts$$

$$V_A = 25.3232 \angle 2.9495^0 \quad Volts$$

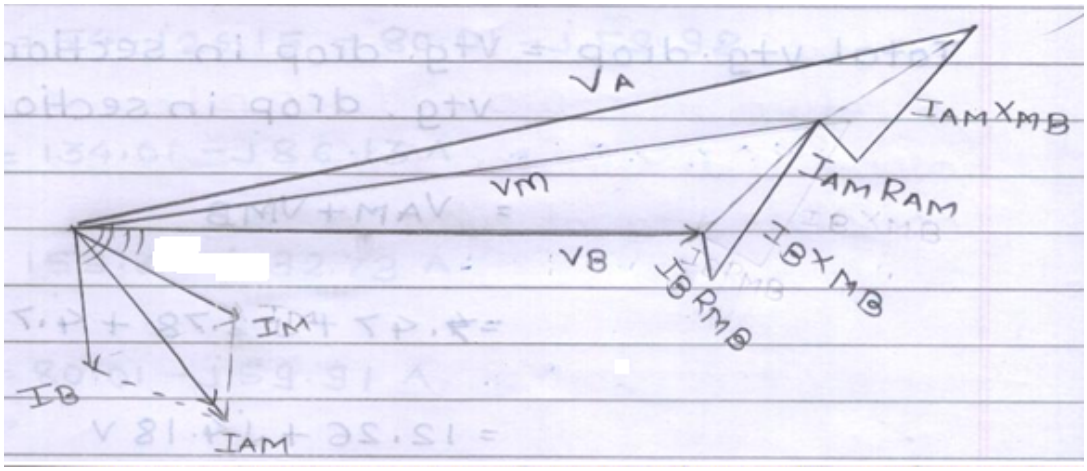
Calculate voltage at Midpoint:

$$V_M = V_{MB} + V_B$$

$$= (16.99 + j\,5.99) + (200 + j\,0) \quad Volts$$

$$= (216.99 + j\,5.99) \quad Volts$$

Step VI : Vector Diagram: **(1 Mark)**



c) State any eight advantages of outdoor sub-station over indoor sub-station.

Answer: - **(Any eight points expected: 1/2 Mark each)**

Following advantages of outdoor substation over indoor sub-station:-

1. **Capital cost:** Less, as construction work cost is less as compare to indoor sub-station.
2. **Time required for completion:** Less, as construction work is less as compare to indoor sub-station.

3. **Distance between two equipment:** More, this will reduce possibility of fault & safety increases.
4. **Access for incoming & outgoing line:** Easy access for incoming & outgoing lines because of outdoor installation.
5. **Cooling arrangement:** Natural cooling is available due to outdoor installation. which reduces energy consumption charges due to outdoor installation.
6. **Availability of natural light:** Natural light is available in day time, so there is no need of illumination during day time. So it saves electrical energy & its cost.
7. **Detection of fault:** Easy, as all equipments are easily viewed.
8. **Replacement of equipment:** Easy, due to outdoor installation.
9. **Future expansion:** Expansion of substation is easy possible whenever needed & can be completed in less time & cost.
10. **In case of accident:** In case of accident there is less risk & damage to other equipments than indoor substation.

d) State the eight requirements of an ideal distribution system.

Answer:- **(Each point: 1/2 Mark)**

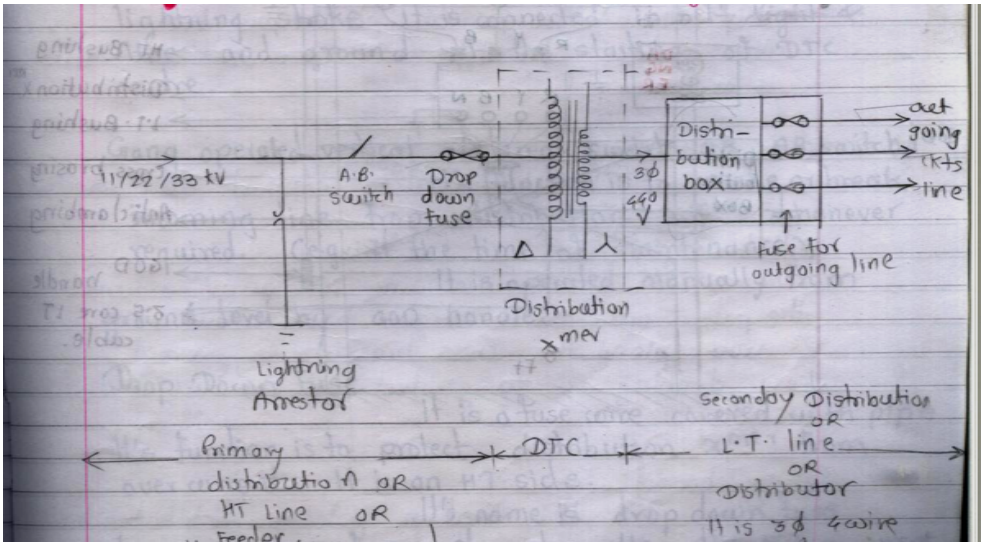
Ideal distribution system should posses following requirements

1) **Design of Layout:** layout should be simple in design.
2) **Time required for completion:** Time required for completion of work should be less.
3) **Initial Cost:** It should be less.
4) **Maintenance:** It should be low, easy, less costly & less time consuming.
5) **Reliability:** It should have high reliability.
6) **Voltage fluctuation:** It should be less and within permissible limit.

7) **Availability of power: -** It should be available whenever needed (Power must be available to all consumers on demand that they may require from time to time.)
8) **Stability:** Fault on nearest distribution system should not affect stability of existing distribution system.

e) Draw single line diagram of pole mounted distribution sub-station. State the points (parts) to be earthed of distribution transformer D.P. Structure.

Answer:- Single line diagram of pole mounted distribution (2 Mark)



OR

or equivalent figure

Following points of DP structure are well earthed: (Any four point expected: 1/2 Mark each)

1. L.A.
2. Transformer body (two earth points).
3. Transformer neutral.
4. Distribution box.
5. Both pole and
6. All fabrication supporting channels.

f) State any eight criteria for selection of site for sub-station.

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

(Any eight factors are expected- 1/2 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.

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.

Q.6 Attempt any FOUR of the following: ----------16 Marks

a) A short three phase overhead transmission line with impedance per phase 5 + j 20 ohm. When sending and receiving end voltages are 46.85 kV and 33 kV respectively at 0.8 p.f. lagging Calculate: i) Current ii) transmission efficiency.

Given Data:-

Vs = 46.85KV V_R = 33KV P.F. = 0.8 lag R_{ph} = 5 ohm X_{ph} = 20 ohm

Step 1: To calculate Phase Voltage

$$V_{Rph} = \frac{V_{RL}}{\sqrt{3}} \quad V_{Rph} = \frac{33}{\sqrt{3}} = 19.05Kv = 19.05\times10^3 v$$

(1/2 Mark)

$$V_{sph} = \frac{V_{sL}}{\sqrt{3}} \quad V_{sph} = \frac{46.85}{\sqrt{3}} = 27.05Kv = 27.05\times10^3 v$$

(1/2 Mark)

Step 2: To calculate value of sin : (1/2 Mark)

$$\therefore Cos\phi_R = 0.8 ; \quad \sin\phi_R = 0.6$$

Step 3: To calculate current:

Sending end phase voltage (V_{Sph})=

$= V_{Rph} + I (R_{Ph} Cos Ø_R + X_{Ph} Sin Ø_R)$

(1/2 Mark)

$$I = \frac{V_{Sph} - V_{Rph}}{R_{ph}Cos\phi_R + X_{ph}Sin\phi_R}$$

$$I = \frac{27.05\times10^3 - 19.05\times10^3}{5\times0.8 + 20\times0.6}$$

I = 500 Amp. **(1/2 Mark)**

Step 4: To calculate Total Line Losses: (1/2 Mark)

Total Line Losses = $3\ I^2\ R_{ph}$
$= 3\,(500)^2 \times 5$
= 3750000 Watt
= 3750 KW

Step 5: To calculate Total Transmission efficiency

Power P_R = $\sqrt{3}\,V_{LR}\,I_R\cos\phi_R$ *for* $3-ph$ **(1/2 Mark)**

$= \sqrt{3}\times33\times10^3\times500\times0.8$
= 22863070.66 watt

= 22863.07066 kW

$$\%\eta_T = \frac{P_R}{P_R + 3I^2R_{ph}} \times 100$$

$$\%\eta_T = \frac{22863.07066 \times 10^3}{22863.07066 \times 10^3 + 3750 \times 10^3} \times 100$$

$$\%\eta_T = 85.914\% \quad \textbf{(1/2 Mark)}$$

b) Classify distribution system: i) According to nature of current ii) According to method of construction ii) According to scheme of connection.

Answer:

i) According to nature of current : **(1 Mark)**

1) AC Distribution system

2b) DC Distribution System

ii) According to Method of construction: - **(1.5 Mark)**

1) Overhead distribution system

2) Underground distribution system

iii) According to scheme of connection: - **(1.5 Mark)**

1) Radial (Tree) distribution system

2) Ring mains distribution system

3) Grid (interconnected) distribution system

c) State one situation (application) for following types sub-station: i) indoor sub-station ii) outdoor sub-station iii) Underground sub-station iv) Plinth mounted sub-station v) Gas insulated sub-station vi) Pole mounted sub-station vii) compact or Prefabricated Sub-station viii) Mobile substation. (Application of each type of sub-station: 1Mark)

Answer:

i) Indoor sub-station:

In places where heavy rainfall, snow fall occurs or there is humidity in atmosphere also where availability of space is less then under such situations sub stations are installed indoor.

ii) Outdoor sub-station:

Where atmospheric conditions are clean and dry also where space available is more then subs stations are installed outdoor.

iii) Underground sub-station:

Underground substation is preferred under following situation: (Any one application expected)

1. In thickly populated area,
2. Space available for building & equipments is limited (In congested place).
3. Where cost of land is very high.
4. In places where heavy rainfall, snow fall occurs or there is humidity in atmosphere.

iv) Plinth mounted sub-station:

Generally large capacity transformers are plinth mounted because its weight is high. Transformer 315 KVA & above are generally plinth mounted.

v) Gas insulated sub-station: (Any one application is expected)

1. Space required for GIS is very less even then indoor substation.
2. In thickly populated area,
3. Space available for building & equipments is limited (In congested place).
4. Where cost of land is very high.
5. In places where heavy rainfall, snow fall occurs or there is humidity in atmosphere.

vi) Pole mounted sub-station:

Generally distribution transformer below 315 KVA substation are **pole mounted in rural area, sub-urban,**

vii) Compact or Prefabricated Sub-station:

Nowadays compact or prefabricated distribution substations are more popular. Its appearance is better than pole mounted and plinth mounted distribution substation.It is used in urban areas for flat system, commercial office building etc.

viii) Mobile substation:

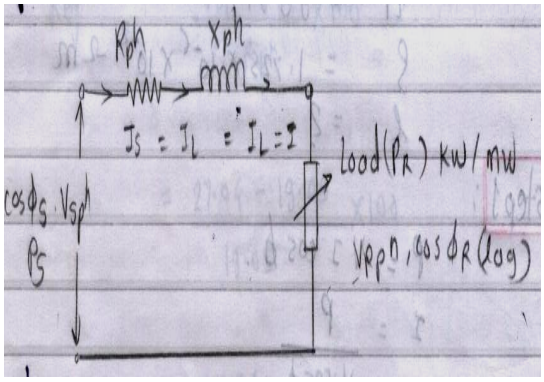
The mobile sub stations are also very special purpose substation temporarily required for construction purpose' for big **construction purpose, large exhibition** this substation fulfils the temporary power requirement during construction work.

d) Derive an expression for voltage regulation of short transmission line by drawing vector diagram. **(Vector diagram-2 Mark & Expression-2 Mark)**

Answer:

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.



or equivalent vector diagram

Where,

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

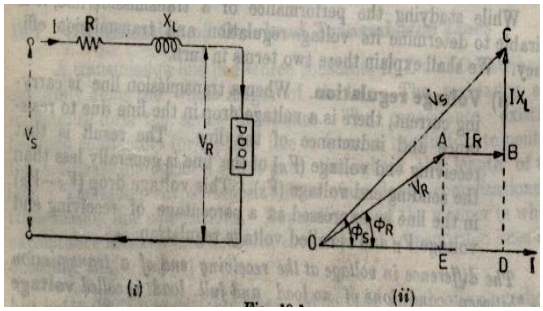
Calculation: (Derivation from phasor diagram)

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 = $\frac{V_{S\,Ph} - V_{R\,Ph}}{V_{R\,Ph}} \times 100$

OR Student may write this way



or equivalent diagram

Let, I = Load current, R= Loop resistance i.e resistance of both conductors

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,

$(OC)^2 = (OD)^2 + (DC)^2$ or

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

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

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

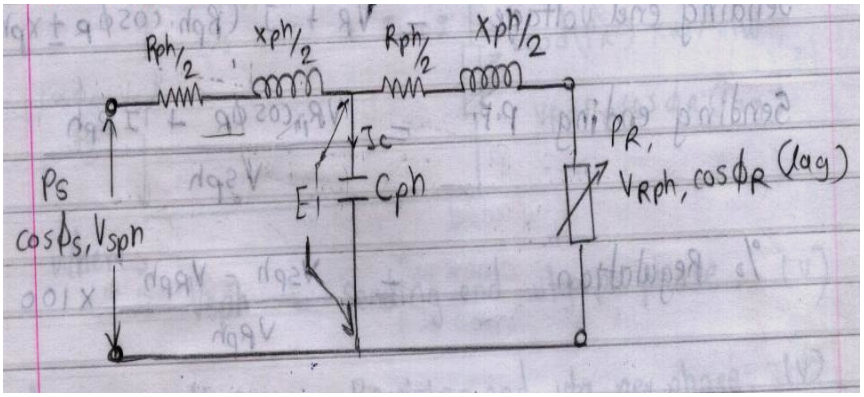
% age Voltage Regulation = $\frac{V_S - V_R}{V_R} \times 100$

e) Draw equivalent circuit and vector diagram for medium transmission line. State assumption made.

(Any one method is expected from the following three methods Of medium transmission line)

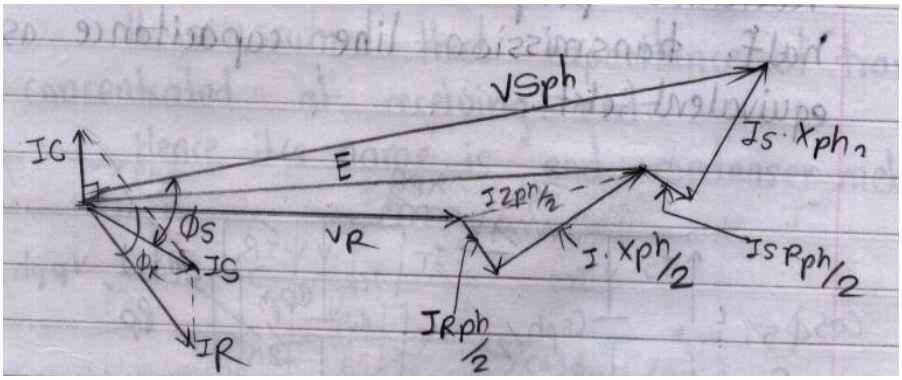
Answer:

1) Equivalent circuit Nominal 'T' network: ---------- **(1.5 Mark)**



OR equivalent circuit diagram

Vector diagram of Nominal 'T' network: ---------- **(1.5 Mark)**



OR equivalent circuit diagram

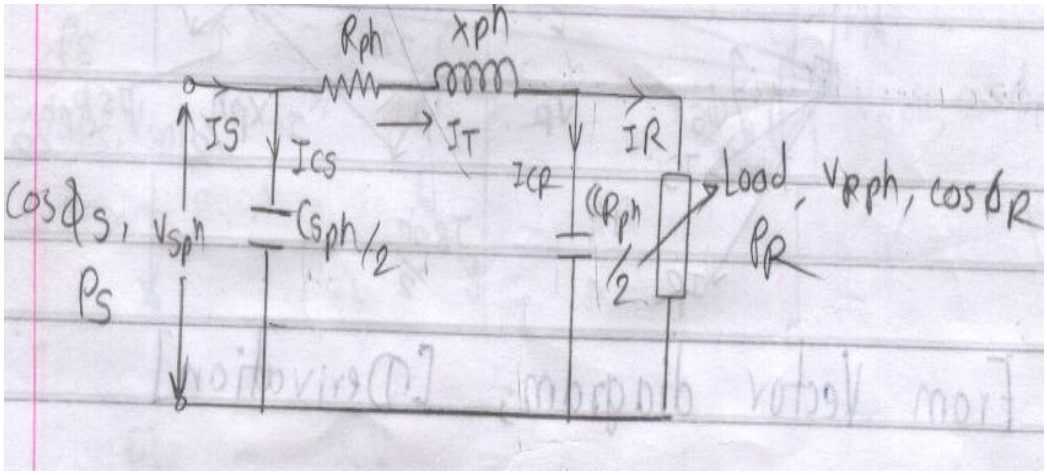
Assumptions: ---------- **(1 Mark)**

1. It is assume that line capacitance is connected at centre of transmission line.
2. It is assume that half of the resistance & reactance per phase are divided in either side of capacitance.

OR student may write this Method

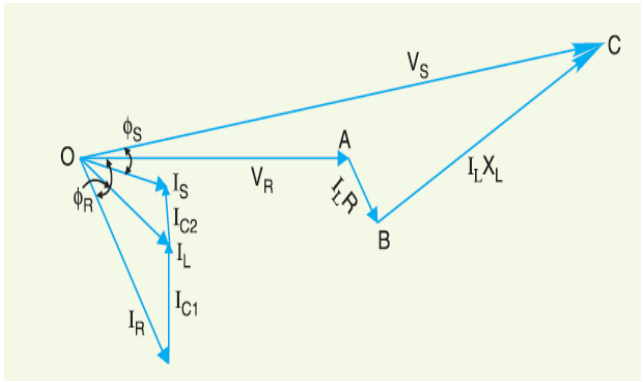
2) Equivalent circuit diagram of π (pi) network method of medium transmission line:

---------- **(1.5 Mark)**



OR equivalent circuit diagram

Vector diagram of π network for: ---------- **(1.5 Mark)**



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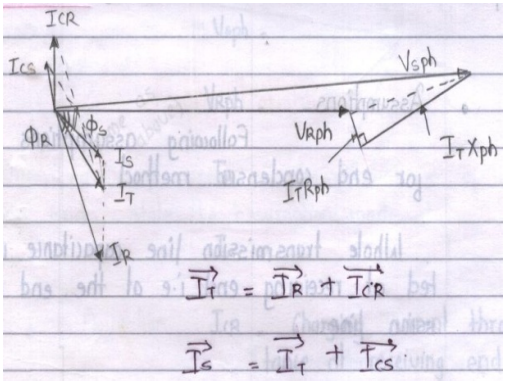


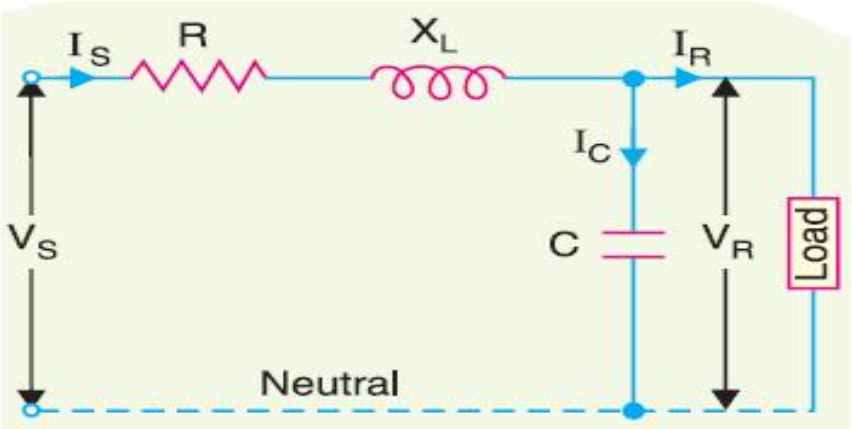
or equivalent vector diagram

Assumption: ---------- **(1. Mark)**

- 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.
- It is assumed that transmission line resistance & reactance per phase is connected in between two half transmission line capacitance

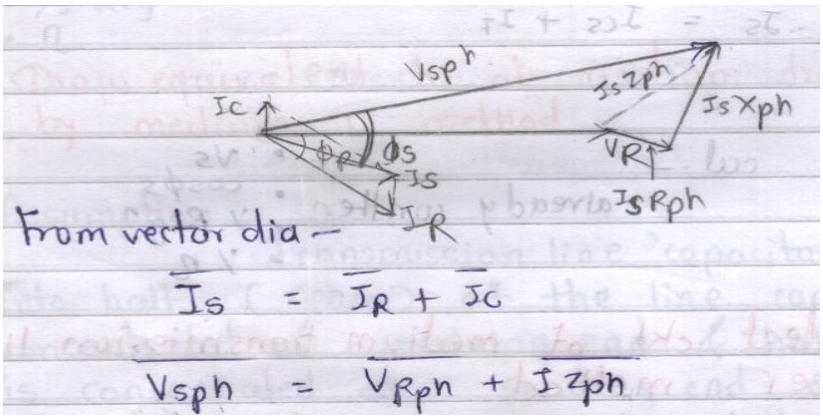
OR student may write this Method

3) Equivalent circuit diagram of End Condenser Method: ---------- **(1.5 Mark)**



OR equivalent circuit diagram

Vector Diagram of End Condenser Method: ---------- **(1.5 Mark)**



OR equivalent circuit diagram

Assumption: ---------- **(1 Mark)**

- All line capacitance is concentrate at receiving end.

f) State the four methods of cable laying. State any six precautions to be taken while laying of underground cable.

Answer: Following are the different methods of Laying of under- ground cable:-

(Any two methods expected: 1/2 each)

1. Direct laying cable
2. Draw- in system
3. Solid System
4. Cable laid in tray

Following precautions to be taken while laying of underground cable.

(Any six precautions expected: 1/2 Mark each)

1. Select proper and short cut route
2. After selecting route take the NOC (No objection certificate) from Telephone, Drainage, water pipe line Office authority
3. If cable route along the public road you have to take permission from Municipal authority
4. Plane the work
5. Start digging the trench
6. Caution board i.e. WORK IN PROGRESS should be used near site
7. Use rotating turn-table for cable drum while unwound the cable from drum.
8. While opening the cable drum, proper care should be taken to avoid damage to the cable
9. The cable shall not be bend to radius of less than 12 times of the overall diameter of cable
10. A cable of different voltages rating shall be layer in different trenches with sufficient separation.
11. Cables of higher voltage shall be laid at a lower level, than the cable of lower voltage.

12. Cable shall not be laid in corrosive soil.

13. Special care should be taken while laying of cable in special locations like: Road crossing, Water main crossing, communication line crossing, In tunnels and On Bridges

14. While crossing roads (public-crossing) cable is laid through cement pipe or DWC pipe, instead of bricks for better mechanical protection.

15. Diameter of pipe is 2 to 3 cm, greater than cable diameter for easy handling of cable.

16. 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.

17. Cable route marker marked “CABLE” shall be provided along the route of the cable & location of routes.