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 FIVE of the following**	**10 Marks**
a)	**List standard voltage level used in India.**	
Ans:	**Standard voltage level used in India:**	**(2 Marks)**
	➢ **Generation Voltage :** 3.3KV, 6.6KV,11KV and 17.5 KV,21KV (Now a days generation voltage is in the range of 11KV- 33KV) ➢ **Primary Transmission voltage :-** 220 KV, 400KV, 765 KV (750 KV) ➢ **Secondary Transmission voltage :-** 220 KV, 132 KV, 110 KV, 66 KV ➢ **Primary Distribution voltage :-** 33 KV, 22KV, 11 KV and for long distance line it may be 66 KV ➢ **Secondary Distribution voltage: -** 3-phase, 400 Volt, for single phase 230 Volt. **OR** ➢ Standard Transmission voltages in India are 765 KV (750KV), 400KV, 220KV, 132KV, 110KV, 66KV, 33KV, 22KV, 11KV.	
b)	**Define: voltage regulation of transmission line.**	
Ans:	**voltage regulation of transmission line:**	**(2 Marks)**
	Voltage regulation is nothing but voltage drop in transmission line expressed in	

% of receiving end voltage

$$\% \textbf{ Regulation} = \frac{Sending\ \ End\ \ Voltage - \text{Re}\, ceiving\ \ End\ \ Voltage}{\text{Re}\, ceiving\ \ End\ \ Voltage} \times 100$$

$$\%regulation = \frac{No\ load\ receiving\ end\ voltage\ -\ \ Full\ loa}{}$$

c) State the disadvantages of skin effect.

Ans: **Disadvantages of skin effect:- (Any Two point expected: 1 Mark each, Total 2 Marks)**

1. Full cross section of conductor is not utilized, Therefore effective area of conductor reduces so its resistance increases $(Since\ R = \rho\frac{l}{A})$
2. Due to increase in resistance, copper losses increases (Since copper losses = I^2R)
3. So transmission efficiency reduces.
4. Due to increase in resistance, Voltage drop increases (Since Voltage drop = IR)
5. So voltage regulation becomes poor (increases)

d) State four HVDC transmission line route on India with their voltage level.

Ans: **HVDC transmission line route on India with their voltage level:**
(Any Four point expected: 1/2 Mark each, Total 2 Marks)

S.N.	From	To
1	Rihand	Dadri
2	Talcher	Kolar
3	Chandrapur	Padghe
4	Bersoor (M.P.)	Lower Sileru
5	Connecting Northern region (Sasaram- Pusawali)	Eastern Region

		6	Connecting Northern region (Vindhyachal)	Western Region
		7	Connecting Southern region (Chandrapur)	Western Region
		8	Connecting Southern region(Vizag- Gajuwaka)	Eastern Region

e) Define: primary and secondary distribution system

Ans:

i) Primary Distribution: **(1 Mark)**

It is a 3-phase, 3-wire transmission line connected in between receiving substation to Distribution substation. **OR** It is link between receiving substation & distribution transformer

ii) Secondary Distribution: **(1 Mark)**

It is a 3-phase, 4-wire Distribution line in between Distribution substation to consumer line. **OR** It is link between distribution transformer substation & consumer.

f) State the classification of distribution substation.

Ans:

The classification of distribution substation.

(Any Four point expected: 1/2 Mark each, Total 2 Marks)

1. Pole mounted distribution substation
2. Plinth mounted distribution substation
3. Compact/prefabricated distribution substation
4. Underground distribution substation
5. Indoor distribution substation
6. Outdoor distribution substation
7. Mobile distribution substation

g)	**State any four properties of conductor material used for overhead conductor.**
Ans:	**Following are the properties of conductor material:-** **(Any Four point expected: 1/2 Mark each, Total 2 Marks)** 1. **High conductivity :-** Material should have high conductivity 2. **High mechanical strength:-** Material should have sufficiently high mechanical strength 3. **Flexible :-** Material should be flexible 4. **Weight: -** Material should be light in weight to reduce transportation & handling cost. 5. **High resistance to corrosion:-** Material should have high resistance to corrosion 6. **Brittleness: -** Material should not be brittle. 7. **Temperature coefficient of resistance:-** Material should have low temperature coefficient of resistance. 8. **Availability & cost: -** Material should be easily available & less costly. 9. **Scrap Value: -** Material should have high scrap value.
Q. 2	**Attempt any THREE of the following** **12 Marks**
a)	**Explain any four advantages of high voltage power transmission.**
Ans:	We know that, $P = \sqrt{3}\ V_L I_L \cos\phi$ For, • Same power to be transferred • At same power factor • At same transmission line distance $I \alpha \frac{1}{V}$ from This Equation It is clear that due to High Transmission Voltage Following are the advantages Hence EHVAC Transmission is adopted: **Advantages:** **(Any Four point expected: 1 Mark each, Total 4 Marks)** 1. As Transmission voltage increases, current decreases. **(as** $I \alpha \frac{1}{V}$ **)** 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 **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.

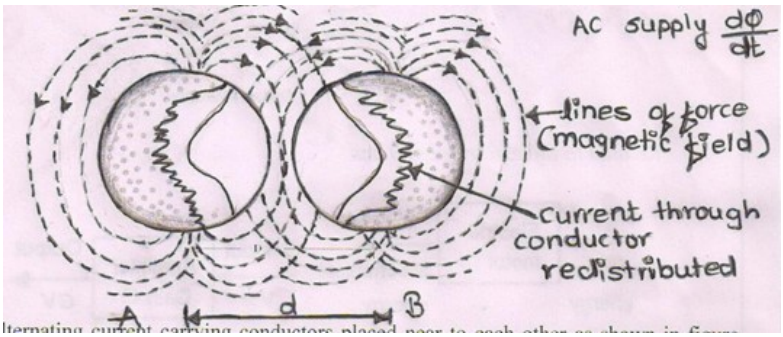
Hence, HVAC transmission line becomes necessary for bulk power to be transmitted over a long distance

b) Describe the proximity effect and state its two disadvantages.

Ans:

Proximity effect:

(Figure: 1 Mark, Explanation: 2 Mark & disadvantages: 1 mark, Total 4 Marks)



Explanation:

Let two alternating current carrying conductors placed near to each other as

shown in figure. Due to electro-magnetic action, flux produced by each conductor links with each other. Due to this super –impose of magnetic field on conductor causes current in each conductor is re-distributed. This is known as proximity effect.

Disadvantages of proximity effect:- (Any Two point expected)

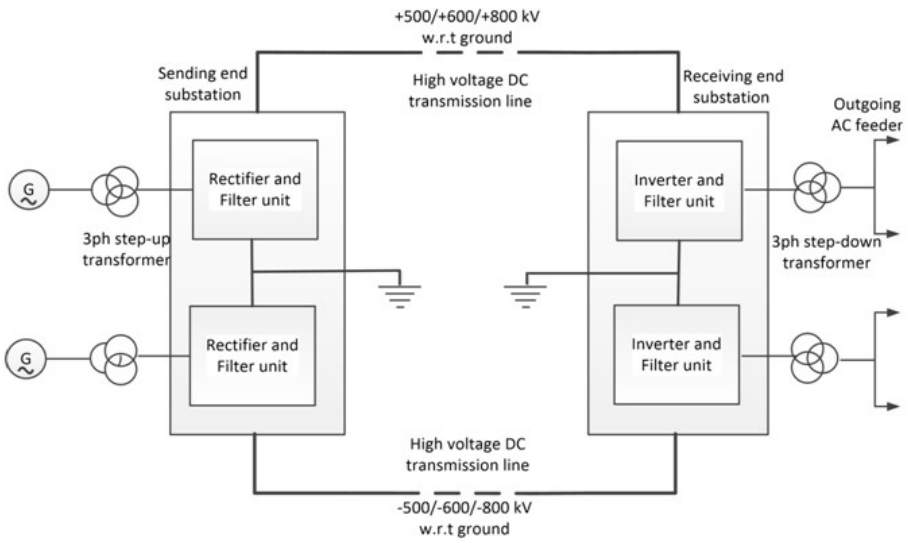
1. Current in each conductor is re-distributed
2. That is current is not uniformly distributed through cross section of conductor
3. Due to above two reasons Cross section of conductor is not fully utilized.
4. Therefore effective area of conductor reduces so its resistance increases

   $(Since\ R = \rho\frac{l}{A})$
5. Due to increase in resistance, copper losses increases (Since copper losses = I^2R)
6. So transmission efficiency reduces.
7. Due to increase in resistance, Voltage drop increases (Since Voltage drop = IR)
8. So voltage regulation becomes poor (increases)

c) Draw and explain Bi-polar HVDC transmission line.

Ans: **Bipolar HVDC transmission line (System):**

(Figure : 2 Mark & Explanation: 2 Mark, Total 4 Marks)



or equivalent figure

Explanation:-

- It has two conductors. One at positive potential & other at negative potential at same magnitude w.r.t. ground
- Both conductors operate at equal potential, so current at ground is zero.

d) State the different methods of improving string efficiency. Explain any one method in detail.

Ans:

The Methods of Improving String Efficiency:-

(Methods : 2 Mark & Any one explanation: 2 Marks : Total 4 Marks)

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 of Insulator.
4) By Using guard ring.

Explanation:-

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

Fig:-

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

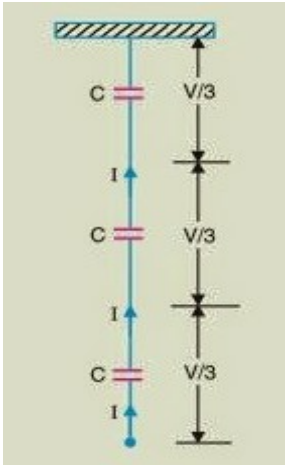
In order to reduce value shunt capacitance (C_1) distance of string of insulator from tower must be increased. i.e. by using longer cross arm. Due to this value of shunt capacitance (C_1) reduces.

Therefore value of m reduces Since ($m = \frac{C_1}{C}$) As value of 'm' reduces there will be more uniform voltage distribution along a string of suspension insulator. In this way string efficiency increases.

Limitation:

In practice there is limitation to increase length of cross arm as cost of tower increases. In practice m= 0.1 is the limit which can be achieved by this method.

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



or equivalent Figure

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,(Capacitance will not form) therefore value of 'm' becomes zero (since m = C_1/C) So string efficiency becomes 100%.

3) By grading Insulator :-

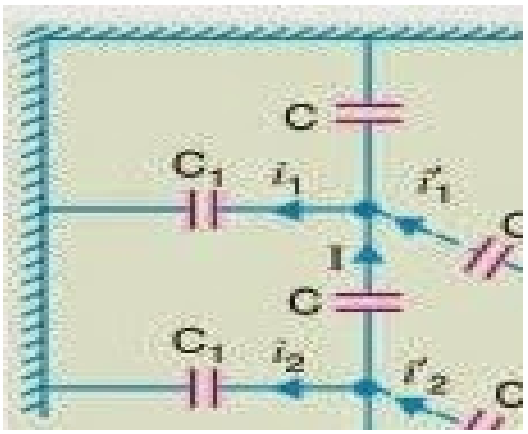
In this method, disc insulators of different dimensions are so selected that each disc has different capacitance. The assembly in the string of suspension insulator is made in such a way that the top unit insulator has fewer dimensions. (Less capacitance) ($C \alpha$ A) and dimensions of insulators progressively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

(Since Q=C/V i.e. **V** is inversely proportional to capacitance So as **A** Increases **C** increases therefore voltage decreases)

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

This method has disadvantages that it requires disc insulator of different dimensions in one string of suspension insulator. Practically it is not possible to obtain such ration. But very high voltage transmission line (1200KV). This method is used.

4) By Using guard ring :-



or equivalent Figure

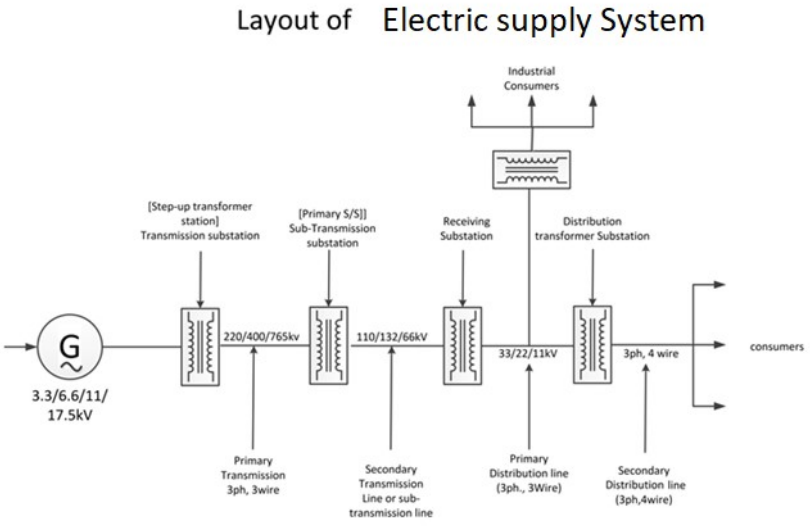
Guard ring is a metal ring electrically connected to conductor and surrounding the bottom insulator.

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.

Q.3	**Attempt any THREE of the following**	**12 Marks**
a)	**Draw the single line diagram of AC electric transmission and distribution system.**	

Ans: **Single line diagram of AC electric transmission and distribution system : (4 Mark)**



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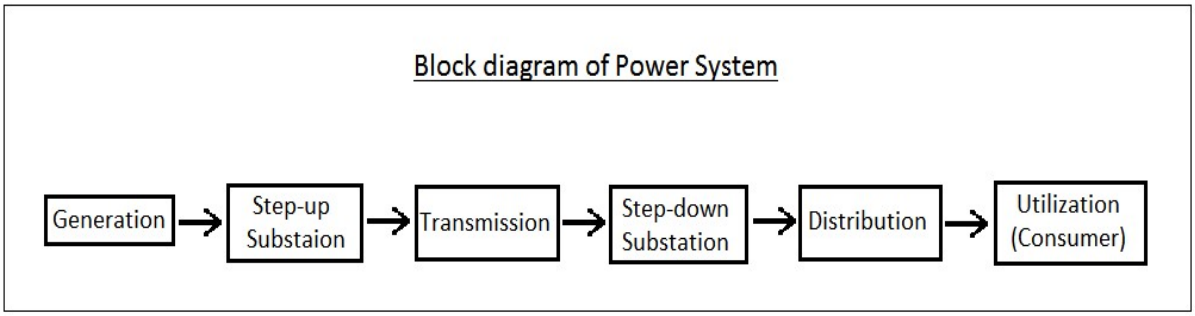

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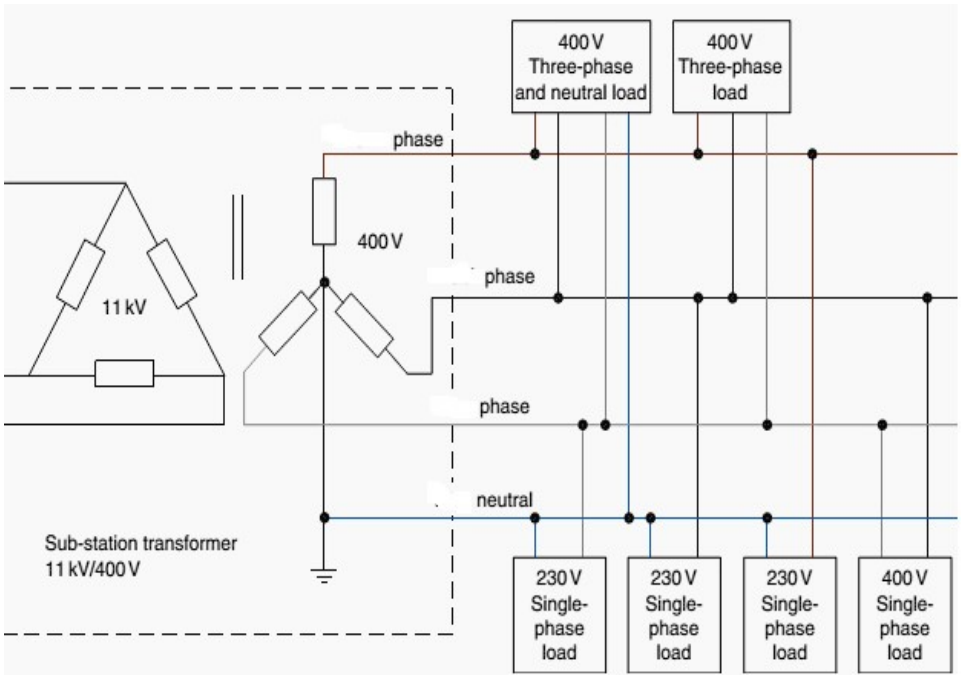


b) Explain the Ferrantio effect in detail.

Ans: **Under Following conditions Ferranti effect occurs:**

(Any Two condition expected: 1 Mark each : Total : 2 Marks)

1. When there is no load on transmission line ($I_L = 0$) **OR**
2. When There is no load at receiving sub-station or Lightly loaded **OR**
3. When there is sudden load thrown OFF. **OR**
4. When there is sudden load shading. **OR**
5. When Transmission line is open circuited due to load failure.

Ferranti effect : **(2 Marks)**

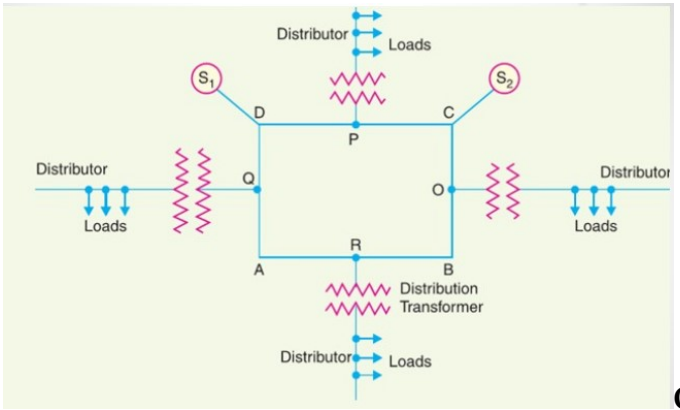
Under any one above condition, it is observe that receiving end voltage (V_R) is found to be greater than sending end voltage (V_S). This phenomenon is known as Ferranti effect.

c) Explain the grid system of distribution and state its advantages.

Ans: **Grid distribution system:-** **(2 Marks)**

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

Layout of Grid distribution scheme: **(1 Marks)**



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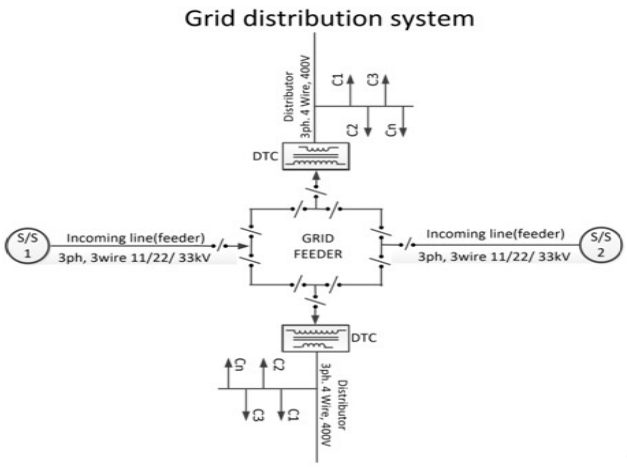


or equivalent figure

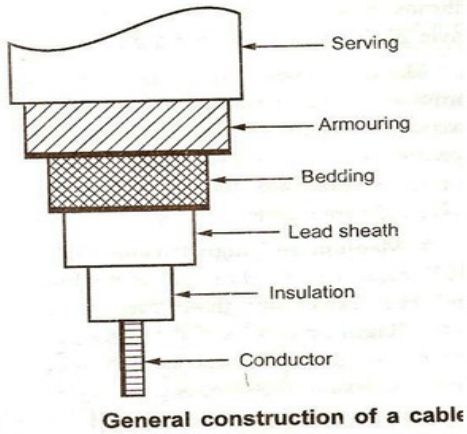
Advantages of Grid distribution scheme:

(Any Two point expected: 1/2 Mark each : Total 1 Mark)

1. Supply to distribution transformer center 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.

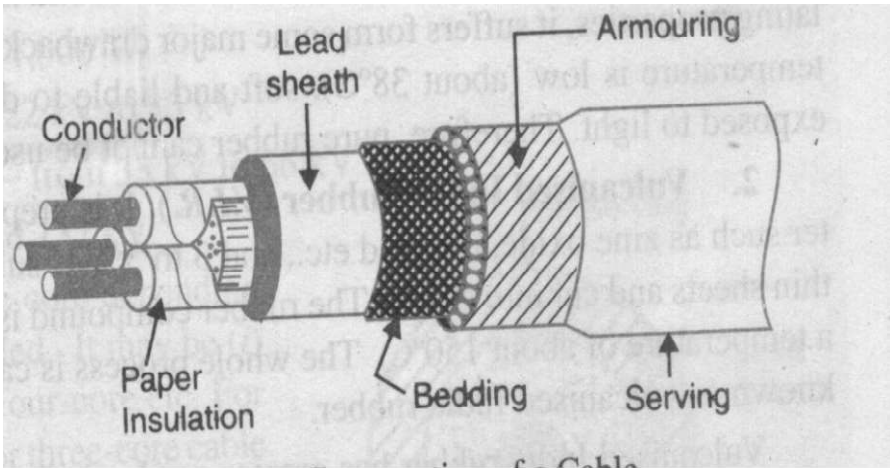
d) Draw and explain the construction of underground cables.

Ans: Underground cables: **(Diagram : 2 Mark & Explanation: 2 Mark, Total 4 Marks)**



General construction of a cable

or equivalent figure OR



or equivalent figure

Explanation:-

i) Core or conductor:

- It function is carry current.
- Cable may have single or more than single core conductor.
- Conductor are made up of copper or aluminium material
- Cross section of conductor is directly proportional to current. (Cross section of conductor depends upon current carrying capacity)
- Conductor used is -
  - Annealed
  - Tinned

ii) Insulation:

- Each core of conductor is provided with suitable thickness of insulation to avoid short circuit between two conductors.
- The thickness of insulation layer depends on **magnitude of voltage** for which it is designed.
- Commonly used materials for insulation are e.g.:-
  - PVC (Polyvinyl Chloride)
  - Polyethene
  - XLPE (Cross- linked polyethylene)

iii) Lead (Metallic) Sheath:

- It is provided over insulation.
- To provide the protection of core from entry of moisture, gases or other damaging liquids (acids & alkaline) in the soil & atmospheric.
- The metallic sheath is made up of lead or lead alloys recently aluminum is also being used as a metallic sheath.

iv) Bedding:

- Over the metallic sheath there is layer of bedding.
- The function of bedding is protecting the metallic sheath against corrosion &

from the mechanical injury due to armouring.

- It is made from fibrous material such as jute, hessian tape

v) Armouring:

- This layer is over a bedding only for underground cable and not for over head cable
- Its function is to protect the cable from mechanical injury.
- It covers the bedding, which consists of 1 or 2 layers of galvanized steel wire or steel tapes

vi) Serving:

- This layer is last layer which comes over armouring.
- Its function is to protect armouring against rusting and it also helps for easy handling of cables.
- It is similar to bedding & consists of fiborous material such as jute.

Q.4	**Attempt any THREE of the following**	**12 Marks**
a)	**State the classification of transmission lines based on voltage level and length of lines.**	

Ans:

A) According to Voltage level: **(2 Marks)**

a) High voltage Transmission Line (HV) up to 33 KV

b) Extra High Voltage Transmission Line (EHV) above 33 KV up to 400 KV

c) Ultra High voltage Transmission Line (UHV) above 400 KV

B) According to Length of Transmission line: **(2 Marks)**

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)

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 **100K**

OR

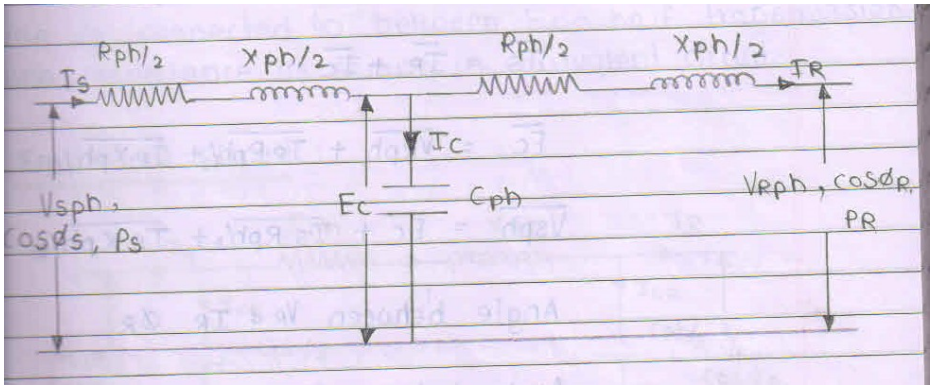
1) **Short Transmission Line: -** The length of Short transmission Line is up to **80KM** and its line voltage **is less than 20 KV**

2) **Medium Transmission Line: -** The length of Medium transmission Line is up to **80KM- 200KM** and its line voltage is between **20KV to 100 KV**

3) **Long Transmission Line: -** The length of Long transmission Line is above **200KM** and its line voltage is above **100KV**

b) **Draw the circuit diagram and phasor diagram of nominal T method of medium transmission line.**

Ans: **Circuit Diagram:-** **(Diagram: 2 Mark & Vector diagram: 2 Mark: Total 4 Marks)**



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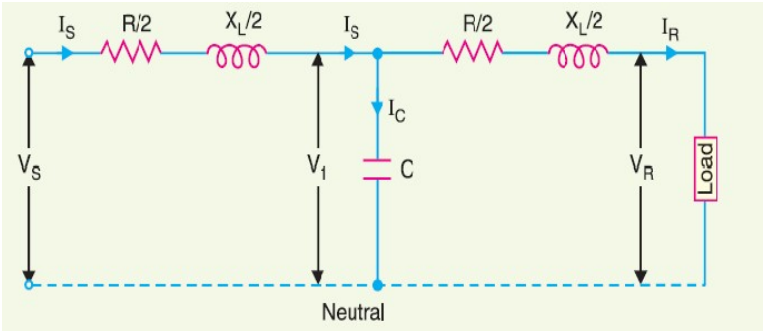

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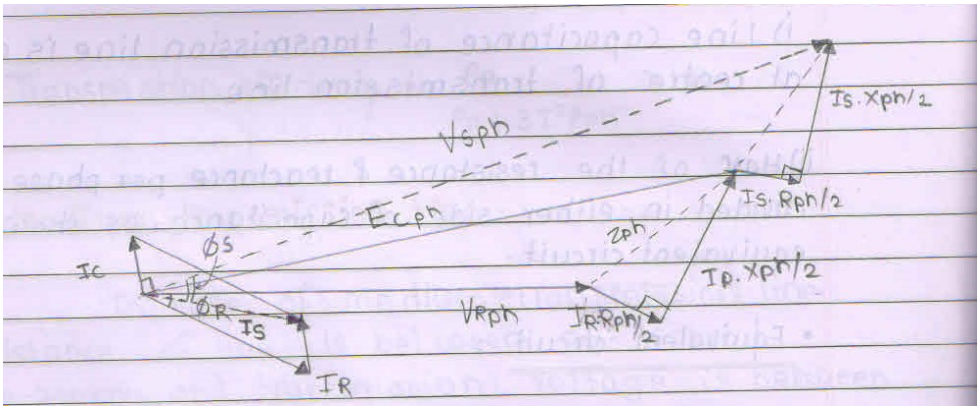
Vector Diagram:-



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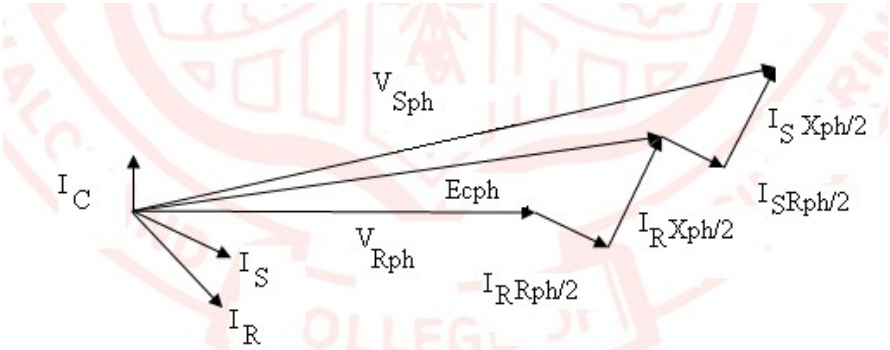
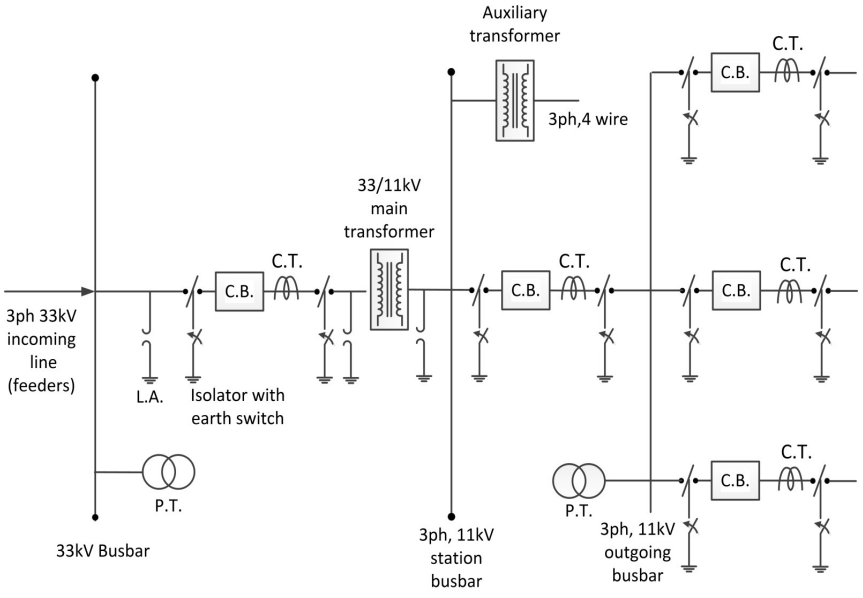


c) State the limitations of EHVAC transmission line.

Ans: **Following are the Limitations of EHVAC Transmission:**

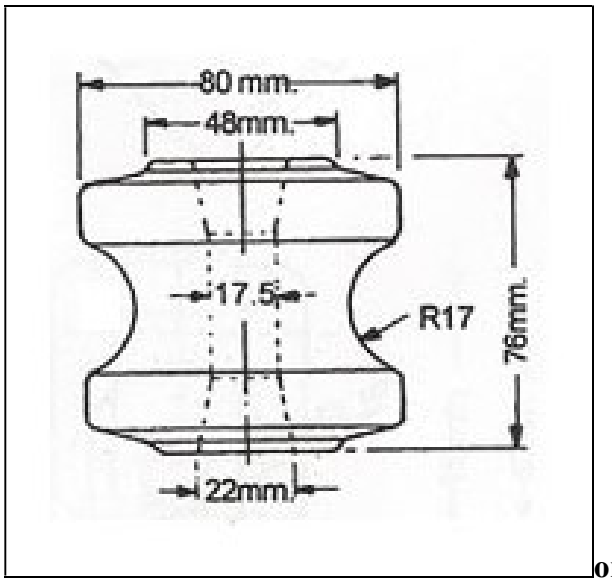
(Any four point expected: 1 each point, Total 4 Marks)

1. Insulation cost increases as voltage increases
2. Skin effect is more
3. Proximity effect is more.
4. Corona loss increases.
5. Radio interference increases
6. String efficiency is less than100%
7. Ground return not possible.
8. Voltage control is not easily possible.
9. Power flow cannot be easily controlled.
10. Short circuit current level is more

	11. In case of EHVAC, Intermediate substation is required at every 250 km to improve the performance of transmission line 12. 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 13. Asynchronous tie not possible. 14. Stability of EHVAC is very low because of presence of inductance. 15. Transient performance is poor. 16. There is limitation on power transfer due to presence of inductance of transmission line & power angle. 17. To improve the performance of transmission line additional equipments such as series & shunt reactor & capacitor are required which increases cost of substation. 18. EHVAC is economical only for bulk amount of power is to be transmitted over long distance.
d)	**Draw the single line diagram (layout) of 33/11 kV substation.**
Ans:	**single line diagram (layout) of 33/11 kV substation :** **(4 Marks)** Layout of 33kV Substation  **OR Equivalent**

e)	Explain the shackle type insulator with neat sketch.
Ans:	**Shackle type insulator with neat sketch:**

(Figure : 2 Mark, Explanation: 2 Marks, Total : 4 Marks)



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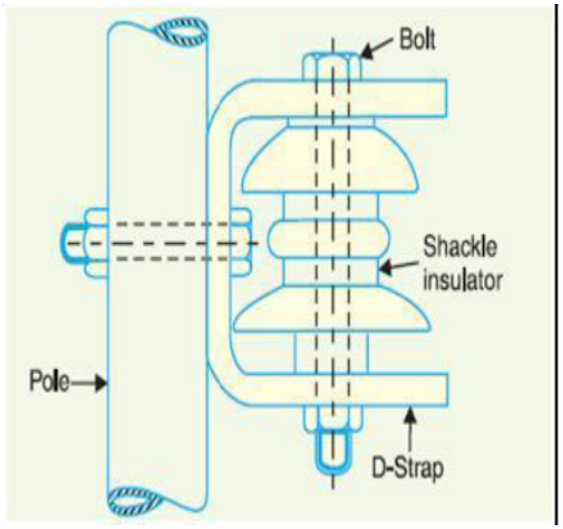


Explanation:

- These insulators are clamped to the cross arms by one metal '**U**' clamp with the help of bolts, nuts & washers.
- Function of Shackle insulator is to reduce excessive tension on line. Also on supporting structure (pole).

Applications:

1) Shackle insulators are used in following circumstances when line is subjected excessive tension. E.g. shackle insulators are used below 11 KV line & above 11 KV line strain insulators are used

2) Shackle insulators are also used when line is going straight but in case of vertical conductor configuration only

Q.5	Attempt any TWO of the following 12 Marks
a)	**Discuss the effect of transmission line parameters on the performance of transmission line (any six points).**
Ans:	**Following are the effect on performance of transmission line:** **(Any Six point expected: 1 Marks each, Total 6 Marks)** 1. Due to resistance (R), voltage drop in transmission line produces 2. Due to resistance (R), copper losses in transmission line produces. 3. Due to inductance (L) voltage drop in transmission line produces. 4. Capacitor (C) draws charging current through transmission line. This charging current produces additional copper losses & voltage drop in transmission line. 5. Due to above reasons, transmission line efficiency gets affected 6. voltage regulation of transmission line gets affected 7. Also power factor of transmission line gets affected
b)	**Explain the features of flexible AC transmission line (any four). State types of FACTS controller.**
Ans:	**Features of flexible AC transmission line:- (Any Four features expected: 1 Mark each, l 4 Mark & Types: 2 Mark, Total 6 Marks)** 1. FACTS increase the reliability of AC grids. 2. It controls the voltage under various load condition 3. It balance reactive power (both lagging and leading reactive power) 4. It improves power quality 5. It increases transmission efficiency 6. It also help to solve technical problems in the interconnected power system. 7. They reduce power delivery costs. 8. There is fast voltage regulation.

9. Increased power transfer over long AC lines.
10. Better utilization of the network,
11. Increased availability and reliability
12. As well as improved network stability are achieved along with higher supply quality.

OR

- In conventional AC transmission system the ability to transfer AC power is limited due to various reasons.
- So the actual amount of power transferred to the load (active power) is always less than apparent power.
- For ideal transmission, the active power should be equal to apparent power.
- The main purpose of facts to obtain active power nearly equal to apparent power by supplying lagging reactive power or leading reactive power as per requirements.
- For this, FACTS uses static power electronics devices for series & shunt compensation automatically as per requirements.

Types of FACTS controller:-

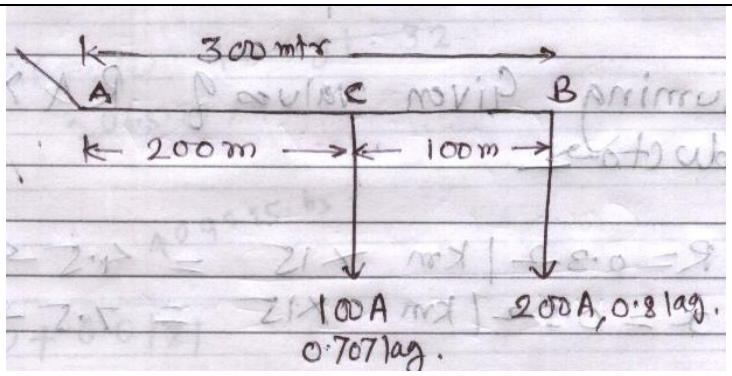
Examples of FACTS for series compensation :- (Any one types expected)

1. Thyristor-controlled series reactor (TCSR)
2. Thyristor-controlled series capacitor (TCSC)

Examples of FACTS for shunt compensation:- (Any one types expected)

1. Static synchronous compensator (STATCOM)
2. Static VAR compensator (SVC)

c)	**A single phase AC distributor AB 300 M long is fed from end A and is loaded as under. (i) 100 A at 0.707 pf lagging 200 m from point A. (ii) 200 A at 0.8 pf lagging 300 m from point A, The load resistance and reactance of the distributor is 0.2 ohm and 0.1 ohm per kilometer. Calculate total voltage drop in the distributor. The load power factors refer to the voltage at the far end.**
Ans:	**Given data:**



$R_T = 0.2$ ohm/km $X_T = 0.1$ ohm/km $\therefore Z_T = (0.2 + j0.1)\Omega / km$

Step :1 : Section Impedance:-

$$Z_{AC} = \frac{200}{1000}(0.2 + j0.1)$$

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

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

Step :2: Calculate Section Current:

Given, I_B = 200A, 0.8 lag

$$200 \angle -36.87^0$$

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

Given, I_C = 100A, 0.707 lag

$$100 \angle -45^0$$

$$70.71 - j70.71 \ Amp$$ ---------- **(1/2Marks)**

Section Current: $I_{CB} = I_B$

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

$= (70.71\text{-}j70.71) + (160\text{-}j120)$

$= 230.71\text{-}j190.71$

$I_{AC} = 299.3282 \angle -39.5778 \ Amp$ ---------- **(1/2Marks)**

Step :3: Calculate Voltage drop in section AC:-

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

$$= (299.3282 \angle -39.5778)\ (0.0447 \angle 26.57)$$

$$= 13.37997054 \angle -13.0078\ V$$

$$= 13.0366 - j\ 3.01161\ V$$ ---------- **(1/2 Mark)**

Calculate Voltage drop in section BC:-

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

$$= (200 \angle -36.87)\ (0.02236 \angle 26.565)$$

$$= 4.48 \angle -10.3 \quad Volts$$

$$V_{BC} = 4.407 - j\ 0.80 \quad Volts$$---------- **(1/2Marks)**

Step 4: Calculate total voltage drop in distributor V_{AB} :-

Voltage drop in section BC + Voltage drop in section AC

$$= (4.407 - j\ 0.80) + (13.0366 - j\ 3.01161)$$

$$= 17.9936 - j\ 3.8116\ Volt$$---------- **(1 Mark)**

$$V_{AB} = 17.8552 \angle -12.359\ Volt$$

Step 5: Calculate Load power factor :-

$$= Cos\ (12.3259)$$

$$= 09769\ lagging$$ ---------- **(1/2Marks)**

Q.6	**Attempt any TWO of the following**	**12 Marks**
a)	**A 3 phase line of 4 km length delivers 4000 kW at a p.f of 0.8 lagging to a load the resistance and reactance per km of each conductor are 0.2 ohm and 0.5 ohm respectively if the voltage at the supply end is maintained at 11 kV. Calculate the received end voltage and efficiency of line.**	

Ans: P_R = 4000KW= 4000 x 10^3 W, V_R = 11KV= 11 x10^{3V} , P.F. = 0.8 lag, R Per conductor =0.2 ohm, X Per conductor = 0.5 ohm

V_{Rph} = $V_{RPh} \equiv \frac{11 \times 10^3}{\sqrt{3}}$ $V_{R_{Ph}} \equiv 6.3508 \times 10^3 V$

To Calculate Total /loop values of R & X

Total resistance R_T = 4 R= 0.2× 4= 0.8 ohm

Total Reactance X_T = 4 X =0.5×4= 2 ohm **Step 1: To calculate current:**

Power P = $VI\cos\phi$

$$I \equiv \frac{P}{\sqrt{3}\, V_L \cos\phi}, \quad I \equiv \frac{4000\times10^3}{\sqrt{3}\times11\times10^3\times0.8}$$

$$I \equiv 262.4319\, amp$$ ---------- **(1 Mark)**

Step 2: To calculate Total Line Losses:

$$\text{Total Line Losses} = 3\, I^2\, R_{Ph}$$

$$= 3\,(262.4319)^2 \times 0.8$$

$$= 16289.2051 \text{ Watt}$$ ---------- **(1 Mark)**

Step 3: To calculate Total Transmission efficiency:

$$\%\,\eta_T = \frac{P_R}{P_R + I^2 R_{Lossses}} \times 100$$ ---------- **(1/2 Mark)**

$$\%\,\eta_T = \frac{4000\times10^3}{4000\times10^3 + 165289.2051} \times 100$$

$$\%\,\eta_T = 69.0317\%$$ ---------- **(1 Mark)**

Step 6:To calculate % regulation:

$$\%\text{ Voltage Regulation} = \frac{I\,(R_{ph}\, Cos\phi R \pm X_{Ph}\, Sin\phi_R}{V_R} \times 100$$ ---------- **(1/2 Mark)**

$$= \frac{262.4319\,(0.8\times0.8 + 2\times0.6)}{6.3508\times10^3} \times 100$$

$$= 7.6034\ \%$$ ---------- **(1 Mark)**

Step 3: To calculate Sending end voltage:

$$\mathbf{V_{Sph}} = V_R + I\left(R_{RPh}\cos\phi_R + X_{Ph}\sin\phi_R\right)$$ ---------- **(1/2 Mark)**

$$= 6.3508\times10^3 + 262.74\,(0.8\times0.8 + 2\times0.6)$$

$$= 6.3508\times10^3 + 483.4416$$

$$V_{SPh} = 6833.6747 \text{ volt}$$

$$V_{SL} = 6833.6747 \times \sqrt{3}$$

$$V_{SL} = 11836.2718 \text{ volt}$$ ---------- **(1/2 Mark)**

b) Each line of a 3 ph system is suspended by a string of 3 similar insulators. If the voltage across the line unit is 17.5 kV, calculate the line to neutral voltage. Assume that the shunt capacitance between each insulator and earth is 1/8th of the capacitance of insulator itself Also find the string efficiency.

Ans:

V_L = 17.5 KV

i) Ratio of capacitance 'm' :-

$$m = \frac{1}{8} = 0.125$$

k = m = 0.125 ---------- **(1 Mark)**

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

$$V_3 = V_1 (1 + 3 \times 0.125 + (0.125)^2)$$

$$17.5 = 1.3906 \; V_1$$

$$V_1 = \frac{17.5}{1.390625}$$

V_1 = 12.58426966 KV

---------- **(1 Mark)**

ii) $V_2 = V1 (1 + m)$

$$V_2 = V_1 (1 + 0.125)$$

V_2 = 12.58426966 x 1.125

V_2 = 14.15730337

---------- **(1 Mark)**

iii) Voltage across string = Vph = $V_1 + V_2 + V_3$

= 12.58426966 +14.15730337 +17.5

V_{Ph}= 44.24157336 KV

---------- **(1 Mark)**

vi) String efficiency :-

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

$$\text{String } \eta\% \equiv \frac{10.1036}{3 \times 17.5} \times 100$$

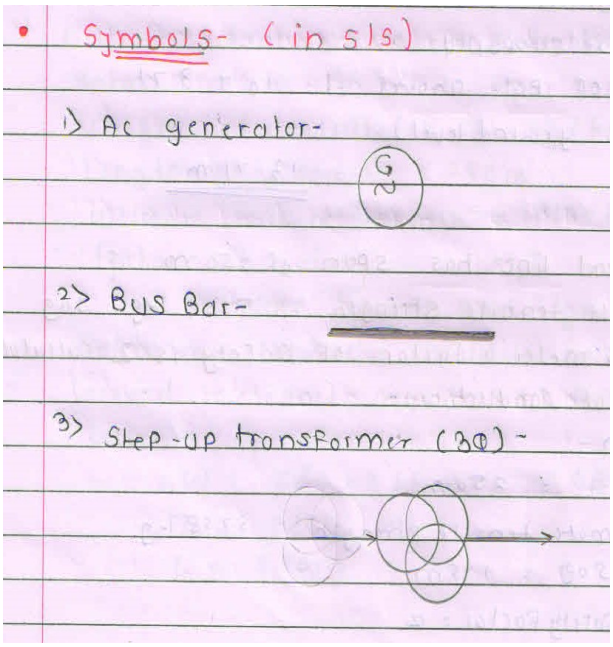
$$\text{String } \eta\% \equiv 84.2696\ \%$$

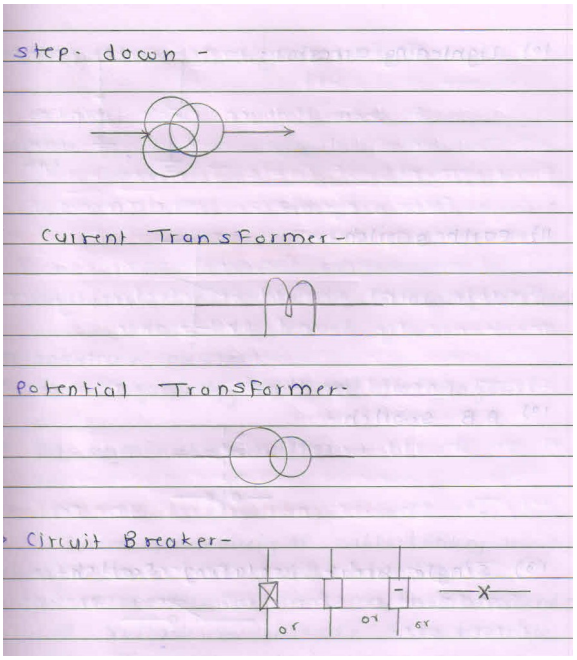
---------- **(1 Mark)**

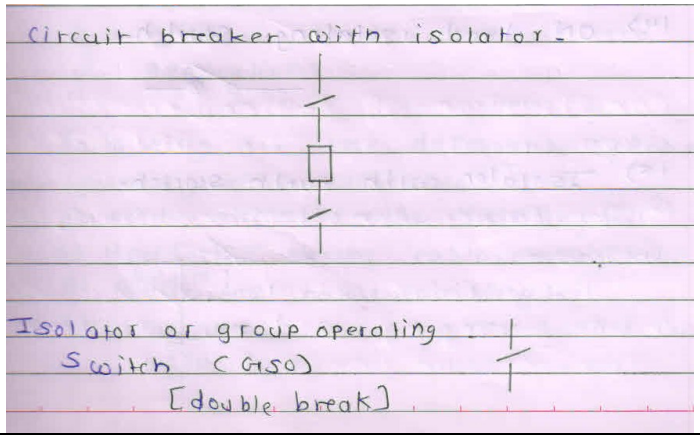
c) Draw the symbols and state their function of components used in substation (any six).

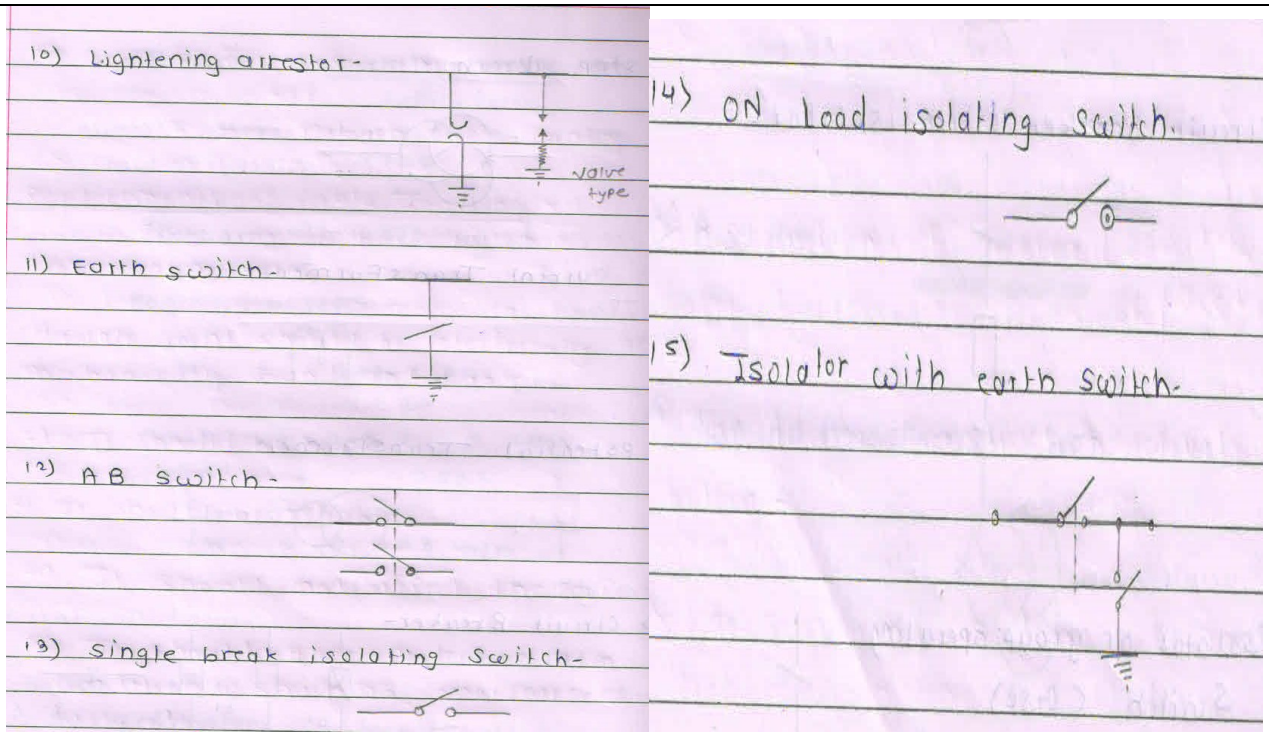
Ans: **Symbols in Sub- Station:**

(Any six symbol from following are equivalent : 1/2 Mark & their function 1/2 Mark expected: 1 Mark each, Total 6 Mark)

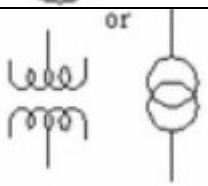
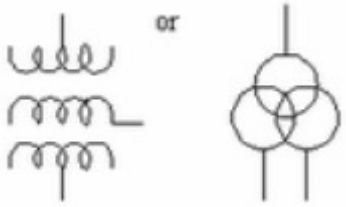
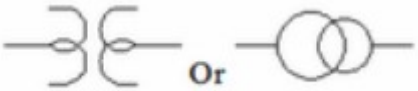
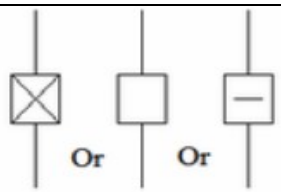
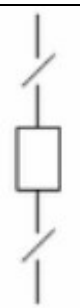


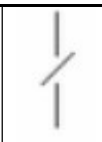
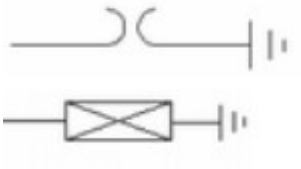
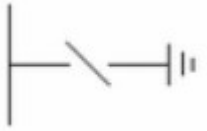
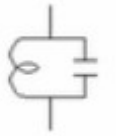
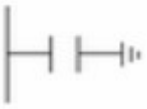
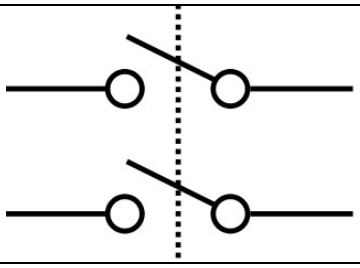






OR

Electrical Equipment	Symbols	Electrical Equipment	Symbols
A C Generator		Bus Bar	
Power Transformer- Two winding		Three Winding Transformer	
Current Transformer (CT)		Voltage Transformer or Potential transformer (PT)	
Circuit Breaker		Circuit Breaker with isolator	

Isolator or Group Operating Switch (GOS)		**Lightening Arrestor (L.A)**	 **OR**
Earth Switch (ES)		**Wave or Line trap**	
Coupling Capacitor (CC)		**A B Switch**	

List of the equipment's, circuit elements in substation & their function:

1) Bus bar: -

Bus bar is common conductor to which incoming & outgoing lines are connected

2) Power Transformer (Main transformer) :-

Its function is to step down the incoming voltage (e.g.33 KV) to outgoing voltage (22/11KV) without change in frequency. Its rating is in MVA.

It is installed on strong concrete foundation (plinth). It is oil cooled also air blast cooling system is provided.

3) Auxiliary Transformer (Station transformer): -

Its function is to step down the input voltage (11 KV) to distribution voltage (3-ph, 4wire, 400V) to give supply to control room, area lighting, staff quarters etc,

4) Lightning Arrester: -

It is provided for protection of substation, transformer against lightning stroke .It is connected in between line and ground at the starting point of substation. Under normal condition it acts as an insulator.

5) Earth switch: -

Its function is to discharge the ground capacitance when line is open circuited for maintenance purpose by isolator.

6) Isolator (No load Switch): -

Its function is to connect or disconnect the circuit only when there is no load.

7) Circuit Breaker: - It is protective device. It open or break the circuit whenever there is fault & protect the equipment. It can be operated manually or remote control whenever required.

8) Relay:

It sense the faults & gives signal to trip circuit of C.B. to open. There are different types of relay e.g. Earth fault relay, Phase to Phase fault relay, Thermal relay etc.

9) Instrumental Transformer (CT & PT):-

C.T & P.T are used for measurement of electrical quantities (Current, voltage, power & energy) also C.T. is used for protection purpose as a part of tripping circuit of C.B.

10) Horn Gap Fuse: -

It is provided to primary side of transformer for protection against over current.(Its frame shape is like a Horn gap due to which arc /spark will extinguish quickly) If C.B. is installed on primary side of transformer than Horn gap fuse is not provided.

----------END----------