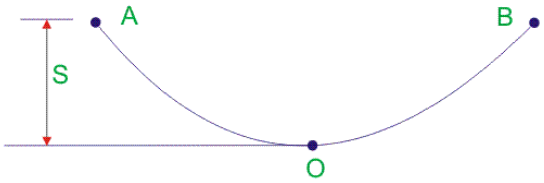
Important suggestions to examiners:

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 necessity of an overhead transmission line.**
Ans:	**Necessity of an overhead transmission line:** **(2 Marks)** The electricity need to transmit from generating stations to the point of actual utilization of it (consumers) for this purpose transmission electricity is necessary.
b)	**State the classification of distribution system.**
Ans:	**Classification of distribution system:** **(2 Marks)** **1) According to nature of Current** **a) DC Distribution System:** i) Two wire DC distribution System ii) Three wires DC distribution System. **b) AC Distribution System:** i) Primary distribution system. ii) Secondary distribution system: **2) According to Method of construction: -** a) Overhead distribution system b) Underground distribution system **3) According to scheme of connection: -** a) Radial (Tree) distribution system b) Ring mains(Loop) distribution system c) Grid (interconnected) distribution system

c)	**State the skin effect.**
Ans:	**The skin effect :** **(2 Marks)** When alternating current flows through conductor it has tendency to flow away from center of conductor is known as skin effect.
d)	**Explain why suspension insulators are preferred for high voltage power transmission.**
Ans:	**Suspension insulators are preferred for high voltage power transmission:** **(2 Marks)** Because of following reasons suspension insulators are preferred for high voltage power transmission:- (Any Two Points Are Expected) 1. If any insulator in the string of suspension insulator breaks down/fails then only that insulator/disc in the string require to be replacing by new one instead of replacement of whole string unit. 2. If operating voltage of existing line has to be increased than we can add required number of disc insulators in existing string instead of replacing whole unit hence it is economical 3. Can be used For Any Higher Voltages by adding number of disc in a string of suspension insulator
e)	**State any four desirable properties of cable.**
Ans:	**Following are desirable properties of cable:** **(Any Four expected:1/2 each, 2 Marks)** 1. **Stranded Conductor:** The conductor used for cable should be stranded specially for large size of cable 2. **Annealed Conductor:** Annealed conductor should be used to become conductor soft. 3.**Tinned conductor:-** Tinned conductor should be used so that conductor will not stick with insulation. 4.**Cross Section Of Conductor:** Cross Section Of Conductor should be proportional to magnitude of current. 5. **Insulation Thickness:** The insulation thickness provided to cable should be proportional to magnitude of voltage, to give high degree of safety and reliability.

	6. **Mechanical Protection:** Especially underground cable should be provided with mechanical protection (armouring). So that it will withstand against rough handling and mechanical injury. 7. **Life:** The material used for cable should have long life.
f)	**State different voltage levels used in transmission of power in India.**
Ans:	**Voltage levels used in transmission of power in India: (Any Four Voltage levels are expected)** **(2 Marks)** Standard Transmission voltages in India are 765 KV (750KV), 400KV, 220KV, 132KV, 110KV, 66KV, 33KV, 22KV, 11KV.
g)	**Define sag in overhead lines.**
Ans:	**Sag in overhead lines:** **(2 Marks)**  **Sag** is **defined** as the different in level between points of supports and the lowest point on the conductor.
h)	**State proximity effect.**
Ans:	**Proximity effect:** **(2 Marks)** Let two alternating current carrying conductors placed near to each other. 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.

i)	**State any two advantages of ACSR conductors.**
Ans:	**Advantages of ACSR Conductors:-** **(Any Two Advantages expected: 1 Mark each, Total 2 Mark)** 1. Due to steel re-enforcement, mechanical strength of conductor increases ➢ So we can increase distance between two poles i.e. Span. ➢ So number of poles require reduces for same transmission distance. ➢ As an effect transmission line cost reduces 2. As the mechanical strength is more ACSR conductors produces small Sag. ➢ So height of pole to maintain ground clearance can be reduced. ➢ So cost of pole reduces, as its height reduces ➢ Hence transmission cost reduces. 3. It takes advantages of Skin effect. So skin effect is minimized. 4. Corona Loss reduces. 5. It is 50% stronger & 20% Lighter than copper. 6. It is cheaper than copper.
j)	**State any two limitations of `EHVAC' transmission.**
Ans:	**Following are the Limitations of EHVAC Transmission:** **(Any Two Limitations expected: 1 Mark each, Total 2 Mark)** 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.
k)	**Define medium transmission line.**
Ans:	**Medium Transmission Line: -** **(2 Marks)** The length of Medium transmission Line is up to **50KM-150KM** and its line voltage is between **20KV to** 100 **KV** OR **Medium Transmission Line: -** The length of Medium transmission Line is up to **80KM-200KM** and its line voltage is between **20KV to 100 KV** OR **Medium Distance Transmission Line -** The length of Medium transmission Line is up to 50 to 150 KM
l)	**Define corona.**
Ans:	**Corona:** **(2 Marks)** When AC Voltage given across two conductors separated by distance 'd' is increased greater than breakdown voltage of air i.e. 30KV/cm, then air around the conductor gets ionized and ionized air is conducting under this condition corona will takes place(form) . During corona following observations are noted: ➢ Luminous violet glow (typically a purple glow) occurs around the conductor. ➢ Hissing or cracking sound will produce. ➢ Ozone gas will produce.(smell the presence of ozone that was produced by the corona) This phenomenon is known as "corona" effect.

m)	**State different types of substation according to service requirements.**
Ans:	**Different types of substation according to service requirements**:- **(Any Two types of substation are expected: 1 Mark each, Total 2 Mark)** 1. Transformer Sub-station 2. Switching sub-station 3. Power Factor improving sub-station 4. Frequency changer sub-station 5. Converting sub-station 6. Industrial Sub-station (Bulk Supply Industrial Consumer Substation) 7. Traction substation 8. Mining Substation 9. Mobile Substation
n)	**Write any two advantages and disadvantages of dc transmission.**
Ans:	**Advantages of HVDC Transmission System:-** **(Any Two Advantages expected: 1/2 Mark each, Total 1 Mark)** 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) Tower required less ground area as its base is less than AC tower. (Right Of Way)So land use benefits are more. 5) No intermediate substation is required like HVAC transmission line. 6) Due to above advantages, Cost of transmission line per KM is less. 7) Skin effect is absent. 8) No proximity effect. 9) No Ferranti effect. 10) String efficiency is 100% 11) Less radio interference. 12) Low corona loss.

13) Copper losses are less, transmission efficiency is more.(As dc resistance is less than AC resistance by 1.6 times)
14) As Copper loss are less So transmission efficiency is more
15) Effect of L & C is absent and value of DC resistance of conductor is less, so voltage drop in D.C. transmission line is less.
16) Voltage regulation is better than HVAC transmission line.
17) Voltage control easy for long distance HVDC transmission line.
18) Power flow control is easy for long distance transmission.
19) There is no limit for transmission of power.
20) Asynchronous tie possible.
21) Distance is not limited by stability point of view
22) HVDC line has more stability than HVAC.
23) If power is to be transmitted through cable than there is no limit on the length of cable as charging current is absent
24) There is no need of reactive power compensation.
25) Two transmission lines of different frequencies can be inter connected to grid system through HVDC link **OR** Asynchronous tie is possible through HVDC link

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Dis-advantages of HVDC Transmission System:-

(Any Two dis-advantages expected: 1/2 Mark each, Total 1 Mark)

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) Cost of DC substation is more than AC substation, due to additional equipment required like rectifier, inverter etc.
4) Maintenance cost of DC substation is more due to additional equipment.
5) Space required for DC substation is more due to additional equipment
6) Losses in DC substation are more due to additional equipment.
7) Over load capacity Converter is very less.
8) Reliable DC circuit breakers are not available like AC circuit breakers.

9) Cost of DC circuit breaker is more than AC circuit breaker.
10) Converters consumes reactive power
11) Generation of harmonics.
12) If ground is used as the return path, then it leads
- Corrosion of underground metallic structure of buildings, pipes, etc. due to chemical action.
- Causes disturbance in underground communication cable.

13) HVDC is not economical for short distance transmission because termination cost equipment is more.

Q.2 **Attempt any FOUR :** **16 Mark**

a) **Compare the merits and demerits of underground system versus overhead system. (any four points)**

Ans: **(Any Two Points Expected from merits and demerits: 1 Mark each,Total 4 Mark)**

Following are the merits of underground cables over overhead cables
(Any Two Points Expected)

SR.No.	Points	Underground system	Overhead system
1.	Chances of fault	Less	More
2.	Chances of accident	No chances of accident	There is chances of accident
3.	Safety	More	Less
4.	Radio interference	Not produces radio interferences	Produces radio interferences
5.	Short cute route	Possible	Not Possible
6.	Theft of energy	Less possibility	More possibility
7.	Reliability	More	Less
8.	Life	More	Less
9.	Space Required	No space is consumed in underground system as against overhead system	Space is consumed
10.	Appearance	Very good.	Not good

Following are the demerits of underground cables over overhead cables. (Any Two Points Expected)

11.	Capital cost	More	Less
12.	Erecting cost	More	Less
13.	Time require for completion of work	More	Less
14.	Overload capacity	Less	More
15.	Fault finding	Difficult	Easy

OR

(Any Four Point expected: 1 Mark each, Total 4 Mark)

Sr.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	Fault finding	Difficult	Easy
8	Charging Current	More	Less
9	Chances of fault	Less	More
10	Chances of accident	No chances of accident	More
11	Safety	More	Less
12	Radio interference	Not produces radio interferences	Produces radio interferences

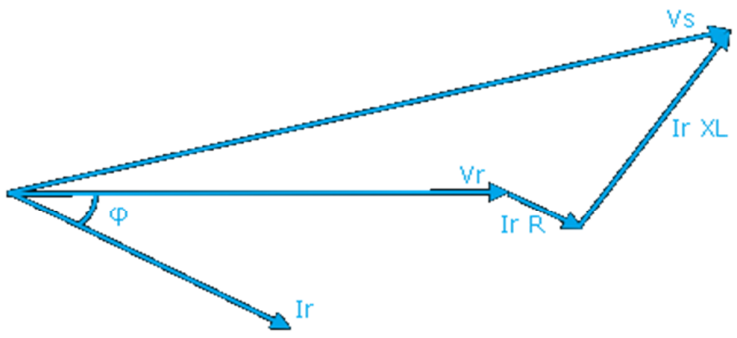
13	Short cute route	possible	Difficult
14	Theft Of energy	Less possibility	More possibility
15	Voltage drop	less	More
16	Power factor	More	Less
17	Reliability	More	Less
18	Life	More	Less
19	Space consumed	No space consumed	Space consumed
20	Appearance	Very good	Not good
21	Application	Short distance transmission & distribution, urban areas, thickly populated area, taking supply in water (ocean) with help ofmarine cable.	For Long distance transmission, For distribution rural and sub urban area.

b) Explain the effects of lagging and leading pf of the load on regulation.

Ans:

Vector Diagram for Lagging Power Factor: **(2 Marks)**

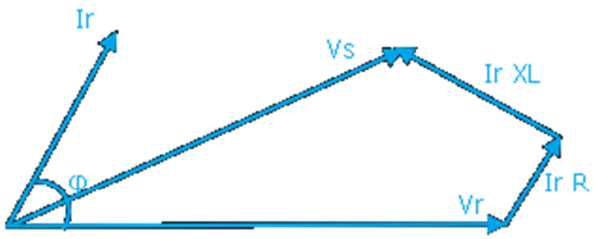
At Lagging P.F. Receiving voltage is less than Sending end hence **regulation is positive**



∴ Inductive load, receiving end voltage Vr is less than sending end voltage Vs

Vector Diagram for Leading Power Factor: **(2 Marks)**

At Leading P.F. Receiving voltage is more than Sending end hence **regulation is negative.**



Capacitive load, receiving end voltage Vr is more than sending end voltage Vs

c) State the comparison between indoor and outdoor substation. (any four points).

Ans: **(Any Four Point expected: 1 Mark each, Total 4 Mark)**

Sr. No.	Points	Indoor substation	Outdoor substation
1	Capital cost	High, as construction work cost is more.	Less, as construction work cost is less.
2	Time required for completion	More, as construction work is more.	Less, as construction work is less.
3	Distance between two equipment	Less, this will increase possibility of fault & safety reduces.	More, this will reduce possibility of fault & safety increases
4	Access for incoming & outgoing line	Difficult access for incoming & outgoing lines because of indoor installation.	Easy access for incoming & outgoing lines because of outdoor installation.
5	Cooling arrangement	Natural cooling is not available so artificial cooling arrangement is required This increases energy consumption charges due to indoor installation.	Natural cooling is available due to outdoor installation. This reduces energy consumption charges due to outdoor installation.

6	Availability of natural light	Natural light is not available even in day time, so there is need of illumination even during a day time. This increases energy consumption charges due to indoor installation	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	Difficult, as all equipments are not easily viewed.	Easy, as all equipments are easily viewed.
8	Replacement of equipment	Difficult, due to indoor installation.	Easy, due to outdoor installation.
9	Future expansion	Expansion of substation is not easily possible whenever needed because of construction work. Also it require more time & cost.	Expansion of substation is easily possible whenever needed & can be completed in less time & cost.
10	In case of accident	In case of accident there is more risk& damage to other equipments than outdoor substation.	In case of accident there is less risk & damage to other equipments than indoor substation.
11	Space Require	Less	More
12	Effect of atmospheric condition	Switching operation is not difficult in rainy season & it is more safe due to indoor installation	Switching operation is difficult in rainy season & it is less safe
13	Chances of leakage current	Less due to indoor installation	More due to outdoor installation
14	Maintenance cost	Less due to indoor installation	More due to outdoor installation.
15	Applications	In places where heavy rainfall, snow fall occurs or there is humidity in atmosphere also where availability of space is less than under such situations sub stations are installed indoor.	Where atmospheric conditions are clean and dry also where space available is more than subs stations are installed outdoor.

d) State four factors which affect the life of line insulators and explain.

Ans: **Following factors affects the life of line insulators:-**

(Any Four Point expected: 1 Mark each, Total 4 Mark)

1. **High voltage stress:** If insulation is used for higher voltage than its designed value then there will be high voltage stresses it may reduce life of insulation.
2. **High Temperature:** Due to over loading, insulation gets heated than its life reduces.
3. **Water:** If insulation is near water for the long period than its life reduces.
4. **Moisture:** If insulation contains moisture for the long period than its life reduces.
5. **Dirt & Dust Particles:** If dirt & dust particles accumulated on insulation than it will absorb moisture in the air which will reduces the insulation resistance it may cause the failure of insulation.
6. **Mechanical Stress:** Any mechanical stress on insulation for the long period than its life reduces
7. **Improper Handling:** If it is handle roughly than it may damage.
8. **Ageing:** Due to ageing effect, it's dielectric strength reduces.
9. **Effect of oxygen & humidity:-**

   Life of insulation reduces due to decomposition.
10. **Chemical Reaction:-**

    Life of insulation reduces due to chemical reaction.
11. **Presence of arc:-**

    If insulation is exposed near arc than it may damage.

e) Compare HVDC transmission with EHV ac transmission (any four points).

Ans:

(Any Four Point expected: 1 Mark each, Total 4 Mark)

S.No	Points	H.V.D.C	EHV A.C.
1	Number of conductor required for single circuit	One conductor.& Ground is used as a return path	Three conductors (R.Y.B)
2	For double circuit	Two conductors.& Ground is used as a return path	Six conductors (R,Y,B & R,Y,B)

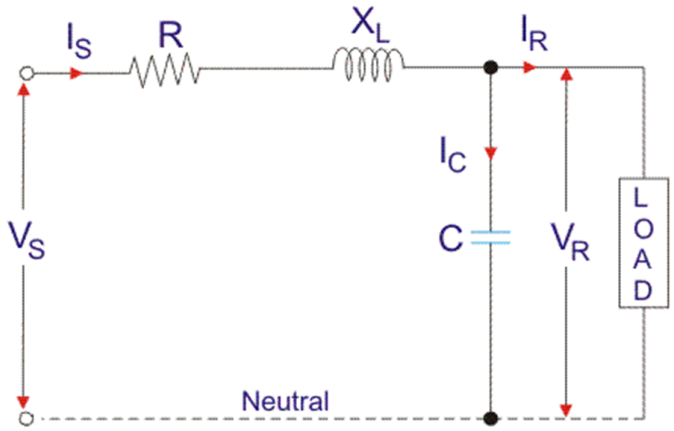
		3	Design of Tower	Light	Heavy
		4	Intermediate substation	Not required	Required at every 250 Km
		5	Capital cost of S/S	More	Less
		6	Transmission line cost/km for long distance. (Above 500km.)	Less	More
		7	Ground return	Possible	Not possible
		8	Frequency	Absent	Present
		9	Skin effect	Absent	Present
		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	Transmission Efficiency	More	Less
		18	Voltage drop in transmission line	Less	More
		19	% Regulation	Better	Good
		20	Limitation on length of cable	Charging current is absent so no limitation on length of cable	Due to charging current there is 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	AC Double circuit are necessary

26	Control system	Difficult, costly	Simpler cheaper
27	Power handling capacity	No limit	There is limit due to inductance &power angle
28	Voltage control for long distance lines	Easier as L&C are not effective	Difficult for long distance lines due to presence of L &C
29	Stability limit	No limit due to absent of inductance &power angle	EHVAC limits due to inductance &power angle
30	Power flow control	Power can be quickly(fast) controlled,	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-circuit 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

f) State the functions of CT equipment of substation.

Ans: **Functions of CT equipment of substation :** **(4 Marks)**

1. C.T are used for measurement of electrical quantities (Current)
2. C.T. is used for protection purpose as a part of tripping circuit of C.B.

Q.3	**Attempt any FOUR :** **16 Mark**
a)	**Calculate the regulation and efficiency of a medium transmission line using "End Condenser Method".**
Ans:	Calculation the regulation and efficiency of a medium transmission line using "End Condenser Method". (Expression of **regulation and efficiency 2 Marks and derivation 2 Marks ,Total 4 Marks**) **(4 Marks)** In this method capacitance is assumed to be lumped at receiving end. One phase is shown  below. Here I_R is the receiving end load current per phase, R is the resistance per phase, X_L is the inductive reactance per phase, C is the capacitance per phase, $\cos\Phi_R$ is the receiving end lagging power factor, V_S is the sending end voltage. Let us assume, $\overrightarrow{V_R}$ as the reference phasor, $\overrightarrow{V_R} = V_R + j0$ Load current at receiving end $\overrightarrow{I_R} = I_R(\cos\Phi_R - j\sin\Phi_R)$ The capacitive current

$$\overrightarrow{I_C} = j\underrightarrow{\omega C} = j2\pi fC\underrightarrow{V_R}$$

Now,

$$\overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_C}$$
$$= I_R(\cos\theta_R - j\sin\theta_R) + j2\pi fCV_R$$
$$= I_R\cos\theta_R + j(-I_R\sin\theta_R + 2\pi fCV_R)$$

$$Voltage\ drop\ per\ phase = \overrightarrow{I_S}\overrightarrow{Z} = \overrightarrow{I_S}(R + jX_L)$$

$$Sending\ end\ Voltage = \overrightarrow{V_S} = \overrightarrow{V_R} + \overrightarrow{I_S}\overrightarrow{Z} = \overrightarrow{V_R} + \overrightarrow{I_S}(R + jX_L)$$

Now,

$$\%VR = \frac{V_S - V_R}{V_R} \times 100$$

and

$$\%\ transmission\ efficiency = \frac{Powerdelivered/phase}{Powerdelivered/phase + Losses/phase} \times 100$$
$$= \frac{V_R I_R\cos\theta_R}{V_R I_R\cos\theta_R + I_S^2 R} \times 100$$

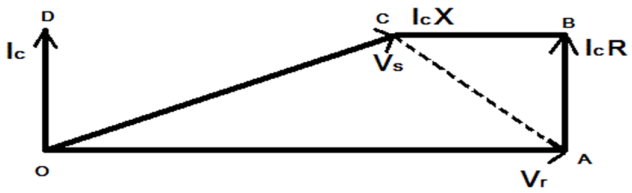
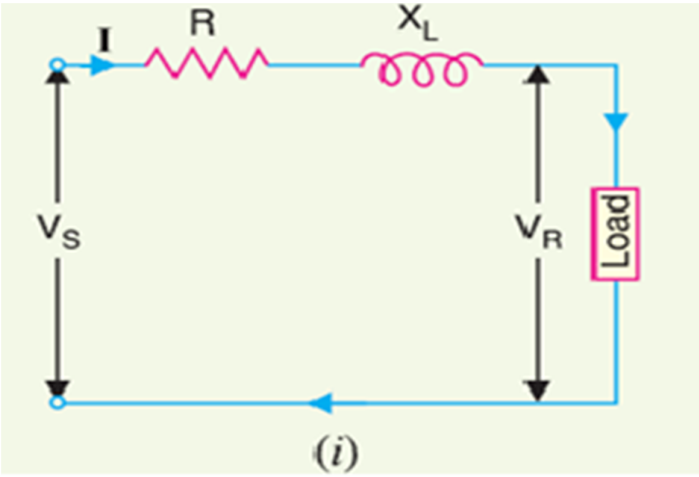
b) State the different transmission line components in the system.

Ans:

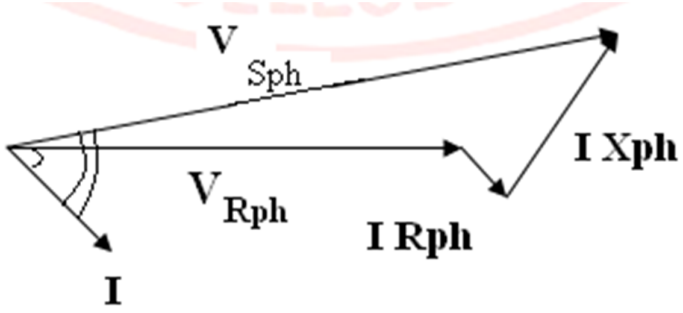
(Any Four transmission line components are expected 1 Mark each, Total 4 Marks)

Following are the some components of transmission Line:-

1. Supporting structure (pole)
2. Line insulator
3. Overhead conductor
4. 'V' Cross arm
5. Top pin support
6. Two Pin Cross arm
7. Four pin cross arm
8. Stay set (Stay wire of 7/8 or 7/10 SWG)
9. Lighting arrestors
10. Guarding wires
11. Continuous earth wire
12. Cables
13. Fuses and Isolating switches

	14. Different types of Clamp (A-type, B-Type) 15. Bird guards 16. Vibration damper 17. Jumpers
c)	**State the Ferranti effect. Explain it with the help of neat phasor diagram.**
Ans:	**Ferranti effect** : **(2 Marks)** Under no load/light load conditions, it is found that receiving end voltage (V_R) is found to be greater than sending end voltage (V_S). This phenomenon is known as Ferranti effect**.** **Phasor Diagram:** **(2 Marks)** Load Current (I_R) is negligible as compare to charging current (I_c)  Ferranti effect in transmission lines.
d)	**Draw short transmission line and its phasor diagram for lagging power factor load.**
Ans:	**(Equivalent Circuit 2 Marks, Phasor diagram 2 Marks , Total 4 Marks)** **Equivalent Circuit:**  (i)

Phasor Diagram of Short transmission Line:



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

e) State difference between feeder and distributor on any four points.

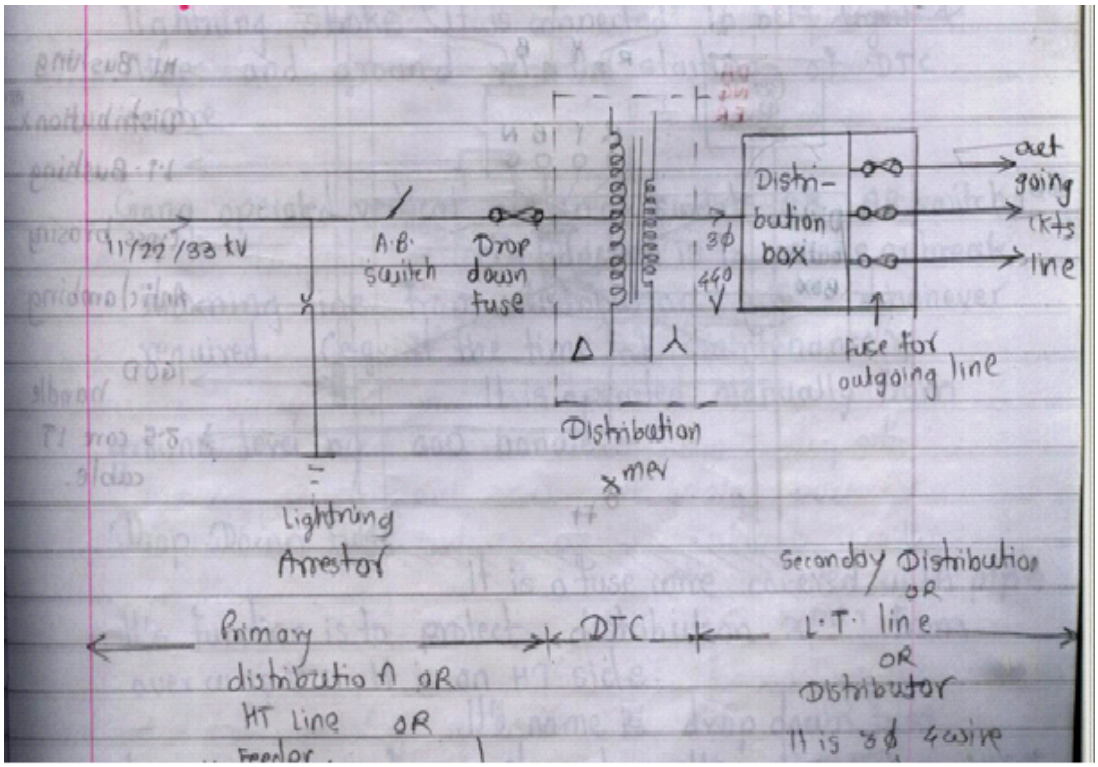
Ans: **(Any Four Point expected: 1 Mark each, Total 4 Mark)**

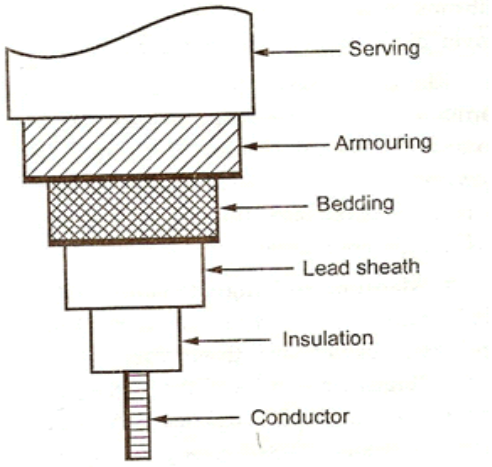
Sr.No.	Feeder	Distributor
1	It is link between receiving substation & distribution transformer	It is link between distribution transformer substation & consumer
2	It is also called as a High Tension Line	It is also called as a low Tension Line
3	It is a 3-Ph, 3 wire system.(R-Y-B)	It is a 3-Ph, 4 wires system. (R-Y-B-N)
4	Feeder voltage is 11KV/22KV/33KV	Distributor voltage is for 3-ph consumer-

	depending upon load	400V and 1-Ph consumer- 230V
5	Feeder is high capacity conductors.	Distributors are low capacity conductors
6	Feeder forms the primary distribution system	Distributors forms secondary distributor system.
7	While designing feeder its current carrying capacity is important	While designing distributor its voltage drop calculation is important.
8	Feeders are not tapped along its length	Distributors are tapped throughout its length.
9	Its loading point is at substation only	Distributors loading point is throughout its length.

f) Draw a typical layout diagram of 11 kV distribution substation.

Ans: **Typical layout diagram of 11 kV distribution substation:** **(4 Marks)**



Q.4	**Attempt any FOUR :** **16 Mark**
a)	**With a neat diagram show the various parts of a high voltage single core cable.**
Ans:	**Neat diagram show the various parts of a high voltage single core cable.** **(4 Marks)**  General construction of a cable
b)	**Explain the factors which affect corona ?**
Ans:	**The Factors affecting corona:-** **(Any Four Factor expected: 1 Mark each, Total 4 Mark)** **1. 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 **2. 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. **3. Size of conductor:** If size (Cross section) of conductor is more, than magnitude of voltage required to occur the corona increases. **4. Condition of conductor & Hardware:** Rough and irregular surface of conductor and hardware will give more corona than solid, smooth body conductor & hardware. **5. 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.

6. **Effect of supply Frequency:**

Corona loss varies directly as the supply frequency

7. **Effect of density of air:**

Corona loss increases with the decrease in the density of air.

c) In a 33 kV overhead line there are three units in the string of insulators. If the capacitance between each insulator pin and earth is 11 % of self-capacitance of each insulator find : (i) the distribution of voltage over 3 insulators and (ii) String efficiency.

Ans:

Step 1 :

$$Voltage\ \ across\ \ String = \frac{V_L}{\sqrt{3}} = \frac{33}{\sqrt{3}}$$

$$Voltage\ \ across\ \ String = 19.05\, Volt$$

Step 2 :

$$\therefore V_2 = V_1\ (1+m)$$ ----**(1/2 Mark)**

$$\therefore V_2 = V_1\ (1+0.11\ )$$

$$\therefore V_2 = 1.11 V_1$$

Step 3 :

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

$$\therefore V_3 = V_1\ (1+3(0.11)+(0.11)^2)$$

$$\therefore V_3 = 1.3421 V_1$$

Step 4 :

$$\therefore Voltage\ across\ string = V_1 + V_2 + V_3$$ ----**(1/2 Mark)**

$$\therefore 19.05 = 1V_1 + 1.11V_1 + 1.3421V_1$$

$$\therefore 19.05 = 3.4521 V_1$$

$$\therefore V_1 = 5.52\ KV$$

Step 5 :

$$\therefore V_2 = 1.11 V_1$$ ----**(1/2 Mark)**

$$\therefore V_2 = 1.11 \times 5.52$$

$$\therefore V_2 = 6.12\ \ KV$$

Step 6 :

$$\therefore V_3 = 1.3421 V_1$$ ----**(1/2 Mark)**

$$\therefore V_3 = 1.3421 \times 5.52$$

$$\therefore V_3 = 7.41\ \ KV$$

Step 7 :

String % $\eta = \dfrac{V_{Ph}}{V_n \times n} \times 100$ ------**(1/2 Mark)**

$$= \frac{19.05}{7.41 \times 3} \times 100$$

= **85.95%** ----------**(1/2 Mark)**

d) How will you solve AC distribution problem ? Explain any one method.

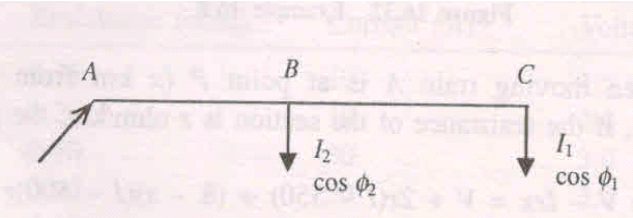
Ans:

Following are the Methods Solve AC distribution problem: **(2 Marks)**

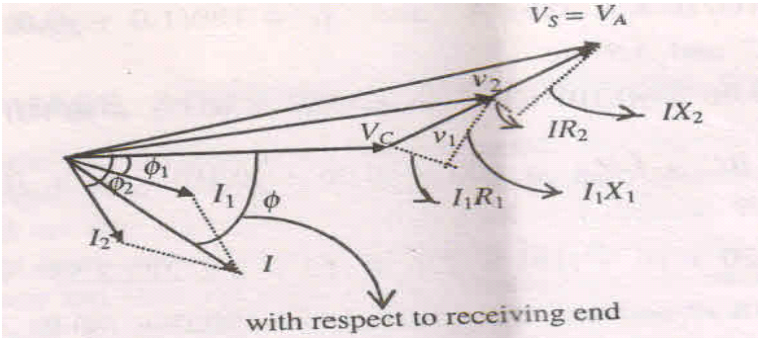
1. Power factor with respect to receiving end
2. Power factor with respect load points

Explanation : **(Any one explanation expected: 2 Marks)**

1. Power factor with respect to receiving end:

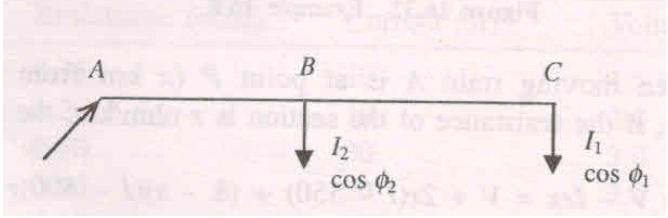


Consider a distributor with two loads I_1 and I_2 at power factors Cos ϕ_1 and Cos ϕ_2 respectively, as shown in above figure . Taking voltage at point C (V_C) as reference, the phasor diagram is shown in below figure



If the resistance of section $BC\ is\ R_1 + jX_1$ and of section $AB\ is\ (R_2 + jX_2)$, the voltage drop in section BC will be $\overline{I}_1(R_1 + jX_1)$ and is section AB it will be $(\overline{I}_1 + \overline{I}_2)(R_2 + jX_2)$, Where $\overline{V}_1$ *and* $\overline{V}_2$ are complex voltage drops in sections BC and AB, respectively.

2. Power factor with respect load points:



If the power factors are with respective load point voltage, the power factor angle ϕ_2 is

with respect to voltage V_B, whereas power factor angle ϕ_1 is with respect to voltage at point C, i.e. receiving end voltage. For calculating the voltage drop, in this case, first the voltage at the respective load is to be determined, Then the actual power factor angle with respect to the reference point is determined to calculate the voltage at other points.

e) Write construction of underground substation. Draw diagram of underground substation.

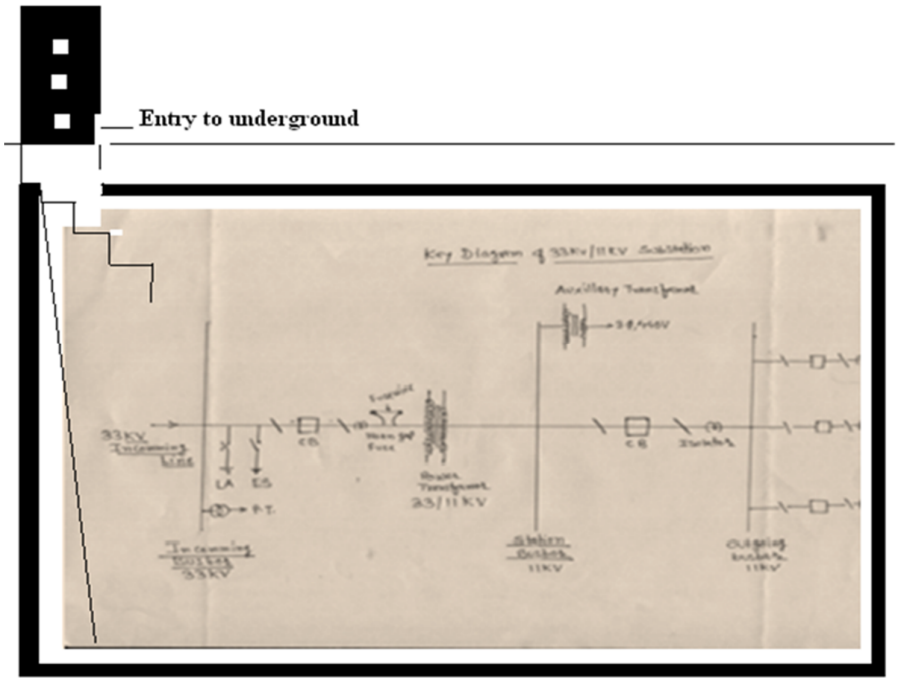
Ans: **Underground Substation:**

In underground substation all equipments including transformer are installed under closed construction in underground.

The construction of underground sub-station consist of : **(2 Marks)**

- The location of the station is under ground.
- There is reasonable distance between two equipment
- There is provision for emergency lighting and protection against fire.
- There is good ventilation.
- There is provision for remote indication of excessive rise in temperature so that H.V supply can be disconnected.
- The transformers, switches and fuses are air cooled to avoid overheating.

NEAT Diagram of underground substation: **(2 Marks)**



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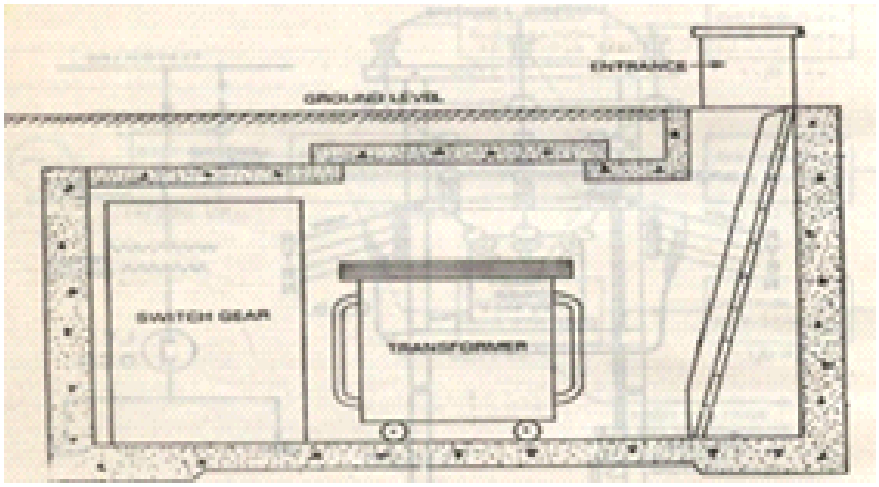
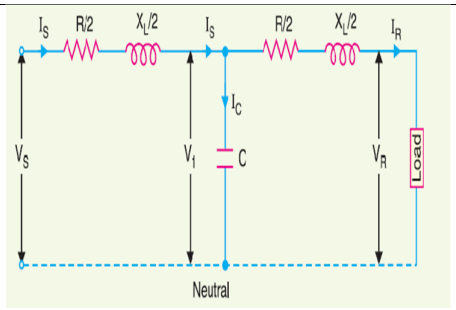
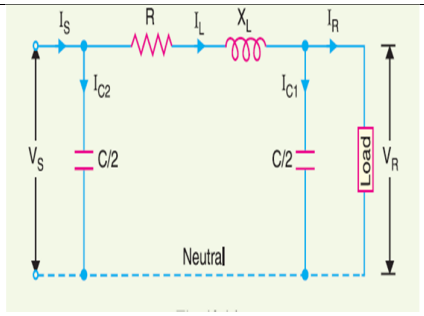


f) Differentiate between nominal T and nominal π method (any four points).

Ans: **(Any Four Point expected: 1 Mark each, Total 4 Marks)**

Sr.No	Nominal T Method	Nominal π Method
1	It is assume that line capacitance is connected at center 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.5 Attempt any FOUR : 16 Mark

a)	**Explain various methods of improving string efficiency.**
Ans:	**(List of methods of improving string efficiency 2 Marks, Explanation any one 2 Marks , Total 4 Marks)**

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:- **(1 Mark)**

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:- **(1 Mark)**

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 :- **(1 Mark)**

In this method, disc insulators of different dimensions are so selected that each

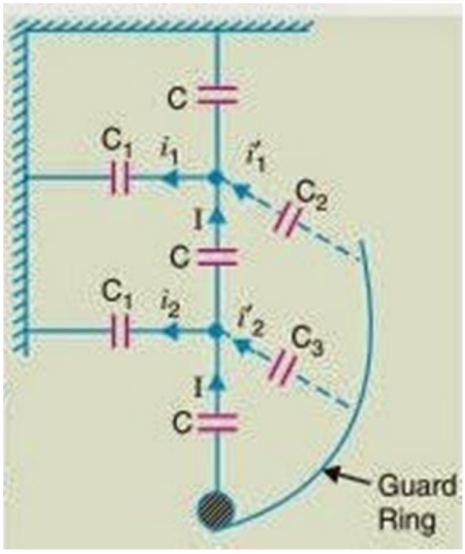
disc has different capacitance. The assembly in the string of suspension insulator is made in such a way that the top unit insulator has fewer dimensions. (Less capacitance) (C α A) and dimensions of insulators progressively goes on increasing i.e. bottom unit has maximum capacitance due to large dimensions of insulators.

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

In this way it equalizes potential distribution across the string and therefore increases 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

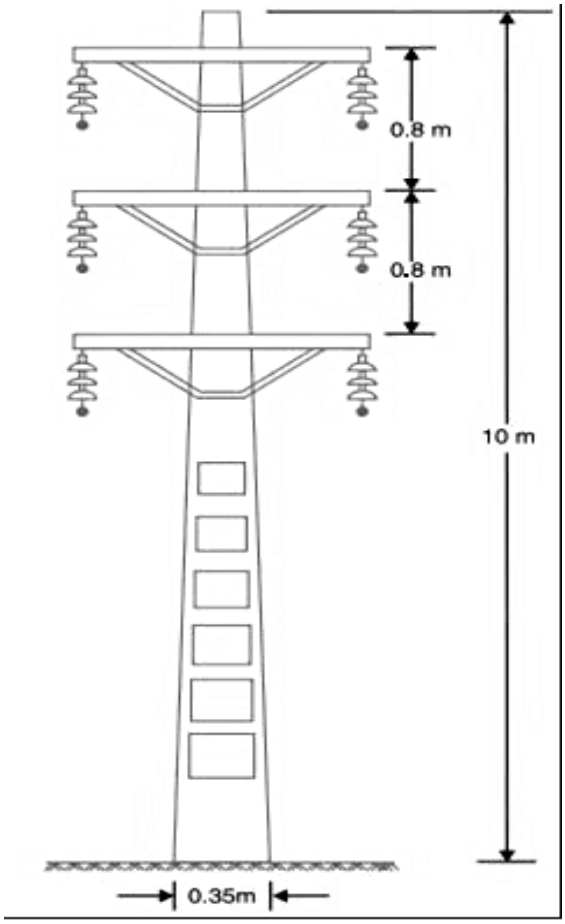
4) By Using guard ring :- **(1 Mark)**



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.

b)	**State the different losses present in Transmission line and explain how they affects its efficiency.**
Ans:	**Following losses present in Transmission:-** **(4 Marks)** 1. Due to resistance (R):- voltage drop & copper losses in transmission line produces. 2. Capacitor (C):- draws charging current through transmission line. This charging current produces additional copper losses in transmission line. As losses in transmission line increases transmission efficiency decreases.
c)	**Draw a neat sketch of double circuit RCC Pole.**
Ans:	**Neat sketch of double circuit RCC Pole:** **(4 Marks)** 

d)	**Explain why electric power is to be transmitted at high voltage?**

Ans:

(Any Four Points Are Expected 1 Mark Each , Total 4 Marks)

Explanation for electric power is to be transmitted at high voltage:

Important Reasons for **why electric power is to be transmitted at high voltage**

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

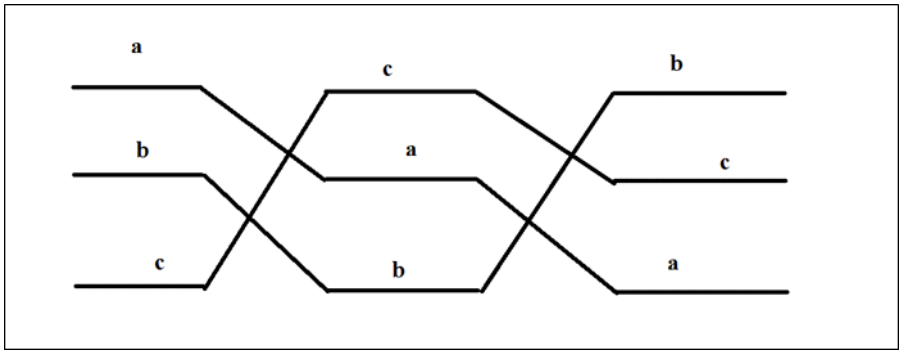
$I \alpha \frac{1}{V}$ from This Equation It is clear that due to High Transmission Voltage Following are the advantages Hence **electric power is to be transmitted at high voltage**

Power is to be transmitted at high voltage due to following Reasons:-

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 current decreases, 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 $P \alpha V^2$)
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.

e) **With the help of neat diagram explain the concept of transposition of conductors.**

Ans: **Concept of transposition of conductors:** **(4 Marks)**



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

f) **An overhead transmission line delivers 5 MW at 22 kV at 0.8 lagging power factor. The resistance and reactance of each conductor is 4 ohm and 6 ohm respectively. Determine sending end voltage and percentage regulation.**

Ans: **(Note :- In Numerical It is not mention Single Phase Or Three Phase transmission line So give Marks Stepwise for Both Single Phase Or Three Phase solved)**

Numerical Is Solved By considering Three Phase transmission line

Given Data:-

P_R =5 MW= 5000KW V_R = 22KV P.F. = 0.8 lag R_{ph} = 4 ohm X_{ph} = 6 ohm

Step 1: To calculate current:

Power P = $\sqrt{3}\, V_L\, I_L \cos\phi \quad for\ 3-ph$ ---------- **(1/2 Mark)**

$$I \equiv \frac{P}{\sqrt{3}\ V_{LR} \times \cos\phi}, \qquad I \equiv \frac{5000}{\sqrt{3} \times 22 \times 0.8}$$

$$I \equiv 164.01996\, amp$$ ---------- **(1/2 Mark)**

Step 2: **To calculate value of sin** :

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

$$V_{Rph} \equiv \frac{V_{RL}}{\sqrt{3}}$$

$$V_{Rph} \equiv \frac{22}{\sqrt{3}}$$

$$V_{Rph} \equiv 12.7017\ KV \ or\ V_{Rph} = 12.7017 \times 10^3\ V$$ ---------- **(1/2 Mark)**

Step 3: To calculate Sending end voltage:

Sending end phase voltage (V_{Sph}) =

$= V_{Rph} + I (R_{Ph} \text{ Cos } \emptyset_R + X_{Ph} \text{ Sin } \emptyset_R)$ ---------- **(1/2 Mark)**

$= 12.7017 \times 10^3 + 164.01996 (4 \times 0.8 + 6 \times 0.6)$

$= 13817.03573V$

$= 13.81703$ KV ----------**(1/2 Mark)**

Sending End Line Voltage = $\therefore V_{SL} = \sqrt{3} \times V_{sph}$

$V_{SL} = \sqrt{3} \times 13.81703$

= 23.9317 KV ---------- **(1/2 Mark)**

Step 4:To calculate voltage regulation:

$$\% \text{ Voltage Regulation} = \frac{V_{S\,Ph} - V_{R\,Ph}}{V_{R\,Ph}} \times 100 \text{ -}$$ ---------- **(1/2 Mark)**

$$= \frac{13.81703 - 12.7017}{12.7017} \times 100$$

= 8.7809 % ---------- **(1/2 Mark)**

OR Student may Write this way

Numerical Is Solved By considering Single Phase transmission line

Given Data:-

P_R =5 MW= 5000KW V_R = 22KV P.F. = 0.8 lag R_{ph} = 4 ohm X_{ph} = 6 ohm

Total Resistance of each conductor = 4 x2 = 8 ohm

Total Reactance of each conductor = 6 x2 = 12 ohm

Step 1: To calculate current:

Power P = $V_L I_L \cos\varphi \quad for\ 1-ph$ ---------- **(1/2 Mark)**

$$I \equiv \frac{P}{V_{LR} \times \cos\varphi}, \quad I \equiv \frac{5 \times 10^6}{22 \times 10^3 \times 0.8}$$

$I \equiv 284.09\ amp$ ---------- **(1/2 Mark)**

Step 2: **To calculate Total Losses** :

$\therefore Total\ \ losses = I^2 R$

---------- **(1/2 Mark)**

$\therefore Total\ \ losses = (284.09)^2 \times 8$

$\therefore$ *Total losses* = 645657 . 02 Watts ---------- **(1/2 Mark)**

Step 2: To calculate Sending end voltage:

Sending end phase voltage **(** V_{Sph}**)** =

$= V_{Rph} + I (R_{Ph} \text{ Cos } \emptyset_R + X_{Ph} \text{ Sin } \emptyset_R)$ ---------- **(1/2 Mark)**

$= 22 \times 10^3 + 284.09 \ (8 \times 0.8 + 12 \times 0.6)$

= 25.86 KV ----------**(1/2 Mark)**

Step 4:To calculate voltage regulation:

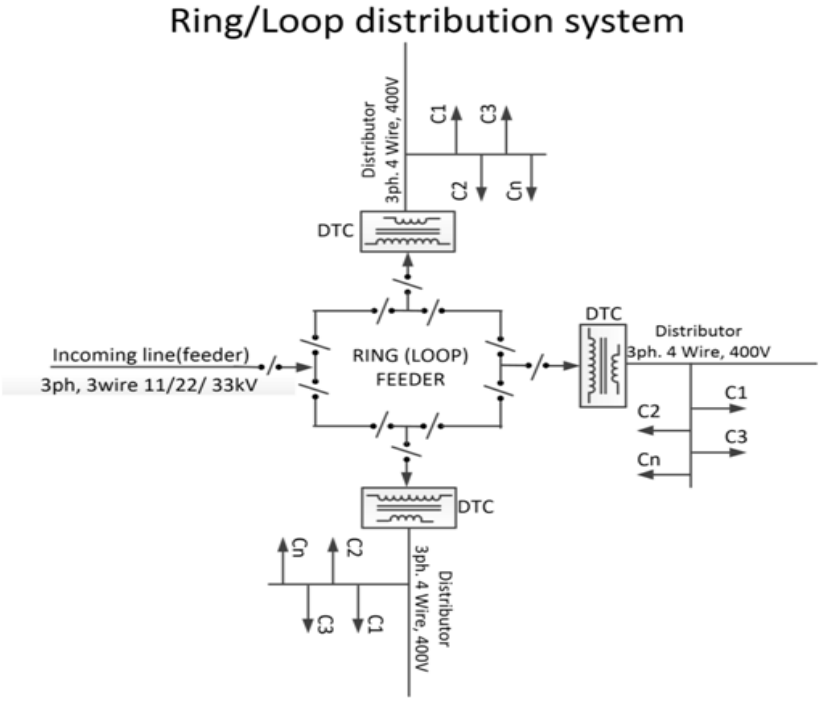
$$\% \text{ Voltage Regulation} = \frac{V_{S\,Ph} - V_{R\,Ph}}{V_{R\,Ph}} \times 100 \text{ -}$$ ---------- **(1/2 Mark)**

$$= \frac{25.86 - 22}{22} \times 100$$

= 17.54 % ---------- **(1/2 Mark)**

Q.6	**Attempt any FOUR :** **16 Mark**
a)	**Describe ring main system of distribution with neat diagram.**
Ans:	**Ring main system of distribution with neat diagram:**

(Figure ; 2 Mark & Explanation: 2 Marks)



Explanation Ring Main system of distribution:

There are two feeders to distribution transformer center which forms a closed loop as shown in layout. Only one feeder is utilized at a time.

Advantages:-(Any one point is expected)

1. Supply to distribution transformer center is given through two different Feeders
2. Reliability to maintain supply is more even when there is a fault on any one feeder.
3. Reliability to maintain supply is more even when there was maintenance on any one feeder

Disadvantages:- :-(Any one point is expected)

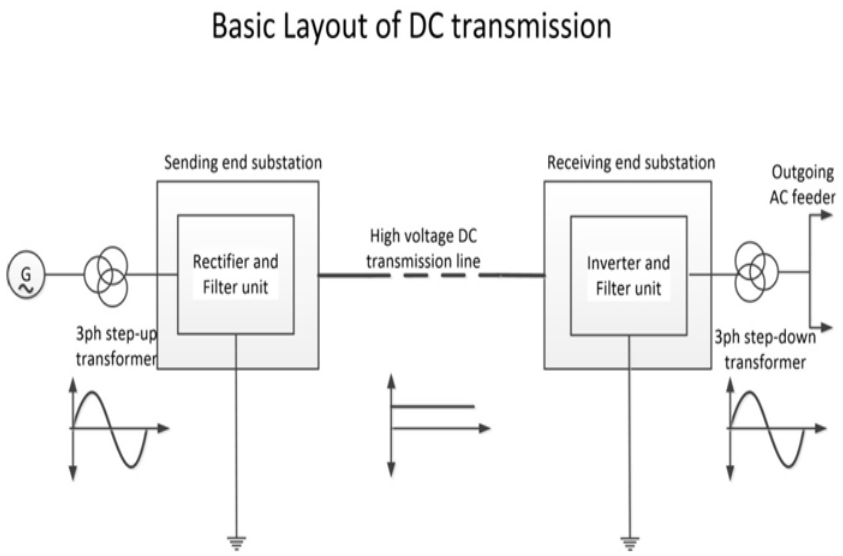
1. Layout & design is complicated.
2. Initial cost &Erecting cost is high because to two incoming feeders.
3. Time required for completion of layout is more.
4. Extra care should be taken at the time of repairing & maintenance, because feeders form a closed loop.

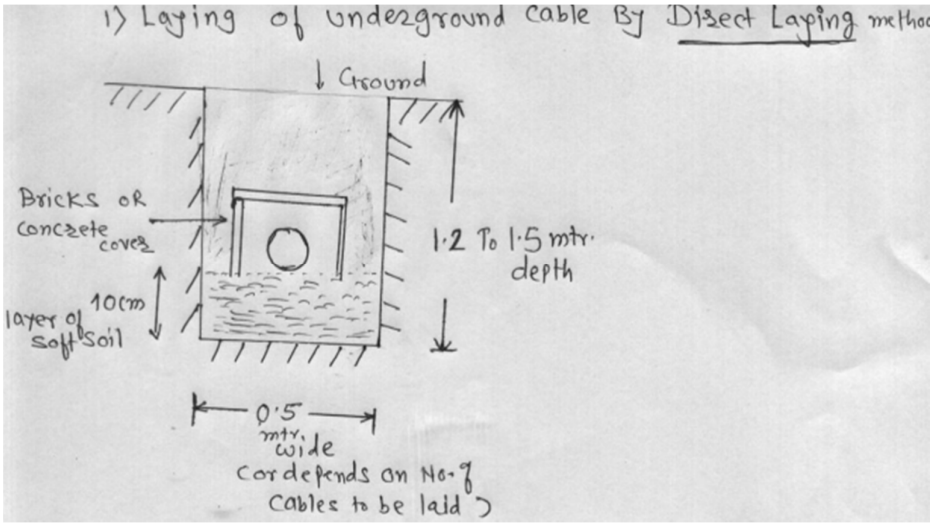
Applications:- :-(Any one point is expected)

1. Where continuity of supply is necessary.
2. In urban areas important industries etc.
3. For long distance primary distribution system.

b) Draw a block diagram of HVDC transmission starting from Generator.

Ans: **Block diagram of HVDC transmission starting from Generator:** **(4 Marks)**



c)	**Explain any one method of laying of cable.**
Ans:	**Following are the different methods of Laying of under- ground cable:-** 1. Direct laying cable 2. Draw- in system 3. Solid System 4. Cable laid in tray **Explanation: -** **(Any one method is expected: Figure : 2 Mark & Explanation: 2 Marks)** **1) Direct laying Cable:**  **Procedure:** ➢ For laying of a cable trench about 1.5m deep and 0.5m wide is made along the cable route. ➢ A layer of 10 cm thickness of soft soil is spread throughout the cable route in trench. ➢ The cable is laid on this soft soil (bed) ➢ A wall of bricks (concrete cover) is provided on either side or top of cable along the length of cable for better mechanical protection. ➢ Another layer of soft sand, about 10 cm thicknesses is spread throughout its cable length. ➢ Refill the remaining trench with the help of remaining soil up to ground level. ➢ Only armored cables are used in this method.

Advantages:- (Any one point is expected)

1. It is a simple and less costly method.
2. It gives the best conditions for dissipating the heat generated in the cables.
3. It is a clean and safe method as the cable is invisible and free from external disturbances.

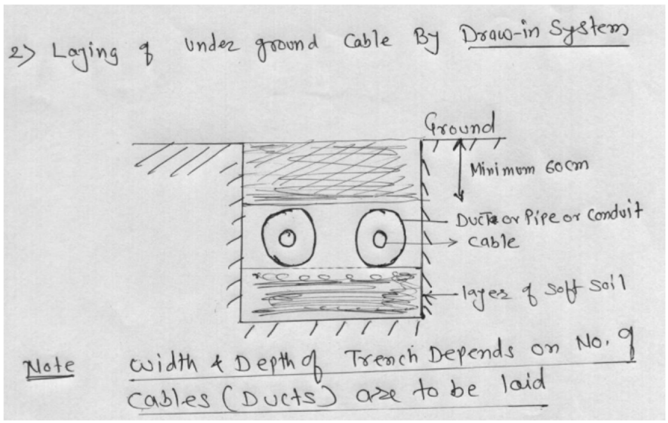
Disadvantages:- (Any one point is expected)

1. The alterations in the cable network cannot be made easily.
2. The replacement of faulty cable cost is very high.
3. Localization of fault is difficult.
4. It cannot be used in congested areas where excavation (digging of trench) is expensive and inconvenient.

Application :

This method of laying cables is used in open areas where excavation can be done conveniently and at low cost.

2) Draw in cable laying System or Duct laid cable laying system:



Procedure:

- A trench of minimum 60cm deep is made along with cable route.
- The pipe is laid on this soft soil (bed)
- Width of trench depends on number of conduits to be laid.
- Separate pipes are provided for each cable.
- Spacing between 2 cables (conduit) is between 25 cm to 75 cm.
- Diameter of pipe is 2 to 3 cm, greater than cable diameter for easy handling of new cable and replacement of cable.
- Pipe used may be cement pipe, DWC pipe or ducts are used.
- For Maintenance and other cable work, man-holes are provided at suitable distance.

- Size of man-holes should be large enough to allow a person to enter into duct without difficulty.
- Unarmored cables are used in this type.

Advantages: :- (Any one point is expected)

a) Repairs, alterations or additions to the cable network can be made without opening the ground.
b) As the cables are not armoured cost is reduced considerably.
c) There are very less chances of fault occurrence due to strong mechanical protection provided by the system.

Disadvantages:- :- (Any one point is expected)

a) The initial cost is very high.
b) As cable is passed through pipes so there is problem of dissipation of heat, so the current carrying capacity of the cable is reduced.

d) Derive the expression for ABCD constants of medium transmission line represented by n circuit.

Ans: **Expression for ABCD constants of medium transmission line**

(Only expressions ABCD constants 3 marks and derivation 1 mark)

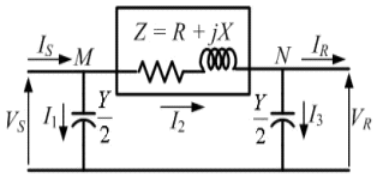


Fig. 2.3 Nominal-π representation.

Let us define three currents I_1, I_2 and I_3 as indicated in Fig. 2.3. Applying KCL at nodes M and N we get

$$I_s = I_1 + I_2 = I_1 + I_3 + I_R$$
$$= \frac{Y}{2}V_s + \frac{Y}{2}V_R + I_R \qquad (2.10)$$

Again

$$V_s = ZI_2 + V_R = Z\left(V_R\frac{Y}{2} + I_R\right) + V_R$$
$$= \left(\frac{YZ}{2} + 1\right)V_R + ZI_R \qquad (2.11)$$

Substituting (2.11) in (2.10) we get

$$I_s = \frac{Y}{2}\left[\left(\frac{YZ}{2}+1\right)V_R + ZI_R\right] + \frac{Y}{2}V_R + I_R$$
$$= Y\left(\frac{YZ}{4}+1\right)V_R + \left(\frac{YZ}{2}+1\right)I_R \qquad (2.12)$$

Therefore from (2.11) and (2.12) we get the following ABCD parameters of the nominal-π representation

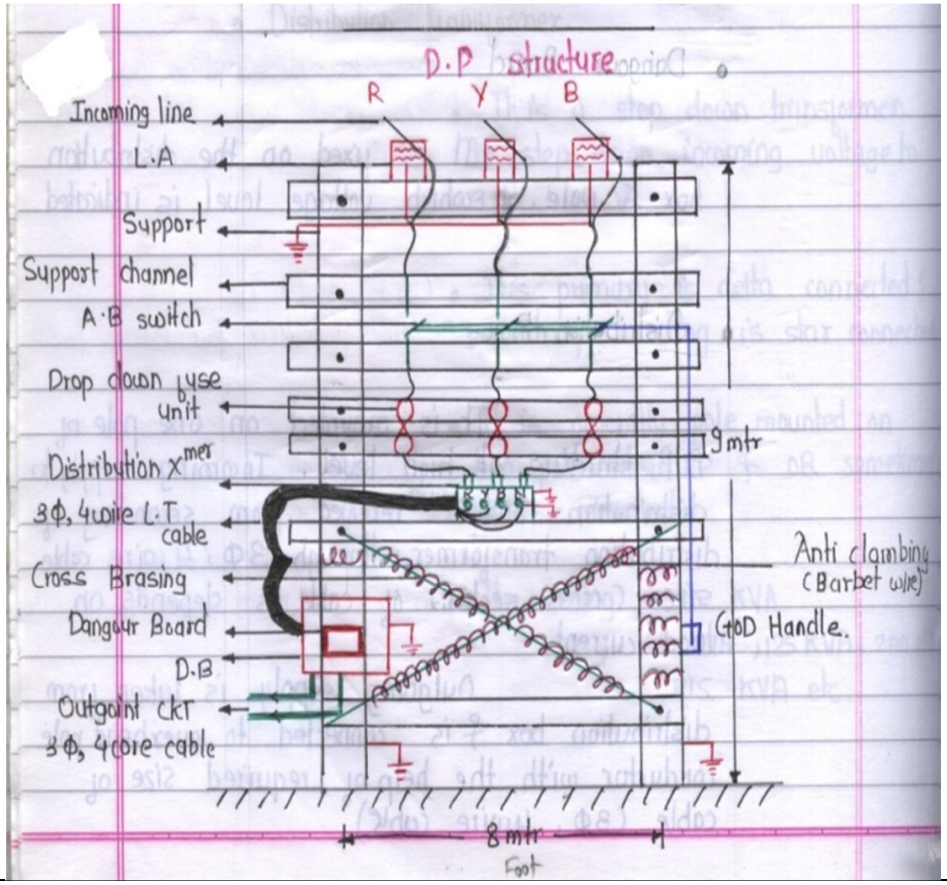
$$A = D = \left(\frac{YZ}{2}+1\right) \qquad (2.13)$$

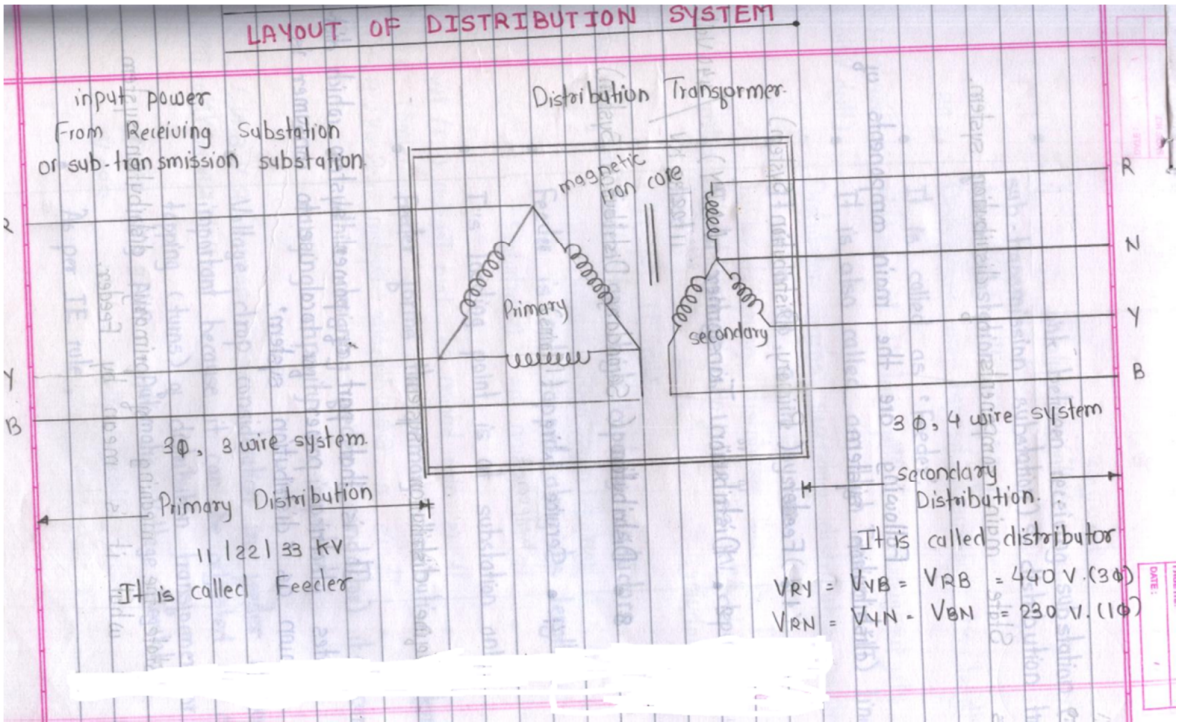
$$B = Z\Omega \qquad (2.14)$$

$$C = Y\left(\frac{YZ}{4}+1\right)\text{mho} \qquad (2.15)$$

e) Draw neat connection diagram of a pole mounted substation.

Ans: **Draw neat connection diagram of a pole mounted substation:** **(4 Marks)**



f)	**Draw a diagram showing primary distribution system and secondary distribution system.**
Ans:	**Diagram showing primary distribution system and secondary distribution system:** **(4 Marks)** 

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