SUMMER – 2022 EXAMINATION

Subject Name: Electrical Power Transmission & Distribution **Model Answer : 22419:EPT**

Important Instructions 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 principal components indicated in the 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 of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
1.		**Attempt any FIVE of the following:**	**10 Marks**
	a)	Write the standard transmission voltages in INDIA. **Ans:** **Standard Transmission Voltages in INDIA:** 765kV (750kV) , 500kV, 400kV, 220 kV, 132 kV, 110 kV, 66kV and 33 kV.	½ Mark for each of any four levels = 2 Marks
	b)	Define – (i) Transmission Efficiency (ii) Voltage regulation in Transmission lines **Ans:** **i) Transmission Efficiency:** The ratio of receiving end power to sending end power of a transmission line is known as transmission efficiency of that line. %Transmission Efficiency = $\frac{Receiving\ end\ power}{Sending\ end\ power} \times 100$ **OR** %Transmission Efficiency = $\frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100$ (where V_R, I_R and $\cos\phi_R$ are the receiving end voltage, current and power factor while V_S, I_S, and $\cos\phi_S$ are corresponding values at the sending end).	1 Mark
		ii) Voltage regulation in Transmission lines: The difference in voltage at the receiving end of a transmission line between conditions of no load and full load is called voltage regulation and is expressed as a percentage of the receiving end voltage. **OR** %Voltage regulation = $\frac{Sending\ end\ voltage - Receiving\ end\ voltage}{Receiving\ end\ voltage} \times 100$ % Voltage regulation = $\frac{V_S - V_R}{V_R} \times 100$ (where V_R is receiving end voltage and V_S is sending end voltage).	1 Mark

c) State any four factors on which skin effect depends.

Ans:

Factors on Which Skin Effect Depends:

1. Frequency of current flowing through the conductor.
2. Diameter of the conductor.
3. The shape of the conductor (solid or stranded).
4. Type of conductor material / permeability of conductor material.

½ Mark for each of four = 2 Marks

d) Give any two limitations of EHVAC w.r.t. distribution system.

Ans:

Limitations of EHVAC w.r.t. Distribution System:

1. Cost of insulation is much more as insulation cost increases with working voltage.
2. Skin effect is more.
3. Proximity effect is more.
4. Corona losses are taking place with EHVAC system and they are almost absent with distribution system.
5. Radio interference is more with EHVAC system.
6. Ground return not possible with EHVAC system.
7. Voltage control is complicated with EHVAC system.
8. Power flow cannot be easily controlled with EHVAC system.
9. Short circuit current level is more with EHVAC system.
10. In case of EHVAC system, intermediate substation is required at every 250 km to improve the performance of transmission line.
11. 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.
12. Stability of EHVAC is very low because of presence of inductance.
13. Transient performance is poor with EHVAC system.
14. To improve the performance of transmission line complex circuitry and additional equipment such as series / shunt reactors, capacitors, FACT controllers etc. are required which increases cost of overall EHVAC system.
15. EHVAC system is economical only for bulk amount of power is to be transmitted over the long distance.
16. Highly skilled engineers / technicians are required for operation and maintenance of EHVAC system.
17. Cost of switchgears utilised with EHVAC system is much more.

1 Mark for each of any two limitations = 2 Marks

e) Compare feeder and distributor on any two parameters.

Ans:

Comparison between feeder and distributor:

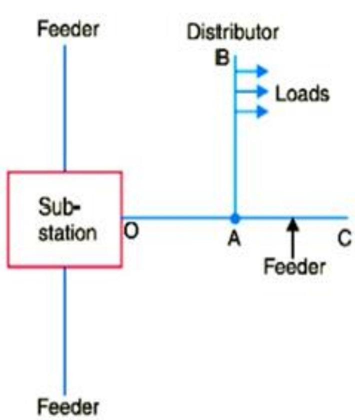
Sr.No.	Feeder	Distributor
1.	It is link between receiving substation and distribution transformer	It is link between distribution transformer substation & consumer.
2.	It is generally a 3 - phase, 3 - wire	It is essentially a 3 - phase, 4 - wire

	system. (R-Y-B)	system. (R-Y-B-N)	
3.	While designing feeder, its current carrying capacity is the main consideration.	While designing distributor, its voltage drop along the length of conductor is the main consideration.	1 Mark for each of any two points = 2 Marks
4.	There is no tapping at all on feeders along its complete length.	Distributors are tapped throughout its Length according to application.	
5.	Feeder voltage is generally of 11kV / 22kV / 33kV.	Distributor voltage is 400 Volts for 3-ph consumers and 230Volts for single phase consumers.	
6.	Feeder forms the primary distribution system.	Distributors forms secondary distributor system.	
7.	Its loading point is at substation only.	Distributors loading points are throughout its length.	
8.	Current through it always remains same.	The current flowing through it does not remain same.	
9.	The length of the feeder is usually longer than that of the distributor.	The length of the distributor is usually longer than that of the service mains.	
10.	The line conduction, which transmits electrical power from the substation to the distributor, is called a feeder or feeder.	The line driver, which transmits the electric power from the substation to the service mains conductor, is called a distributor.	

f) Draw the simple arrangements for radial distribution system.

Ans:

Arrangements for Radial Distribution for D. C. / A. C. System Respectively:



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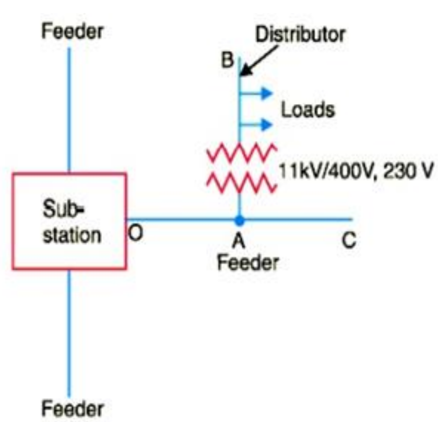


2 Marks

g) State any two advantages of ACSR conductors.

Ans:

Advantages of ACSR Conductors:

1. The mechanical strength of the ACSR conductor is high.
2. The tensile strength of the ACSR conductor is high.

3. Higher reliability due to the steel wires, which ensures the safety margins of the ACSR conductors.
4. Due to the highest mechanical resistance, better transport capacity and high tensile strength the
5. ACSR conductors can be used for medium and long spans and needs less support.
6. Low weight and economical design.
7. Due to the greater diameter of ACSR conductors a much higher corona limit can be obtained causing big advantages on high as well as extra high voltage overhead lines.
8. Because of high tensile strength the sag of the conductor is less and the conductor breakdown chances reduces.
9. ACSR cables are structurally plain. The lightness of aluminium contributes to effortless installation and the easy maintenance of the system.
10. The cost of setting up an aluminium conductor steel reinforced line is low. At the same time, the transmission capacity is large.
11. They are highly flexible and the bending performance of such conductors is more than satisfactory.
12. They are suitable for both overhead transmission and distribution line utilization (versatility).
13. ACSR conductors are of quite long-life.
14. The ACSR conductors are highly corrosion resistant. They can withstand some of the harshest environments so they have been utilized extensively in industrial and marine installations.
15. Impact of skin effect is very less with ACSR conductors.

1 Mark for each of any two advantages = 2 Marks

OR Equivalent Answer

2. **Attempt any <u>THREE</u> of the following:** **12 Marks**

a) "Electrical power is to be transmitted at high voltage". Justify this statement.

Ans:

Justification of Why Electrical Power is to be Transmitted at High Voltage?

Generally long distance transmission lines are designed to operate at high voltage because of the following characteristics / advantages / reasons.

1. Reduction in size of conductor so saving of conductor material and its cost:

Let,

P = power transmitted in watts

V = line voltage in volts

$\cos\varphi$ = power factor of the load

l = length of the line in meters

R = resistance per conductor in ohms

ρ = resistivity of conductor material

Load current (I) = $\frac{P}{\sqrt{3}V\cos\phi}$

Resistance per conductor (R) = $\frac{\rho l}{a}$

Total power (W) = $3I^2R = 3\left(\frac{P}{\sqrt{3}V\cos\phi}\right)^2 \times \frac{\rho l}{a} = \frac{P^2 \rho l}{V^2 \cos^2\phi\, a}$

Area of cross section of conductor (α) = $\frac{P^2 \rho l}{WV^2 cos^2 \phi}$

Total volume of conductor material required = $3\alpha l = 3(\frac{P^2 \rho l}{WV^2 cos^2 \phi})\, l$

It is clear from this expression that for given values of *P*, *l*, ρ & *W*, the cross sectional area (volume of conductor material) required is inversely proportional to the square of transmission voltage & power factor. In other words, the greater the transmission voltage, the lesser is the conductor material required. Hence there is saving of the conductor material and its cost.

1 Mark for each of any four points = 4 Marks

2. Reduction in cost of supporting structures:
As cross sectional area of conductor reduces because of high voltage transmission, the supporting structure, required to carry these less weight conductors, is heavily reduced resulting into saving in the cost of supporting structures.

3. Less voltage drop in lines / Better voltage regulation:
As we know, $P = \sqrt{3} \times V_L \times I_L \cos\phi$, if transmission voltage is increased, then to transfer same power, current gets reduced & hence the IR drop / voltage drop in line get reduced, providing better voltage regulation of system.

4. Less line / copper losses:
As line losses = $3I^2R$, because of less current or reduction in line current, ultimately the line / copper losses are reduced in the system with high transmission voltage.

5. Increase in transmission efficiency:
For high transmission voltage, system operates at less currents resulting into low losses and ultimately increases the transmission efficiency.

6. Increases the transmission / power handling capacity of the line:
As the power transmission capacity is directly proportional to square of transmission voltage, by increasing the transmission line voltage, power handling capacity of transmission line / system get increases (as $P \propto V^2$).

OR Equivalent Answer

b) Explain the effect of load power factor on performance of the transmission line.

Ans:

Effect of Load Power Factor on Performance of the Transmission Line:

The performance of transmission line i.e. regulation and efficiency of a transmission line depend to a considerable extent upon power factor of the load.

1. Effect on regulation:

The expression for voltage regulation of a short transmission line is given by:

$$\%\text{Voltage Regulation} = \frac{IR\cos\phi_R + IX_L \sin\phi_R}{V_R} \times 100 \text{ ……….. (For lagging p.f.)}$$

$$\%\text{Voltage Regulation} = \frac{IR\cos\phi_R - IX_L \sin\phi_R}{V_R} \times 100 \text{ ………… (For leading p.f.)}$$

The following conclusions can be drawn from the above expressions: 2 Marks

1. When load power factor is lagging / unity or such leading that $IR\cos\phi_R > IX_L\sin\phi_R$, then voltage regulation is positive *i.e.*, receiving end voltage V_R will be less than the sending end voltage *Vs*. Hence for given V_R and *I*, voltage regulation of line increases

with the decrease in power factor for lagging loads.

2. When the load power factor is leading to this extent that $IX_L \sin\phi_R > IR\cos\phi_R$, then voltage regulation is negative *i.e.*, the receiving end voltage V_R is more than the sending end voltage *Vs*. Hence for given V_R and *I*, voltage regulation of line decreases with the decrease in power factor for leading loads.

2. Effect on transmission efficiency:

The power delivered to the load depends upon the power factor. The power equation is:

$$P = V_R \times I \times \cos\phi_R \quad \text{……… (For single phase)}$$

$$\text{Hence, } I = \frac{P}{V_R \cos\phi_R}$$

$$P = 3\, V_R \times I \times \cos\phi_R \quad \text{……. (For three phase)}$$

$$\text{Hence, } I = \frac{P}{3V_R \cos\phi_R}$$

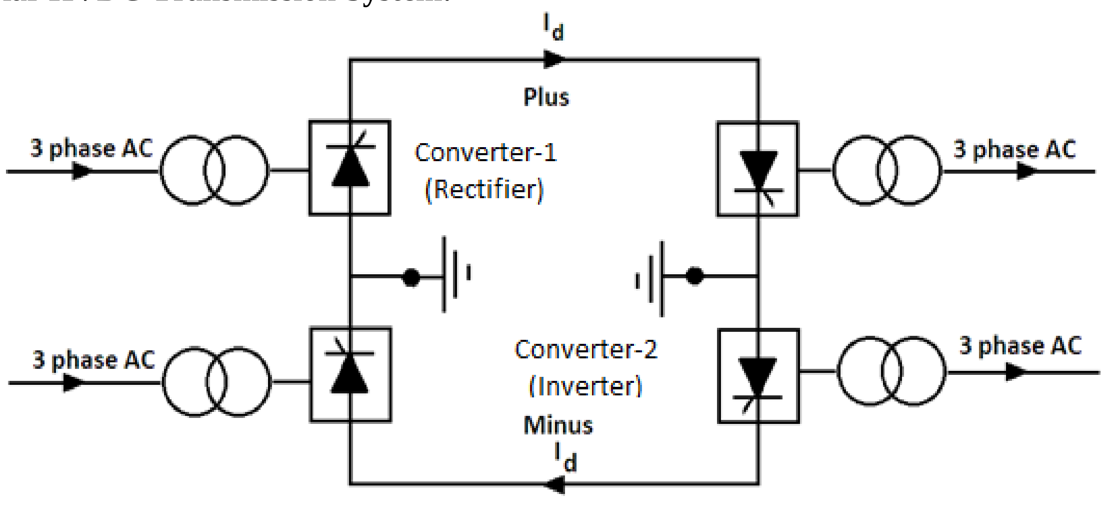
2 Marks

It is clear that in each case, for a given amount of power to be transmitted (*P*) and receiving end voltage (V_R), the load current (I) is inversely proportional to the load power factor $\cos\phi_R$. Consequently, with the decrease in load power factor, the load current and hence the line losses are increased. This leads to conclusion that transmission efficiency of a line decreases with the decrease in load power factor and vice-versa.

c) Draw a neat sketch of Bipolar HVDC transmission system. State any two merits of the same.

Ans:

Bipolar HVDC Transmission System:



Biopolar HVDC transmission system

2 Marks for Sketch

Merits of Bipolar HVDC Transmission System:

1. The transmission of power between two stations or on main-line is continuous.
2. The fault on one link does not affect the operation of another link.
3. During fault conditions, this link can also be used as the mono-polar link.
4. The direction of power flow can be changed by changing polarities of two poles.
5. The voltage in the bipolar link is twice between the poles when compared to the voltage between the pole and the earth of a mono-polar link.

1 Mark for each of any two merits = 2 Marks

d) Compare overhead system with underground system on the following parameter –
   (i) Useful life.
   (ii) Maintenance cost.
   (iii) Interference with communication lines
   (iv) Conductor size

Ans:

Comparison Between Overhead System and Underground System:

Sr. No.	Parameter	Overhead System	Underground System
1.	Useful life	Useful life of overhead system is less, approximately 20 to 25 years.	Useful life of underground system is more, approximately 40 to 50 years.
2.	Maintenance cost	In this system, no need to dig at the time of maintenance. Hence, for the same number of faults, the maintenance cost is less.	In this system, to find the fault, digging is compulsory. It increases labour cost. Hence, for the same number of faults, the maintenance cost is more.
3.	Interference with communication lines	The communication lines are run along transmission line, so it is possible to cause the electromagnetic interference.	In this case, there is no chance of interference with communication lines.
4.	Conductor size	As conductors are placed in atmosphere, heat dissipation is better. Therefore, required size of conductor is relatively small.	Because of poor heat dissipation, the required size of the conductor / cable is relatively more.

1 Mark for each of any four comparison points = 4 Marks

3. **Attempt any THREE of the following:** **12 Marks**

a) Describe with neat sketch the construction method of 33 kV distribution system.

Ans:

Construction Method of 33 kV Distribution System:

Construction Method of 33 kV Distribution System has the following steps:

Step – I (Survey):

Before erecting the distribution line, first of all survey of route of line is exercised. Survey is carried out accurately to avoid unnecessary expenditure and inconvenience. The route should be as short as possible from economic point of view and the legal point of view. Ultimately the route of lines should be such that as:

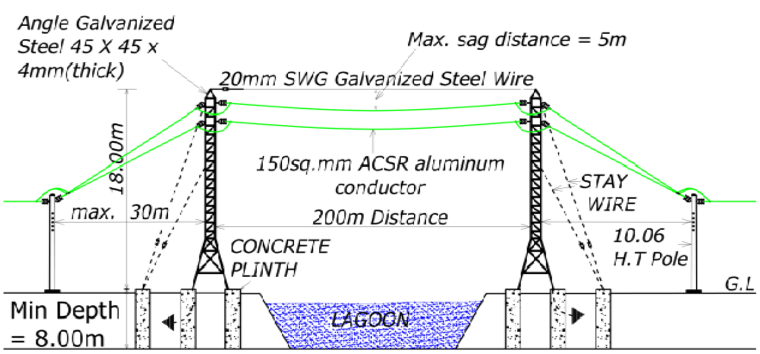
4 Marks for stepwise explanation of construction of line

1. Avoid excessive deviation of lines.
2. Avoid excessive rock blasting for pole / tower foundations.
3. Avoid the places which requires the special foundations.
4. Avoid long poles / towers, long spans.
5. Avoid wells, bridges, steep slopes, water logged areas, gardens, urban development areas, aerodromes etc.
6. Crossings of railway lines, grid lines, telephone lines, rivers shall be as minimum as possible.
7. Lines along the road side should be carefully erected as safety and transport is of

highly concern.
8. Necessary permissions should be taken from various authorities.

Step – II (Construction):
Generally, the 33 kV distribution system is overhead system with poles. The consumer services (HT connection) are directly tapped from such lines. All work is carried out as per IE Rules as lines are in the localities, lines are erected outside town, within towns, cities, rural areas etc. A map (blue print) is already ready after survey work. Then as per the map the positions of poles and spans marking is done and poles are fixed. The required accessories and conductors are installed.

Step – III (Testing):
The testing is very important as it should simulate every possible operating condition. Besides visual & mechanical inspections, the earth fault tests are carried out, technical tests in transformer sections, line sections, protection sections etc. are also carried out as per IS Standards. After successful testing, the lines are now available for the supply distribution. After all, testing work has been completed, the relevant re-cultivation work is carried out and completed. Now the line is charged as per application.



OR Equivalent Answer

b) Explain the features of wireless transmission of electrical power.

Ans:

Features of Wireless Transmission of Electrical Power:

Wireless power transfer works on inductive power transfer principle, as in the transformers. The only difference is that in the transformer two coils are in very close proximity and contain a ferrite material to increase the coupling but in wireless power transfer, inductive chargers have an air gap between the two coils. The process has following features:

1 Mark for each of four features = 4 Marks

- The mains voltage is converted into alternating current, preferably, high-frequency AC
- This current (the high-frequency AC) is transferred to the coil via transmitter circuit. This AC induces a magnetic field in the transmitter coil.
- The induced magnetic field generates a current in the adjacent receiver coil.
- As the strength of a magnetic field decreases to the square of the distance from the source which made it difficult to regulate power and reduced energy efficiency.
- The introduction of resonance solves this and the introduction of resonators with the same frequency in the sources and receiver coil respectively ensures that the two systems couple magnetically, thus allowing for higher energy transfer efficiency.

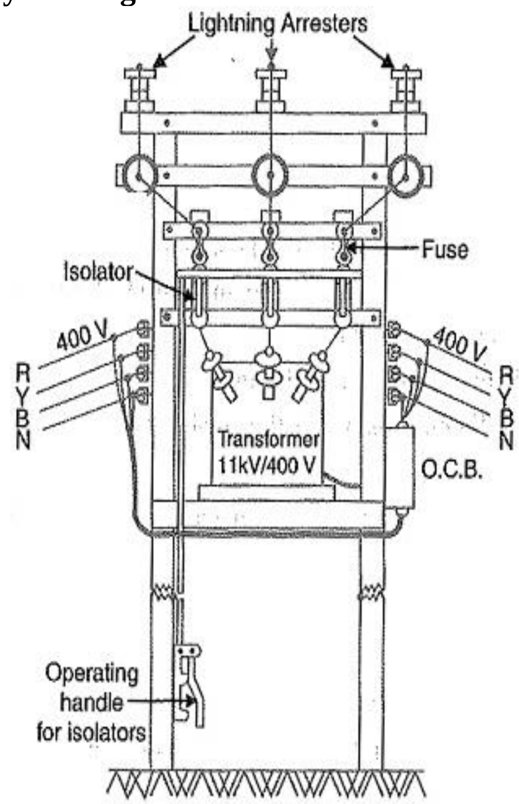
- This means that the power transfer happens over an air gap without the need for metal or other material connection. For this to happen, both the transmitter and the receiving coil must resonate at the same frequency.

OR Equivalent Answer

c) Draw the typical layout diagram of 11 kV/400 sub station.

Ans:

Layout Diagram of 11 kV/400 Substation:



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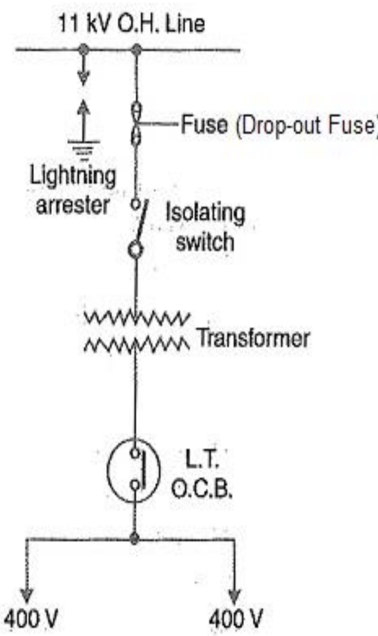


4 Marks For labeled diagram

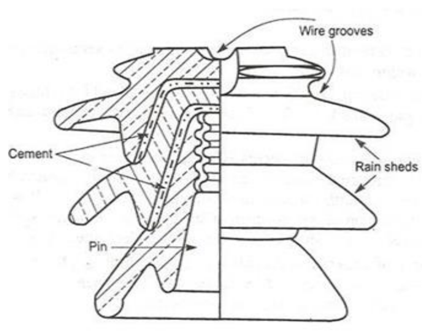
2 Marks for partially labeled diagram

OR Equivalent layout diagram

d) Draw a neat sketch of pin insulator. State any two causes of failure with its limitations.

Ans:

Pin Insulator:



Pin-type insulator

2 Marks for sketch

Causes of Failure of Pin Insulator:

1. Cracking of insulator because of improper heating etc.
2. Use of defective materials for manufacturing the insulator.
3. Porosity of the insulation material of insulator.

4. Improper glazing on the insulator surface.
5. Flash over across the insulator.
6. High / improper mechanical stress on the insulator.
7. Short circuit through the insulator.
8. Over voltages / impulses / electrical stress across insulator.
9. Aging of insulator.
10. Contaminants inter into insulator.
11. Lightning stroke falls on the insulator.
12. Defective design of insulator.
13. Bad workmanship with insulator / Improper handling.
14. Wrong selection / use of insulator.

½ Mark for each of any two causes = 1 Mark

Limitations of Pin Insulator:

1. It should be used with the spindle.
2. The voltage rating is limited / up to 33kV.
3. The insulator pin can damage the thread of an insulator.
4. For above 33kV, these insulators will become uneconomical and bulky.
5. Replacement cost is more.
6. Cost of pin insulator increases rapidly for higher range of voltages.
7. Pin insulators offers less flexibility to the line conductors.

½ Mark for each of any two limitations = 1 Mark

OR Equivalent Answer

4. Attempt any THREE of the following: **12 Marks**

a) Compare primary transmission and secondary transmission system (any four points).

Ans:

Comparison Between Primary Transmission and Secondary Transmission System:

Sr. No.	Primary Transmission System	Secondary Transmission System
1.	The generated electrical power at 11kV is step up at 132kV / 220kV / 400kV / 765kV etc. with help of transformers and transmitted by 3 – phase, 3 – wire, overhead line system to the out skirts of the city. This forms the primary transmission.	The primary transmission line terminates at the receiving station which is usually situated at the outer parts of the city. At the receiving station the voltage is reduced to 33kV / 66kV / 110kV etc. by step down transformer. From this receiving station electrical power is transmitted at 33kV / 66kV / 110kV etc., 3 – phase, 3 - wire overhead system to various substations located at different point in the city. This forms the secondary transmission.
2.	It is link between Generating station and Primary substation.	It is link between Primary substation and receiving substation.
3.	Generally, the voltage rating of this system is 132kV / 220kV / 400kV / 765kV etc.	Generally, the voltage rating of this system is 33kV / 66kV / 110kV etc.
4.	Its loading point is at Generating station.	Its loading point is at Primary substation.

1 Mark for each of any four comparison points = 4 Marks

5.	Here the height of towers is more than secondary transmission system.	Here the height of towers is less than primary transmission system.
6.	The primary transmission is a power transmission type that transfers a large quantity of electrical power	The secondary transmission is a power transmission type that transfers relatively less quantity of electrical power than primary transmission.
7.	The electrical power is stepped up to an elevated voltage level so that it can be more efficient by reducing the I^2R losses that take place when power is transmitted.	In the secondary transmission, the voltage is further stepped back down when electrical power reaches a receiving station.
8.	Here the primary transmission phase graduates to the secondary transmission phase.	Here the secondary transmission phase graduates to the distribution phase.

b) Describe the need for transposition of conductor with neat sketch.

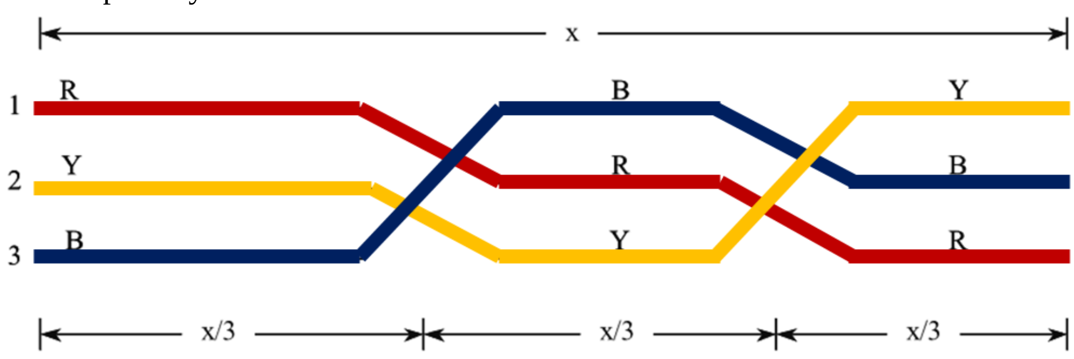
Ans:

Need for Transposition of Conductors:

In the power transmission line when the line conductors are asymmetrically spaced i.e., not equally spaced, the inductance of each phase is different, causing voltage drops of different magnitudes in the three phases even if the system is operating under balanced condition (load currents are balanced in the three phases). Also, the magnetic field external to the conductors is not zero thereby inducing voltages in adjacent communication lines and causing what is known as "telecommunication interference". Hence transposition of conductors is required to overcome these problems.

In a transposed transmission line, each of the three conductors occupies all the three positions relative to other conductors (position 1, position 2, and position 3) for one - third of the total length of the transmission line. Figure shows the transposition of conductors over a complete cycle.

1 Mark for sketch and 3 Marks for description = 4 Marks



c) Give the comparison between HVDC and EHVAC transmission on any four points.

Ans:

Comparison Between HVDC Transmission and EHVAC Transmission System:

Sr. No.	Parameter / Point	HVDC Transmission System	EHVAC Transmission System

1.	Number of conductors	Only two conductors required.	For bulk power transmission, six conductors are used.	
2.	Effect of Capacitance	There is no effect of capacitance in the case of HVDC. Hence, the charging current is not produced. So, there is no restriction on the length of a line.	Because of effect of capacitance charging current produced in the line. The length of the line is limited due to the charging current.	
3.	Intermediate Substations	Does not require any intermediate substations for reactive power compensation.	Requires intermediate substations for reactive power compensation (Almost after every 300KM)	1 Mark for each of any four comparison points = 4 Marks
5.	Skin Effect	There is no skin effect and associated power loss.	In the EHVAC system, the skin effect produced due to the non-uniform distribution of charge in a conductor. The power loss increases due to the skin effect.	
6.	Economy	It is economical for transmission of power above break-even point i.e., for long distances.	It is economical for transmission of power below break-even point i.e., for small distances.	
7.	Cost of Supports	The cost of supports is less as the use of lightweight supports.	Heavy supports needed, so the cost is more.	
8.	Corona Effect	Very less effect of the corona. Power loss is less and no disturbance to the communication line.	Corona effect is more in the EHVAC system. Which results in the power loss and disturbance to the communication lines.	
9.	Reactive Loss	There is no reactive loss.	There are net reactive losses.	
10.	Ferranti Effect	In this system, the Ferranti effect is absent.	In this system, the Ferranti effect produced.	
11.	Power Factor	There is no question of the power factor in the case of HVDC.	The transmission line behaves as an inductor. Therefore, the power factor is lagging. Synchronous condenser or FACTS devices used to improve power factor.	
12.	Use of Earth Return	It is possible to use earth as a return path.	It is not possible to use earth as a return path.	
13.	Line Losses	Less.	More.	
14.	Stability	This system is more stable.	Stability of this system is less.	
15.	Voltage Regulation	Voltage regulation is good.	Voltage regulation is poor.	
16.	Overload Capacity	Less overload capacity.	More overload capacity.	

17.	Possibility of System Failure	Possibility of system failure is more.	Possibility of system failure is less.
18.	Volume of Conductor	Less.	More
19.	Power Transfer & Control	Very fast and accurate power flow control is possible.	Power flow control is slow and is very difficult.
20.	Complexity of System	More.	Less.
21.	Overall Cost	More.	Less.
22.	Maintenance	Difficult to maintain and highly qualified staff needs to maintain.	Easy to maintain.
23.	Short Circuit Level	Fault level remains the same.	Increases.
24.	Change in the Voltage Level	Not possible	Possible.
25.	Radio Interference	Almost absent	Present.

OR Equivalent Answer

d) Classify distribution substation on the basis of –
(i) Service requirement
(ii) Constructional feature

Ans:

Classification of Distribution Substations on the Basis of Service Requirement:

1. Transformer Sub-station.
2. Switching sub-station.
3. Power factor correction 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.

½ Mark for each of any four = 2 Marks

Classification of Distribution Substations on the Basis of Construction Feature:

1. Indoor Substation.
2. Outdoor Substation.
3. Gas insulated Substation.
4. Underground Substation.
5. Pole mounted substation.
6. Plinth Substation.
7. Compact/prefabricated substation.

½ Mark for each of any four = 2 Marks

e) A 3 phase overhead transmission line is being supported by 3 disc insulators. The potential across top unit and middle units are 8 kV and 11kV.
Calculate: -
(i) Line voltage
(ii) String efficiency

Ans:

Data given: Number of discs (n) = 3, Potential across top unit (V_1) = 8kV and Potential across middle unit (V_2) = 11kV.

As $V_2 = V_1(1+K)$

Therefore the Ratio of Capacitance (K) = $\frac{V_2}{V_1} - 1 = \frac{11000}{8000} - 1$

(K) = 0.375

Now, Potential across third unit (V_3) = $V_1(1+3K+K^2)$

$V_3 = 8000\ [1 + 3(0.375) + (0.375)^2\ ] = 18124.8$ Volts. = 1801248 kV

Voltage across string, (Vph) = $V_1 + V_2 + V_3 = 8000 + 11000 + 18124.8 = 37124.8$ Volts
= 37.1248 kV.

Line Voltage across string, (V_L) = $\sqrt{3}$ Vph = $\sqrt{3} \times 37124.8 = 64302.039$ Volts
= **64.302039 kV**

% String Efficiency (% η) = $\frac{V_{ph}}{3 \times V_3} \times 100 = \frac{37124.8}{3 \times 18124.8} \times 100 =$ **68.2762 %**

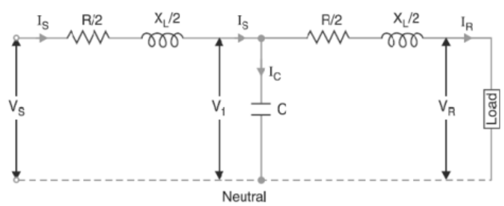
2 Marks for stepwise solution of each bit = 4 Marks

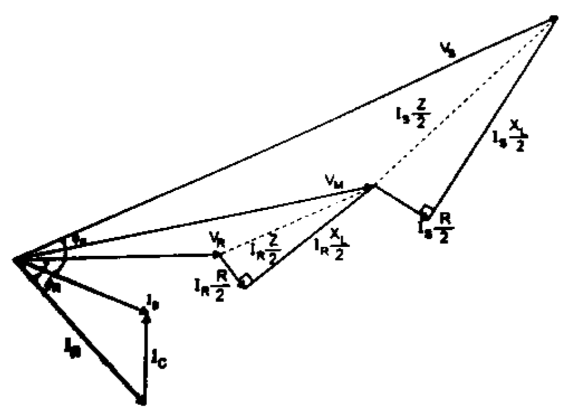
5. Attempt any TWO of the following: **12 Marks**

a) In medium transmission line, for nominal T method, show the derivation for sending end voltage with the help of neat phasor diagram.

Ans:

Equivalent circuit & Phasor Diagram of medium transmission line with nominal T method:





Phasor Diagram for Nominal T-Method

Let,
- I_R be the load current per phase
- R be the resistance per phase
- X_L be the inductive reactance per phase
- C be the capacitance per phase
- $\cos\phi_R$ be the receiving end lagging pf
- V_S be the sending end voltage per phase
- V_R be the receiving end voltage per phase
- V_1 be the voltage across capacitor C

1 Mark for equivalent circuit

Taking receiving end voltage V_R as the reference phasor,

Receiving end voltage $\overline{V_R} = V_R + j0$

Load current $\overline{I_R} = I_R(cos\emptyset_R - jsin\emptyset_R)$

Voltage across C, $\overline{V_1} = \overline{V_R} + \overline{I_R}\frac{\bar{Z}}{2}$

3 Mark for labeled phasor diagram

$$= V_R + I_R(cos\emptyset_R - jsin\emptyset_R)(\frac{R}{2} + j\frac{X_L}{2})$$

Capacitive current $\overline{I_C} = j\omega C\overline{V_1} = j2\pi fC\overline{V_1}$

Sending end current $\overline{I_S} = \overline{I_R} + \overline{I_C}$

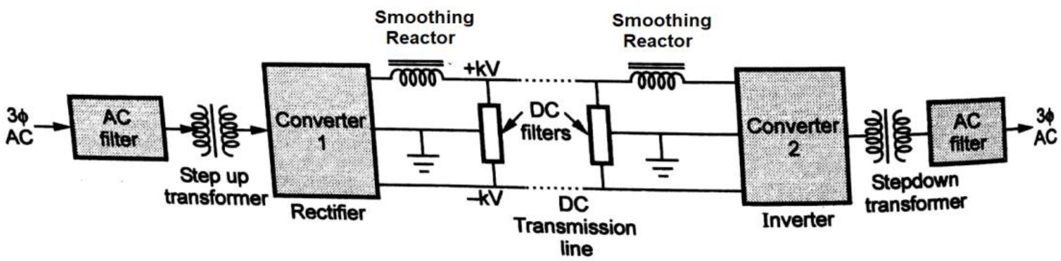
Sending end voltage $\overline{V_S} = \overline{V_1} + \overline{I_S}\frac{\bar{Z}}{2} = \overline{V_1} + \overline{I_S}(\frac{R}{2} + j\frac{X_L}{2})$

2 Marks for stepwise derivation

b) Draw a neat block diagram of HVDC system. Also give any two advantages and limitations of the same.

Ans:

High Voltage DC system (HVDC):



2 Marks for Block diagram

OR Equivalent block diagram

Advantages of HVDC System:

1. A lesser number of conductors and insulators are required thereby reducing the cost of the overall system.
2. It requires less phase to phase and ground to ground clearance.
3. Their towers are less costly and cheaper.
4. Corona loss is less as compared to HVAC transmission lines of similar power.
5. Power loss is reduced with DC because fewer numbers of lines are required for power transmission.
6. The HVDC system uses earth return. If any fault occurs in one pole, the other pole with 'earth returns' behaves like an independent circuit. This results in a more flexible system.
7. The HVDC has the asynchronous connection between two AC stations connected through an HVDC link; i.e., the transmission of power is independent of sending end frequency and receiving end frequency. Hence, it interconnects two substations with different frequencies.
8. Due to the absence of frequency in the HVDC line, losses like skin effect and proximity effect does not occur in the system.
9. It does not generate or absorb any reactive power. So, there is no need for reactive power compensation.
10. There is very accurate and lossless power flows through DC link.

1 Mark for each of any two advantages = 2 Marks

Limitations of HVDC System:

1. Converter substations are placed at both the sending and the receiving end of the transmission lines, which result in increasing the cost.
2. Inverter and rectifier terminals generate harmonics which can be reduced by using active filters which are also very expensive.

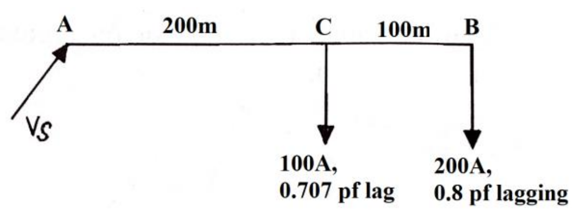
3. If a fault occurs in the AC substation, it may result in a power failure for the HVDC substation placed near to it.
4. Inverter used in Converter substations have limited overload capacity.
5. It does not have transformers for changing the voltage levels.
6. Heat loss occurs in converter substation, which has to be reduced by using the active cooling system.
7. HVDC link itself is also very complicated.

1 Mark for each of any two limitations = 2 Marks

c) A single phase AC distributor 'AB' 300 meter long is fed from end A and loaded as under:-
   (i) 100A at 0.707 pf lagging 200m from point A
   (ii) 200A at 0.8 pf lagging 300m from point A.

The load resistance and reactance of distributor is 0.2 Ω and 0.1 Ω per km. Calculate the total voltage drop in the distributor. The load power factors refer to the voltage at the far end.

Ans:



1 Mark for diagram

Impedance of distributor Z = (0.2+j0.1) Ω per km

Section impedances:

$$Z_{AC} = \frac{200}{1000}(0.2 + j0.1) = (0.04 + j0.02)\Omega = (0.04472\angle 26.56°)\Omega$$

$$Z_{CB} = \frac{100}{1000}(0.2 + j0.1) = (0.02 + j0.01)\Omega = (0.02236\angle 26.56°)\Omega$$

1 Mark for section impedances

Section Currents:

$I_C = 100\ A\ at\ 0.707 lag$ or $I_C = 100\angle -45° = (70.71 - j70.71)amp$

$I_B = 200\ A\ at\ 0.8\ lag$ or $I_B = 200\angle -36.87° = (160 - j120)amp$

Now

$I_{CB} = I_B = 200\angle -36.87° = (160 - j120)amp$

$I_{AC} = I_B + I_C = (160 - j120) + (70.71 - j70.71) = (230.71 - j190.71)$

$= 299.33\angle -39.58° amp$

1 Mark for section currents

Calculation of voltage drops:

$V_{CB} = I_{CB} \times Z_{CB} = (200\angle -36.87°)(0.02236\angle 26.56°) = 4.472\angle -10.31°$ volt

= (4.4 - j0.8) volt

1 Mark for V_{CB}

$V_{AC} = I_{AC} \times Z_{AC} = (299.33\angle -39.58°)(0.04472\angle 26.56°) = 13.39\angle -13.02°$ volt

= (13.05- j3.02) volt

1 Mark for V_{AC}

Total voltage drop = $V_{AB} = V_{AC} + V_{CB}$

= (13.05- j3.02) + (4.4 - j0.8)

= **(17.45 - j 3.82)** = $\mathbf{17.86\angle -12.35°\ volt}$

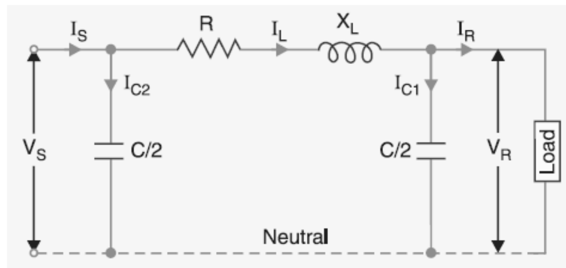
1 Mark for V_{AB}

6. Attempt any <u>TWO</u> of the following: **12 Marks**

a) A 3 phase, 50 Hz overhead transmission line has the following distributed parameters. R=30 Ω, Inductive reactance = 60 Ω and capacitive susceptance = 4×10^{-4} mho. If load at the receiving end is 75 MVA at 0.8 pf lagging with 132 kV between lines, Calculate:
(i) Regulation
(ii) Efficiency of transmission for this load
Use nominal π method.

Ans:

Data Given:



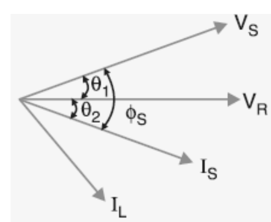
1 Mark for equivalent circuit diagram

Resistance of line R = 30Ω
Inductive reactance of line $X_L = 60\Omega$
Capacitive susceptance Y= 4×10^{-4} mho
Load = 75 MVA at 0.8 pf lagging
Receiving end line voltage
V_{R-LL}= 132 kV = 132 x 10^3 volt
∴ Receiving end phase voltage

$V_{R-Ph} = \frac{V_{R-LL}}{\sqrt{3}} = \frac{132\times10^3}{\sqrt{3}} = 76210.24$ volt

½ Mark for each of I_R, I_{C1}, I_L, I_{C2}, I_S and V_S = 3 Marks

Load current per phase $I_R = \frac{75\times10^6}{\sqrt{3}\times132\times10^3} = 328.04$ A
Receiving end pf = 0.8 lagging
∴ $\cos\emptyset_R = 0.8$ *and* $\sin\emptyset_R = 0.6$
Taking receiving end phase voltage as reference phasor,
$\overline{V_R} = V_R + j0 = 76210.24 + j0 = 76210.24$ volt
Load current $\overline{I_R} = I_R(cos\emptyset_R - jsin\emptyset_R) = 328.04(0.8 - j0.6) = (262.432 - j196.824)$
Charging current at the receiving end is,
$\overline{I_{C1}} = \overline{V_R} j\frac{Y}{2} = j(76210.24)\left(\frac{4\times10^{-4}}{2}\right) = j15.24$
Line current $\overline{I_L} = \overline{I_R} + \overline{I_{C1}} = (262.432 - j196.824) + j15.24 = (262.432 - j181.584)$
Sending end voltage $\overline{V_s} = \overline{V_R} + \overline{I_L}\overline{Z} = 76210.24 + (262.432 - j181.584)(30 + j60)$
$= 76210.24 + 7872.96 + 10895.04 + j15745.92 - j5447.52$
$\overline{V_s} = 94978.24 + j10298.4 = 95534.93\angle 6.19°$
Sending end Line to line voltage = $\sqrt{3} \times 95534.93 = 165471.35$ volt = 165.47 kV
Charging current at the sending end is,
$\overline{I_{C2}} = \overline{V_S} j\frac{Y}{2} = (94978.24 + j10298.4).j\left(\frac{4\times10^{-4}}{2}\right) = -2.06 + j19$
Sending end current $\overline{I_S} = \overline{I_L} + \overline{I_{C2}} = (262.432 - j181.584) + (-2.06 + j19)$
$= (260.372 - j162.584) = 306.96\angle -31.98°$
Referring to phasor diagram,



$\theta_1 = Angle\ between\ \overline{V_R}\ and\ \overline{V_S} = 6.19°$
$\theta_2 = Angle\ between\ \overline{V_R}\ and\ \overline{I_S} = -31.98°$
∴Sending end pf angle $\emptyset_S$
$= Angle\ between\ \overline{V_S}\ and\ \overline{I_S} = 6.19 + 31.98 = 38.17°$
∴Sending end pf = $\cos\emptyset_S$= cos(38.17°) = 0.7862
∴% Voltage Regulation = $\frac{V_S - V_R}{V_R} \times 100 = \frac{95534.93 - 76210.24}{76210.24} \times 100$
$= 0.2536 \times 100 = \mathbf{25.36}\%$

1 Mark for regulation

1 Mark for efficiency

Sending end power $= 3V_S I_S cos\emptyset_S = 3(95534.93)(306.96)(0.7862) = 69166893.42W$

Transmission Efficiency $\%\eta = \frac{Receiving\ End\ Power}{Sending\ End\ Power} \times 100 = \frac{75\times10^6\times0.8}{69166893.42} \times 100$

= **86.75%**

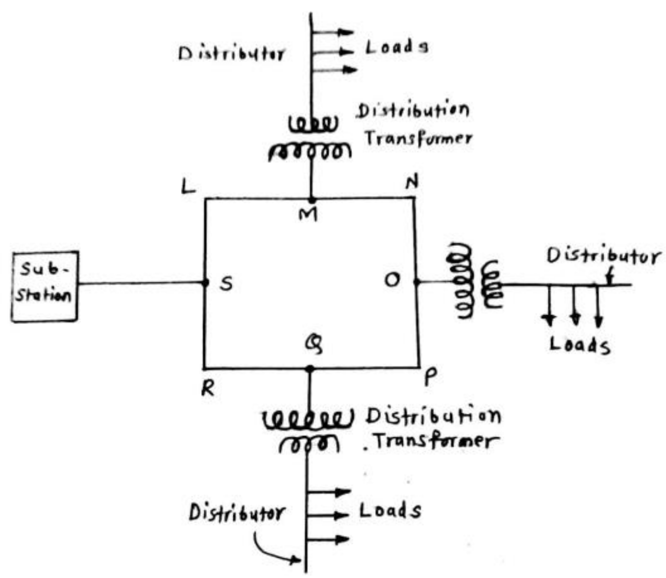
b) Describe ring main system of distribution with diagram. Also state any two advantages of ring distribution load.

Ans:

Ring main system of distribution:

In this system, each distribution transformer is fed with two feeders but in different paths. The feeders in this system form a loop which starts from the substation bus-bars, runs through the load area feeding distribution transformers and returns to the substation bus-bars. The following figure shows a typical single line diagram of a ring main distribution system.

2 Marks for explanation



2 Marks for diagram

Advantages:

i) Supply to distribution transformer centre is given through two different Feeders
ii) Reliability to maintain supply is more even when there is a fault on any one feeder, as the continuity of the supply is ensured from the alternative path.
iii) Reliability to maintain supply is more even when there was maintenance on any one feeder, as the continuity of the supply is ensured from the alternative path.
iv) There are less voltage fluctuations at consumer's terminals.
v) Voltage at far away load from substation is less affected.

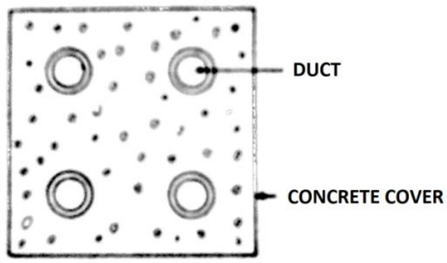
1 Mark for each of any two advantages = 2 Marks

c) With the help of neat diagram explain draw-in system for laying of underground system. Also give any two disadvantages of this system.

Ans:

Draw-in system for laying of underground cables:

This method is adopted in the congested area where direct laying of cable is expensive. In this method, conduit or duct of glazed stone or cast iron or concrete are laid in the ground with manholes at suitable positions along the cable route. The cables are then pulled into positions from manholes. Figure shows section through four way underground duct line. Out of four ducts, three duct carries main power cable and fourth duct carries control cable for protection and switchgear equipment. The diameter of duct pipe should always be larger than the diameter of cable in order to pull cable safely. The duct always made straight but sometimes it is made curved if any obstacles. Care must be taken that where the duct line changes direction, depths, dips and offsets be made with a very long radius or it will be difficult to pull a large cable between the manholes. The distance between the manholes should not be too long so as to simplicity for the pulling of the cables. The vertical distance between two adjacent pipes should be 0.25 m – 0.75 m. The cables to be laid in this way must be provided with Serving of hessian and jute in order to protect them when being pulled into the ducts.



1 Mark for diagram

3 Marks for explanation

Disadvantages of Draw-in system:

1. The initial cost is very high.
2. Heat dissipation is less due to close grouping of cables.
3. Due to unfavourable conditions for dissipation of heat, current carrying capacity of the cables is reduced.

1 Mark for each of any two disadvantage = 2 Marks