Hall Ticket Number: 14EE503

III/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

November, 2019 **Electrical &Electronics Engineering**

Fifth Semester **Transmission & Distribution**

Time: Three Hours **Maximum:** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)

a) **What are the advantages of bundled conductors?**
Bundled conductors are primarily employed to reduce the corona loss and radio interference.

b) **What is meant by transposition of line conductors?**
Transposition is the periodic swapping of positions of the **conductors** of a transmission **line**, in order to reduce crosstalk and otherwise improve transmission. In telecommunications this applies to balanced pairs whilst in power transmission **lines** three **conductors** are periodically **transposed**.

c) **Mention the units of generalized constants of a transmission line.**
the ABCD parameters of transmission line A= Vs/Vr, unit less, B= V_S / I_R Ω, C = I_S / V_R Mho, D = I_S / I_R unit less.

d) **Write ABCD constants for short transmission line.**
The ABCD constants for a short line are given by A=1 ,B=Z, C=0,D=1.

e) **Define sag in transmission system.**
Sag is **defined** as the different in level between points of supports and the lowest point on the conductor.

f) **What is interconnected system?**
In this **system**, the feeder ring is energized by two or more than two generating stations or substations.

g) **Define Surge Impedance loading of a line.**
The surge impedance loading or SIL of a transmission line is the MW loading of a transmission line at which a natural reactive power balance occurs.

h) **State Kelvin's law.**
The **Kelvin's law states** that the most economical size of a conductor is that for which annual interest and depreciation on the capital cost of the conductor is equal to the annual cost of energy loss

i) **What is the value of velocity of propagation of travelling waves for an underground cable?**
A theoretical loss less coaxial cable working at high frequencies has a velocity of propagation $V_p = 1/\sqrt{LC}$ Where v_p is the velocity of propagation in m/s,C is the distributed capacitance per unit length in pF,L is the distributed inductance per unit length in μH.

j) **Why are copper conductors not used in underground cables?**
Because it's cheaper and lighter than a **copper** wire of the same resistance per length; about 6 times cheaper and twice as light as **copper. Aluminum** has 61% conductivity of **copper**, but only 30% of weight.

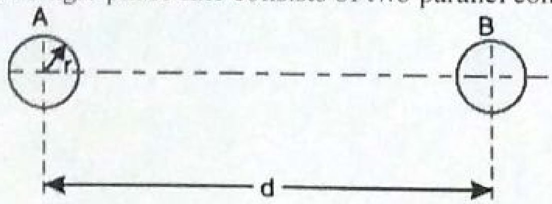
k) **What is meant by proximity effect?**
When the conductors carry the high alternating voltage then the currents are non-uniformly distributed on the cross-section area of the conductor. This effect is called proximity effect.

l) Define string efficiency
The **string efficiency** is **defined** as the ratio of total voltage across the string to the product of number of units and the voltage across the unit adjacent to the line.

UNIT I

2\. a) **Derive expression for loop inductance of a single phase transmission line?** 6M

A single phase line consists of two parallel conductors which form a rectangular loop of one turn.



(1M)

Consider a single phase overhead line consisting of two parallel conductors A and B spaced d meters apart as shown in Fig. Conductors A and B carry the same amount of current (i.e. IA = IB),
but in the opposite direction because one forms the return circuit of the other .IA+IB = 0
The flux linkages with conductor A due to its own current IA and also A due to the mutual inductance effect of current IB in the conductor B Flux linkages with conductor A due to its own current

$$= \frac{\mu_0 I_A}{2\pi}\left(\frac{1}{4}+\int_r^\infty \frac{dx}{x}\right)$$

Flux linkages with conductor A due to current I_B

$$= \frac{\mu_0 I_B}{2\pi}\int_d^\infty \frac{dx}{x}$$

(2 M)

Total flux linkages with conductor A is

$$\psi_A = \text{exp. } (i) + \text{exp } (ii)$$

$$= \frac{\mu_0 I_A}{2\pi}\left(\frac{1}{4}+\int_r^\infty \frac{dx}{x}\right) + \frac{\mu_0 I_B}{2\pi}\int_d^\infty \frac{dx}{x}$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4}+\int_r^\infty \frac{dx}{x}\right) I_A + I_B\int_d^\infty \frac{dx}{x}\right]$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4}+\log_e \infty - \log_e r\right) I_A + (\log_e \infty - \log_e d) I_B\right]$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{I_A}{4}+\log_e \infty\,(I_A + I_B) - I_A \log_e r - I_B \log_e d\right)\right]$$

$$= \frac{\mu_0}{2\pi}\left[\frac{I_A}{4} - I_A \log_e r - I_B \log_e d\right] \quad (\because I_A + I_B = 0)$$

Now, $I_A + I_B = 0$ or $-I_B = I_A$

$\therefore \quad -I_B \log_e d = I_A \log_e d$

$$\therefore \quad \psi_A = \frac{\mu_0}{2\pi}\left[\frac{I_A}{4} + I_A \log_e d - I_A \log_e r\right] \text{ wb-turns/m}$$

$$= \frac{\mu_0}{2\pi}\left[\frac{I_A}{4} + I_A \log_e \frac{d}{r}\right]$$

$$= \frac{\mu_0 I_A}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{ wb-turns/m}$$

2M

Inductance of conductor $A, L_A = \frac{\psi_A}{I_A}$

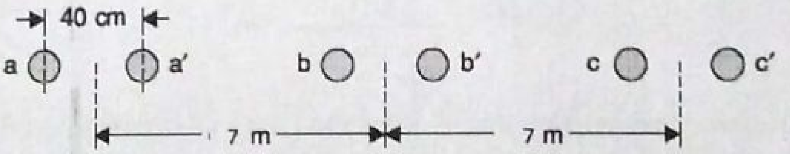
$$= \frac{\mu_0}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{H/m} = \frac{4\pi \times 10^{-7}}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{H/m}$$

$$L_A = 10^{-7}\left[\frac{1}{2} + 2\log_e \frac{d}{r}\right] \text{H/m}$$

Loop inductance $= 2 L_A$ H/m $= 10^{-7}\left[1 + 4\log_e \frac{d}{r}\right]$ H/m (1M)

Loop inductance $= 10^{-7}\left[1 + 4\log_e \frac{d}{r}\right]$ H/m

b) **Find the inductive reactance of a 3-phase bundled conductor line with 2 conductors per phase with spacing of 40cm. Phase to phase separation is 7m in horizontal configuration. All conductors are of ACSR with diameter of 3.5cm.** 6M



(1M)

Solution:

Assuming the effect of transposition to be negligibly small,

$Ds = \sqrt{0.175 * 0.4 * 0.7788} = 0.0545$m (2M)

$Dm = \sqrt[3]{7 * 14 * 7} = 8.82$m 2M

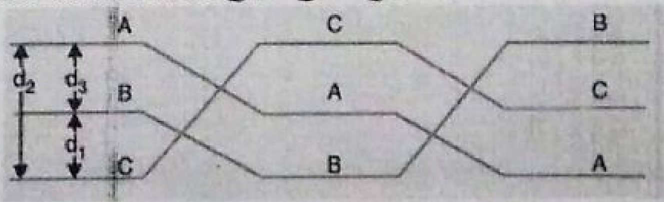
Inductance per km/phase $= 2 \times 10^{-4} \ln \frac{8.82}{0.0545} = 1.017$mH/km/phase **Ans**

Inductive reactance $= 2\Pi fL = 2*\Pi*50*1.017*10^{-3} = 0.32$ohms (1M)

(OR)

3. a) **Derive the expression for capacitance of a single circuit 3-phase transmission line with Unsymmetrical spacing** 6M

Unsymmetrical spacing. Fig. shows a 3-phase transposed line having unsymmetrical spacing. Let us assume balanced conditions *i.e.* $QA + QB + QC = 0$.



1M

Considering all the three sections of the transposed line for phase A,

As $Q_A + Q_B + Q_C = 0$, therefore, $Q_B + Q_C = -Q_A$

$$\therefore \quad V_A = \frac{1}{6\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r^3} - Q_A \log_e \frac{1}{d_1 d_2 d_3}\right]$$

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Potential of 1st position, $V_1 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_3} + Q_C \log_e \frac{1}{d_2}\right)$

Potential of 2nd position, $V_2 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_1} + Q_C \log_e \frac{1}{d_3}\right)$

Potential of 3rd position, $V_3 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_2} + Q_C \log_e \frac{1}{d_1}\right)$

Average voltage on condutor A is

(2M)

$$V_A = \frac{1}{3}(V_1 + V_2 + V_3)$$

$$= \frac{1}{3 \times 2\pi\varepsilon_0} * \left[Q_A \log_e \frac{1}{r^3} + (Q_B + Q_C) \log_e \frac{1}{d_1 d_2 d_3}\right]$$

As $Q_A + Q_B + Q_C = 0$, therefore, $Q_B + Q_C = -Q_A$

$$\therefore \quad V_A = \frac{1}{6\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r^3} - Q_A \log_e \frac{1}{d_1 d_2 d_3}\right]$$

$$= \frac{Q_A}{6\pi\varepsilon_0} \log_e \frac{d_1 d_2 d_3}{r^3}$$

$$= \frac{1}{3} \times \frac{Q_A}{2\pi\varepsilon_0} \log_e \frac{d_1 d_2 d_3}{r^3}$$

$$= \frac{Q_A}{2\pi\varepsilon_0} \log_e \left(\frac{d_1 d_2 d_3}{r^3}\right)^{1/3}$$

$$= \frac{Q_A}{2\pi\varepsilon_0} \log_e \frac{(d_1 d_2 d_3)^{1/3}}{r}$$ (2M)

$\therefore$ Capacitance from conductor to neutral is

$$C_A = \frac{Q_A}{V_A} = \frac{2\pi\varepsilon_0}{\log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r}} \; F/m$$ (1M)

b) **A 3- phase transmission line of 50km long have its conductor of 0.5 cm diameter spaced at the corners of an equilateral triangle of 120 cm side at an average height of 120 cm side at an average height from the ground of 1000cm. the line is fed from a star connected transformer with neutral point earthed at 4400 V between lines. Find the charging current at 50Hz operated frequency** 6M

Solution:

Length of the transmission line=50Km

$$C_{ab} = \frac{\pi k}{\ln \frac{D}{r(1+(D^2/4h^2))^{1/2}}}$$ **F/m line-to-line** (2M)

Average height from the ground, h=1000cm=100m

Radius of the conductor=0.25cm=0.0025m (2M)

$r(1+(D^2/4h^2))^{1/2} = 0.0025(1+(1.2^2/4*100^2))^{1/2}=0.0025$

$C_{ab} = \prod*k/(\ln(1.2/0.0025)) = 4.5\times10^{-12}F/m=4.5\times10^{-9}$F/Km

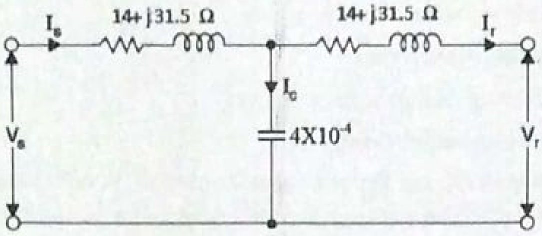
$C_{ab} = 4.5\times10^{-12} \times 50\times10^{3} = 225$ nF

The charging current=$(4400/\sqrt{3})\times(225\times10^{-9}\times314)=0.1795$Amps/m (2M)

UNIT II

4. a) A 3-phase, 50Hz overhead transmission line has following constants Resistance=28Ω, inductive reactance=63Ω, capacitive susceptance =$4X10^{-4}$ mho. If the load at receiving end is 75MVA at 0.8pf lagging with 132kv between lines calculate voltage, current, power factor at sending end, regulation, efficiency of transmission line using nominal T method. 6M

Solution:



The resistance of the line = 28 ohms

The inductive reactance = 63 Ω

The capacitive susceptance = $4X10^{-4}$ mho

The receiving end line to neutral voltage Vr = 132 X 1000 / √3 = 76200 volts

Receiving end current Ir = 75* 1000/√3*132 = 328Amps (1M)

Taking receiving end current as reference,

$$Vc = 76200(0.8 + j0.6) + 328(14 + j32.5)$$
$$= 60960 + j45720 + 4592 + j10660$$
$$= 65552 + j56380$$
$$Ic = j4X10^{-4}(65552 + j56380) = j26.22 - 22.55$$ (2M)
$$\therefore Is = 328 + j26.22 - 22.55 = 305.45 + j26.22 = 306.57\angle 4.9^0$$

$$Vs = 65552 + j56380 + (305.45 + j26.22)(14 + j32.5)$$
$$= 65552 + j56380 + 3424 + j10294$$
$$= 68976 + j66674$$ (2M)
$$= 95.94\angle 44^\circ.$$ **Ans.**

The Total loss = $3 \times 14(306.57^2 + 328^2) = 8.465MW$

Efficiency= 75/(75+8.465)X100 = 89.85% (1M)

Regulation = $(V_s - V_R)/V_R$ X100 = (95.94 - 76.2)/76.2 X100 = 25.9%

b) **Discuss the classifications of overhead transmission lines. Define A,B,C,D constants of transmission line?** 6M

Depending upon the manner in which capacitance is taken into account, the overhead transmission lines are classified as :

(*i*) *Short transmission lines.* When the length of an overhead transmission line is upto about 50 km and the line voltage is comparatively low (< 20 kV), it is usually considered as a short transmission line. Due to smaller length and lower voltage, the capacitance effects are small and hence can be neglected. Therefore, while studying the performance of a short transmission line, only resistance and inductance of the line are taken into account.

(*ii*) *Medium transmission lines.* When the length of an overhead transmission line is about 50-150 km and the line voltage is moderatly high (>20 kV < 100 kV), it is considered as a medium transmission line. Due to sufficient length and voltage of the line, the capacitance effects are taken into account. For purposes of calculations, the distributed capacitance of the line is divided and lumped in the form of condensers shunted across the line at one or more points.

(*iii*) *Long transmission lines.* When the length of an overhead transmission line is more than 150 km and line voltage is very high (> 100 kV), it is considered as a long transmission line. For the treatment of such a line, the line constants are considered uniformly distributed over the whole length of the line and rigorous methods are employed for solution.

A transmission line is a 4-terminal network; two input terminals where power enters the network and two output terminals where power leaves the network. (3M)

The **ABCD parameters** or the transmission line parameters provide the link between the supply and receiving end voltages and currents, considering the circuit elements to be linear in nature.

Therefore, the input voltage $(\vec{V_S})$ and input current $(\vec{I_S})$ of a 3-phase transmission line can be expressed as :

$$\vec{V_S} = \vec{A}\,\vec{V_R} + \vec{B}\,\vec{I_R}$$
$$\vec{I_S} = \vec{C}\,\vec{V_R} + \vec{D}\,\vec{I_R}$$

where $\vec{V_S}$ = sending end voltage per phase

$\vec{I_S}$ = sending end current

$\vec{V_R}$ = receiving end voltage per phase

$\vec{I_R}$ = receiving end current

and $\vec{A}, \vec{B}, \vec{C}$ and $\vec{D}$ (generally complex numbers) are the constants known as *generalised circuit constants* of the transmission line. The values of these constants depned upon the particular method adopted for solving a transmission line. Once the values of these constants are known, performance calculations of the line can be easily worked out. The following points may be kept in mind :

(*i*) The constants $\vec{A}, \vec{B}, \vec{C}$ and $\vec{D}$ are generally complex numbers.

(*ii*) The constants $\vec{A}$ and $\vec{D}$ are dimensionless whereas the dimensions of $\vec{B}$ and $\vec{C}$ are ohms and siemen respectively.

(*iii*) For a given transmisson line,

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

(*iv*) For a given transmission line,

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

(3M)

(OR)

5. a) **Deduce an expression for sag in overhead lines when supports are at equal levels.** 6M

(*i*) **When supports are at equal levels.** Consider a conductor between two equilevel supports *A* and *B* with *O* as the lowest point as shown in Fig. 8.24. It can be proved that lowest point will be at the mid-span.

Let

l = Length of span

w = Weight per unit length of conductor

T = Tension in the conductor.

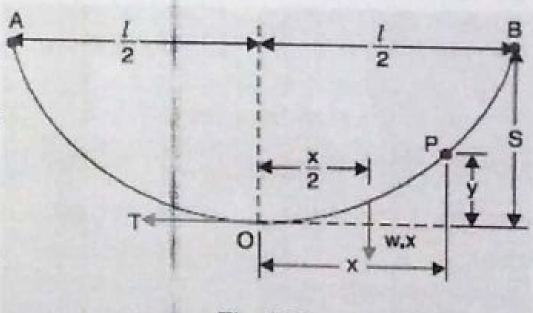


Fig. 8.24

(2 M)

Consider a point *P* on the conductor. Taking the lowest point *O* as the origin, let the co-ordinates of point *P* be *x* and *y*. Assuming that the curvature is so small that curved length is equal to its horizontal projection (*i.e.*, *OP* = *x*), the two forces acting on the portion *OP* of the conductor are :

(*a*) The weight *wx* of conductor acting at a distance *x*/2 from *O*.

(*b*) The tension *T* acting at *O*.

Equating the moments of above two forces about point *O*, we get,

$$Ty = w\,x \times \frac{x}{2}$$

or

$$y = \frac{w\,x^2}{2\,T}$$

(2M)

The maximum dip (sag) is represented by the value of *y* at either of the supports *A* and *B*.

At support *A*, $x = l/2$ and $y = S$

$$\therefore \quad \text{Sag,}\ S = \frac{w(l/2)^2}{2T} = \frac{w\,l^2}{8\,T}$$

(2M)

b) **Explain visual critical voltage and corona power loss.** 6M

(ii) Visual critical voltage. *It is the minimum phase-neutral voltage at which corona glow appears all along the line conductors.*

It has been seen that in case of parallel conductors, the corona glow does not begin at the disruptive voltage V_c but at a higher voltage V_v, called *visual critical voltage*. The phase-neutral effective value of visual critical voltage is given by the following empirical formula :

$$V_v = m_v g_o \delta r \left(1 + \frac{0 \cdot 3}{\sqrt{\delta r}}\right) \log_e \frac{d}{r} \text{ kV/phase}$$ (3M)

where m_v is another irregularity factor having a value of 1·0 for polished conductors and 0·72 to 0·82 for rough conductors.

(iii) Power loss due to corona. Formation of corona is always accompanied by energy loss which is dissipated in the form of light, heat, sound and chemical action. When disruptive voltage is exceeded, the power loss due to corona is given by :

$$P = 242 \cdot 2 \left(\frac{f+25}{\delta}\right) \sqrt{\frac{r}{d}} \, (V - V_c)^2 \times 10^{-5} \text{ kW / km / phase}$$

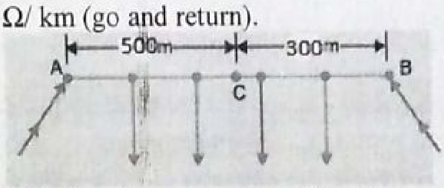
where f = supply frequency in Hz

V = phase-neutral voltage (*r.m.s.*)

V_c = disruptive voltage (*r.m.s.*) per phase (3M)

UNIT III

6. a) A two wire distributor, 800 m long is fed from both the ends. It is uniformly loaded at the rate of 1.1 Amp/meter run. Calculate the voltage at the feeding points A and B if the minimum potential of 230 V occurs at a point C at a distance of 500 meters from end A. Resistance of the distributor is 0.1 Ω/ km (go and return). 6M



(2M)

Fig. shows the single line diagram of the distributor.
Current loading, $i = 1 \cdot 1$ A/m
Resistance of distributor/m, $r = 0.1/1000 = 0.0001\Omega$ (go and return).
Voltage at C, $V_C = 230$ V
Length of distributor, $l = 800$ m (2M)
Distance of point C from A, $x = 500$ m

Voltage drop in section AC = $irx^2 / 2 = 1.1 * 0.0001*500*500/2 = 13.75$ V

∴ Voltage at feeding point A, $V_A = 230 + 13.75 =$ **243.75 V**
Voltage drop in section BC = $ir(l-x)^2/2 = 1.1*0.0001*300*300/2=4.95$V (2M)
∴ Voltage at feeding point B, $VB = 230 + 4.95 =$ **234.95 V**

b) **Discuss the design of primary distribution system with respect to following** 6M
i)Selection of voltage ii) Choice of scheme iii) Size of feeders

DESIGN CONSIDERATIONS IN DISTRIBUTION SYSTEM

Good voltage regulation of a distribution network is probably the most important factor responsible for delivering good service to the consumers. For this purpose, design of feeders and distributors requires careful consideration.

(i)Selection of Voltage: One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumer terminals are within permissible limits. (2M)

The statutory limit of voltage variations is ± 6% of the rated value at the consumer's terminals. Thus, if the declared voltage is 230 V, then the highest voltage of the consumer should not exceed 244 V while the lowest voltage of the consumer should not be less than 216 V.

(ii) Choice of scheme: Distribution primary systems come in a variety of shapes and sizes. Arrangements depend on street layouts, the shape of the area covered by the circuit, obstacles (like lakes), and where the big loads are Radial distribution feeders may also have extensive branching – whatever it takes to get to the loads. An express feeder serves load concentrations some distance from the substation. A three-phase mainline runs a distance before tapping loads off to customers. The circuits are still operated radially, but if a fault occurs on one of the circuits, the tie switches allow some portion of the faulted circuit to be restored quickly. The most common distribution primaries are **four-wire, multi-grounded systems**: three-phase conductors plus a multigrounded neutral. Single-phase loads are served by transformers connected between one phase and the neutral. Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by (a) interconnected system (b) reliable automatic control system (c) providing additional reserve facilities.

(2M)

(iii) **Size of Feeders**: A feeder is designed from the point of view of its current carrying capacity while the voltage drop consideration is relatively unimportant. It is because voltage drop in a feeder can be compensated by means of voltage regulating equipment at the substation. A distributor is designed from the point of view of the voltage drop in it. It is because a distributor supplies power to the consumers and there is a statutory limit of voltage variations at the consumer's terminals (± 6% of rated value). The size and length of the distributor should be such that voltage at the consumer's terminals is within the permissible limits. **A feeder is one of the circuits out of the substation.** The main feeder is the three-phase backbone of the circuit, which is often called the mains or mainline. The mainline is normally a modestly large conductor such as a 500- or 750-kcmil aluminum conductor. Utilities often design the main feeder for **400 A** and often allow an emergency rating of 600 A. Branching from the mains are one or more laterals, which are also called taps, lateral taps, branches, or branch lines. These laterals may be single-phase, two- phase, or three-phase.

(2M)

(OR)

7. a) **Explain briefly the classification of substations?** 6M

Classification of Sub-Stations

There are several ways of classifying sub-stations. However, the two most important ways of classifying them are according to (1) service requirement and (2) constructional features.

1. According to service requirement. A sub-station may be called upon to change voltage level or improve power factor or convert a.c. power into d.c. power etc. According to the service requirement, sub-stations may be classified into :

***(i)* Transformer sub-stations.** Those sub-stations which change the voltage level of electric supply are called transformer sub-stations. These sub-stations receive power at some voltage and deliver it at some other voltage. Obviously, transformer will be the main component in such substations. Most of the sub-stations in the power system are of this type.

***(ii)* Switching sub-stations.** These sub-stations do not change the voltage level *i.e.* incoming and outgoing lines have the same voltage. However, they simply perform the switching operations of power lines.

***(iii)* Power factor correction sub-stations.** Those sub-stations which improve the power factor of the system are called power factor correction sub-stations. Such sub-stations are generally located at the receiving end of transmission lines. These sub-stations generally use synchronous condensers as the power factor improvement equipment.

***(iv)* Frequency changer sub-stations.** Those sub-stations which change the supply frequency are known as frequency changer sub-stations. Such a frequency change may be required for industrial utilisation.

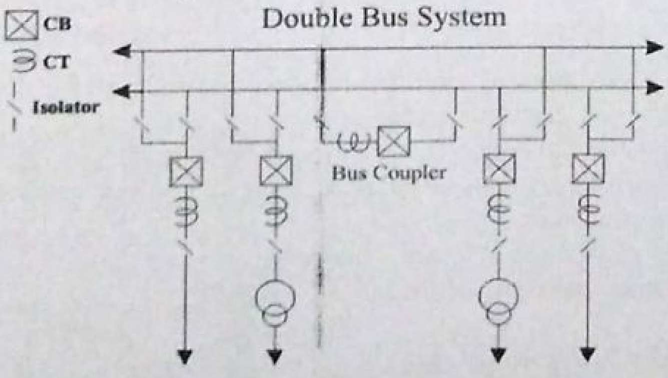
(3M)

(*v*) **Converting sub-stations.** Those sub-stations which change a.c. power into d.c. power are called converting sub-stations. These sub-stations receive a.c. power and convert it into d.c. power with suitable apparatus (*e.g.* ignitron) to supply for such purposes as traction, electroplating, electric welding etc.
(*vi*) **Industrial sub-stations.** Those sub-stations which supply power to individual industrial concerns are known as industrial sub-stations.
2. According to constructional features. A sub-station has many components (*e.g.* circuit breakers, switches, fuses, instruments etc.) which must be housed properly to ensure continuous and reliable service. According to constructional features, the sub-stations are classified as :
(*i*) Indoor sub-station (*ii*) Outdoor sub-station
(*iii*) Underground sub-station (*iv*) Pole-mounted sub-station
(*i*) **Indoor sub-stations.** For voltages upto 11 kV, the equipment of the sub-station is installed indoor because of economic considerations. However, when the atmosphere is contaminated with impurities, these sub-stations can be erected for voltages upto 66 kV.
(*ii*) **Outdoor sub-stations.** For voltages beyond 66 kV, equipment is invariably installed outdoor. It is because for such voltages, the clearances between conductors and the space required for switches, circuit breakers and other equipment becomes so great that it is not economical to install the equipment indoor.
(*iii*) **Underground sub-stations.** In thickly populated areas, the space available for equipment and building is limited and the cost of land is high. Under such situations, the sub-station is created underground.
(*iv*) **Pole-mounted sub-stations.** This is an outdoor sub-station with equipment installed overhead on *H*-pole or 4-pole structure. It is the cheapest form of sub-station for voltages not exceeding 11kV (or 33 kV in some cases). Electric power is almost distributed in localities through such substations.
3. **Depending upon the purpose served**, transformer sub-stations may be classified into :
(*i*) Step-up sub-station (*ii*) Primary grid sub-station
(*iii*) Secondary sub-station (*iv*) Distribution sub-station (3M)

b) With a neat sketch explain double bus with double breaker and double bus with single breaker also write their advantages and disadvantages. 6M

Double Bus System

1. In double bus bar system two identical bus bars are used in such a way that any outgoing or incoming feeder can be taken from any of the bus.
2. Actually every feeder is connected to both of the buses in parallel through individual isolator as shown in the figure.



(2M)

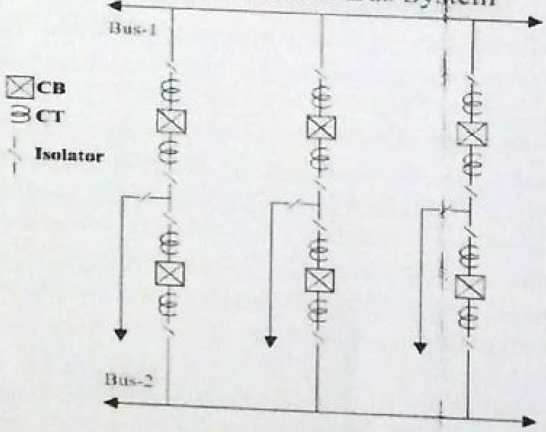
By closing any of the isolators, one can put the feeder to the associated bus. Both of the buses are energized, and total feeders are divided into two groups, one group is fed from one bus and other from other buses. But any feeder at any time can be transferred from one bus to other. There is one bus coupler breaker which should be kept close during bus transfer operation. For transfer operation, one should first close the bus coupler circuit breaker then close the isolator associated with the bus to where the feeder would be transferred and then open the isolator associated with the bus from where the feeder is transferred. Lastly, after this transfer operation, he or she should open the bus coupler breaker. (1M)

Advantages of Double Bus System
Double Bus Bar Arrangement increases the flexibility of system.
Disadvantages of Double Bus System
The arrangement does not permit breaker maintenance without interruption.

Double Breaker Bus System

In double breaker bus bar system two identical bus bars are used in such a way that any system. The only difference is that here every feeder is connected to both of the buses in parallel through individual breaker instead only isolator as shown in the figure. By closing any of the breakers and its associated isolators one can put the feeder to respective bus. Both of the buses are energized, and total feeders are divided into two groups, one group is fed from one bus and other from other buses similar to the previous case. But any feeder at any time can be transferred from one bus to other. There is no need for bus coupler as because the operation is done by breakers instead of isolators. For transfer operation, one should first close the isolators and then the breaker associated with the bus to where the feeder would be transferred, and then he or she opens the breaker and then isolators associated with the bus from where the feeder is transferred.

Double Breaker Bus System (1M)



(2 M)

UNIT IV

8. a) **Write short notes on different types of insulators used for overhead lines** 6M

Types of Insulator

There are mainly three types of insulator likewise
1. Pin Insulator
2. Suspension Insulator (1M)
3. Stray Insulator

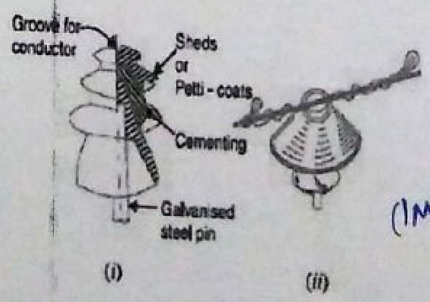
In addition to that there are other two types of electrical insulator available mainly for low voltage application, i.e stay insulator and shackle insulator.

1. Pin Type Insulators

The pin type insulator is secured to the cross-arm on the pole. There is a groove on the upper end of the insulator for housing the conductor.

The conductor passes through this groove and is bound by the annealed wire of the same material as the conductor.

Pin type insulators are used for transmission and distribution of electric power at voltages up to 33 kV. Beyond operating voltage of 33 kV, the pin type insulators become too bulky and hence Un economical.



(1M)

2. Suspension Type

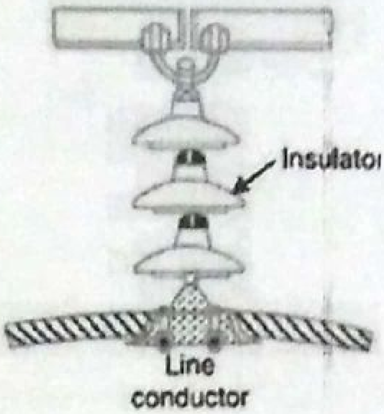
For high voltages (>33 kV), it is a usual practice to use suspension type insulator shown in Figure. Consist of a number of porcelain discs connected in series by metal links in the form of a string. The conductor is suspended at the bottom end of this string while the other end of the string is secured to the cross arm of the tower. Each unit or disc is designed for low voltage, say 11 kV.

(1M)

The number of discs in series would obviously depend upon the working voltage. For instance, if the working voltage is 66 kV, then six discs in series will be provided on the string.

Advantages of suspension type:

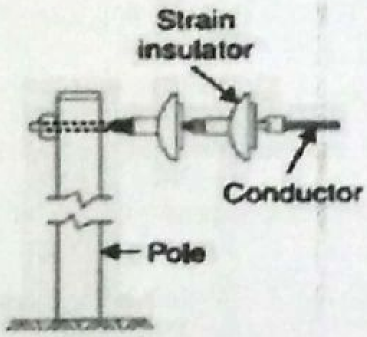
Suspension type insulators are cheaper than pin type insulators for voltages beyond 33 kv.

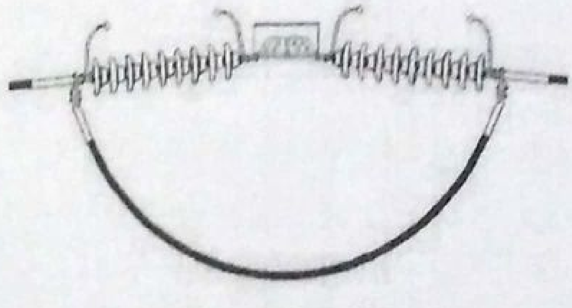


Each unit or disc of suspension type insulator is designed for low voltage, usually 11 kV. Depending upon the working voltage, the desired number of discs can be connected in series. If anyone disc is damaged, the whole string does not become useless because the damaged disc can be replaced.

The suspension arrangement provides greater flexibility to the line. The connection at the cross arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.

In case of increased demand on the transmission line, it is found more satisfactory to supply the greater demand by raising the line voltage than to provide another set of conductors. The additional insulation required for the raised voltage can be easily obtained in the suspension





STRAIN INSULATOR

arrangement by adding the desired number of discs.

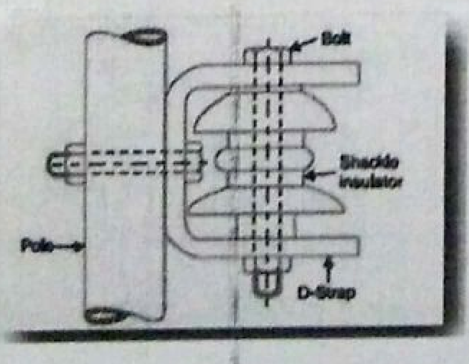
The suspension type insulators are generally used with steel towers. As the conductors run below the earthed cross-arm of the tower, therefore, this arrangement provides partial protection from lightning.

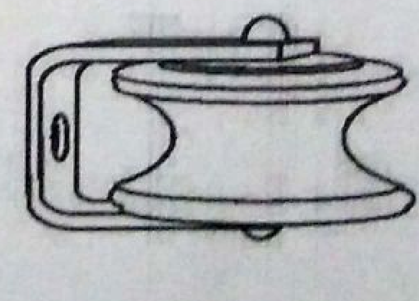
3. Strain Insulators (1M)

When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension. In order to relieve the line of excessive tension, strain insulators are used. For low voltage lines (< 11 kV), shackle insulators are used as strain insulators. However, for high voltage transmission lines, strain insulator consists of an assembly of suspension insulators as shown in Figure. The discs of strain insulators are used in the vertical plane. When the tension in lines is exceedingly high, at long river Fig. spans; two or more strings are used in parallel.

4. Shackle Insulators (1M)

In early days, the shackle insulators were used as strain insulators. But now a day, they are frequently used for low voltage distribution lines. Such insulators can be used either in a horizontal position or in a vertical position. They can be directly fixed to the pole with a bolt or to the cross arm.





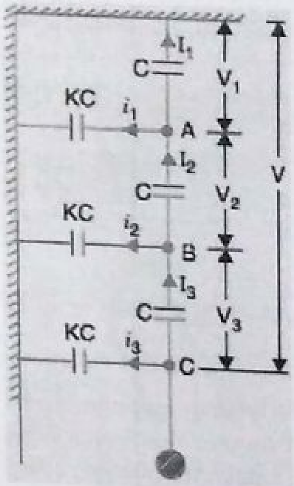
5. Stay Insulator (1M)

For low voltage lines, the stays are to be insulated from ground at a height. The insulator used in the stay wire is called as the **stay insulator** and is usually of porcelain and is so designed that in case of breakage of the insulator the guy-wire will not fall to the ground. There are several methods of increasing the string efficiency or improving voltage distribution across different units of a string.

Stay Insulator

b) **A 3 phase overhead transmission line is being supported by three disc insulators. The potential across top unit (i.e. near the tower) and the middle unit are 8kV and 11Kv respectively. Calculate Line Voltage and String Efficiency.** 6M

Solution. The equivalent circuit of string insulators is the same as shown in previous Fig. It is given that $V_1 = 8$ kV and $V_2 = 11$ kV.



(i) Let K be the ratio of capacitance between pin and earth to self-capacitance. If C farad is the self-capacitance of each unit, then capacitance between pin and earth = KC.

Applying Kirchoff's current law to Junction A,

$$I_2 = I_1 + i_1$$

or $$V_2 \omega C = V_1 \omega C + V_1 K \omega C$$

or $$V_2 = V_1(1+K)$$

$$\therefore \quad K = \frac{V_2 - V_1}{V_1} = \frac{11-8}{8} = 0{\cdot}375$$ (2M)

(ii) Applying Kirchoff's current law to Junction B,

$$I_3 = I_2 + i_2$$

or $$V_3 \omega C = V_2 \omega C + (V_1 + V_2) K \omega C$$

or $$V_3 = V_2 + (V_1 + V_2)K = 11 + (8+11) \times 0{\cdot}375 = 18{\cdot}12 \text{ kV}$$

Voltage between line and earth $= V_1 + V_2 + V_3 = 8 + 11 + 18{\cdot}12 = 37{\cdot}12$ kV (2M)

$\therefore$ Line Voltage $= \sqrt{3} \times 37{\cdot}12 = 64{\cdot}28$ kV

(iii) String efficiency $= \dfrac{\text{Voltage across string}}{\text{No. of insulators} \times V_3} \times 100 = \dfrac{37{\cdot}12}{3 \times 18{\cdot}12} \times 100 = 68.28\%$ (2M)

(OR)

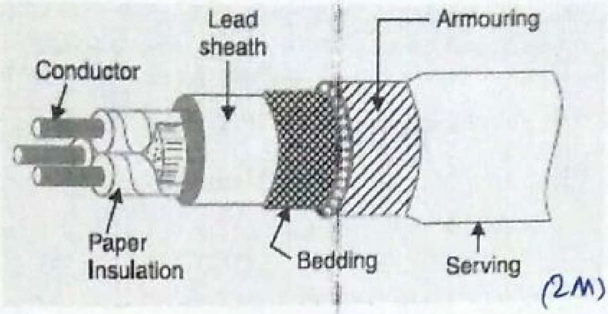
9. a) **Describe the general construction of underground cable with neat sketch. Explain each part?** 6M

the general construction of a 3-conductor cable. The various parts are : (4M)

(i) Cores or Conductors. A cable may have one or more than one core (conductor) depending upon the type of service for which it is intended. For instance, the 3-conductor cable shown in Fig. is used for 3-phase service. The conductors are made of tinned copper or aluminium and are usually stranded in order to provide flexibility to the cable.

(ii) Insulatian. Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable. The commonly used materials for insulation are impregnated paper, varnished cambric or rubber mineral compound.

(iii) Metallic sheath. In order to protect the cable from moisture, gases or other damaging liquids (acids or alkalies) in the soil and atmosphere, a metallic sheath of lead or aluminium is provided over the insulation as shown in Fig



(2M)

(*iv*) *Bedding.* Over the metallic sheath is applied a layer of bedding which consists of a fibrous material like jute or hessian tape. The purpose of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armoring.

(*v*) *Armouring.* Over the bedding, armoring is provided which consists of one or two layers of galvanised steel wire or steel tape. Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling. Armouring may not be done in the case of some cables.

(*vi*) *Serving.* In order to protect armoring from atmospheric conditions, a layer of fibrous material (like jute) similar to bedding is provided over the armoring This is known as *serving.*

b) **Deduce an expression for insulation resistance of a single core cable in terms of specific resistance of dielectric its core and sheath diameter.** 6M

The cable conductor is provided with a suitable thickness of insulating material in order to prevent leakage current. The path for leakage current is radial through the insulation.

The opposition offered by insulation to leakage current is known as insulation resistance of the cable. For satisfactory operation, the insulation resistance of the cable should be very high. (2M)

Consider a single-core cable of conductor radius $r1$ and internal sheath radius $r2$ as shown in Fig.

Let l be the length of the cable and ρ be the resistivity of the insulation.

Consider a very small layer of insulation of thickness dx at a radius x. The length through which leakage current tends to flow is dx and the area of X-section offered to this flow is $2\pi x l$.

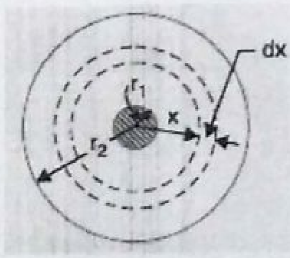
∴ **Insulation resistance of considered layer**

$$= \rho \frac{dx}{2\pi x l}$$

Insulation resistance of the whole cable is

$$R = \int_{r_1}^{r_2} \rho \frac{dx}{2\pi x l} = \frac{\rho}{2\pi l}\int_{r_1}^{r_2} \frac{1}{x} dx$$

$$\therefore \quad R = \frac{\rho}{2\pi l} \log_e \frac{r_2}{r_1}$$ (2M)



2M

Dr G. Ravikumar
Prof, EEE

Dr N. Karthik
Assoc, Prof, EEE

Mr G. Rajesh
Asst. Prof EEE
Ph: 9866162657