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Internal Assesment Test - I

Sub:	Transmission & distribution							Code:	17EE43
Date:	06/03/2019	Duration:	90 mins	Max Marks:	50	Sem:	4	Branch:	EEE
Answer Any FIVE FULL Questions									

		Marks	OBE	
			CO	RBT
1	Explain the advantages of high voltage transmission system with necessary derivations.	[10]	CO2	L2
2a	With a neat diagram explain feeders, distributors and service main of a distribution system.	[5]	CO2	L2
2b	Draw the line diagram of a typical transmission and distribution system indicating the standard voltage levels.	[5]	CO2	L2
3	With usual notations derive an expression for the sag of a transmission line when the supports are 1) at equal levels 2) at unequal levels. Include the effect of ice loading and wind pressure on the conductor.	[10]	CO2	L2
4	A transmission line over a hillside where the gradient is 1:20 ,is supported by two 22m high towers with a distance of 300m between them. The lowest conductor is fixed 2 m below the top of each tower .Find the clearance of the conductor from the ground. Given that conductor weighs 1 kg/m and the allowable tension is 1500kg.	[10]	CO2	L3
5	The towers of height 30m and 90m respectively support a transmission line conductor at water crossing .The horizontal distance between the towers is 500m.If the tension in the conductor is 1600kg, find the minimum clearance of the conductor and water and clearance mid way between the supports .Weight of conductor is 1.5kg/m. Base of the towers can be considered to be at water level.	[10]	CO2	L3
6	Write a short note about different types of insulators used in overhead transmission line	[10]	CO6	L2

1

Why higher voltages for transmission

$P = VI\cos\phi$

For the same power P, higher the voltage lesser the current. So I^2R loss is less in line conductors so η will be high.

If I is less the conductor cross section will be less. So it will be more economical. (saving copper)

1) Reduces volume of conductor material

$$P = \sqrt{3}VI\cos\phi$$

$$I = \frac{P}{\sqrt{3}V\cos\phi} \qquad R = \frac{\rho l}{a}$$

Total Power loss, $W = 3I^2R = \frac{3P^2}{3V^2\cos^2\phi} \cdot \frac{\rho l}{a}$

$$= \frac{P^2}{V^2\cos^2\phi}\frac{\rho l}{a}$$

(or) $a = \frac{P^2\rho l}{WV^2\cos^2\phi}$

Volume of conductor required in 3ph $= 3\left(\frac{P^2\rho l}{WV^2\cos^2\phi}\right)l$

So it is clear that volume of conductor is inversely proportional to square of voltage and greater the trans voltage lesser is the conductor ma[illegible] required

2) <u>Increase transmission efficiency</u>

Input = output power + losses

$$= P + \frac{P^2 \rho l}{V^2 \cos^2\phi\, a}$$

Current density $J = \frac{I}{a}$ $\therefore a = I/J$

$$\therefore \text{Input power} = P + \frac{P^2 \rho l J}{V^2 \cos^2\phi\, I}$$

$$= P + \frac{P^2 \rho l J}{V^2 \cos^2\phi} \cdot \frac{\sqrt{3}\, V \cos\phi}{P}$$

$$= P + \frac{\sqrt{3}\, P J \rho l}{V\cos\phi} = P\left[1 + \frac{\sqrt{3}\, J \rho l}{V\cos\phi}\right]$$

$$\text{Transmission } \eta = \frac{\text{o/p power}}{\text{I/p power}} = \frac{P}{P\left[1 + \frac{\sqrt{3}\, J \rho l}{V\cos\phi}\right]}$$

$$= \frac{1}{1 + \frac{\sqrt{3}\, J \rho l}{V\cos\phi}} \approx \left[1 - \frac{\sqrt{3}\, J \rho l}{V\cos\phi}\right]$$

As J, ρ, l are constants, transmission η increases when the line voltage is increased.

3) Decreases percentage line drop

line drop = IR

$$= I \cdot \frac{\rho l}{a} = I \frac{\rho l \cdot J}{I} = \rho l J$$

$$\% \text{ line drop} = \frac{J \rho l}{V} \times 100$$

As J, ρ, l are constants, Percentage line drop decreases when the transmission voltage increases.

Limitations of high transmission voltage

1) Increased cost of insulating the conductor.

2) Increased cost of transformers, switchgear and other terminal apparatus.

Saving of cost of conductor material (cu)

↓↑

Increased cost of insulation, transformer, switchgear

4) Power transfer

$$P = \frac{|V_s||V_R|}{X_s} \sin \delta$$

$|V_s|$ ← sending end voltage

$|V_R|$ ← receiving end voltage

X_s ← series reactance

δ ← angle b/w V_s & V_R

↓

Power transfer MW per phase

max power is at $\sin 90^\circ$, $\delta = 90^\circ$

$$\therefore P = \frac{|V_s||V_R| \sin 90}{X_s} = \frac{|V_s||V_R|}{X_s}$$

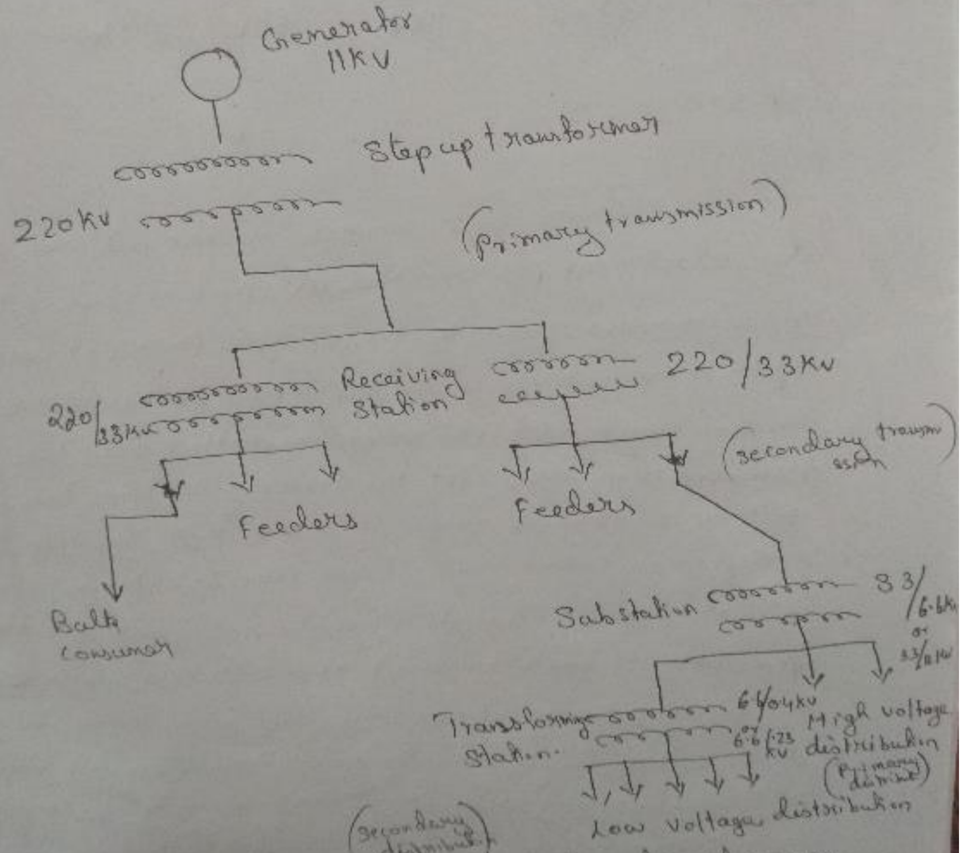
$$P \propto V^2$$

By increasing rated voltage of transmission line (V_s & V_R) we get increased power limit.

2B

module I

Introduction to power system



Power transmission System line diagram

Distribution : 33KV 11KV

at 50Hz.

Power plant converts mechanical energy into electrical power. The alternators coupled to the Prime movers generate the electric power at voltage upto 11 KV which is stepped upto 220KV at the sending end and power is transmitted over the transmission lines. At the receiving stations the voltage is reduced again to 33KV with the help of a step down transformer. From these substations power is distributed through a number of feeders, each feeding a bulk consumer or substation. Voltage is further reduced to 11KV and no. of low voltage distributors will radiate out from these substations to transforming stations reducing the voltage to 400/230 volt.

2A

Components of distribution

1) Substation: Power is transmitted at a very high voltage. It is reduced to 11 kV / 3.3 kV / 6.6 kV. Then power is distributed to local centers using feeders.

2) Local distribution station: It consists of distribution transformer which steps down the voltage to 400V or 230V and it is further distributed

3) Feeders.

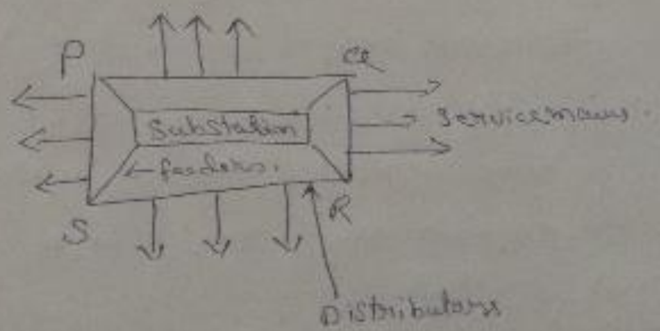
These are conductors which are of large current carrying capacitor. Feeders connect the substation to the area where power is to be finally distributed to consumers. No tappings are taken from the feeders. Feeder current always remains constant. Voltage drop along the feeder is compensated by compounding the generators.

4) Distributors

These conductors are used to transfer power from distribution centre to consumers.

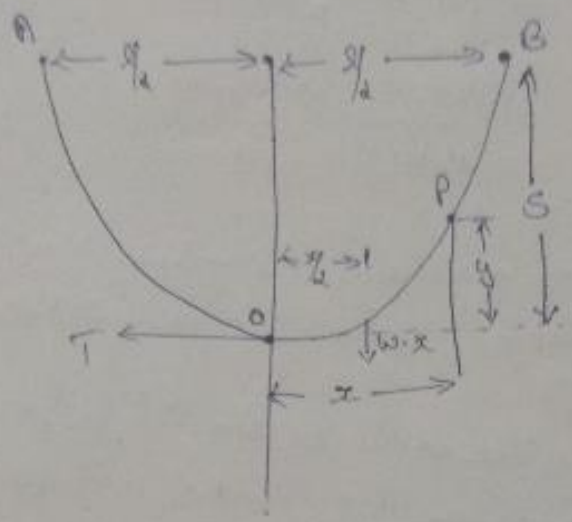
From distributors, tappings are taken for the supply to the consumers. Voltage drop along the distributors is the main criterion to design the distributors.

5) Service main: These are the small cables between the distributors and the actual consumer premises.



3

① At equal levels



l – length of span.
w – weight per unit length of cond.
T – Tension in conductor.

Consider a pt on the conductor P. Coordinates of P are x and y. Two forces are acting on OP.

→ wt wx at a distance $x/2$ from O.
→ tension T acting at O.

Taking moments and equal.

$$Ty = wx \cdot x/2$$

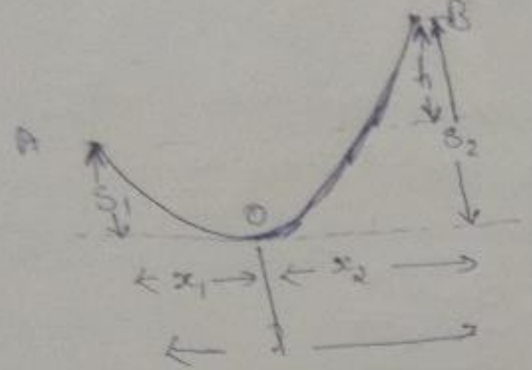
$$y = \frac{wx^2}{2T}$$

Max sag is when $y = S$ at the pt A and B

$$x = l/2, \; y = S$$

$$\Rightarrow S = \frac{wl^2}{8T}$$ //

At unequal levels.



$$S_1 = \frac{w x_1^2}{2T} \qquad S_2 = \frac{w x_2^2}{2T}$$

$$x_1 + x_2 = l \quad \text{--- (1)}$$

$$S_2 - S_1 = \frac{w}{2T}\left[x_2^2 - x_1^2\right] =$$

$$S_2 - S_1 = \frac{w}{2T}\left[x_2 - x_1\right]\left[x_2 + x_1\right]$$

$$h = \frac{w\, l\,(x_2 - x_1)}{2T}$$

$$x_2 - x_1 = \frac{2Th}{wl} \quad \text{--- (2)}$$

$$x_1 = \frac{l}{2} - \frac{Th}{wl}$$

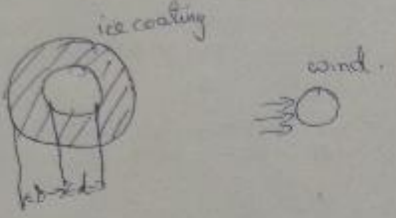
$$x_2 = \frac{l}{2} + \frac{Th}{wl}$$

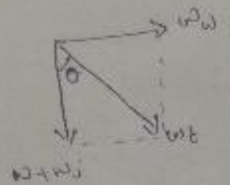
(3) Effect of wind of ice load

Above is breeze at Still air of normal temp.

ice coating along with ~~wt~~ wind force acts ~~along the tangent~~

wt of ice acts vertically downward. force due to wind act horizontally. Total force is the vector sum of these forces





total weight / unit length

$$W_t = \sqrt{(w + w_i)^2 + w_w^2}$$

w = wt of conductor per unit length
= conductor material density × volume per unit length

w_i = wt of ice per unit length
= density of ice × volume of ice per unit length
= density of ice × $\frac{\pi}{4}\left[(d+2t)^2 - d^2\right] \times 1$
= $\pi t(d+t)$

w_ω = wind force per unit length.

= wind pressure per unit area × projected area per unit leng

= wind pressure × [(d + 2t) × 1]

When the conductor has wind and ice coating it sets at an angle θ i.e. $\tan\theta = \frac{w_\omega}{w + w_i}$

$$S = \frac{wl^2}{2T}$$

↓ at an angle θ

Vertical sag = $S\cos\theta$.

4

Solution. The conductors are supported between towers AD and BE over a hillside having gradient of 1 : 20 as shown in Fig. 8.31. The lowest point on the conductor is O and $\sin\theta = 1/20$.

Effective height of each tower (AD or BE)

$$= 22 - 2 = 20 \text{ m}$$

Vertical distance between towers is

$$h = EC = DE \sin\theta = 300 \times 1/20 = 15 \text{ m}$$

Horizontal distance between two towers is

$$DC = \sqrt{DE^2 - EC^2} = \sqrt{(300)^2 - (15)^2} = 300 \text{ m}$$

or

$$x_1 + x_2 = 300 \text{ m}$$

Now

$$h = \frac{w\,x_2^2}{2T} - \frac{w\,x_1^2}{2T} = \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$$

or

$$x_2 - x_1 = \frac{2T\,h}{w\,(x_2 + x_1)} = \frac{2 \times 1500 \times 15}{1 \times 300} = 150 \text{ m}$$

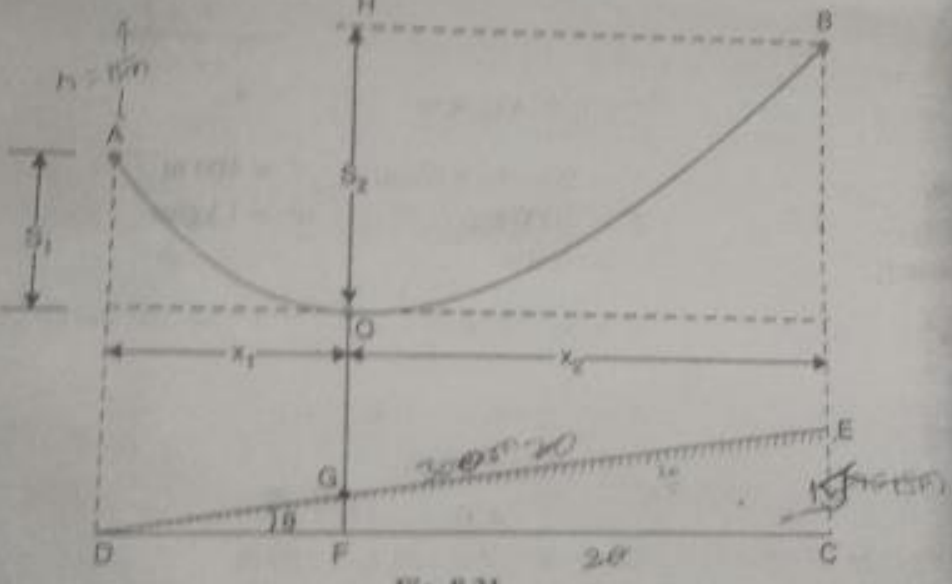


Fig. 8.31

Solving exps. (*i*) and (*ii*), we have, $x_1 = 75$ m and $x_2 = 225$ m

$$\text{Sag } S_2 = \frac{w\,x_2^2}{2T} = \frac{1 \times (225)^2}{2 \times 1500} = 16{\cdot}87 \text{ m}$$

Now

$$BC = BE + EC = 20 + 15 = 35 \text{ m}$$

Clearance of the lowest point O from the ground is

$$OG = HF - S_2 - GF$$

$$= BC - S_2 - GF \qquad (\because BC = HF)$$

$$[\text{Now } GF = x_1 \tan\theta = 75 \times 0{\cdot}05 = 3{\cdot}75 \text{ m}]$$

$$= 35 - 16{\cdot}87 - 3{\cdot}75 = 14{\cdot}38 \text{ m}$$

Clearance of mid-point P from water level

$$= 23 + 7{\cdot}68 = 30{\cdot}68 \text{ m}$$

5

... levels between supports, $h = 90 - 30 = 60$ m. Let the lowest point O of the ... be at a distance x_1 from the support at lower level (*i.e.*, support A) and at a distance x_2 from ... support at higher level (*i.e.*, support B).

Obviously,

$$x_1 + x_2 = 500 \text{ m} \quad \text{...(i)}$$

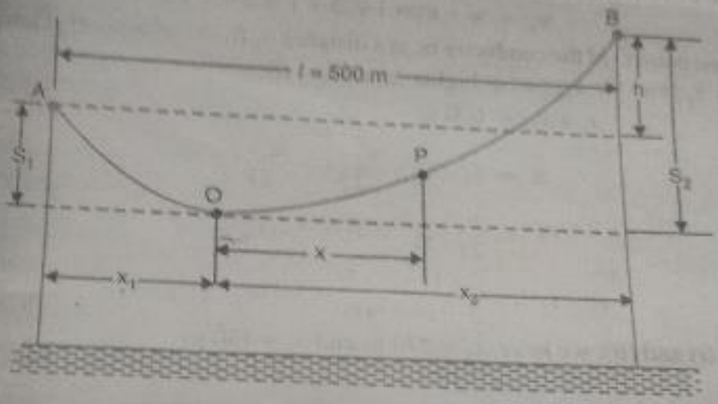


Fig. 8.28

Now,

$$\text{Sag } S_1 = \frac{w\,x_1^2}{2T} \quad \text{and} \quad \text{Sag } S_2 = \frac{w\,x_2^2}{2T}$$

$$\therefore \quad h = S_2 - S_1 = \frac{w\,x_2^2}{2T} - \frac{w\,x_1^2}{2T}$$

or

$$60 = \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$$

$$\therefore \quad x_2 - x_1 = \frac{60 \times 2 \times 1600}{1 \cdot 5 \times 500} = 256 \text{ m}$$

Solving exps. (*i*) and (*ii*), we get, $x_1 = 122$ m; $x_2 = 378$ m

Now,

$$S_1 = \frac{w\,x_1^2}{2T} = \frac{1 \cdot 5 \times (122)^2}{2 \times 1600} = 7 \text{ m}$$

Clearance of the lowest point O from water level

$$= 30 - 7 = 23 \text{ m}$$

Let the mid-point P be at a distance x from the lowest point O.

Clearly,

$$x = 250 - x_1 = 250 - 122 = 128 \text{ m}$$

6

(i)

Fig. 8.4 Steel Towers

220 kV, Span 320 m

(ii)

hanical strength in order to withstand conductor load, wind load etc.

electrical resistance of insulator material in order to avoid leakage currents to earth.

High relative permittivity of insulator material in order that dielectric strength is high.

The insulator material should be non-porous, free from impurities and cracks otherwise the permittivity will be lowered.

High ratio of puncture strength to flashover. Saftey factor.

most commonly used material for insulators of overhead line is *porcelain* but glass, steatite al composition materials are also used to a limited extent. Porcelain is produced by firing at mperature a mixture of kaolin, feldspar and quartz. It is stronger mechanically than glass, s trouble from leakage and is less effected by changes of temperature.

pes of Insulators

cessful operation of an overhead ends to a considerable extent upon er selection of insulators. There ral types of insulators but the most nly used are pin type, suspension ain insulator and shackle insulator.

Pin type insulators. The part sec- pin type insulator is shown in Fig. As the name suggests, the pin type r is secured to the cross-arm on the

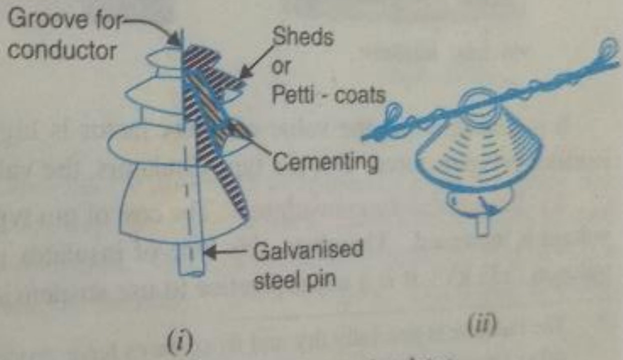


Fig. 8.5. Pin-type insulator

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 [See Fig. 8.5 (*ii*)].

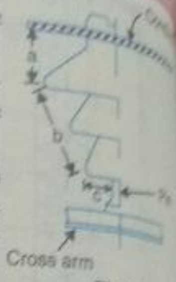


Fig. 8.6

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

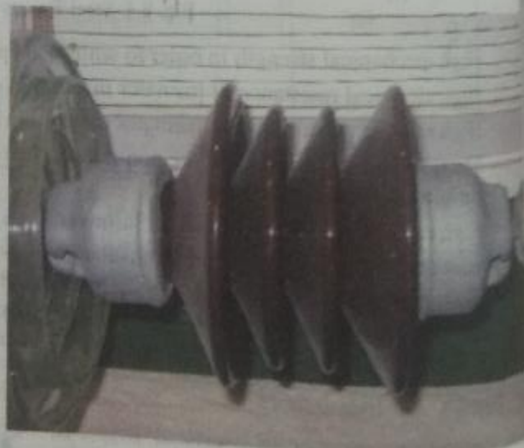
Causes of insulator failure. Insulators are required to withstand both mechanical and electrical stresses. The latter type is pirmarily due to line voltage and may cause the breakdown of the insulator. The electrical breakdown of the insulator can occur either by *flash-over* or *puncture*. In flash-over, an arc occurs between the line conductor and iHsulator pin (*i.e.*, earth) and the discharge jumps across the *air gaps, following shortest distance. Fig. 8.6 shows the arcing distance (*i.e.* $a + b + c$) for the insulator. In case of flash-over, the insulator will continue to act in its proper capacity unless extreme heat produced by the arc destroys the insulator.

Fig. 8.7

In case of puncture, the discharge occurs from conductor to pin through the body of the insulator. When such breakdown is involved, the insulator is permanently destroyed due to excessive heat. In practice, sufficient thickness of porcelain is provided in the insulator to avoid puncture by the line voltage. The ratio of puncture strength to flash-over voltage is known as safety factor *i.e.*,

$$\text{Safety factor of insulator} = \frac{\text{Puncture strength}}{\text{Flash - over voltage}}$$


Pin type insulator


Suspension insulator

It is desirable that the value of safety factor is high so that flash-over takes place before the insulator gets punctured. For pin type insulators, the value of safety factor is about 10.

2 **Suspension type insulators.** The cost of pin type insulator increases rapidly as the working voltage is increased. Therefore, this type of insulator is not economical beyond 33 kV. For high voltages (>33 kV), it is a usual practice to use suspension type insulators shown in Fig. 8.7. The

* The insulator is generally dry and its surfaces have proper insulating properties. Therefore, arc can only occur through air gap between conductor and insulator pin.

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. 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

(*i*) Suspension type insulators are cheaper than pin type insulators for voltages beyond 33 kV.

(*ii*) 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.

(*iii*) If any one disc is damaged, the whole string does not become useless because the damaged disc can be replaced by the sound one.

(*iv*) 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.

(*v*) 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 arrangement by adding the desired number of discs.

(*vi*) 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.** 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 Fig. 8.8. The discs of strain insulators are used in the vertical plane. When the tension in lines is exceedingly high, as at long river spans, two or more strings are used in parallel.

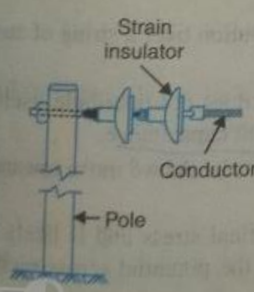


Fig. 8.8. Strain insulator.

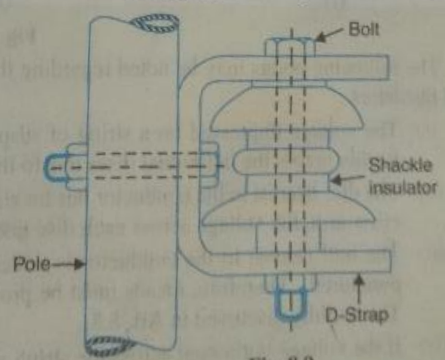


Fig. 8.9

4. **Shackle insulators.** In early days, the shackle insulators were used as strain insulators. But now a days, 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. Fig. 8.9 shows a shackle insulator fixed to the pole. The conductor in the groove is fixed with a soft binding wire.