

LECTURE NOTES
ON
Generation Transmission & Distribution
(GTD)

Fourth Semester
Electrical Engineering

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Steam Power Station : (Thermal Power Plant)

A Generating Station which converts heat energy of coal combustion into electrical energy is known as a steam power station.

The whole arrangement of thermal power plant can be divided into the following stages for the sake of simplicity:

1. Coal and ash handling arrangement.

2. Steam generating plant

3. Steam turbine

4. Alternator

5. Feed water

6. Cooling arrangement;

1. Coal and ash handling plant:

Coal is transported to the power station by road or rail and is stored in the coal storage plant. Coal storage is essential to avoid coal strikes, failure of transportation system and general coal shortages.

From the coal storage plant, coal is delivered to the coal handling plant where it is pulverised (crushed into small pieces) in order to increase its surface exposure. Pulverised coal increases its surface exposure, thus promoting rapid combustion without using large quantity of excess air. The pulverised coal is fed to the boiler by belt conveyors.

The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant and then delivered to the ash storage plant for disposal.

The removal of the ash from the boiler furnace is necessary for proper burning of coal.

2. Steam Generating Plant:

The Steam generating plant consists of a boiler for the production of steam and other auxiliary equipment for the utilization of flue gases.

(i) Boiler: The heat of combustion of coal in the boiler is utilized to convert water into steam at high temperature and pressure. The flue gases from the boiler make their journey through superheater, economiser, air pre-heater and are finally exhausted to atmosphere through the chimney.

Superheater: The steam produced in the boiler is wet and is passed through a superheater where it is dried and superheated by the flue gases on their way to chimney.

Superheating provides two principal benefits:-

(i) the overall efficiency increased

(ii) too much condensation in the last stages of turbine is avoided.

The superheated steam from the superheater is fed to steam turbine through the main valve.

Economiser: An economiser is a feedwater heater and derives heat from flue gases for this purpose. The feedwater is fed to the economiser before supplying to the boiler.

The economiser extracts a part of heat of flue-gases to increase the feedwater temperature.

Air preheater: An air preheater increases the temperature of the air supplied for coal burning by deriving heat from the flue gases. The principal benefits of preheating the air are-

(i) increased thermal efficiency and

(ii) increased steam capacity per square metre of boiler surface.

Steam Turbine: The dry and superheated steam from the superheater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy.

After giving heat energy to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation.

Alternator: The steam turbine is coupled to an alternator. The alternator converts mechanical energy of turbine into electrical energy. The electrical output from the alternator is delivered to the bus bars through transformer, circuit breakers and isolators.

Feed Water: The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external sources. The feed water on its way to the boiler is heated by water heaters and economiser. This helps in raising the overall efficiency of the plant.

Cooling arrangement: In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed by means of a condenser.

Water is drawn from a natural source of supply such as a river, canal or lake and is circulated through the condenser. The circulating water takes up the heat of the ~~heat of the~~ exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river.

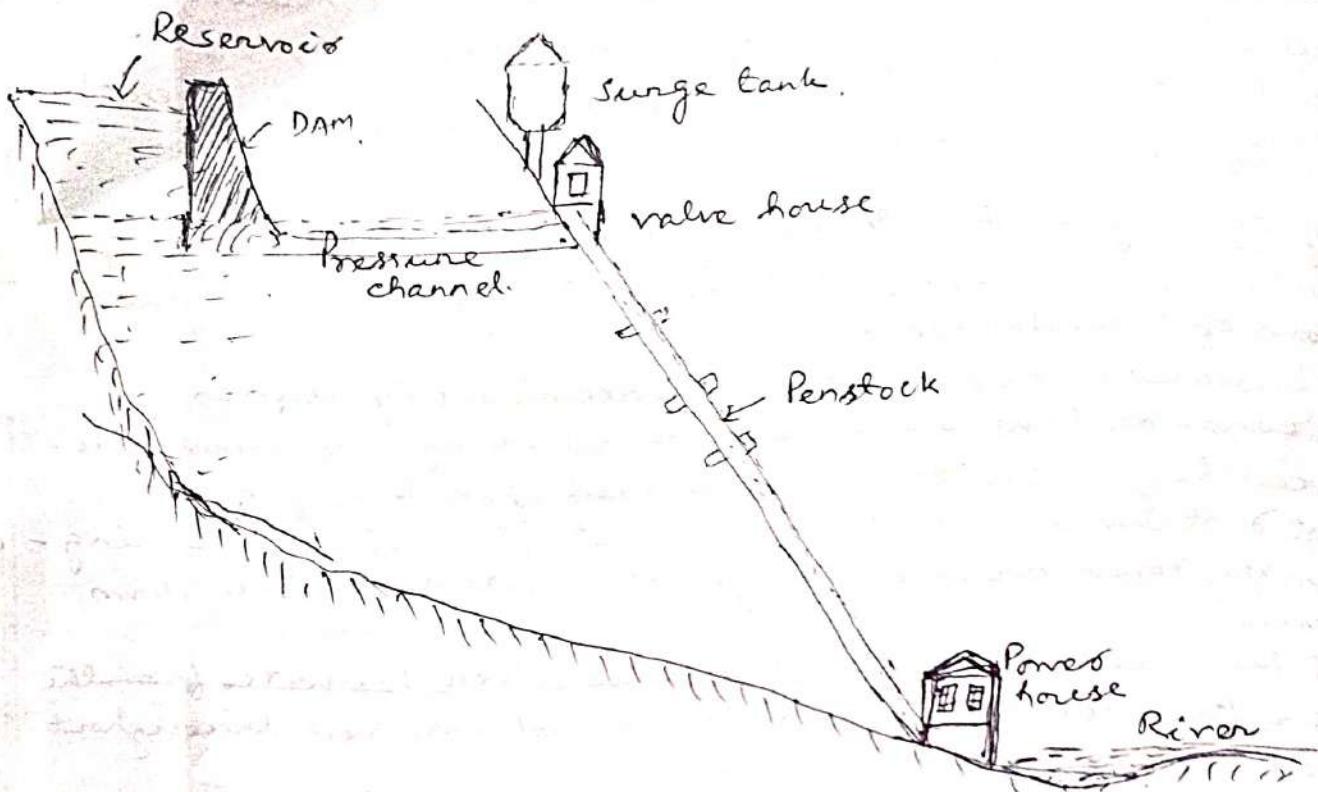
In case the availability of water in the river, hot water from the condenser from the source of supply is not assured throughout the year, cooling towers are used.

During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

Concentrated acids should be avoided. A good example is "Guanabana Oil" which was found to be quite effective against certain infections in India, particularly in Bihar, Jharkhand, West Bengal, Maharashtra and Andhra Pradesh. It is a mixture of concentrated Sulphuric acid and a number of essential oils. It is also known as "Kamala Oil".

Water Treatment and Reuse: A portion of the treated effluent is used for irrigating agricultural fields with maximum efficiency. This can be done by using various methods such as drip irrigation, sprinkler irrigation, etc. The treated effluent can also be used for industrial purposes such as cooling towers, washing of vehicles, etc. It can also be used for domestic purposes such as washing clothes, etc.

Schematic arrangement of Hydro-electric Power Station.



The constituents of a hydroelectric plant are

1) hydraulic structure

2) water turbine and 3) electrical equipment

1) Hydraulic structures in a hydroelectric plant includes dam, spillways, headworks, surge tank, penstock and accessory works

(i) DAM: A dam is a barrier which stores water and creates water head. Dams are built of concrete or stone masonry, earth or rock fill. The type and arrangement depends upon the topography of the site. The type of dam also depends upon the foundation conditions

(ii) Spillways: There are times when the river flow exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area.

In order to discharge the surplus water from the storage reservoir into the river on the downstream side of the dam, spillways are used. Spillways are constructed of concrete piers on the top of the dam. Gates are provided between these piers and surplus water is discharged

over the crest of the dam by opening these gates.

(ii) Headworks : The headworks consists of the diversion structures at the head of an intake. They generally include booms and racks for diverting floating debris, sluices for bypassing debris and sediments and valves for controlling the flow of water to the turbine.

The flow of water into and through headworks should be as smooth as possible to avoid head loss. For this purpose, it is necessary to avoid sharp corners and abrupt contractions or enlargements.

(iii) Surge tank : Open conduits leading water to the turbine no protection. When close conduits are used, protection becomes necessary to limit the abnormal pressure in the conduit.

A surge tank is a small reservoir or tank in which water level rises or falls to reduce the pressure swings in the conduit. A surge tank is located near the beginning of the conduit.

When the load on the turbine decreases, the governor closes the gates of turbine, reducing water supply to the turbine. The excess water at the lower end of the conduit rushes back to the surge tank and increases its water level. Thus the conduit is prevented from bursting. On the other hand, when load on the turbine increases, additional water is drawn from the surge tank to meet the increased load requirement.

Hence, a surge tank overcomes the abnormal pressure in the conduit when load on the turbine falls and acts as a reservoir during increase of load on the turbine.

(iv) Penstocks : Penstocks are open or closed conduits which carry water to the turbines. They are generally made of reinforced concrete or steel. Concrete penstocks are suitable for low heads ($< 30\text{ m}$)

The steel penstocks can be designed for any head. The thickness of the penstock increases with the head or working pressure.

Various devices such as automatic butterfly valve, air valve and surge tank are provided for protection of penstocks. Automatic butterfly valve shuts off water flow through the penstocks promptly if it ruptures.

Air valve maintains the air pressure inside the penstock equal to outside atmospheric pressure. When water runs out of a penstock faster than it enters, a vacuum is created which may cause the penstock to collapse.

Under such situations, air valve opens and admits air in the penstock to maintain inside air pressure equal to the outside air pressure.

2. Water turbine: Water turbines are used to convert the energy of falling water into mechanical energy. The principal types of water turbines are:

(i) Impulse turbines

(ii) Reaction turbines.

(i) Impulse turbines: are used for high heads. In these turbines, the entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the jet drives the wheel. This type of turbine is pelton wheel turbine.

(ii) Reaction turbines: Reaction turbines are used for low and medium heads. The important types of reaction turbines are:

① Francis turbines ② Kaplan turbines

Francis turbine is used for low to medium heads.
Kaplan turbine is used for low heads and large quantities of water.

3. Electrical equipment: The electrical equipment of a hydro-electric power station includes alternators, transformers, circuit breaker and other switching and protective devices.

Nuclear Power Station :

A generating station in which nuclear energy is converted into electrical energy is known as a nuclear power station.

In nuclear power station, heavy elements such as Uranium (U^{235}) or Thorium (Th^{232}) are subjected to nuclear fission in a special apparatus known as a reactor. The heat energy thus released is utilised in raising steam at high temperature and pressure. The steam runs the steam turbine which converts steam energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

In a Nuclear power plant ~~small~~ huge amount of electrical energy can be produced from a relatively small amount of ~~heat~~ nuclear fuel as compared to other conventional types of power stations.

Complete fission of 1 kg of uranium (U^{235}) can produce as much energy as can be produced by the burning of 4500 tons of high grade coal.

The whole arrangement of Nuclear Power Plant can be divided into the following main stages : -

- 1. Nuclear reactor.
- 2. Heat Exchangers.
- 3. Steam Turbine
- 4. Alternator

1. Nuclear Reactor. : It is an apparatus in which nuclear fuel (U^{235}) is subject to nuclear fission. It controls the chain reaction that starts once the fission is done. If the chain reaction is not controlled, the result will be an explosion due to the fast increase in the energy released.

A nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of uranium moderator and control rods. The fuel rods constitute the fission material and release huge amount of energy when bombarded with slow moving neutrons. The moderator consists of graphite rods which enclose the fuel rods. The moderator consists of graphite rods which enclose the fuel rods. The moderator slows down the neutrons before they bombard the fuel rods. The control rods are of cadmium and are inserted into the reactor. Cadmium is strong neutron absorber and thus

regulates the supply of neutrons for fission. When the control rods are pushed in deep enough they absorb most of fission neutrons and hence few are available for chain reaction with which, therefore, stops. However, as they are being withdrawn, more and more of these fission neutrons cause fission, and hence the intensity of chain reaction (or heat produced) is increased. Therefore, by pulling out the control rods, power of the nuclear reactor is increased whereas by pushing them in, it is reduced. In actual practice, the lowering or raising of control rods is accomplished automatically according to the requirement of load. The heat produced in the reactor is removed by the coolant, generally a sodium metal. The coolant carries the heat to the heat exchanger.

(ii) Heat exchanger: The coolant gives up heat to the heat exchanger which is utilised in raising the steam.

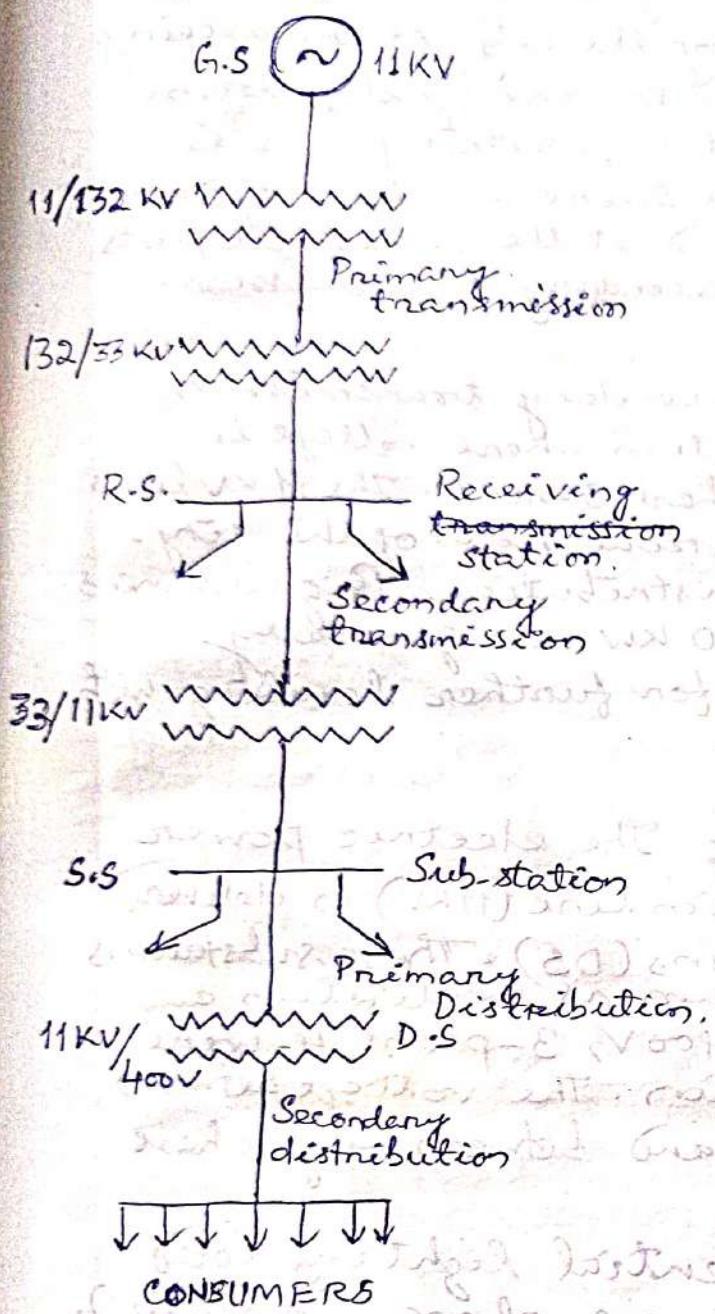
After giving up heat, the coolant is again fed to the reactor.

(iii) Steam Turbine: The steam produced in the heat exchanger is led to the steam turbine through a valve. After doing a useful work in the turbine, the steam is exhausted to the condenser.

The condenser condenses the steam which is fed to the heat exchanger through feed water pump.

(iv) Alternator: The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to the bus-bars through transformer, circuit breaker and isolators.

Layout of Transmission and distribution Scheme:



The Network of conductors between the generating station and the consumers can be divided into two parts, such as:-

Transmission System and Distribution System.

Each part can be further sub-divided into two parts, such as:-

Primary transmission & Secondary transmission. and

Primary distribution and Secondary distribution.

The figure shows the layout of a typical ac power supply scheme by a single line diagram.

In a certain power scheme, there may be no secondary transmission and in another case, the scheme may be so small that there is only distribution and no transmission.

The various section of the line diagram is described below.

(i) Generating Station:

In the figure, G.S. represents the generating station where electric power is produced by 3-phase alternators operating in parallel.

The usual generation voltage is 11 KV. For economy, in the transmission of electric power, the generation voltage is stepped up to 132 KV or more at the generating station with the help of 3-phase transformers.

(ii) Primary transmission:- The electric power at 132 KV is transmitted by 3-phase, 3-wire overhead system to the outskirts of the city. This forms the primary transmission.

Secondary transmission: The primary transmission line terminates at the receiving station (RS) which usually lies at the outskirts of the city. At the receiving station, the voltage is reduced to 33 KV by step-down transformer. From this station, electric power is transmitted at 33 KV by 3-phase, 3-wire overhead system to various substations located at the strategic points in the city. This forms the secondary transmission.

Primary distribution: The secondary transmission line terminates at the sub-station where voltage is reduced from 33 KV to 11 KV, 3phase, 3-wire. The 11 KV lines run along the important road sides of the city. This forms the primary distribution. Big consumers having demand more than 50 KW are generally supplied power at 11 KV for further handling with their own sub-stations.

Secondary distribution: The electric power from primary distribution line (11 KV) is delivered to distribution sub-stations (DS). These substations are located near the consumers localities and step down the voltage to 400 V, 3-phase, 4-wire for secondary distribution. The voltage between any two phases is 400 V and between any phase and neutral is 230 V.

The single phase residential lighting load is connected between any one phase and neutral whereas 3 phase, 400 V motor load is connected across 3-phase lines directly.

* Voltage Regulation: When a transmission line is carrying current, there is a voltage drop in the line due to resistance and inductance of the line. The result is that receiving end voltage (V_R) of the line is generally less than the sending end voltage (V_S).

This voltage drop in the line is expressed as a

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percentage of receiving end voltage V_R and is called voltage regulation.

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.

$$\% \text{age Voltage Regulation} = \frac{V_s - V_{R2}}{V_R} \times 100.$$

Voltage regulation of a transmission line should be low.

* Transmission Efficiency:

The power obtained at the receiving end of a transmission line is generally less than the sending end power due to losses in the line resistance.

The ratio of receiving end power to the sending end power of a transmission line is known as the transmission efficiency of the line.

%age Transmission Efficiency, η_t .

$$= \frac{\text{Receiving end Power}}{\text{Sending end Power}} \times 100$$

$$= \frac{V_R I_R \cos \phi_R}{V_s I_s \cos \phi_s} \times 100. \quad \text{where } V_R, I_R \text{ and } \cos \phi_R$$

are the receiving end voltage, current and power factor while V_s, I_s and $\cos \phi_s$ are the corresponding value at the sending end.

$$\boxed{S = P + jQ}$$

$$\boxed{S^2 = P^2 + Q^2}$$

Kelvin's law for economical size of conductor

Kelvin's law states that, the most economical size of 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.

Let area of cross-section of conductor = a
 annual interest and depreciation on capital cost of the conductor = C_1

annual running charges = C_2

Now, annual interest and depreciation cost is directly proportional to the area of conductor
 i.e. $C_1 = K_1 a$

And annual running charges are inversely proportional to the area of conductor.

$C_2 = \frac{K_2}{a}$ where K_1 and K_2 are constants.

Now total annual cost (C) = $C_1 + C_2$.

$$\Rightarrow C = K_1 a + \frac{K_2}{a}$$

for ' C ' to be minimum, the differentiation of ' C ' with respect to ' a ' must be zero.

$$\text{i.e. } \frac{d}{da} (C) = 0$$

$$\text{Therefore, } \frac{de}{da} = \frac{d}{da} \left[K_1 a + \frac{K_2}{a} \right] = 0$$

$$\Rightarrow K_1 - \frac{K_2}{a^2} = 0$$

$$\Rightarrow K_1 = \frac{K_2}{a^2} \Rightarrow K_1 a = \frac{K_2}{a}$$

$$\therefore C_1 = C_2$$

$$\Rightarrow a = \sqrt{\frac{K_2}{K_1}}$$

CORONA.

The Phenomenon of violet glow, hissing noise and production of ozone gas in an overhead transmission line is known as Corona.

When an alternating potential difference is applied across two conductors whose spacing is large as compared to their diameters, there is no apparent change in the condition of atmospheric air surrounding the wires if the applied voltage is low.

However, when the applied voltage exceeds a certain value, called critical disruptive voltage, the conductors are surrounded by a faint violet glow called corona.

If the conductors are polished and smooth, the corona glow will be uniform throughout the length of the conductors otherwise the rough points will appear brighter.

Critical disruptive Voltage.

It is the minimum phase neutral voltage at which corona occurs.

Consider two conductors of radius 'r' cm and spaced 'd' cm apart. If 'V' is the phase-neutral potential, then potential gradient at the conductor surface is given by

$$g = \frac{V}{r \log_e \frac{d}{r}} \text{ volts/cm}$$

In order that corona is formed, the value of 'g' must be made equal to the breakdown strength of air.

The breakdown strength of air at 76 cm pressure and temperature of 25°C is 30 kV/cm (max.) or 21.2 kV/cm (r.m.s) and is denoted by g_0 . If V_c is the phase neutral potential required under these conditions, then

$$g_0 = \frac{V_c}{r \log_e \frac{d}{r}} \quad \text{where } g_0 = \text{breakdown strength of air at 76 cm of mercury and } 25^{\circ}\text{C}$$

$$= 30 \text{ kV/cm (max.)}$$

$$\text{or } 21.2 \text{ kV/cm rms.}$$

\therefore Critical disruptive voltage

$$V_c = g_0 r \log_e \frac{d}{r}$$

The above expression for disruptive voltage is under standard condition -

i.e at 76 cm of Hg and 25°C

The breakdown strength of air at a barometric pressure of 6 cm of mercury and temperature of 0°C becomes δ_{go} where

$$S_{air density factor} = \frac{3.92 b}{273 + t}$$

Under standard conditions, the value of S_{air} is 1.

$$\therefore \text{Critical disruptive voltage } V_c = g \delta_r \log_e \frac{d}{r}$$

Correction must also be made for the surface condition of conductors. This is accounted for by multiplying the above expression by irregularity factor m_0 .

∴ Critical disruptive voltage V_c

$$= m_0 g \delta_r \log_e \frac{d}{r} \text{ kv/phase}$$

where $m_0 = 1$ for polished conductors

= 0.98 to 0.92 for dirty conductors

= 0.87 to 0.8 for standard conductors.

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 not begins 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

$$V_v = m_v g \delta_r \left(1 + \frac{0.3}{\sqrt{\delta_r}}\right) \log_e \frac{d}{r} \text{ kv/phase}$$

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46 where m_2 is another irregular factor having a value of 1.0 for polished conductors and 0.72 to 0.82 for rough conductors

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 :

$$P = 242 \cdot 2 \left(\frac{f+25}{8} \right) \sqrt{\frac{r}{d}} (V - V_c)^2 \times 10^{-5} \text{ KW/km/phase.}$$

Where f = Supply frequency in Hz

V = Phase-neutral voltage (r.m.s.)

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

Advantages of Corona:

- (i) Due to corona formation, the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increased diameter reduces the electrostatic stresses between the conductors.
- (ii) Corona, reduces the effects of transients produced by surges.

Disadvantages of Corona:

- (i) Corona is accompanied by a loss of energy. This affects the transmission efficiency of the line.
- (ii) Corona Ozone is produced by corona and may cause corona of the conductor due to chemical action.
- (iii) The current drawn by the line due to corona is non-sinusoidal and hence non-sinusoidal voltage drop occurs in the line. This may cause inductive interference with neighbouring communication lines.

Metho~~s~~ds of Reducing Corona Effect:

- (i) By increasing conductor size : By increasing conductor size, the voltage at which corona occurs is raised and hence corona effects are considerably reduced. This is one of the reasons that ACSR conductors which have a larger cross-sectional area are used in transmission lines.
- (ii) By increasing conductor Spacing : By increasing the spacing between conductors, the voltage at which corona

Occurs if raised and hence corona effects can be eliminated. However, spacing cannot be increased too much otherwise the cost of supporting structure (bigger cross arms and supports) may increase to considerable extent.

Main Components of Overhead Lines

The main components of an overhead line are :

- (i) Conductors : Conductors which carry electric power from the sending end station to the receiving end station.
- (ii) Supports : Supports which may be poles or towers and keep the conductors at a suitable level above the ground.
- (iii) Insulators which are attached to supports and insulate the conductors from the ground.
- (iv) Cross arms which provide support to the insulators.
- (v) Miscellaneous items such as phase plates, danger plates, lightning arrestors, anti-climbing wires etc.

Properties of Conductor material used for Transmission and Distribution of electric Power

- (i) high electrical conductivity.
- (ii) high tensile strength in order to withstand mechanical stresses.
- (iii) low cost so that it can be used for long distances.
- (iv) low specific gravity so that weight per unit volume is small.

All above requirements are not found in a single material. Therefore, while selecting a conductor material for a particular case, a compromise is made between the cost and the required electrical and mechanical properties.

Commonly used conductor materials.

The most commonly used conductor materials for overhead lines are copper, aluminium, steel-coated aluminium, galvanised steel, and Cadmium copper.

The choice of a particular material will depend upon the cost, the required electrical and mechanical properties and the local conditions.

Always stranded conductors are preferable for overhead lines in order to increase the flexibility.

In stranded conductors, there is generally one central wire and round this, successive layers of wires containing 6, 12, 18, 24 - wires. Thus, if there are n layers, the total number of individual wires is $3n(n+1) + 1$. In the manufacture of stranded conductors, the consecutive layers of wires are twisted or spiralled in opposite direction so that layers are bound together.

Steel cored Aluminium:

Due to low tensile strength, aluminium conductors produce greater sag. This prohibits their use for large spans and makes them unsuitable for long distance transmission.

In order to increase the tensile strength, the aluminium conductor is reinforced with a core of galvanised steel-wire. The composite conductor thus obtained is known as Steel Cored Aluminium and is abbreviated as ACSR.

(Aluminium Conductor Steel Reinforced)

ACSR consists of central core of galvanised steel wire surrounded by a number of aluminium strands. Usually diameter of both steel and aluminium wires is the same.

The X-section of the two metals are generally in the ratio of 1:6 but can be modified to 1:4 in order to get more tensile strength for the conductor. The result of this composite conductor is that steel core takes greater percentage of mechanical strength while aluminium strands carry the bulk of current.

Advantages of steel cored aluminium conductors;

- (i) The reinforcement with steel increases the tensile strength but at the same time keeps the composite conductor light. Therefore steel cored aluminium conductors will produce smaller size and hence longer spans can be used.
- (ii) Due to smaller sag with steel cored aluminium conductors, towers of smaller heights can be used.

Galvanised Steel

Steel has a very high tensile strength. Therefore, galvanised steel conductors can be used for extremely long spans. They have been found very suitable in rural areas where cheapness is the main consideration. Due to poor conductivity and high resistance of steel, such conductors are not suitable for transmitting large power over a long distance.

Line Supports : The supporting structures for overhead line conductors are various types of poles and towers called line supports. The line supports should have the following properties:

- (i) High mechanical strength to withstand the weight of conductors and wind loads etc.
- (ii) Light in weight without the loss of mechanical strength.
- (iii). Cheap in cost and economical to maintain.

(iv). Longer life

(v). Easy accessibility of conductors for maintenance.

The line supports are of various types including wooden poles, steel poles, R.C.C. poles and lattice steel towers.

The choice of supporting structures for a particular case depends upon the line span, Consec-sectional area, line voltage, cost and local conditions.

Performance of Transmission Lines:

A transmission line has three constants, R , L and C distributed uniformly along the whole length of the line.

The resistance and inductance form the series impedance. The capacitance existing between conductors for 1-phase line or from a conductor to neutral for a 3-phase line forms a shunt path throughout the length of the line. Therefore, capacitance effects introduces complications in transmission line calculations.

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

1) Short transmission line 2) Medium transmission lines and (iii) Long transmission lines -

(i) Short Transmission lines; When the length of an overhead transmission line is upto about 50 km and the line voltage is comparatively low ($< 20 \text{ kV}$), 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 moderately high ($> 20 \text{ kV} < 100 \text{ kV}$), it is considered as a medium transmission line. Due to sufficient length and voltage of the line, the capacitance effects are taken into account.

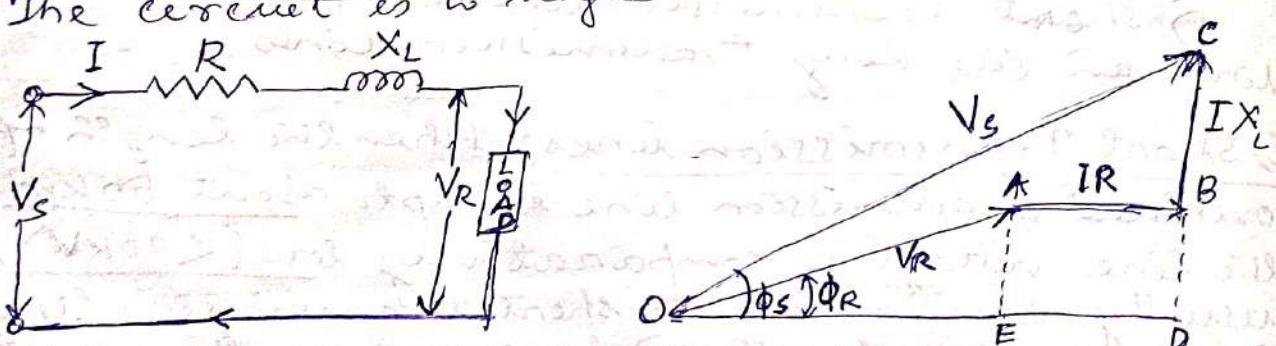
For purposes of calculations, the distributed capacitance of the line is divided and lumped in the form of condensers shunted across the line at one or more points.

(a) Long Transmission lines:

When the length of an overhead transmission line is more than 150 km and line voltage is very high ($> 100 \text{ kV}$), it is considered as a long transmission line. For the treatment of such a line, the line constants are considered uniform distributed over the whole length of the line.

Performance of Single Phase Short Transmission lines:

While studying the performance of a short transmission line, only resistance and inductance of the line are taken into account. The equivalent circuit of a single phase transmission line is shown in the figure. The circuit is a single a.c. series circuit.



Let I = load current

R = loop resistance i.e. resistance of both conductors

X_L = loop reactance

V_R = receiving end voltage

$\cos\phi_R$ = receiving end power factor (lagging)

V_s = sending end voltage

$\cos\phi_s$ = sending end power factor

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The vector diagram of the line for lagging load power factor is shown in figure.

From the right angled triangle ODC, we get

$$(OC)^2 = (OD)^2 + (DC)^2$$

$$\text{or, } V_s^2 = (OE + ED)^2 + (DB + BC)^2 \\ = (V_R \cos\phi_R + IR)^2 + (V_R \sin\phi_R + IX_L)^2$$

$$\therefore V_s = \sqrt{(V_R \cos\phi_R + IR)^2 + (V_R \sin\phi_R + IX_L)^2}$$

$$\% \text{age Voltage regulation} = \frac{V_s - V_R}{V_R} \times 100$$

$$\text{Sending end power factor, } \cos\phi_S = \frac{OD}{OC} = \frac{V_R \cos\phi_R + IR}{V_s}$$

$$\text{Power delivered} = V_R I_R \cos\phi_R$$

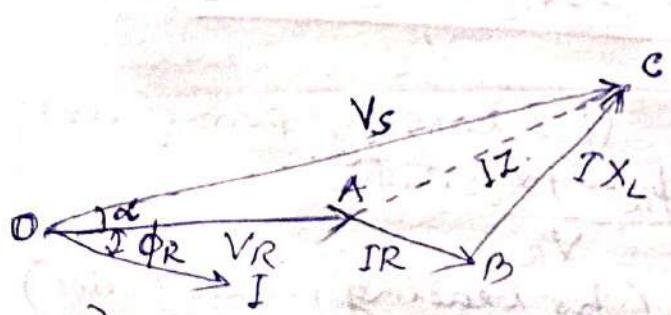
$$\text{Line losses} = I^2 R$$

$$\text{Power sent out} = V_R I_R \cos\phi_R + I^2 R$$

$$\% \text{ Transmission efficiency} = \frac{\text{Power delivered}}{\text{Power sent out}} \times 100$$

$$= \frac{V_R I_R \cos\phi_R}{V_R I_R \cos\phi_R + I^2 R} \times 100$$

Solution in Complex notation: It is often convenient to make the line calculations in complex notation.



Taking \vec{V}_R as the reference vector, we can draw the vector diagram as shown in figure.

\vec{V}_s is the vector sum of \vec{V}_R and $\vec{j}Z$.

$$\vec{V}_R = V_R + j0$$

$$\vec{I} = \vec{I} \angle -\phi_R = I (\cos\phi_R - j\sin\phi_R)$$

$$\vec{Z} = R + jX_L$$

$$\therefore \vec{V}_s = \vec{V}_R + \vec{j}Z \\ = (V_R + j0) + I (\cos\phi_R - j\sin\phi_R) (R + jX_L)$$

$$= (V_R + IR \cos\phi_R + IX_L \sin\phi_R) + j(IX_L \cos\phi_R - IR \sin\phi_R)$$

$$\therefore V_s = \sqrt{(V_R + IR \cos\phi_R + IX_L \sin\phi_R)^2 + (IX_L \cos\phi_R - IR \sin\phi_R)^2}$$

The second term under the root is quite small and can be neglected with reasonable accuracy. Therefore, approximate expression for V_s becomes:

$$V_s = V_R + I R \cos \phi_R + I X_L \sin \phi_R$$

- * The approximate formulae for V_s ($= V_R + I R \cos \phi_R + I X_L \sin \phi_R$) gives fairly correct result for lagging power factors. However, appreciable errors is caused for leading power factor. Therefore, approximate expression for V_s should be used for lagging power factor only.
- * The solution in complex notation is in more presentable form.

Effect of load power factor on Regulation and Efficiency

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

1. Effect on Regulation:

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

$$\% \text{age Regulation} = \frac{I R \cos \phi_R + I X_L \sin \phi_R}{V_R}$$

(for lagging power factor)

$$\% \text{age Regulation} = \frac{I R \cos \phi_R - I X_L \sin \phi_R}{V_R}$$

(for leading power factor)

- * When the load power factor is lagging or unity or such leading that $I R \cos \phi_R > I X_L \sin \phi_R$, then voltage regulation is positive i.e. receiving end voltage V_R will be less than the sending end voltage V_s .
- * For a given V_R and I , the voltage regulation of the line increases with the decrease in power factor for lagging loads.

When the load power factor is leading to the extent that $\sqrt{S} \cos \phi_R > \sqrt{P} \cos \phi_R$, then voltage regulation is negative i.e. the receiving end voltage V_R is more than the sending end voltage V_S .

- * for a given V_R and I , the voltage regulation of the line decreases with the decrease in power factor for leading loads.
- * Effect on transmission Efficiency:

The power delivered to the load depends upon the power factor. $P = V_R I \cos \phi_R$

$$\Rightarrow I = \frac{P}{V_R \cos \phi_R} \quad (\text{for single phase line})$$

$$I = \frac{P}{3V_R \cos \phi_R} \quad (\text{for three phase line})$$

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 the conclusion that transmission efficiency of a line decreases with the decrease in load power factor and vice versa.

Question: What is the minimum length in Km for a single phase transmission line having copper conductors of 0.775 cm^2 cross-section over which 200 kW at unity power factor and at 3300 V are to be delivered. The efficiency of transmission is 90% . Take specific resistance as $1.725 \mu\Omega \text{ cm}$.

Solution: Receiving end power = 200 kW

$$= 2,00,000 \text{ W.}$$

Transmission Efficiency = 0.9

$$\text{Sending end power} = \frac{200,000}{0.9} = 2,22,222 \text{ W.}$$

$$\text{Line losses} = 2,22,222 - 2,00,000 = 22,222 \text{ W.}$$

$$\text{Line current } I = \frac{200 \times 10^3}{3,300 \times 3} = 60.6 \text{ A}$$

Let $R \Omega$ be the resistance of one conductor,

$$\text{Line losses} = 2I^2 R$$

$$\therefore 22,222 = 2(60.6)^2 \times R.$$

$$R = \frac{22,222}{2 \times (60.6)^2} = 3.025 \Omega$$

$$\text{Now, } R = \frac{\rho l}{a}$$

$$l = \frac{Ra}{\rho} = \frac{3.025 \times 0.775}{1.725 \times 10^{-6}}$$

$$= 1.36 \times 10^6 \text{ cm} = 13.6 \text{ km}$$

(Answer)

Underground Cables:

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

The types of cable used will depend upon the working voltage and service requirements.

A cable must fulfil the following necessary requirements:

- (i) The conductor used in cables should be tinned stranded copper or aluminium of high conductivity. Stranding is done so that conductors may become flexible and carry more current.
- (ii) The conductor size should be such that the cable carries the desired load current without over-heating and causes voltage drop within permissible limits.
- (iii) The cable must have proper thickness of insulation in order to give high degree of safety and reliability at the voltage for which it is designed.

L.T. Cables: Low Tension cables are widely used for low voltage (1-1 KV).

These cables must have proper protection from water, corrosion and mechanical strength must be high. These cables must sustain a longer life for that various protections are required.

In this type of cables, the electrostatic stresses are less. The thermal conductivity is also very less.

The material used for construction of L.T. cables are:-

- Paper and cotton tapes.
- Lead sheath
- Serving
- 1st lead sheath
- 2nd lead sheath.
- Brass tape.

The conductors in the cable are surrounded by lead sheath with an insulating layer of paper-insulation.

Compounded fibrous material is surrounded around the lead sheath. The fibrous compounded material and wire armored is covered around the cable.

Multi-Core cables are of two types

- 1) Shaped Conductors
- 2) Round Conductors.

The copper space factor is good in case of shaped conductors and it is given by formula.

$$\text{Copper space factor} = \frac{\text{Copper area}}{\text{overall cable area}}$$

In case of shaped conductors, the overall diameter is very less. The whole insulation is provided by impregnated paper only. A paper belt is provided around the conductors and the fillings between them are filled with fibrous insulating material.

Again a lead sheath with fibrous material is provided with paper belt.

The standards applicable on these cables are

- IS 1554, - BS 6346, • IEC 60502

These cables are generally manufactured with copper conductors of size 1.5 Sqmm, 2.5 Sqmm and 4 Sqmm.

General Construction - L.T. Copper control cables.

Voltage : These cables can be used on AC voltage upto and including 1100V on DC upto and including 1500V.

Size : 1.5 Sq.mm and 2.5 Sq.mm upto 61 cores in control cables.

Conductors : - Annealed Bare Electrolytic Copper, solid / stranded copper.

Insulation : Conductors are insulated with PVC compound as per IS 5831:1984. On demand insulation is provided with XLPE also.

Color on Cores : Cores are identified with a color scheme as per IS: 1554 (Pt-1) : 1988 as under.

1. Core - Red, Black, Yellow, Blue

2 Cores - Red and Black

3 Cores - Red, Yellow, & Blue

4 Cores - Red, yellow, Blue and Black.

5 Cores - Red, yellow, Blue, Black and Grey.

In case of cable exceeding five cores,

Cones: Adjacent in each layer shall be coloured Blue.
Laying of cones: Cones are laid up with a suitable lay. The final layer direction shall be kept right hand lay.

Inner Sheath: The inner sheath is applied over laid up of cones by extrusion.

Armouring: Armouring is applied over inner sheath in case the calculated diameter over inner sheath does not exceed 13 mm, the armour consists of galvanised round steel wires. Where the calculated diameter over the inner sheath is greater than 13 mm the armour generally consists of flat steel. If required, the cable can be manufactured with steel wire where calculated diameter of cable exceeds 13 mm. Single core cables are provided with Aluminium Wire/ Steel armouring.

Outer Sheath: A final covering of PVC compound, conforming to IS: 5831:84, is applied over Armouring in case of Armored cable or over inner sheath in case of Unarmoured cable, called as "Outer Sheath".

The insulation, Inner Sheath and outer sheath can be HR PVC, FRLS PVC or FRHF compound depending upon their application.

Application of L.T. Cables:

Application of LT cables are:-

- ① Interconnection of process control in chemical plant, Petrochemical plant, Thermal plant etc.
- ② Communication and Signaling.

H.T. Cables:-

A high tension cable is a cable used for electric power transmission at high voltage. A cable includes a conductor and insulation and is suitable for being run underground or underwater. This is in contrast to an overhead line, which does not have insulation. High-voltage cable of differing types have a variety of applications in instruments, ignition systems, and alternating current (AC) and direct current (DC) power transmission. In all application, the insulation of the cable must not deteriorate due to the high-voltage stress, ozone produced by electric discharges in air, or tracking. The cable system must prevent contact of the high-voltage conductor with other objects or persons, and must contain and control leakage current. Cable joints and terminals must be designed to control the high-voltage stress to prevent breakdown of the insulation.

Often a high-voltage cable will have a metallic shield layer over the insulation, connected to the ground and designed to equalize the dielectric stress on the insulation layer. High voltage cables may be any length, with relatively short cables used in apparatus, longer cables run within buildings or as buried cables in an industrial plant or for power distribution, and the longest cables often run as submarine cables under the ocean for power transmission.

* Like other power cables, high voltage cables have the structural elements of one or more conductors, insulation, and a protective jacket. High voltage cables differ from lower voltage cable in that they have additional internal layers in the insulation jacket to control the electric field around the conductor.

For circuits operating at or above 2,000 volts between conductors, a conductor shield may surround each insulated conductor. This equalizes electrical stress on the cable insulation.

Cables for power distribution of 10kV and higher may be insulated with oil and paper, and are run in a rigid steel pipe, semi-rigid aluminium or lead sheath. For higher voltages, the oil may be kept under pressure to prevent formation of voids that would allow partial discharges within the cable insulation.

Sebastian Ziani de Ferranti was the first to demonstrate in 1887 that carefully dried and prepared paper could form satisfactory cable insulation at 11,000 volts.

Previously paper insulated cable had only been applied to low voltage telegraph and telephone circuits.

An extended lead sheath over the paper cable was required to ensure that the paper remained absolutely dry.

Laying of Underground Cables :

Reliability of underground cable network depends upon the proper laying and attachment of fittings i.e. cable end boxes, joints, branch connectors etc.

The methods of cable laying is discussed below:

1. Direct laying:

This method of laying underground cables is simple and cheap and is much favoured in modern practice.

In this method, a trench of about 1.5 metre deep and 45cm wide is dug. The trench is covered with a layer of

fine sand (of about 10 cm thickness) and the cable is laid over this sand bed. The sand prevents the entry of moisture from the ground and thus protects the cable from decay.

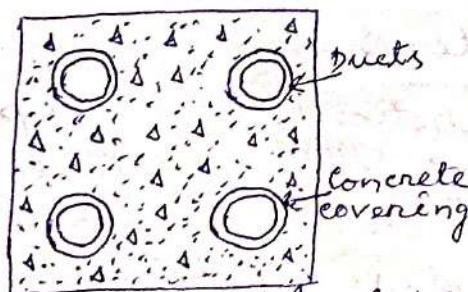
After the cable has been laid in the trench, it is covered with another layer of sand of about 10 cm thickness. The trench is then covered with bricks and other material in order to protect the cable from mechanical injury.

If more than one cable is to be laid in the same trench, a horizontal or vertical inter-axial spacing of at least 30 cm is provided in order to reduce the effect of mutual heating and also to ensure that a fault occurring on one cable does not damage the adjacent cable.

Cable to be laid in this way must have serving of bituminised paper and hessian tape so as to provide protection against corrosion and electrolysis.

2. Draw-in System: In this method, conduit or ducts 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 position from manholes.



The figure shows section through four-way under ground duct-line. Three of the ducts carry transmission cables and the fourth duct carries relay protection connection, pilot wires.

Care must be taken that where the duct line changes direction, depth, 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 simplify the pulling in of the cables. The cables to be laid in this way need not be armoured but must be provided with serving of hessian and jute in order to protect them when being pulled into the ducts.

D.C. Distribution.

D.C. Distribution Fed at one end:

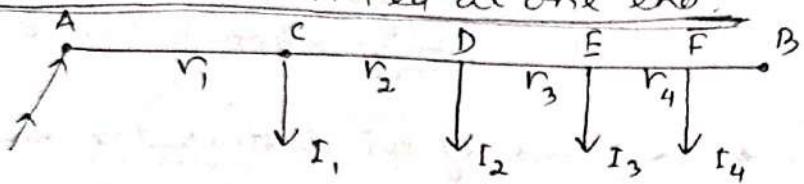


Figure shows the single line diagram of a 2-wire d.c. distribution AB fed at one end A and having concentrated loads I_1, I_2, I_3 and I_4 tapped off at points C, D, E and F respectively.

Let r_1, r_2, r_3 and r_4 be the resistances of both wires of the sections AC, CD, DE and EF of the distribution respectively.

Current fed from point A = $I_1 + I_2 + I_3 + I_4$

Current in section AC = $I_1 + I_2 + I_3 + I_4$

Current in section CD = $I_2 + I_3 + I_4$

Current in section DE = $I_3 + I_4$

Current in section EF = I_4

Voltage drop in section AC = $r_1 (I_1 + I_2 + I_3 + I_4)$

Voltage drop in section CD = $r_2 (I_2 + I_3 + I_4)$

Voltage drop in section DE = $r_3 (I_3 + I_4)$

Voltage drop in section EF = $r_4 I_4$.

\therefore Total voltage drop in the distribution

$$= r_1 (I_1 + I_2 + I_3 + I_4) + r_2 (I_2 + I_3 + I_4) + r_3 (I_3 + I_4) + r_4 I_4.$$

Minimum Potential will occur at point F which is farthest from the feeding point A .

Q:- A 2-wire d.c. distributor cable AB is 2 km long and supplies loads of 100A, 150A, 200A, and 50A situated 500m, 1000m, 1600m and 2000m from the feeding point A . Each conductor has a resistance of 0.01Ω per 1000 m. Calculate the Potential difference at each load point if a potential difference of 300V is maintained at point A .

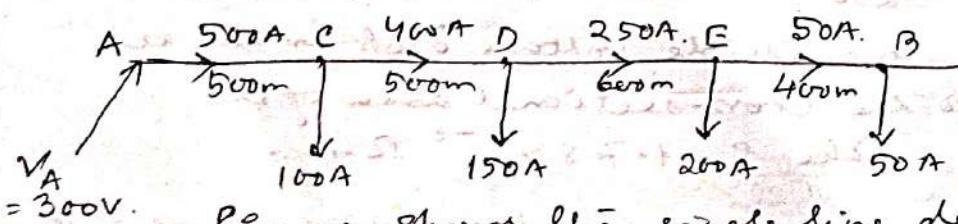


Figure shows the single line diagram of the distribution with its tapped currents.

Resistance per 1000 m of distribution = $2 \times 0.01 = 0.02\Omega$

Resistance of section AC , $R_{AC} = 500 \times \frac{0.02}{1000} = 0.01\Omega$

Resistance of section CD $R_{CD} = 0.01\Omega$

$$\text{Resistance of section DE, } R_{DE} = \frac{0.02}{1000} \times 600 = 0.012 \Omega$$

$$\text{Resistance of section EB, } R_{EB} = \frac{0.02}{1000} \times 400 = 0.008 \Omega$$

Current in various sections of the distributor are

$$I_{EB} = 50A.$$

$$I_{DE} = 50A + 20A = 250A$$

$$I_{CD} = 250A + 150A = 400A$$

$$I_{AC} = 400A + 100A = 500A$$

Potential difference at load point C, $V_C =$

$$\text{Voltage at A} - \text{voltage drop in AC} \\ = V_A - I_{AC} R_{AC} = 300 - (500 \times 0.01) = 295V$$

$$\text{P.D at load point D, } V_D = V_C - I_{CD} R_{CD} \\ = 295 - (400 \times 0.01) = 291V$$

$$\text{P.D at load point E, } V_E = V_D - I_{DE} R_{DE} \\ = 291 - (250 \times 0.012) = 288V$$

$$\text{P.D. at load point B, } V_B = V_E - I_{EB} R_{EB} \\ = 288 - 50 \times 0.008 = 287.6V$$

Avg

Q:- A 2-wire d.c. distributor AB is 300 metres long. It is fed at point A. The various loads and their positions are given below

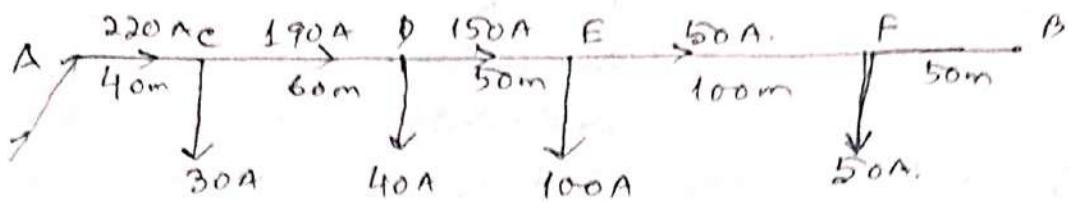
<u>At point</u>	<u>distance from A in meters.</u>	<u>concentrated load in amperes.</u>
-----------------	---------------------------------------	--

C	40	30
D	100	40
E	150	100
F	250	50

If the maximum permissible voltage drop is not to exceed 10V, find the cross-sectional area of the distributor. Take $f = 1.78 \times 10^{-8} \Omega \cdot m$.

Soln:- The single line diagram of the distributor along with its tapped currents is shown in figure. Suppose that resistance of 100 metres length of the distributor is r ohms. The resistance of various sections of

The distributor is in 6 phases



Then resistance of various sections of the distributor is:

$$R_{AC} = 0.48 \Omega, R_{CD} = 0.6 \Omega$$

$$R_{DE} = 0.5 \Omega, R_{EF} = 0.5 \Omega$$

Current in the various sections of the distributor are

$$I_{AC} = 220A, I_{CD} = 190A, I_{DE} = 150A, I_{EF} = 50A.$$

Total voltage drop over the distributor.

$$\begin{aligned} &= I_{AC} R_{AC} + I_{CD} R_{CD} + I_{DE} R_{DE} + I_{EF} R_{EF} \\ &= 220 \times 0.48 + 190 \times 0.6 + 150 \times 0.5 + 50 \times 0.5 \\ &= 327 \Omega. \end{aligned}$$

As the maximum permissible drop in the distributor is 10V,
 $\therefore 10V = 327 \Omega$.

$$\text{or, } r = \frac{10}{327} = 0.03058 \Omega.$$

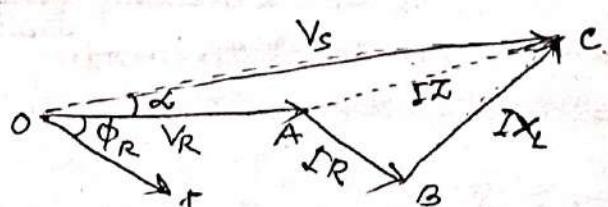
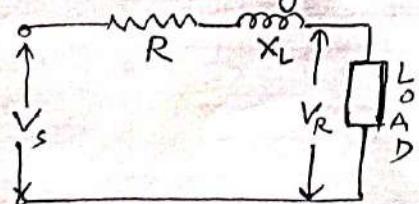
$$R = \rho \frac{l}{a}$$

\therefore Cross-sectional area of conductor

$$\begin{aligned} &= \frac{\rho l}{\sigma/2} = \frac{1.78 \times 10^{-8} \times 100}{0.03058/2} \\ &= 116.4 \times 10^{-6} \text{ m}^2 = 1.164 \text{ cm}^2. \quad \underline{\text{Ans.}} \end{aligned}$$

Q:- A single phase overhead transmission line delivers 1100 kW at 33 kV at 0.8 p.f. lagging. The total resistance and inductive reactance of the line are 10 Ω and 15 Ω respectively. Determine (i) Sending end voltage (ii) Sending end power factor and (iii) Transmission efficiency.

Solution:



Load power factor, $\cos \phi_R = 0.8$ lagging.

$$\text{Total line impedance } Z = R + jX_L = 10 + j15.$$

$$\text{Receiving end voltage, } V_R = 33 \text{ kV} = 33,000 \text{ V}$$

$$\therefore \text{Line current, } I = \frac{Kw \times 10^3}{V_R \cos \phi_R}$$

$$= \frac{1100 \times 10^3}{33,000 \times 0.8} = 41.67 \text{ A}$$

As $\cos \phi_R = 0.8$, $\therefore \sin \phi_R = 0.6$

Taking receiving end voltage \vec{V}_R as the reference vector,

$$\vec{V}_R = V_R + j0 = 33,000 \text{ V}$$

$$\vec{I} = I(\cos \phi_R - j \sin \phi_R)$$

$$= 41.67(0.8 - j0.6) = 33.33 - j25$$

$$(i) \text{ Sending end voltage } \vec{V}_S = \vec{V}_R + \vec{I}Z$$

$$= 33,000 +$$

Variable load on Power Station

The load on a power station varies from time-to-time due to uncertain demands on the consumers and is known as variable load on the station.

A power station is designed to meet the load requirements of consumers. The load demand of one consumer at any time may be different from that of the other consumer.

Effects of variable load: Some of the important effects of variable load on power station are:-

(i) Need of additional equipment: - If a power demand on a plant increases, it must be followed by the increased flow of coal, air and water to the boiler in order to meet the increased demand.

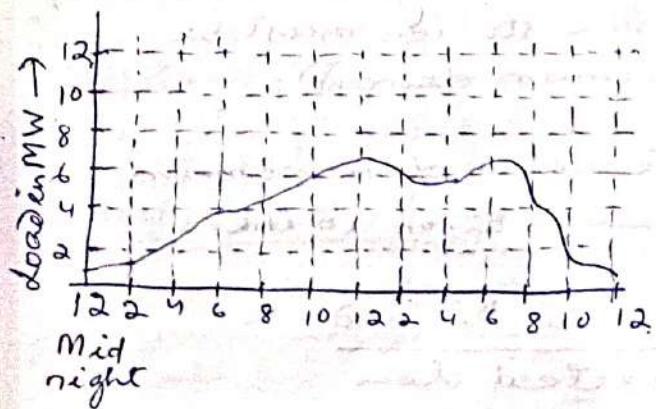
Therefore additional equipment has to be installed to accomplish the job.

(ii) Increased in production cost: The variable load on the plant increases the cost of the production of electrical energy

LOAD CURVES:

The curve showing the variation of load on the power station with reference to time is known as load curve. The load on a power station is never constant, it varies from time to time.

These load variations during the whole day are recorded and are plotted against time on the graph. The curve thus obtained is known as daily load curve.



The monthly load curve can be obtained from the daily load curves of that month.

For this purpose, average values of power over a month at different times of the day are calculated and then plotted on the graph.

The monthly load curve is generally used to fix the rates of energy.

The yearly load curve is obtained by considering the monthly load curves of that particular year. Yearly load curve is generally used to determine the annual load factor.

- * The area under the load curve gives the number of units generated in the day.

$$\text{Units generated/day} = \text{Area (in kwh) under daily load curve.}$$
- * Highest point on the load curve represents the maximum demand on the station on that day.
- * Average load = $\frac{\text{Area under daily load curve}}{24 \text{ hours.}}$
- * The load curve helps in selecting the size and number of generating units.
- * Load curve helps in preparing the operation schedule of the station.

Connected load.

It is the sum of continuous ratings of all the equipments connected to supply system.

Maximum Demand: It is the greatest demand of load on the power station during a given period.

Maximum demand is generally less than the connected load because all the consumers do not switch on their connected load to the system at a time.

The knowledge of maximum demand is very important as it helps in determining the installed capacity of the station. The station must be capable of meeting the maximum demand.

Demand factor: It is the ratio of maximum demand on the power ~~system~~ station to the connected load.

$$\text{Demand factor} = \frac{\text{Maximum Demand.}}{\text{Connected load.}}$$

The value of demand factor is usually less than 1.

Average load: The average of loads occurring on the power station in a given period (day or month or year) is known as average load or average demand.

Daily average load = $\frac{\text{No. of units generated in a day}}{24 \text{ hours}}$

Monthly average load = $\frac{\text{No. of units generated in a month}}{\text{Number of hours in a month}}$

Yearly average load = $\frac{\text{No. of units generated in a year}}{8760 \text{ hours}}$

Load Factor: The ratio of average load to the maximum demand during a given period is known as load factor.

$$\text{Load factor} = \frac{\text{Average load}}{\text{Max. demand}}$$

If the plant is in operation for T hours,

$$\text{Load factor} = \frac{\text{Average load} \times T}{\text{Max. demand} \times T}$$

$$= \frac{\text{Units generated in } T \text{ hours}}{\text{Max. demand} \times T}$$

~~Load~~ Load factor is always less than 1 because average load is smaller than the maximum demand.

Diversity factor: The ratio of the sum of individual maximum demands to the maximum demand on power station is known as Diversity Factor.

$$\text{Diversity factor} = \frac{\text{Sum of individual max. demands}}{\text{Max. demand on power station}}$$

* Diversity factor ~~will~~ always be greater than 1.

* The greater the diversity factor, the lesser is the cost of generation of power.

Capacity factor: It is the ratio of the actual energy produced to the maximum possible energy that could have been produced during a given period.

$$\text{Capacity factor} = \frac{\text{Actual energy produced}}{\text{Maximum energy that could have been produced}}$$

$$= \frac{\text{Average Demand} \times T}{\text{Maximum demand} \times T}$$

$$= \frac{\text{Average demand}}{\text{Plant capacity}}$$

Thus if the considered period is one year,

$$\text{Annual Capacity factor} = \frac{\text{Annual Kwh output}}{\text{Plant capacity} \times 8760}$$

Reserve capacity = Plant capacity - Maximum demand.

Plant use factor = It is the ratio of KWh generated to the product of plant capacity and the number of hours for which the plant was in operation.

Plant use factor = $\frac{\text{Station output in KWh.}}{\text{Plant capacity} \times \text{Hours of use.}}$

Units generated per Annum

It is essential to find the KWh generated per annum from maximum demand and load factor.

Load factor = $\frac{\text{Average load.}}{\text{Maximum demand}}$

Average load = Maximum demand \times Load factor
 $= MD \times LF$

Units generated/annum =

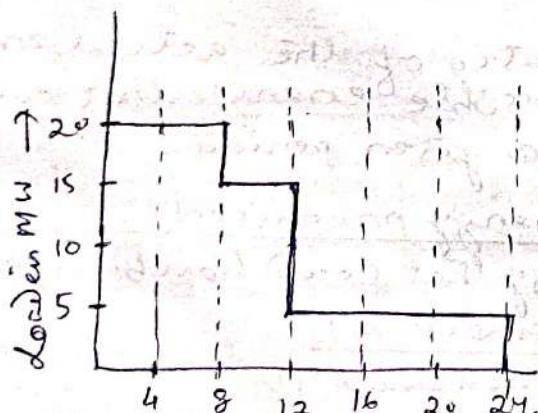
Average load (in kW) \times Hours in a year

$= \text{Maximum demand} \times LF \times \text{Hours in a year}$

Units generated/annum

$$= MD \times L.F \times 8760.$$

Load Duration Curve.



When the load elements of a load curve are arranged in the order of descending magnitudes, the curve thus obtained is called a load Duration Curve.

The load duration curve is obtained from the same data as the load curve but the ordinates are arranged in the order of descending magnitude.

Area under the load curve and load duration curve is equal.

TARIFF:

The rate at which electrical energy is supplied to a consumer is known as tariff.

Objective of Tariff: Like other commodities, electrical energy is also sold at such a rate ^{so} that it not only recovers the cost but also earns reasonable profit. Therefore, a tariff should include the following items:

(i) Recovery of cost of producing electrical energy at the power station.

(ii) Recovery of cost of on the capital investment in transmission and distribution systems.

(iii) Recovery of cost of operation and maintenance of supply of electrical energy e.g. metering equipment, billing etc.

(iv) A suitable profit on the capital investment.

Block rate tariff.

When a given block of energy is charged at a specific rate and the succeeding blocks of energy are charged at progressively reduced rates, it is called a block rate tariff.

In block rate tariff, the energy consumption is divided into blocks and the tariff price per unit is fixed in each block. The price per unit in the first block is the highest and it is progressively reduced for the succeeding blocks of energy.

The advantage of such a tariff is that the consumer gets an incentive to consume more electrical energy.

This increases the load factor of the system and hence the cost of generation is reduced.

Its principal defect is that it lacks a measure of the consumers demand.

This type of tariff is being used for majority of residential and small commercial consumers.

Maximum demand Tariff. It is similar to two-part tariff with the only difference that the maximum demand is actually measured by installing maximum demand meter in the premises of the consumer. This removes the objection of two-part tariff where the maximum demand is assessed merely on the basis of the rateable value.

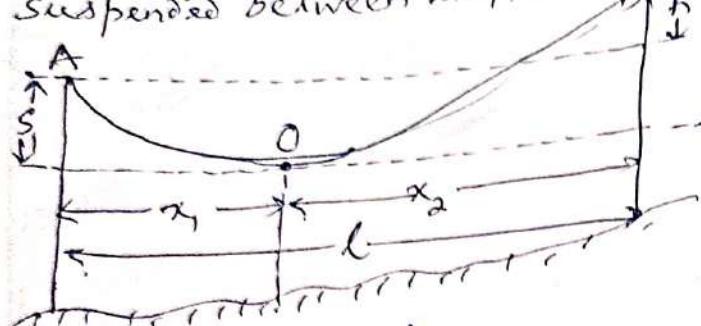
This type of tariff is mostly applied to big consumers.

However, it is not suitable for a small consumer (e.g. residential consumer) as a separate maximum demand meter is required.

Calculation of sag wire - 1

Unequal levels.

In hilly areas, we generally come across conductors suspended between supports at unequal levels.



at different levels.

The lowest point on the conductor is 'O'

Let l = Span length

h = Difference in levels between two supports

x_1 = Distance of support at lower level (A) from 'O'

x_2 = Distance of support at higher level (B) from 'O'

x_2 = Distance of support at higher level (B) from 'O'

T = Tension in the conductor.

If 'w' is the weight per unit length of the conductor, then $\text{Sag } S_1 = \frac{wx_1^2}{2T}$

$$\text{and } \text{Sag } S_2 = \frac{wx_2^2}{2T}$$

(i).

$$\text{Also } x_1 + x_2 = l.$$

$$\text{Now, } S_2 - S_1 = \frac{wx_2^2}{2T} - \frac{wx_1^2}{2T}$$

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

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

$$= \frac{wl}{2T} (x_2 - x_1) \quad (\because x_1 + x_2 = l)$$

$$\text{But, } S_2 - S_1 = h.$$

$$\therefore h = \frac{wl}{2T} (x_2 - x_1)$$

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

Now, we have to solve eqn (i) and (ii).

$$\text{Adding (i) & (ii)} \Rightarrow 2x_2 = l + \frac{2Th}{wl}$$

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

Putting the value of x_2 in eqn. (1)

$$x_1 + \frac{l}{2} + \frac{Th}{wl} = l.$$

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

$$\therefore x_1 = \frac{l}{2} - \frac{Th}{wl} \text{ and } x_2 = \frac{l}{2} + \frac{Th}{wl}$$

Putting the above values of x_1 and x_2 , we can easily calculate the value of S_1 and S_2 .

MODEL QUESTION - I

Full Mark - 80.

TIME - 3 hours

Answer any FIVE Questions including Q-No. 1 and 2.No.1 Answer ALL the following questions in brief 2x10

- (a) Define load factor?
- (b) What is Sag in overhead line?
- (c) What is tariff?
- (d) What is corona?
- (e) Define Transmission efficiency?
- (f) What is voltage regulation?
- (g) What is Superheater?
- (h) What is Economiser?
- (i) What is the function of Surge tank?
- (j) Write the advantages of hydroelectric power plant?

No.2 Answer any six?

5x6

- (a) Discuss two part tariff and three part tariff?
- (b) State and prove Kelvin's law for size of conductor for transmission line.
- (c) A Substation transformer is to serve the following loads.

Classification	Total loads	Demand factor
Lighting	300 kW	60%
Power	1200 kW	80%
Heating	500 kW	90%

If the diversity factor among load types is 1.5, determine the maximum demand on the transformer?

- (d) State advantages of H.V.D.C. transmission system
- (e) Write the disadvantages of EHV transmission system.

(b) Describe String Efficiency. MQ2

No. 3 Q) Describe Primary Distribution system and Secondary distribution system? (10)

No. 4 Q) A 132 KV transmission line has the following data

Weight of conductor = 680 kg/km. (10)

Length of span = 260 m

Ultimate Strength = 3100kg.

Safety factor = 2.

Calculate the height above ground at which the conductors should be supported? (8)

Ground Clearance required is 10 meters. (2)

No. 5 Q) A Substation has a maximum demand of 15000 KW. (10)
The annual load factor is 50% and Plant capacity factor is 40%. Determine the reserve capacity of the plant. (2)

No. 6. Q) Discuss the advantages and disadvantages of Thermal Power Plant. (10)

Advantages
1. It is a cheap form of generation.
2. It is a reliable source of generation.
3. It can be started and stopped quickly.
4. It can be easily controlled.
5. It is a clean form of generation.

Disadvantages
1. It is a non-renewable source of energy.
2. It produces a lot of pollution.
3. It requires a lot of water.
4. It is a capital intensive form of generation.
5. It is a non-renewable source of energy.

4th Sem. Electrical Engineering

MQ2-1

Subject : - GENERATION TRANSMISSION AND DISTRIBUTION.

MODEL QUESTION-2

FULL MARK - 80

TIME - 3 HOURS

Answer 5 Questions including Q. No. 1 and 2

No. 1. Answer All Questions. (2x10)

- a) Write the various components of power system?
- b) Why high voltage is preferred for power transmission?
- c) What are the transmission line parameters?
- d) What is characteristics impedance?
- e) What are the advantages of using bundle conductors in transmission lines?
- f) What is load curve?
- g) What is Skin effect?
- h) Describe flat rate tariff?
- i) What is critical disruptive voltage?
- j) Define Demand factor?

No. 2 (a) Answer any six questions. (5x6)

- a) State disadvantages of H.V. D.C. transmission systems?
- b) State methods of reducing corona effect?

c) Write the advantages of Suspension type insulators?

d) A substation supplies the following loads to various consumers:

Industrial consumer = 1500 kW, Domestic light = 450 kW

If the maximum demand on the station is 2500 kW

and the number of Kwh generated per year is

45×10^5 ; Determine (i) the diversity factor and

(ii) Annual load factor.

(e) How to improve string efficiency by grading the insulators?

(b) Describe Radial Distribution System

- (Q1) Explain the working principle of a transmission system. (10)
- No.3 Explain E.H.V.A.C. Transmission. (10)
- No.4 Derive Sag for overhead line with level supports (10) considering effect of wind and ice loading.
- No.5 A transmission line has a span of 150 m between level supports. The conductor has a cross-sectional area of 2cm^2 . The tension in the conductor is 2000 kg. If the specific gravity of the conductor material is 9.9 gm/cm³ and wind pressure is 1.5 kg/m length calculate the sag? (10)
- No.6 Write a comparison between HVDC Transmission system and HVAC Transmission System? (10)
- (Q7) List out pros and cons of insulation. A (10)
- (Q8) Define insulation resistance. (10)
- (Q9) Define insulation resistance factor. (10)
- (Q10) Define insulation resistance factor. (10)

MODEL QUESTION-3

Full Mark - 80

TIME :- 3 HOURS

Answer five Questions including Q. No. 1 and 2

No. 1

Answer all questions:

(2x10)

- (a) Why are insulators used in overhead lines?
- (b) What is Surge Tank?
- (c) What is Plant capacity factor?
- (d) What is air preheater?
- (e) What is ACSR conductor?
- (f) What is Base load?
- (g) Describe coal and ash handling plant.
- (h) Write the principle of Thermal Power Plant.
- (i) How coal is fed to the boilers of a Power Plant?
- (j) What is Condenser?

No. 2 Answer any six questions: (5x6)

- (a) Describe pin type insulators used in overhead transmission lines?
- (b) Derive sag of transmission line when supports are at equal level?
- (c) Write the desire properties of insulators used in overhead transmission line?
- (d) What are the main features when selecting Tariff of electricity consumption?

(Q) What is Transmission Efficiency ?

What will be the Transmission Efficiency if 1000 watts of power were fed to a feeder ~~line~~ and 900 watts is received at the other end ?

(Q) Describe Feeder ~~and Distribution~~

in electrical Power system ?

No.3 Q) Describe Hydro electric Power Plant (10)

No.4 Q) Write a Comparison between overhead system (10) and underground system ?

No.5 Q) Describe various methods to improve the (10) string efficiency.

No.6 Q) A 3phase line having per phase resistance and (10) reactance of 2Ω and 4Ω respectively is delivering 10 MW at 22 KV at 0.8 Power factor lagging - Determine the (i) sending end voltage (ii) percentage regulation (iii) total line losses and (iv) line - efficiency ?

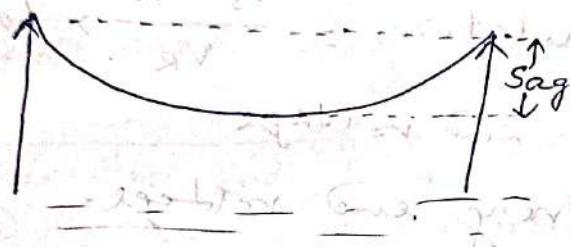
Sub:- GENERATION, TRANSMISSION AND DISTRIBUTION

No.1.(Ans) - a) Load factor is the ratio of energy consumed the average load over a given period to the maximum demand (peak load) occurring in that period.

$$\text{Load factor} = \frac{\text{average load}}{\text{Peak load}}$$

Load factor means how efficiently we use energy.

(b) Sag in Overhead line :-



Sag is defined as the difference in level between points of supports and the lowest point on the conductors.

(c) Tariff : - The amount of money frame by the supplier for the supply of electrical energy to various types of consumers is known as an electricity tariff. Furthermore, the tariff is the methods of charging a consumer for consuming electric power.

(d) Corona : - The phenomenon of ionisation of surrounding air around the conductors due to which luminous glow with hissing noise is rise is known as the corona effect.

(e) Transmission Efficiency :

$$\text{Transmission Efficiency} = \frac{P_o}{P_i} \times 100$$

where P_o is the amount of Power reaching the receiving end.

P_i is the amount of Power fed at the sending end.

(b) Voltage Regulation :- When a transmission line supplies a load current, there is a voltage drop in the line due to resistance and inductance (inductive reactance) of line. Therefore, receiving end voltage V_R is generally less than the sending end voltage V_S .

This voltage drop in the line is expressed as a percentage of receiving end voltage V_R and is called voltage regulation.

$$\text{Percentage Voltage Regulation} = \frac{V_S - V_R}{V_R} \times 100$$

where V_S = Sending end voltage

V_R = Receiving end voltage.

(g) Superheater :- A superheater is a device used to convert saturated steam or wet steam into superheated steam or dry steam. Superheated steam is used in steam turbines for electricity generation.

(h) Economiser :- Function of economiser in thermal power plant is to recover some of the heat from the heat carried away in the flue gases up the chimney and utilize for heating the feed water to the boiler.

(i) Surge Tank : Surge Tank is a device introduced within a hydropower water conveyance system having a rather long-pressure conduit to absorb the excess pressure rise in case of a sudden valve closure.

(j) Advantages of hydroelectric power plant:

- (i) Hydro power is ~~fuelled~~ fueled by water, so it is a clean fuel source
- (ii) It does not pollute the environment
- (iii) hydro power creates reservoirs that offer a variety of recreational opportunities, notably fishing, agriculture etc.
- (iv) In addition to a sustainable fuel source, hydropower efforts produce a number of benefits such as flood-control, irrigation and water supply.

No.2 Two part tariff and Three part Tariff:-

Two-part tariff :- In this type of tariff, the total bill is divided into two parts. The first one is the fixed charge and the second is the running charge.

The fixed charge is because of the maximum demand and the second charge depends on the energy consumption by the loc.

$$\text{Total Cost} = (A \text{ kw} + B \text{ kwh}) \text{ Rs.}$$

Where A = charge per kw of maximum demand

B = charge per kwh of energy consumed

The fixed charges will depend upon ~~maximum demand of the consumer and the are due to the interest and depreciation on the capital cost of building and equipment, taxes and a part of operating cost which is independent of energy generated.~~

The running charges are due to the operating cost which varies with variation in generated (~~or supplied~~) energy.

Three Part Tariff: In this Scheme, the total costs are divided into three sections; such as : - ① Fixed Cost ② Semi-fixed cost and running costs.

Total charges

$$= [A + B \text{ kw} + C \text{ kwh}]$$

where A = fixed charges

B = charge per kw of maximum demand.

C = charge per kwh of energy consumed

(b) Kelvin's law:

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.

Let area of cross-section of conductor = a ,
annual interest and depreciation on capital cost of the conductor = C_1 ,

annual running charges = C_2

Now, annual interest and depreciated cost is directly proportional to the area of conductor i.e.

$$\text{i.e. } C_1 = K_1 a.$$

And annual running charges are inversely proportional to the area of conductor

$$C_2 = \frac{K_2}{a}$$

where K_1 and K_2 are constants.

Now, total annual cost = $C = C_1 + C_2$

$$C = K_1 a + \frac{K_2}{a}$$

for C to be minimum, the differentiation of C with respect to a must be zero

$$\text{i.e. } \frac{d}{da}(C) = 0.$$

$$\text{Therefore, } \frac{dc}{da} = \frac{d}{da} \left[K_1 a + \frac{K_2}{a} \right] = 0$$

$$\therefore K_1 - \frac{K_2}{\alpha^2} = 0$$

$$\therefore K_1 = \frac{K_2}{\alpha^2}$$

$$\therefore K_1 \alpha = \frac{K_2}{\alpha}$$

$$\therefore \boxed{c_1 = c_2} \Rightarrow \alpha = \sqrt{\frac{K_2}{K_1}}$$

(c) Demand factor = $\frac{\text{Peak load}}{\text{Connected load}}$

Peak load = Demand factor \times Connected load

Diversity factor = $\frac{\sum \text{individual peak load}}{\sum \text{peak load of the transformer}}$
 $= \frac{\sum \text{individual peak load}}{\sum \text{peak load of the transformer}}$

Peak load = $\frac{\sum \text{individual peak loads}}{\text{Diversity factor}}$

$$(0.6 \times 300) + (0.8 \times 1200) + (0.9 \times 500)$$

$$= 1060 \text{ kW}$$

\therefore Peak load = 1060 kW

Maximum demand on the transformer = 1060 kW

d). Advantages of H.v-D.C. Transmission System.

1) Controlled Power Exchange

2) Improve stability of A.C. System

3) Transmission at reduced Voltage.

4) Minimize power reduction in case of pole outage.

5) Benefits at low ambient temperature.

6) Asynchronous link.

(e) Write the disadvantages of EHV transmission system?

Ans:- The major disadvantages are:

1) Corona loss and Radio interference.

2) Line supports

3) Erection difficulties

4) Insulation needs

5) The cost of transformers, switchgear equipments increases with increase in transmission line.

6) The EHV lines generates electrostatic effects which are harmful to human beings and animals.

(f) String Efficiency:

String efficiency is the ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor.

String efficiency = $\frac{\text{Voltage across the string}}{n \times \text{Voltage across disc nearest to the conductor}}$

Where n = no. of discs in the string

The voltage applied across the string of suspension insulators is not uniformly distributed across various units or discs.

The disc nearest to the conductor has much higher potential than the other discs.

The unequal potential distribution is undesirable and is usually expressed in terms of string efficiency.

No-3 Primary Distribution and Secondary Distribution.

Primary Distribution System:

The Primary Distribution System is that part of the electric distribution system between the distribution substation and distribution transformers.

It is made up of circuits called primary feeder or distribution feeders. A typical power distribution feeder provides power for both primary and secondary circuits.

Secondary Distribution System:

A low voltage network or secondary network is a part of electric power distribution which carries electric energy from distribution transformers to electricity meters of end customers.

Secondary networks are operated at a low voltage level, which is typically equal to the mains voltage of electric appliances. Most modern secondary networks are operated at AC rated voltage of 100-120 to 230-240 volts at the frequency of 50Hz.

Electric power distribution systems are designed to serve their customers with reliable and high quality power. The most common distribution system consists of simple radial circuits (feeders) that can be overhead, underground or a combination.

No-5 Energy generated/annum = Maximum Demand \times load-factor \times hours in a year.

$$\text{Energy generated} = (1500 \times 0.5 \times 8760) \text{ kWh.}$$

$$= 65.7 \times 10^6 \text{ kWh.}$$

$$\text{Plant capacity factor} = \frac{\text{Units generated/annum}}{\text{Plant capacity} \times \text{hours in a year}}$$

11A1-8

Plant Capacity = $\frac{\text{Units generated/annum.}}{\text{Plant capacity factor} \times \text{hours in a year}}$

$$= \frac{65.7 \times 10^6}{0.4 \times 8760} = 18,750 \text{ kW.}$$

Reserve Capacity

= Plant capacity - Maximum demand

$$= 18,750 - 15,000 = 3750 \text{ kW.}$$

No-6

Advantages of Thermal Power Plant

- Thermal Power Station has less initial cost as compared to hydro-electric generating station.
- It requires less space as compared to the hydro-electric power station.
- The fuel cost is less as compared to gas.
- Huge amount of power can be generated by Thermal Power Stations.
- The cost of generation is less as compared to diesel power station.

Disadvantages of Thermal Power Plant :

- The running cost of thermal Power station is more as compared to hydro power stations.
- It pollutes the atmosphere due to production of large amount of smoke and fumes.
- Maintenance cost is more.
- Skilled persons are required for erecting and maintaining the power station.
- Land requirement is more for storage of coal and ash.

No.1 a) Various Components of Power System:

The power plant, transformer, transmission line, substations, distribution line and distribution transformer are the six main components of the power system.

b) High voltage is preferred for power transmission

Explanation: The power that is generated will be of high current. In order to reduce the current voltage is increased so that the copper usage will be reduced. Another reason for high voltage transmission is that losses can be reduced.

c) Transmission line parameters: The Parameters of transmission lines are Resistance (R), inductance (L), capacitance (C), conductance (G).

• Resistance is defined as the loop resistance per unit length of the wire. Its unit is ohm/km.

• Inductance is defined as the loop inductance per unit length of the wire. Its unit is Henry/km.

• Conductance is defined as the loop conductance per unit length of the wire. Its unit is mho/km

d) Characteristics Impedance: Characteristics impedance is the impedance measured at the sending end of the line

$$Z = R + j\omega L \text{ is the series impedance}$$

$$Y = G + j\omega C \text{ is the shunt admittance.}$$

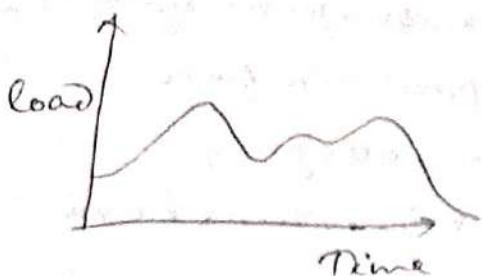
$$\text{Characteristics impedance } Z_0 = \sqrt{\frac{Z}{Y}}$$

e) Bundle conductors are primarily employed to reduce the corona loss and radio interference.

• Bundle conductors lines will have higher capacitance to neutral in comparison with single lines.

• Bundle conductors lines will have higher capacitance and lower inductance than ordinary lines they will have higher surge impedance. They have higher maximum power transfer ability.

(b) Load curve :-



Load curve is the variation of load with time on a power station.

Load on a power station never remain constant rather at various time to time, these variation in load

is plotted on half hourly or hourly basis for the whole day. The curve thus obtained is known as Daily Load Curve.

(g) Skin Effect : - Skin effect is a tendency for alternating current (AC) to flow mostly near the outer surface of an electrical conductor, such as metal wire. The effect becomes more and more apparent as the frequency increases.

(h) Flat rate Tariff : - In this tariff, different types of consumers are charged at different rates of cost per unit (1 kWh) of electrical energy consumed. Different consumers are grouped under different categories.

Each category is charged money at a fixed rate similar to Simple Tariff. The different rates are decided according to the consumers, their loads and load factors.

i) Disruptive Voltage : - Critical Disruptive voltage is defined as the minimum phase to neutral voltage required for the corona discharge to start. Basically corona discharge is the current discharge in the air.

j) Demand Factor : - Demand factor is the ratio of the sum of the maximum demand of a system (or part of a system) to the total connected load on the system (or part of the system) under consideration. Demand-factor is always less than one.

Load factor and Demand factor are not same. Load factor is the ratio of actual load to maximum load. Demand factor is the ratio of maximum load to total connected load.

- No. 2 (a) Disadvantages of H.V.D.C. transmission Systems:-
- 1) The D.C. voltages ~~cannot~~ be stepped up for transmission of power at high voltages.
 - 2) The D.C. switches and circuit breakers have their own limitations.
 - 3) Power transmission with HVDC is not economical if the length of transmission line is less than 500 km.
 - 4) Considerable reactive power is required by converter stations.
 - 5) Maintenance of insulators is more.
- (b) Methods of reducing corona effect.
- i) By increasing conductor size : By increasing conductor size, the voltage at which corona occurs is raised and hence corona effects are considerably reduced. Due to this, ACSR conductors which have a large cross-sectional area are used in transmission lines.
 - ii) By increasing conductor spacing : By increasing the spacing between conductors, the voltage at which corona occurs is raised and hence corona effects can be eliminated. However, spacing cannot be increased too much otherwise the cost of supporting structure (bigger cross arms and supports) may increase to a considerable extent.
- (c) Advantages of Suspension type insulators:
- Suspension type insulators are cheaper in cost compared to pin type insulators for operating voltage above 50 kV.

MA 2-4

- MA 2

 - Each unit of suspension insulators (insulator disc) is designed for comparatively low voltage (11 kV) and can be increased the insulation strength by connecting these insulators disc modules in series.
 - If one of the units is damaged, then it is replaced by the new one and hence no need of replacing the whole string.
 - The string is free to swing in any direction and, therefore, great flexibility is provided to the transmission line.
 - The conductors are placed below the suspension insulators and hence it partly protects the conductors from lightning.

$$\text{d) Diversity factor} = \frac{1500 + 750 + 100 + 450}{2500}$$

$$= 1 \cdot 12$$

Annual Demand = kwh generated/annum

Hours in a year
 $2 \text{ months} \times 2 \text{ weeks} \times 168 \text{ hours}$

$$\frac{45 \times 10^5}{8760} = 51.3 \text{ kWh}$$

Annual load factor = $\frac{\text{Average load}}{\text{maximum demand}}$

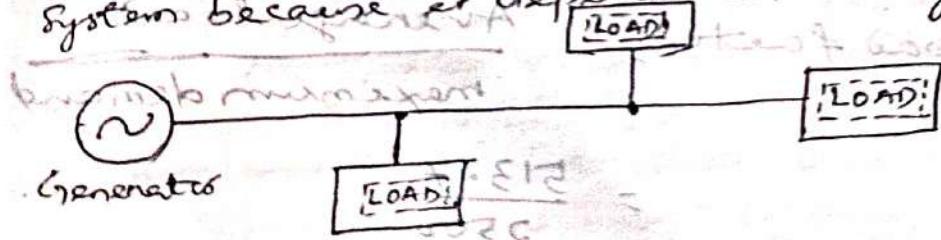
$$= \frac{513.7}{2500} \quad \text{वर्तनारप्त}$$

513.7
2500

- (b) String efficiency can be improved by grading the insulators.
- In this method, insulators of different dimensions are so chosen that each has a different capacitance. The insulators are capacitance graded i.e. they are assembled in the string in such a way that the top unit has a minimum capacitance, increasing progressively as the bottom unit (nearest to conductor) is reached. Since voltage is inversely proportional to capacitance, this method tends to equalize the potential distribution across the units in the string.
- This method has the disadvantage that a large number of different sized insulators are required. However, good results can be obtained by using standard insulators for most of the string and larger units for that near to the line conductor.

(b) Radial Distribution System =

The simplest and least expensive (as well as least reliable) configuration is the radial distribution system because it depends on a single power source,



Despite their lower reliability, radial systems remain the most economical and widely used distribution systems for serving homes because

an electrical power outage there is less likely to have serious economic or public safety consequences.

No.3 E.H.V. A.c. Transmission:

With the increase in transmission voltage, for same amount of power to be transmitted current in the line decreases which reduces I^2R losses. This will lead to increase in transmission efficiency.

- With decrease in transmission current, size of conductors required reduces which decreases the volume of conductors.
- The transmission capacity is proportional to square of operating voltages. Thus the transmission capacity of line increases with increase in voltage.
- With increase in level of transmission voltage, the installation cost of the transmission line per km decreases.
- It is economical with EHV transmission to interconnect the power systems on a large scale.
- The number of circuits and the land requirement for transmission decreases with the use of higher transmission voltage.

No.4 Sag for overhead line with level supports considering effect of wind and ice loading.

$$\text{Sag of transmission line } (S) = \frac{wl^2}{8T}$$

When l = length of span.

Effect of wind and ice loading given by

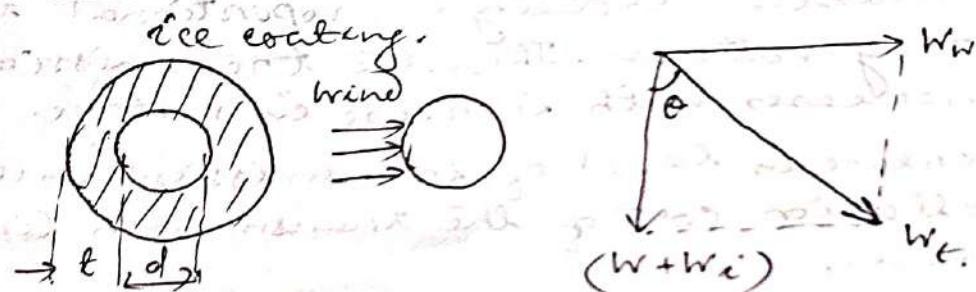
w = weight/unit length of conductors

Tension in the conductors. Given =

The above formula for sag in overhead line are true only in still air at normal temperature when the conductors is acted by its weight only.

However, in actual practice, a conductor may have ice coating and simultaneously subjected to wind pressure. The weight of ice acts vertically downwards, in the same direction as the weight of conductor.

The force due to the wind is assumed to act horizontally, i.e. at right angle to the projected surface of the conductor. Hence the total force on the conductor is the vector sum of horizontal and vertical force.



Total weight of conductor per unit length is

$$W_e = \sqrt{(W + W_i)^2 + (W_w)^2}$$

W = Weight of conductor per unit length
= Conductor material density \times volume per unit length

W_i = Weight of ice per unit length
= Density of ice \times volume of ice per unit length
= Density of ice $\times \frac{\pi}{4} [(d+2t)^2 - d^2] \times l$
= Density of ice $\times \pi t (d+t)$

W_w = Wind force per unit length
= Wind pressure per unit area \times projected area

and conductor is good of unit length
= Wind pressure $\times [(d+2t) \times l]$
Thus, if the gage factor is constant and equal

- When the conductor has wind and ice coatings also, the following points may be noted. MA-2-8

- (i) The conductor sets itself in a plane at an angle θ to the vertical where

$$\tan\theta = \frac{W_w}{W_p W_i}$$

- (ii). The sag in the conductor is given by

$$S = \frac{W_e h^2}{2T}$$

Hence, 'S' represents the slant sag in a direction making an angle ' θ ' to the vertical. If no specific mention is made in the problem, then slant sag is calculated by using the above formula.

- (iii) Vertical Sag = $S \cos\theta$.

No-6 Comparison between HVDC Transmission system and HVAC Transmission System?

HVDC transmission system.

- 1) Low losses.
- 2) Better voltage regulation and controllability
- 3) Transmit more power over longer distance
- 4) Less insulation is needed
- 5) Reliability is high.

HVAC transmission system.

- 1) Losses are high due to skin effect and corona.
- 2) Voltage regulation and control ability is low.
- 3) Transmit less power compared to HVDC system.
- 4) More insulation is required
- 5) Low reliability.

No. 15

Span length = $l = 150\text{ m}$

Working tension, $T = 2000\text{ kg}$.

Wind force/m length of conductors, $w_w = 1.5\text{ kg}$.

Weight of conductors/m length,

$$w = \text{specific gravity} \times \text{volume of 1m conductor}$$
$$= 9.9 \times 2 \times 100 = 1980 \text{ gram}$$
$$= 1.98 \text{ kg.}$$

Total weight of 1m length of conductors

$$w_e = \sqrt{w^2 + w_w^2}$$
$$= \sqrt{(1.98)^2 + (1.5)^2}$$
$$= 2.48 \text{ kg.}$$

$$\therefore \text{Sag} = s = \frac{w_e l^2}{8T}$$

$$= \frac{2.48 \times 150^2}{8 \times 2000} = 3.48 \text{ m}$$

Q. Why is the overall efficiency of a Steam power station very low?

A: The Overall efficiency of Steam Power Station is quite low due to the following two reasons

Firstly, a huge amount of heat is lost in the condenser and secondly heat losses occur at various stages of the Plant.

The heat loss in the condenser cannot be avoided.

It is because heat energy cannot be converted into mechanical energy without temperature difference.

The greater the temperature difference, the greater is the heat energy converted into mechanical energy. This necessitates to keep the steam in the condenser at the lowest temperature.

But, we know that greater the temperature difference, greater is the amount of heat lost. This explains for the low efficiency of such plants.

Q. Describe thermal efficiency and overall efficiency?

A: The ratio of heat equivalent of mechanical energy transmitted to the turbine shaft to the heat of combustion of coal is known as thermal efficiency of steam power station.

$$\text{Thermal efficiency} = \frac{\text{Heat equivalent of mech. energy transmitted to turbine shaft.}}{\text{Heat of coal combustion.}}$$

The thermal efficiency of Steam power station is about 30% it means that if 100 Calories of heat is supplied by coal combustion, then mechanical energy equivalent of 30 Calories will be available at the turbine shaft and rest is lost.

It may be important to note that more than 50% of total heat of combustion is lost in the condenser. The other heat losses occur in the flue gases, radiation, ash etc.

Overall Efficiency: The ratio of heat equivalent of electrical output to the heat of combustion of coal is known as overall efficiency of steam power station.

$$\text{Overall Efficiency} = \frac{\text{Heat equivalent of electrical output}}{\text{Heat of combustion of coal.}}$$

(Overall)

The overall efficiency of a steam power station is about 29%. It may be seen that overall efficiency is less than the thermal efficiency.

$$\text{Overall efficiency} = \text{Thermal efficiency} \times \text{Electrical efficiency}$$

Q. Describe Calorific Value of Fuels?

A. The amount of heat produced by the complete combustion of a unit ~~length~~ of weight of fuel is known as Calorific Value. Calorific value indicates the amount of heat available from a fuel.

The greater the calorific value of fuel, the higher is its ability to produce heat.

In case of solid and liquid fuels, the calorific value is expressed in Cal/gm or kcal/kg. However, in case of gaseous fuels, it is generally expressed by Cal/litre or kcal/litre.

Calorific value of some solid (Coal) fuels.

	<u>Calorific value.</u>	<u>Composition</u>
(i) Lignite.	5000 Kcal/kg.	C = 67%, H = 5%, O = 20%, ash = 8%.
(ii) Bituminous Coal.	7,600 Kcal/kg	C = 83%, H = 5.5%, O = 5%, ash = 6.5%.
(iii) Anthracite Coal.	8500 Kcal/kg	C = 90%, H = 3%, O = 2%, ash = 5%

Q: What is Steam Power Station? Writes its advantages and disadvantages.

A. A generating station which converts heat energy of coal combustion into electrical energy is known as steam power station.

Advantages: - i) The fuel used is quite cheap.

ii) Less initial cost as compared to other generating station.

L.N.

(3)

- 3) (i) It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road.
- (ii) It requires less space as compared to the hydro-electric power station.
- (iii) The cost of generation is lesser than that of diesel power stations.

Disadvantages:

- ① It pollutes the atmosphere due to the production of large amount of smoke and fumes.
- ② It's costlier in running cost as compared to hydro-electric plant.

Q: Write the function of Condenser in Thermal Power Plant

A: A condenser is a device which condenses the steam at the exhaust of turbine. It serves two important functions. Firstly it creates a very low pressure at the exhaust of turbine, thus permitting expansion of the steam in the prime mover to a very low pressure. This helps in converting heat energy of steam into mechanical energy in the prime mover. Secondly, the condensed steam can be used as feed water to the boiler. Condenser is of two types:-

1. Jet Condenser
2. Surface condenser.

Q:- A thermal station has the following data.

Maximum demand = 20,000 kW; Load factor = 40%

Boiler efficiency = 85%; Turbine efficiency = 90%

Coal consumption = 0.9 kg/kWh.; Cost of 1 tonne of Coal = Rs 300/-

Determine (i) thermal efficiency and (ii) Coal bill per annum?

Sol: Thermal efficiency = Boiler efficiency \times turbine efficiency

$$\text{Efficiency} = n_{\text{boiler}} \times n_{\text{turbine}}$$

$$\text{Efficiency} = 0.85 \times 0.9$$

$$\text{Efficiency} = 0.765 = 76.5\%$$

$$\therefore (\text{i}) \eta_{\text{thermal}} = 76.5\%$$

$$\therefore \text{Coal bill} = \text{Efficiency} \times \text{Load demand}$$

Units generated/annum

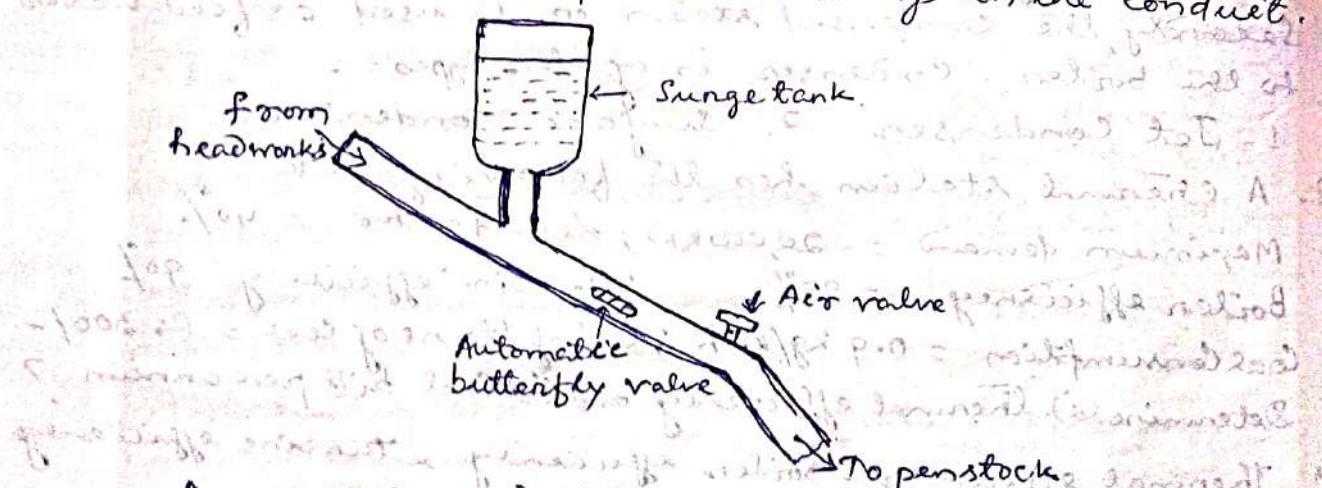
$$\begin{aligned} &= \text{Maximum demand} \times \text{Load factor} \times \text{Hours in a year} \\ &= 20,000 \times 0.4 \times 8760 \\ &= 7008 \times 10^4 \text{ kwh} \end{aligned}$$

$$\begin{aligned} \text{Coal consumption/annum} &= 0.9 \times \text{Coal consumption} \\ \text{per kwh} \times \text{kwh generated}(\text{units generated})/\text{annum} \\ &= \frac{0.9 \times (7008 \times 10^4)}{1000} = 63,072 \text{ tons} \end{aligned}$$

$$\begin{aligned} \text{Annual coal bill} &= \text{Cost of 1 ton of coal} \times \text{Coal consumption/ton} \\ &= \text{Rs } 300 \times 63,072 \\ &= \text{Rs } 1,89,21,600/- \text{ Ans} \end{aligned}$$

Q: What is the function of Surge Tank in Hydroelectric Power Plant?

A: When closed conduits are used, protection becomes necessary to limit the abnormal pressure in the conduit. For this reason, closed conduits are always provided with a surge tank. A surge tank is a small reservoir or tank (open at the top) in which water level rises or falls to reduce the pressure swings in the conduit.



A surge tank is located near the beginning of the conduit. When the turbine is running at a steady load, there are no surges in the flow of water through the conduit. The quantity of water flowing in the conduit is sufficient to meet the turbine requirement.

LN 33 However, when the load on the turbine decreases, the governor closes the gates of turbine, reducing water supply to the turbine.

The excess water at the lower end of the conduit rushes back to the surge tank and increases its water level. Thus, the conduit is prevented from bursting. On the other hand, when load on the turbine increases, additional water is drawn from the surge tank to meet the increased load requirement. Hence, a surgetank overcomes the abnormal pressure in the conduit when load on the turbine falls and acts as a reservoir during increase of load on the turbine.

Q Describe the function of Penstocks in Hydroelectric power plant?

A- Penstocks are open or closed conduits which carry water to the turbines. They are generally made of reinforced concrete or steel. Concrete penstocks are suitable for low heads ($< 30m$) as greater pressure causes rapid deterioration of concrete.

The steel penstocks can be designed for any head, the thickness of the penstock increases with the head or working pressure.

Various devices such as automatic butterfly valve, air-valve and surgetank are provided for the protection of penstocks.

Automatic butterfly valve shuts off water flow through the penstocks, promptly if it ruptures.

Air valve maintains the air pressure inside the penstock equal to outside atmospheric pressure.

When water runs out of a penstock faster than it enters, a ~~vacuum~~ vacuum is created which may cause the penstock to collapse. Under such situations, air valve opens and admits air in the penstock to maintain inside air pressure equal to the outside air pressure.

Surge tank is constructed by forming

elliptical shape on both ends and one end is closed. This is done to store extra water when there is no load on the turbine.

Q:- A hydroelectric generating station is supplied from a reservoir of capacity 5×10^6 cubic metres at a head of 200 metres. Find the total energy available in kWh if the efficiency (overall) is 75%.

SOL.

$$\text{Capacity of the reservoir} = 5 \times 10^6 \text{ m}^3$$

$$\text{Water head} = 200 \text{ m}$$

$$\text{Overall} = 75\%$$

$$\text{Weight of water available} = 5 \times 10^6 \times 1000 \text{ kg}$$

$$(\because 1 \text{ m}^3 \text{ of water} = 1000 \text{ kg})$$

$$= 5 \times 10^9 \text{ kg}$$

$$= 5 \times 10^9 \times 9.81 \text{ N}$$

$$\text{Electrical energy available} = W \times H \times \% \text{ overall}$$

$$= (5 \times 10^9 \times 9.81) \times 200 \times 0.75 \text{ N-m}$$

$$= 5 \times 10^9 \times 9.81 \times 200 \times 0.75 \text{ W-s}$$

$$= \frac{5 \times 10^9 \times 9.81 \times 200 \times 0.75}{1000 \times 3600} \text{ kWh}$$

$$= 2.044 \times 10^6 \text{ kWh}$$

Q. Write Advantages of Nuclear Power Plant ?

A- Following are the advantages of Nuclear Power plant:-

1) The amount of fuel required is quite small.

Therefore, there is a considerable saving in the cost of fuel transportation.

2) A nuclear Power Plant requires less space as compared to any other type of the same size.

3) It has low running charges as a small amount of fuel is used for producing bulk electrical energy.

4) This type of plant is very economical for producing bulk electrical power.

5) It can be located near the load centres because it does not require large quantities of water and need not be near coal mines. Therefore, cost of primary distribution is required.

6) There are large deposits of nuclear fuels available all over the world. Therefore, such plants can ensure continued supply of electrical energy for thousands of years.

(7)

35 \Rightarrow It ensures reliability of operation.

Q. Write the disadvantages of Nuclear Power Plant?

- A. Following are the disadvantages of Nuclear power plant:-
- The fuel used is expensive and is difficult to recover.
 - The capital cost on a nuclear plant is very high as compared to other types of plant.
 - The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.
 - Maintenance charges are high due to lack of standardization. High salaries of specially trained personnel employed to handle the plant further raise the cost.
 - Nuclear power plants are not well suited for varying loads as the reactor does not respond to the load fluctuation efficiently.
 - The disposal of the products, which are radioactive, is a big problem. They have either to be disposed off in a deep trench or in a sea away from sea-shore.

Q:- At the end of a power distribution system, a certain feeder supplies three distribution transformers, each one supplying a group of customers whose connected loads are as under:

<u>Transformer.</u>	<u>Load</u>	<u>Demand factor</u>	<u>Diversity of groups</u>
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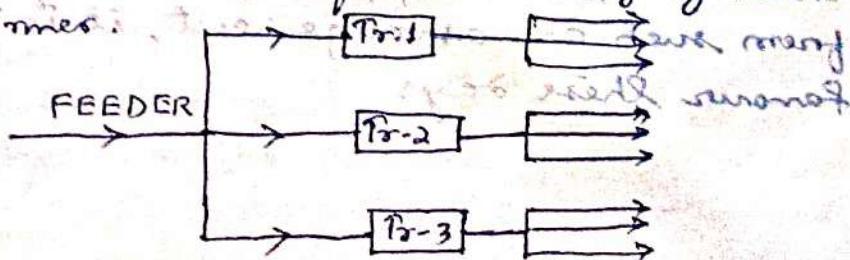
Transformer No.1 10kW 0.65 8.1 1.5

Transformer No.2 and 12 kW 0.65 8.1 3.5

Transformer No.3 15 kW 0.7 1.5

If the diversity factor among the transformers is 1.3, find the maximum load on the feeder.

Sol:- The figure given below shows a feeder supplying three distribution transformers.



Sum of maximum demands of customers on Transformer 1 = Connected load \times demand factor
 $= 10 \text{ kW} \times 0.65 = \underline{\underline{6.5 \text{ kW}}}$

Diversity factor among consumers connected to transformer No. 1 is 1.5.

\therefore Maximum Demand on Transformer 1
 $= \frac{6.5}{1.5} = \underline{\underline{4.33 \text{ kW}}}$

Maximum demand on Transformer 2

$$\text{Total load} = \frac{12 \times 0.6}{3.5} = \underline{\underline{2.057 \text{ kW}}}$$

Maximum demand on Transformer 3.

$$\begin{aligned} &= \frac{\text{Connected load} \times \text{demand factor}}{\text{Diversity factor of group - 3}} \\ &= \frac{15 \times 0.7}{1.5} = \underline{\underline{7 \text{ kW}}} \end{aligned}$$

Maximum demand on feeders

$$\begin{aligned} &= \frac{\text{Max. demand on Tr-1} + \text{Max. demand on Tr-2} + \text{Max. demand on Tr-3}}{\text{Diversity factor among the transformers}} \\ &= \frac{4.33 + 2.057 + 7}{1.3} = \underline{\underline{10.3 \text{ kW}}} \end{aligned}$$

Q: What is Interconnected Grid System?

Write the advantages of Interconnected Grid System?

Ans: The connection of several generating stations in parallel is known as interconnected grid system.

The various problems facing the power engineers are considerably reduced by interconnecting different power stations in parallel. Although interconnection of stations involves extra cost, yet considering the benefits derived from such an arrangement, it is gaining much favour these days.

