# LECTURE NOTES

# ON

# Generation Transmission & Distribution

Name of the course: Diploma in Electrical Engineering.

(4th Semester)

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## Generation

Electrical power can be generated by several sources like,

1) Thermal power → 65%
2) Hydro power → 23%
3) Nuclear power → (9-10)%
4) Solar power → 4%
5) Diesel power → Rest
+ Tidal wind.

**Thermal Power** :- The generating station, which will convert heat energy of coal combustion into electrical energy is known as thermal power plant.

Ex :- Talcher Thermal power plant
NALCO
NTPC

Imp It generally works on **Rankine Cycle**

## Site Selection

1) Supply of fuel :- The power plant should be located nearer to coal mines. So the transportation cost for coal will be less.
2) Supply of water : A huge amount of water is also necessary for boiler, so it is necessary that the plant must be nearer to the water source.
3) Transportation facility should be good, as the heavy machines, transformers and condensers, turbines can be brought easily.
4) Cost and type of land must be cheap and its bearing capacity must be very good, because we are going to install heavy machines on it.
5) The plant must be located nearer to the load centre in order to reduce the transmission loss.
6) It must be far from the populated area, because of its pollution nature.

## GTD (Generation, Transmission, Distribution)



### Generation

Electrical power can be generated by several methods like,

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Advantages

1) The fuel i.e. coal is quite cheap.
2) Initial cost or installation cost is very low as compared to hydro power.
3) It can be installed far from the coal mines if necessary as coal can be brought through road or rail or port.
4) It requires less space as compared to hydro.
5) The cost of generation is very low as compared to diesel power.

Disadvantages

1) It pollutes the environment because of coal combustion. It leaves fumes and smoke to the atmosphere.
2) It is costlier in running condition and also its maintenance cost is high.
3) It does not give us instant energy like hydro power.

Schematic Arrangement of Steam Power Plant:

This can be studied by following stages.

(a) Coal and Ash handling plant.
(b) Steam generating plant.
(c) Steam Turbine
(d) Alternator.
(e) Feed water.
(f) Cooling Arrangement.

[Do the Diagram from any book]

(a) Coal and Ash handling plant :- The coal is transported through rail or road or port and stored in the storage plant. Then it is delivered to the coal handling plant by kind of conveyer belt where it is pulverising to increase its thermal efficiency. Because of pulverization, fire catches rapidly.

After this the ash produced after complete coal combustion, Then these ash delivered to the ash handling plant for disposal.

It is always necessary to burn the coal completely because coal is a Non-renewable energy source. A 100MW power can be generated with 50% Load factory when we burn (2000×10³) kg of coal. The cost of the total budget is around (50-60)% of Total budget for this coal and ash handling stage.

(b) Steam generating plant:-

Steam is generated by heating the water in boiler and we use other auxiliary equipments to enhance the efficiency of the power plant. The auxiliary equipments are 1) Super heater
2) Economizer
3) Air preheater

1) Super heater :- It is used to dry the wet steam, because dry steam will have more temperature as compare to wet steam, and the flue gas will be more useful. It helps to increase the efficiency and also avoid too much condensation. The flue gas goes to the turbine through the valve from the superheater.

2) Economizer :- The feed water is first given to the economizer before giving it to boiler. Because economizer extract the heat from the flue gas and it helps to heats up the feed water, hence the efficiency can be increased.

3) Air pre-heater :- Air preheater is used to heats up the air extracted through the draught fan. So this heated air can be given to the boiler to heat the water and as well as it is taken from the atmosphere, we can use this air to burn the coal as it contains oxygen.

Because of this the efficiency increases and steam capacity increases too.

(c) Steam Turbine :- The dry and super heated steam is fed to the turbine through a valve, the heat energy of the steam passes over the blades, so heat energy converted into rotational energy.

After this steam is given to the condenser and it condense it to the liquid form and given to the water handling plant.

(d) Alternator :- The steam turbine is coupled with the alternator and it converts the mechanical energy or the rotational energy into the electrical energy. This electrical energy then goes to the Transformer and then to the Transmission line and load centre.

(e) Feed water :- Normally water is taken from the river and then by doing water treatment, all impurities, dust particles, hardness of the water are removed in water treatment plant. This water then goes to the boiler. To increase the thermal efficiency, the steam after condenser (liquid form) again used in boiler by passing through water heater and economizer.

(f) Cooling Arrangement :-

The water we use in steam power plant is used in a circulating manner. We use that water again and again to enhance thermal efficiency. Still some % of water can't be reused and taken through the condenser and we do cooling it through cooling tower. In this cooling tower, large fans are used to cool down the temperature of the water and then this water is disposed to the river or lake at suitable location.

→ Efficiency of steam power plant :-

The overall efficiency of this power plant is very less. It is about (30-32)%. But as it is very reliable and the generation cost is very low, we use this type of power plant everywhere.

The reason for low efficiency is the heat loss at various stages of the plant.

Thermal efficiency can be calculated as ;

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

$$\eta_{overall} = \frac{\text{Heat eq. of Electrical o/p.}}{\text{Heat of coal combustion}}$$

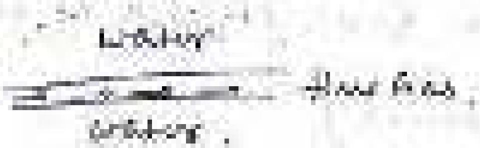
→ Equipment of Steam Power Plant :-

A. Steam Generating Equipments :-

(i) Boiler → Boiler is that place where we heat the water and steam is produced. This can be done in 2 ways.

(a) → Fire tube boilers

In fire tube boilers the flue gas is passed through the tubes.




(b) → Water tube boilers

In water tube boilers, water is passed through the tubes and flue gas all over it.

This method is very popular and effective because it needs less space, it is smaller in size, explosion chances are less and high working rate due to pressure.

(ii) Boiler Furnace :- It is a chamber in which coal is burned to liberate heat and it also provide support for other combustion equipments. The wall of the boiler furnace is made of clay, silica and kaolin because these materials don't change their shape in high heating conditions.

1) weight
2) physical properties

(iii) Super heater :- It is a device which superheats the steam and raise the temperature above the boiling point. So efficiency increases. The steam produced in the boiler is led through the superheaters to the turbine.

→ It is classified into 2 types (a) Radiant
(b) Convection

We normally use convection type, because the water gets heat from the flue gas entirely by convection method. Here the temperature increases as the increase of steam o/p but in radiation superheater, the temperature reduces when steam o/p increases. And another disadvantage is; it is overheated by radiation method and there is a chance of damage to the superheater.

(iv) Economizer :- It is a device which heats the feed water on its way to boiler by extracting heat from the flue gases. This is the reason, the thermal efficiency increases. Economizer is large number of closely spaced parallel tubes connected by header of drums. The feed water passes through the tube and flue gases flow outside of the tubes.

(v) Air pre-heater : (Repeat)

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B. Condensers :- This is a device which condense the steam at exhaust of turbine. It has 2 functions.

1. It creates low pressure at exhaust of turbine, so it permits expansion of steam in prime mover, to a very low pressure. So steam energy can be easily converted to mechanical energy.
2. The condensed steam can be used as feed water again, so the coal needed for heating will be less, hence efficiency will be enhanced.

There are 2 types of condensers;

1) Jet condenser :- Here we mix cooling water and exhausted steam, so the temperature of both will be same while leaving the condenser.

Adv. Low initial cost
Less floor area required
Less cooling water required
Less maintainance

Disadv. The condensate will be wasted and again we need to pump water.

2) Surface condenser :- Here we don't allow the mix- of cooling water with exhausted steam. So we provide the cooling water through the tubes here and exhausted steam around the surface. The steam gives up the heat to the water in tube and itself condensed

So Adv. The condensate is used to feed water pumping will be less.
It creates vacuum at turbine exhaust.

Disadv. Cost, required area, cooling water and maintainance will be more.

C. Prime mover.

Prime mover is nothing but the heart of generating station which will provide rotational energy or mechanical energy to the alternator. It is coupled to the alternator and in Thermal power plant we use steam turbine as the prime mover.

This is of two types.

1) Impulse Type  2) Reaction type.

In impulse turbine, the steam expands completely in the blades and the pressure built up in the moving blade remains constant. By doing so, the steam attains a very high velocity and it helps to rotate the prime mover with a very high speed.

But in reaction turbine, the steam is partially expanded in the stationary nozzle, the remaining expansion happens during its flow over the moving blades. As a result, the steam will cause a reaction force to move the blade and so as the prime mover.

D. Water Treatment Plant: The boiler requires clean and soft water, otherwise the life of boiler and also the turbine will be less. So in water treatment plant the river water undergoes several chemical process to remove the dirt, hardness of water and other impurities and then deliver to the boiler.

The name of some chemical process are,

Sedimentation, Coagulation, Filtration, Hard water treatment to remove permanent and temporary hardness.

E. Electrical Equipments:

1) Alternator → Repeat.

2) Transformer :- It is used to step up the generated emf to very high voltage and then transmit through transmission lines to load centres.

3) Switch gear :- It helps to locate electrical faults in the system and isolates the faulty part to save the healthy part. It consists of 1) Relay

2) Circuit breaker

# Hydro Power Plant :-



A generating station which utilise the potential energy of water at a very high level for the generation of electrical energy is called as Hydro-electric power station. It is generally situated in hilly areas where dams can be built easily to store water.

This is more popular because it uses water which is renewable energy source, caused no harm to the environment and it gives instant power during sudden load needed.

There are some secondary benefits of this power plant also. It helps in flood control and also irrigation.

## Site Selection

1) Availability of water :- As its main component is water, so such plants should be built at a place where adequate water is available and that to at a high head.

2) Storage of water :- We need to store water because water availability depends on weather condition. So a place should be selected where we can build dam and store sufficient amount of water.

3) Cost, Type of Land :- The cost of land should be cheap as well as its bearing capacity must be adequate to stand the weight of heavy machines and other equipments.

4) Transportation facility should be there else we could take equipments to the site and it will be very difficult for us to transmit generated power.

## Constituents of Hydro Electric Power :-

There are 3 constituents
A) Hydraulic structure
B) Water Turbine
C) Electrical Equipments

(Draw the Schematic Diagram here)

A. Hydraulic Structure -

(i) Dam - Basically, dam is a barrier which stores water and creates water head. Dam is made of stone, rock fill or concrete. This depends on the topography of the site.

(ii) Spillway - There will be a time in rainy season when there a lot of water stores in reservoir. So to discharge these extra water spillways are constructed on top of the dams. So the surplus water can be discharged to downstream of the river. For this some kind of gates are given to discharge the water.

(iii) Head works :- These are diversion structures at the head of an intake. They normally bypasses the water to avoid head loss. These things should be done as smooth as possible to avoid cavitation. So it is necessary to avoid sharp corners and abrupt contractions.

(iv) Surge Tank :- This is a tank like structure present on the open conduit to counter abnormal pressure. We can say, surge tank is the protection used for penstocks. It this tank, water level either increases or decreases to reduce the pressure swings.

It is located at the beginning of the penstock. At steady condⁿ, water level is same, but when the load suddenly decreases, the governor closes to reduce the flow of water, so the existing water will go to the surge tank and the level of water increases.

Similarly when the load increases, the turbine will need more water to meet the load, so the excess water in surge tank will go to the turbine. Here it works as a temporary reservoir.

So basically surge tank helps the penstock or the water conduits to work smoothly and prevent them from bursting.

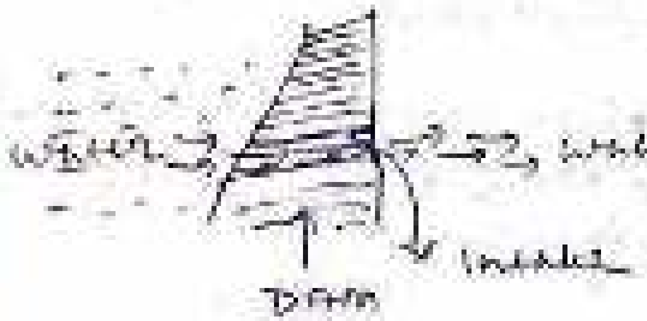
(V) Penstocks - These are the open or closed conduits which carry water to the turbine. It is made of reinforced concrete or steel.

Steel is used for medium and high head and concrete penstocks are used for small head (<30m)

Thickness of the penstock depends on the head on the working pressure.

(VI) Governor :- Governors are the devices that helps us to control the pressure at which the water will be provided to the turbine. It is basically a valve that can be opened or closed when needed.

(VII) Intake - It is basically a valve located at the dam, which helps to provide water to the penstock.

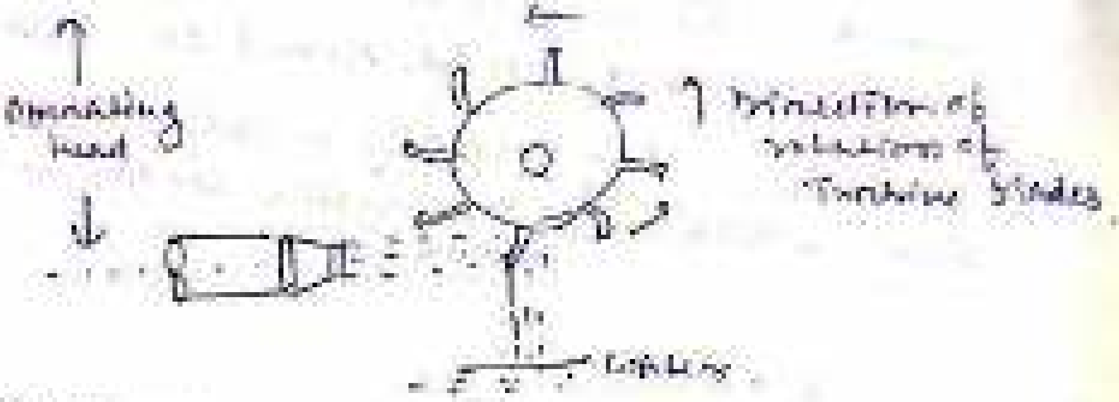



B. Water Turbine :- Turbines are the machines or equipment that will help to convert the potential energy of the water or in some case kinetic energy of water to rotational / mechanical energy. In hydro power plant this is the prime mover coupled with generator.

The principal type of water turbine :-

1) Impulse    2) Reaction

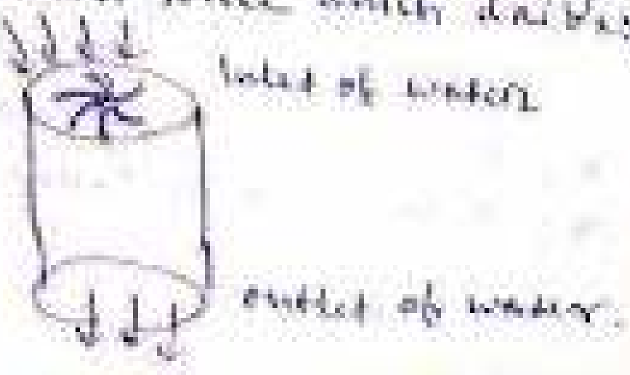
1) Impulse turbine :- These are for high heads. Here the entire pressure converts to kinetic energy in a nozzle and the velocity of the jet drive the blades. Here the water jet is controlled by the needle or spear which is placed in the tip of nozzle. This movement of needle is controlled by the governor. An example of impulse Turbine is Pelton.




2) Reaction Turbine :- These turbines are used for low and medium head. The examples of these turbines are Kaplan and Francis respectively.

Both turbine have similar working style.

These turbines consist of outer ring of stationary guide blades which are fixed to turbine casing. The inner rings are rotating blades. The outer blade controls the flow of water to the turbine and inner blade keeps rotating. As the water passes over the rotating blades of the runner, water both pressure and velocity decrease and this causes a reaction force which drives the turbine.



c. Electrical Equipments :-

The electrical equipments are a salient pole Alternator, Transformer, protection devices such as isolators, circuit breakers and relays

c. Advantages :-

1) This energy is a clean energy. It doesn't do any pollutions. No ash, No smoke is produced.
2) This energy is instant in nature. So it helps to maintain the load factor.
3) No fuel is needed for this.
4) Its running cost is almost negligible.
5) Its robust in nature and it has longer life.
6) It helps to control flood as well as the stored water can be used for irrigation purpose.
7) Plant construction is very simple.

c. Disadvantages :-

1) It involves high capital cost because of Dam construction. Its installation cost is very high.
2) It is weather dependent. In summer/ rainy or draught year, it can't be used fully.
3) It requires high cost for transmission line, because its very difficult to construct transmission line in hilly areas.
4) Skilled and experienced engineers are required to build this plant.

c. Load factor = $\frac{\text{Avg demand}}{\text{max demand}}$

c. Wt of water = W = (Vol of water (V) × density (ρ)) kg.

or, W can be calculated W = (V × ρ × g) N.

g → Acceleration of gravity

⇒ Electrical Energy available = $w \times Q \times H \times \eta$ (13)

$H$ = head,
$\eta$ = efficiency

⇒ Firm capacity

= (Plant efficiency × Gross plant capacity) kW

⇒ Yearly Gross o/p = Firm capacity × hours in a year (8760)

Note:
⇒ Volume of storage → (unit in $m^3$)
Discharge ($Q$) → (unit in $m^3/s$)
Take both are same when calculating height of the water.

→ NUCLEAR POWER PLANT :-

⇒ A generating station in which nuclear energy is converted to electrical energy is known as Nuclear Power station.

⇒ In nuclear power plant heavy elements like Uranium (U-235) and Thorium (Th-232) are subjected to nuclear fission in a reactor. The heat energy released because of chain reaction and this heat energy is used to the heat water. Then the steam is used to drive the turbine to convert heat energy an i.e. the way it converts kinetic energy into rotational energy and again alternator converts rotational energy into electrical energy.

⇒ 1kg of U-235 can produce as much as heat produced by burning high efficient coal.

Advantages

1) The amount of fuel needed is quite small, transportation cost is less.

2) Nuclear power plant needs less space as compared to other power plant.

3) This power plant is very economical for producing bulk amount of power.

4) It ensures reliability of operation. (17)

5) Since we have a large deposit of fuel, nuclear power plant can ensure continuous supply of electrical energy for thousand years.

6) It can be established near to load centre as it doesn't require a large amount of water.

Disadvantages:

1) Fuel is used which is very expensive and it requires high technology as well as high expensive machinery to recover energy.

2) It requires more protection as Uranium and Thorium are radioactive in nature.

3) It needs best engineers to maintain and run the plant.

4) The by-product of this plant may cause dangerous radioactive pollution, so needs plans to dispose the wastes.

5) It is very difficult for engineers to control such power, as it doesn't work well with variable load.

6) The radio-active pollutants or by-products need to dispose at deep sea or deep ground which is very costly and difficult as compared to other power plants.

New Schematic Diagram of Nuclear Power Plant and its Arrangement —

(Draw the Arrangement)

The important stages of this power plant:

(A) Nuclear Reactor
(B) Heat exchanger
(C) Steam Turbine
(D) Alternator.

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(A) Nuclear Reactor :- This is an apparatus in which U-235 / Th-232 are subjected to nuclear fission. It controls the chain reaction and if it is not controlled then it may explode because of fast increase in energy released.

(Draw Nuclear Reactor). (Page 33) [VR Mehta Book]

→ A nuclear reactor consists of U-235/Th-232 rods, moderator and control rods.

→ The U-235 rod undergoes Nuclear Fission and a huge amount of heat energy is released.

→ The moderator consists of Graphite rod which encloses the fuel rods. The moderators are used to slow down the chain reaction to control the severity of reaction.

→ The control rods are Cadmium and are inserted into the reactor. They absorb the neutrons. It basically regulates the supply of neutrons for fission. The control rods are movable. When we want to stop the reaction, we push the control rods little deeper; so the number of neutrons will be less.

In practical case, the pulling or pushing of control rods are automatic in nature. We can vary it according to load. Heat produced in reactor can be removed by coolants. These carries heat from reactor to heat exchanger. Ex - Na metal

(B) Heat Exchanger

The coolant gives up heat to the heat exchanger which utilizes in raising the steam. After giving up heat, the coolant is again fed to the reactor.

(C) Steam Turbine :- The steam produced in heat exchanger is led to steam Turbine through a valve. After doing useful work, the steam again goes to the condenser. The condenser feeds the condensed steam to heat exchanger through water pump.

(D) Alternator :- It converts the mechanical energy or rotational energy into electrical energy. Then the electrical energy goes to busbar through Transformer, circuit breaker and Isolators.

=> Selection of Sites :-

→ Availability of water :- It requires water, so the location must have water supply for steam and cooling purpose.

→ Disposal of waste :- The waste products are generally radio active in nature. So these should be disposed to deep sea or deep Ground.

→ Distance from populated area :- As this power plant is having radioactive elements and risky procedure it should be established from populated area for safety.

→ Availability of Load Centre and Transportation facilities are also needed before selecting the site. As it needs high heavy equipments during establishment of power plant and heavy apparatus are needed for this, Transportation facility should be available.

=> 1 moles → $6.023 \times 10^{23}$

=> Energy received in hour = $(x \times 3600)$ J or energy/hour.

=> 1 eV = $1 \times 1.6 \times 10^{-19}$ J.

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(19) Transmission and Distribution

→ What is Power Sys ?

→ Power System is that study of engineering, where we study about the efficient Generation, Transmission, Distribution of power along with great control and protection and with greater reliability and in an economic way.

→ Requirement of Satisfactory Electrical Power :

1) We always want constant voltage without flowing and constant freq operation to make power sys healthy.

2) The voltage regulation must be as low as possible and the efficiency must be as high as possible for better power supply.

3) The voltage must be balanced otherwise at consumer end, our day today equipments' life will be less.

4) The waveform of our power must be sinusoidal in order to make power system harmonics free. With harmonics, the efficiency will be less as well as the max power o/p will be less.

5) The communication sys must be free from inductive or radio interference caused by power line. So proper transposition must be done in transmission line.

6) The supply must be reliable or dependable. We should always provide the customers with uninterrupted power supply.

→ Transmission :-

This is the method in which we transmit heavy/bulk amount of power from the generating station to distribution end, This is one of the major section of power system where we use some equipments for better power supply.

→ Distribution :

This is the method in which we get power from the transmission line and then we provide power to our consumers according to their convenience. Mainly our consumers are;

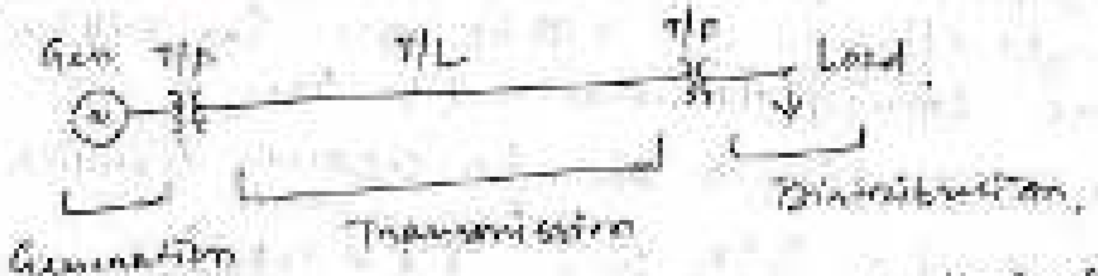
1) Industries [small and medium]
2) Households
3) Shoping centres or market buildings.
4) Hospitals, Govt or private offices.
5) Govt school, college, Universities.

→ What is the Transmission and Distribution scheme?

or

How power is transmitted or distributed?

Ans:




→ 1st power is generated at Thermal, Hydral and Nuclear power plants. Then this power is transmitted through T/L and then power is distributed at load end.

→ Power is generally produced at several (kV) level. Then we use a power Transformer (step up type) to enhance the voltage level from smaller level to high level. Then the power is fed to transmission line. Then again we use another step down type power T/F to decrease the voltage level. Then this level power is given to distribution and the power distributors then supply power to the consumers and collect money from them.

→ Generally voltage level fed to T/L are; 33kV, 66kV, 132 kV, 220kV, 400kV, 765kV.

(19) → At Distribution and the level of voltage is 11kv, 6.6kv, 1.2 kv, 440mv. In our house, voltage level is 230v (1 phase) or 440v (3phase).

Q) Why voltage level is so high when we want to transmit a bulk amount of power?

Ans:- ① As we know power is to transmit through power lines on thick conductors. If the voltage level would be high then the current level will be more. If current will be more, $I^2R$ loss will be more and the efficiency will be very less.

② If current will be very high, we need thick conductors for that. If the conductors will be very thick, it will be difficult to provide that in Transmission Tower. The weight of conductor will be more. Sag will be more, hence Ground clearance will be less.

③ As we know power transfer capacity formula is

$$P = \frac{V_1 V_2}{X} \sin\delta \quad (P \propto V_1 V_2)$$

If we will enhance the voltage level, then the power transmission capacity will be very high.

Q) What are the Disadvantages of High Voltage Transmission

Ans:- 1) Insulation cost will be more. As we need more thick insulation for more voltage level.
2) The switch gear and protection system also need that kind of construction to deal with high voltage.
3) We need more conductor spacing.
4) We need more clearance to the ground.
5) Corona effect will be there in high voltage.

→ But still we use HV Transmission because we always give importance to efficient power system. If 30-40% of the power will be loss through $I^2R$ loss, then the power cost will be very high and it will compromise the stability.

→ Performance of T/L :-

Performance of T/L can be calculated by 3 parameters.

(1) Efficiency (2) Voltage Regulation

(3) Thermal limit.

☞ Efficiency is the ratio of receiving end power to sending end power; so this can be calculated by :

$$\eta = \left(\frac{P_{receiving}}{P_{sending}} \times 100\right)\% = \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100$$

☞ Voltage regulation is the ratio of difference of sending end voltage and receiving end voltage to sending end voltage.

or

Ratio of difference of sending end and receiving end voltage to receiving end voltage.

$$\% VR = \left(\frac{V_S - V_R}{V_R} \times 100\right)\%$$

Note
Important Concept → Actually, VR is difference in voltage at receiving end of T/L between condition of No load to Full load.

but at no load $V_{R} = V_S$ $\Rightarrow \% VR = \left(\frac{V_S - V_R}{V_R} \times 100\right)\%$

→ As we have learnt how High voltage is useful for our economic transmission, let discuss how important is choosing size of conductors.

Q) State Kelvin's Law and derive it.

Ans :- Kelvin's Law :- The most economic area of conductor is that for which the variable part of annual charge is equal to the cost of energy loss per year.

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The total annual cost of transmission line can be divided into, (5)

1. Annual charge on capital (cost) of outlay
2. Annual cost of energy wasted in conductors

(1) Annual charge for over-head line can be divided into cost of support, conductors and insulators.

- → Conductors' cost is ∝ cross sectional area.
- → Insulation cost is same or constant for a given voltage level.
- → Support cost is partly constant and partly proportional to area of cross-section.

So total charge $= P_1 + P_2 a$

$P_1$ = const charge

$P_2$ = charges depends on area of conductor

$a$ = Area of cross section.

(2) Annual cost of energy wasted is inversely proportional to area. Because more area means more conductivity and less loss,

So cost of energy loss $= P_3/a$

Total cost : $(C) = P_1 + P_2 a + P_3/a$

$$\Rightarrow \frac{dC}{da} = \frac{dP_1}{da} + \frac{dP_2 a}{da} + \frac{d}{da}\left(\frac{P_3}{a}\right)$$

$$= 0 + P_2 - \frac{P_3}{a^2}$$

Let $\frac{dC}{da} = 0 \Rightarrow P_2 - \frac{P_3}{a^2} = 0 \Rightarrow P_2 = \frac{P_3}{a^2}$

$$\Rightarrow \boxed{P_2 a = \frac{P_3}{a}}$$

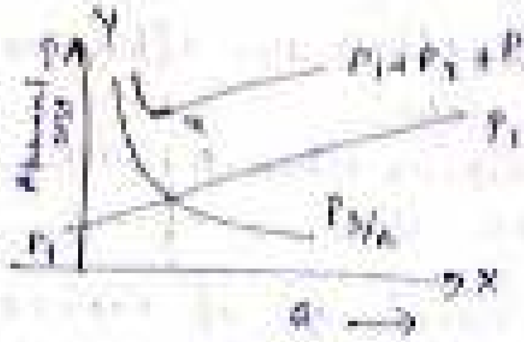
⇒ This is the point at which the minima occurs

So $a = \sqrt{P_3/P_2}$

and we should choose the conductors where;

variable part of annual charge = Annual cost of energy wasted.

If we will illustrate it on a graph, then the plot will be, (23)




x → this is the minimum point

Limitations

1) This method needs load curve at the time which is not available at the time of calculation.
2) The values we have taken or we have assumed are totally theoretical, not practical.
As the conductor's cost is not only the metal but also the insulations we have given in them or other charges to make it.
3) The method doesn't take other important factors like take current density, Corona or its mechanical strength.
4) Interest or depreciation calculations are not easy or it is not accurate all the time.

4. Corona :-

Corona is a major phenomenon which will happen in extra high voltage transmission line. There are some provisions to know whether it happened or not.
1) Hissing sound.
2) Bluish or reddish or sometimes violet colour glow will be seen in TL.

Q) What are the reasons for Corona?
Ans :- If the voltage gradient of surface of the conductor will be more than the Dielectric strength of the air surrounding on it, the air particles will be ionized and they act as conductors. Because of that current pass through the air are for short time and

that's why corona happens.

→ Because of corona effect the effective radius of the conductor will be more.

→ Generally this happens when the voltage level will be more than ~~[illegible]~~ 33kV.

Q) What are the disadvantages of Corona?

Ans: 1) It will lead to energy loss. So Transmission efficiency will be less.

2) It produces Ozone Gas, which is very dangerous in atmosphere for humans as well as other biological species.

3) Ozone production also leads to corrosion of conductor because of chemical action.

4) The current produces in corona effect is non-sinusoidal So it will lead to harmonic distortion as well as it will hamper communication lines too.

Q) What are the advantages of Corona?

Ans: 1) Because of ionization, around the air surrounding conductors, the effective ~~[illegible]~~ diameter of conductor will be more. So power transfer capacity will be more.

2) Corona helps to reduce the transients produced by the surges.

→ Factors affecting Corona :-

A. Atmosphere :- In stormy weather, the number of ions is more than normal and as such corona can be formed at less voltage than the actual voltage.

B. Conductor Size :- If we will have rough and irregular surface, it will give rise to more corona. Because the unevenness of surface will reduce the value of breakdown voltage. Corona can puncture the insulations of insulators too.

C. Spacing betn conductors :- If we will maintain sufficient distance betn two conductors, then the chances of occurrence of corona can be minimised. Because this large distance will reduce electro-static stresses at conductor surface.

D. Line voltage :- The line voltage effects the corona. If the line voltage will be such that it will create sufficient electro-static stresses, then corona can be happened.

## Methods of reducing corona effect :-

1) By increasing conductor size → By increasing conductor size, if we can raise the critical disruptive voltage, then we can counter corona to happen.
Ex → we use ACSR by increasing its cross-sectional area and hence corona can be reduced.

2) By increasing conductor spacing :- By this also, we can raise the critical disruptive voltage, hence corona can be countered.

3) We can use Bundle conductor to again increase the critical disruptive voltage.

## Some Important Terms :-

(i) Critical Disruptive Voltage ($V_c$) :-
This is the min voltage at which corona occurs.

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

For corona g must be 21.2 kV/cm ~~per phase~~ (rms value)

or 30 kV/cm (max value)

[ This 30kV/cm is the break down voltage of air at 760 mm pressure and 25°C Temp ]

$$g = \frac{V_c}{r \ln \frac{d}{r}} \Rightarrow \boxed{V_c = g\, r \ln \frac{d}{r}}$$

(This is at 760mm Hg pressure and 25°C temp)

The actual formula is :

$$V_c = m_o\, g_o\, \delta\, r \ln \left| \frac{d}{r} \right| \text{ kV/ph.}$$

① $m_o$ = Irregularity factor.
= 1 for polished conductors
= 0.98 for dirty conductors.

② $g_o$ = voltage gradient

③ $\delta$ = Air Density factor

$$\Rightarrow \delta = \frac{3.92\, b}{273 + t}$$ # b = pressure, # t = temp (°C)

④ d = Distance bet^n 2 conductors

⑤ r = radius of conductor

(ii) Visual Critical Voltage ($V_v$) :- This is the min voltage at which corona glow appears all along the conductor.

$$V_v = m_v\, g_o\, \delta\, r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \ln \frac{d}{r} \text{ kV/ph}$$

$m_v$ = Irregular factor
= 1 (for polished conductor)
= 0.72 to 0.82 (for rough conductor)
[All other notation are written above]

(iii) Power Loss due to Corona :-

$$P = 242.2 \left(\frac{f + 25}{\delta}\right) \sqrt{\frac{r}{d}}\, (V - V_c)^2 \times 10^{-5} \text{ kW/km}$$

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Here; $f$ = frequency

$V$ = phase value (rms)

$V_c$ = Critical Disruptive Voltage/ph.

Important Conclusion

- $V_v$ will always be more than $V_c$.
- Power loss in corona $\propto (f+25)$

So in DC; Power loss $\propto (0+25)$

$\Rightarrow P_{loss} \propto (25)$

But in AC; Power loss $\propto (75)$ (India)

In America; AC power loss $\propto (60+25)$

Power loss $\propto (85)$.

- Power Transfer in T/L;

$$P = \frac{V_1 V_2}{X} \sin\delta$$

$V_1 = V_S$

$V_2 = V_R$

$X$ = Reactance of line because R value can be neglected.

$\delta$ = Angle b/w $V_1$ and $V_2$.

= Power Angle.

# Mechanical Design of Over-Head T/L

→ Over-head T/L :- Over head T/L can be used to transmit on to distribute electrical power. For successful operation mechanical design is important to consider. The design of OHTL should be like that which can sustain most probable weather conditions.

→ What are the components we use ?

① Conductors ② Supports ③ Insulators
④ Cross Arms ⑤ Other items

T.L → Lighting arrestors,
Anti climbing wires
Stock bridge Dampers.

⇐ What are the materials we use to make conductors ?

Ans :- Materials which have high conductivity are used for T/L towers ; They are ;

① Cu (Copper)
② Al (Aluminium)
③ Steel cored Al
④ Galvanised Steel
⑤ Cadmium Copper.

⇐ What are the qualities we expect a good conductor to have ?

Ans :- ① High electrical conductivity
② High tensile strength in order to withstand mechanical stress
③ Low cost
④ Low specific gravity / weight/volume & small.

⇐ Copper → Copper is one of the best metal to be used in electricity flowing. It has almost negligible resistance and it has high tensile strength.

It has the highest current density value, which means it can transmit a large amount of current in small cross-sectional area, so its sag is very less.

But we don't use it. Because of its unavailability and high cost. It is generally used in machine winding or in some wiring (house wiring)

→ Aluminium :- It is very cheap and it is the 2nd highest abundant metal on earth. It has 60 % of conductivity of Cu, but we use Al because of its cheapness.

Al has very poor tensile strength, so we can't use this in its purest form. It gives greater sag as well as it will give more swing in wind flow time.

→ Steel cored Al :- Due to low tensile strength, Al produces more sag, so we can't use it when length is more. So in order to make Al useful or to enhance its tensile strength, Al is reinforced with a core of Galvanised steel wire. The composite conductor provide higher tensile strength.

Advantages:- 1) Increases its tensile strength.

2) Less weight

3) Less sag, so more ground clearance.

4) Because of less sag, the tower height is very less.

→ Galvanised Iron :- These are having very high tensile strength. These are very cheap but its conductivity is very poor. Its resistivity is very high, so these types of conductors are normally used in low level grounding or earthing.

→ Cd Copper :- Cadmium is very costly. So its used (1-2%) in making conductor along with Cu. These are having high tensile strength but 15 % less conductivity. (50% more)

It is used at low cross-section conductors at longer span length application.

Q) What are the types of conductors we use in electrical application?

Ans :- 1) Solid conductors.
2) All Aluminium Conductors (AAC) or (Stranded conductors)
3) Aluminium conductor Steel Reinforced (ACSR)
4) All Aluminium Alloy Conductor (AAAC)
5) Hollow Conductor
6) Bundle Conductor

1:- Solid Conductors :- These conductors are used for low power rating electrical machines, earthing & grounding.
→ These are very rigid (Not flexible) types.
→ It is very tough to coil it and very difficult to transport for large power sys use.

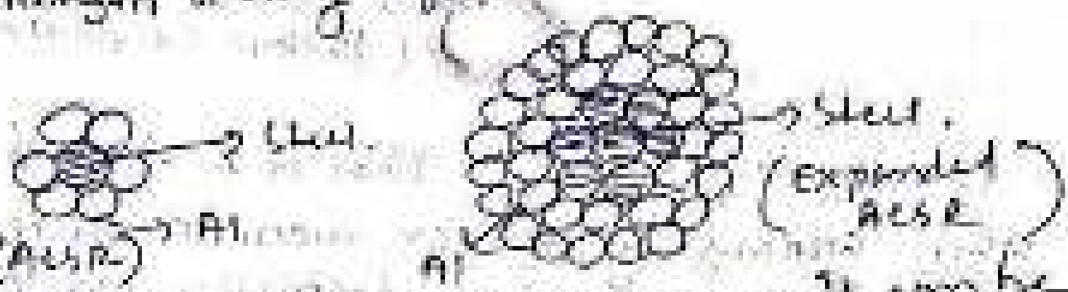
2:- Stranded Conductors :- (AAC)
→ It is formed by gathering smaller cross-sectional area conductors bunched together to a single conductor.

(Solid) (Stranded)

→ Here each strand is a solid conductor of smaller cross-section.
→ It has less tensile strength, so it has more sag and clearance is very less. To accommodate we need to increase tower height or to decrease span length, both are uneconomical.
→ So these are used in distribution sys. Not in Transmission.

## ACSR

→ Its structure is similar to AAC but the middle conductor/ middle strand is made of Steel, So the tensile strength is very high.




→ Its tensile strength is very very good. It can be used in Transmission lines.

→ It has the best advantage which is, it reduces skin effect. The steel conductor has minimum or negligible current where max current flow in Al conductors. So line losses is very less.

→ There is a special type of conductor we call it as expanded ACSR; which has higher diameter, so it can reduce corona loss also.

Corona ∝ Voltage Gradient ∝ $\frac{V}{d}$

V → Voltage
d → diameter.

In this, the gap is filled with paper or with hessian tape.

## AAAC

→ Here all conductors/strands are Al but alloy mixed. This is lighter in weight but it has almost same tensile strength as ACSR.

→ It has very less sag and more clearance.

→ This is used in large span length application and in higher power distribution system.

→ In Transmission line we use this at river crossing road, fly over crossings. It is used at hilly area to stabilise tower structure.

⇝ Hollow Conductors - It has no material inside the conductors. It has no electric field inside the conductor and used as bus bar.


⇝ Bundle conductors :- This is a type of structure when arranging two or more conductors in a way so that the effective diameter can be more and it is specially used to control Corona loss.


Q) What is Skin Effect ??

Ans :- The tendency of alternating current to concentrate near the surface of the conductor is known as Skin Effect.

But in direct current, the current density is distributed uniformly over the whole cross-sectional area.

Due to skin effect the effective cross-section is reduced, so the resistance is very large.

AC resistance = 1.6 times of DC resistance.

Why ??

All the flux produced by the conductors linked the centre region but the flux near to surface is very less. So less flux means less inductance, less inductance means less inductive reactance so greater current density.

⇝ It is dependent on frequency. So in DC skin effect = 0.

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* In AAC and in solid conductors skin effect takes place. So the affective radius decreases. It is uneconomical to use it in T/L. So we use ACSR, AAAC as the current density will be around the surface and the steel conductor will have less current in ACSR and an aluminium conductor (middle one) will have less current in AAAC.

* Factors affecting Skin-effect:

| | Skin effect |
|---|---|
| → Size of conductor ↑ | → ↑ |
| → freq ↑ | → ↑ |
| → Relative permeability ↑ | → ↑ |
| → Resistivity ↑ | → ↓ |

* The opposite of skin effect is **Skin depth**

→ Line Supports

Characteristics of Good Support :-

1) High mechanical strength
2) Light in weight without loss in mech. strength.
3) Cheap in cost
4) Longer life
5) Easy to access for maintenance.

→ What are the supports we use?

Ans :- A. Wooden poles :-

→ These poles are made of wood (sal) and suitable for moderate cross-sectional conductors.

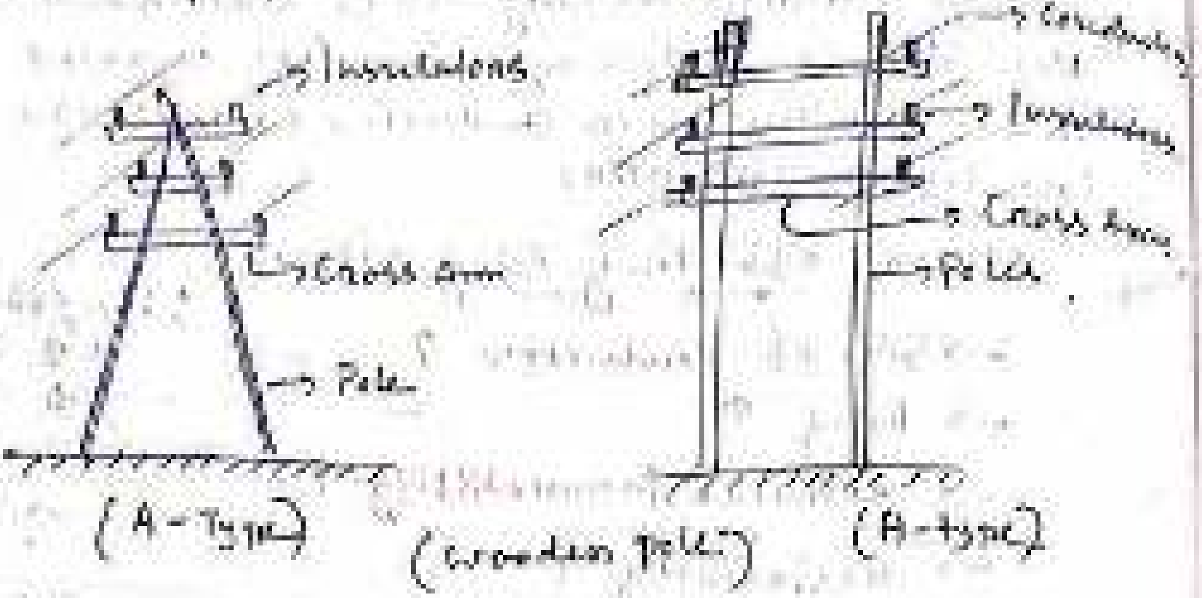
→ It is used for span length upto 50m.

→ These are cheap, easily available, provides insulating properties.

Disadv :- ① There is a chance, it will be rotten in ground when water contact happens.

② Less life (20-25 yrs)

3) Can't be used for higher voltage level.
4) Less mechanical strength
5) It requires periodical inspection.




B. Steel Poles:-

1. These have greater life span.
2. Strong mechanical properties.
3. Used at distribution line and railways.
4. It has longer span length.
5. It is painted ~~with~~ Galvanised to increase its life span as the corrosion can be countered.

C. RCC poles (Reinforced Concrete Cement)

1. It has greater mechanical strength, longer life and this permits longer span length.
2. It provides good outlook and the required maintainance is very little.
3. It can be used for single and double line.

Disadvantages

1) Weight is more. So basically, it is constructed where it required or on the site to reduce transportation charges.
2) It is costlier than other poles.

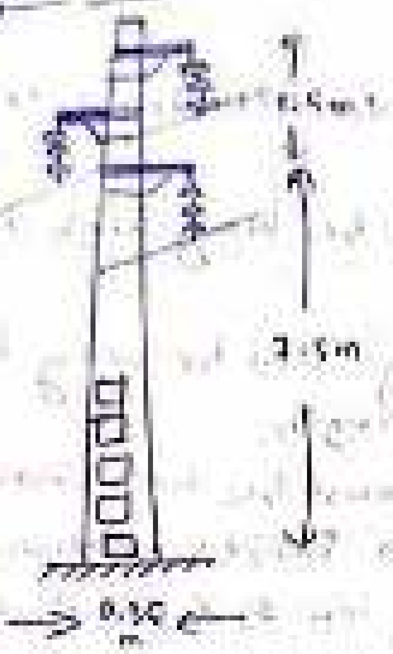
D. Steel Towers:-

1. These are used in Transmission line (more than 11kv voltage level).

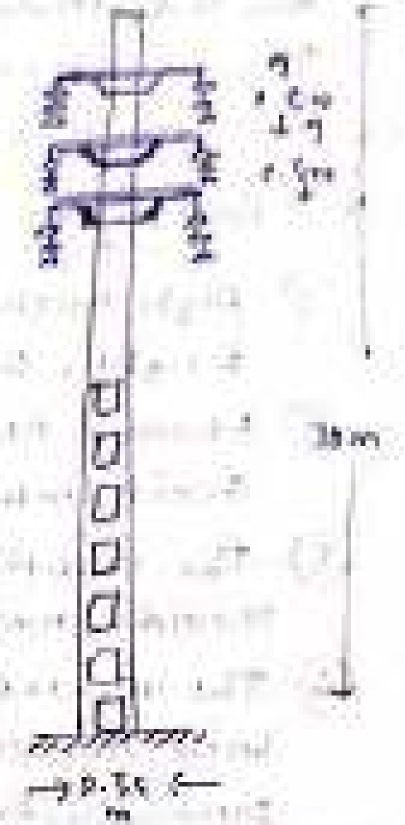
2. It has longer life, better mechanical strength. It can be used for longer span length.
3. It can be established at hilly areas, river areas.
4. We use ground wires for bypassing surge currents to the ground.

Diagrams

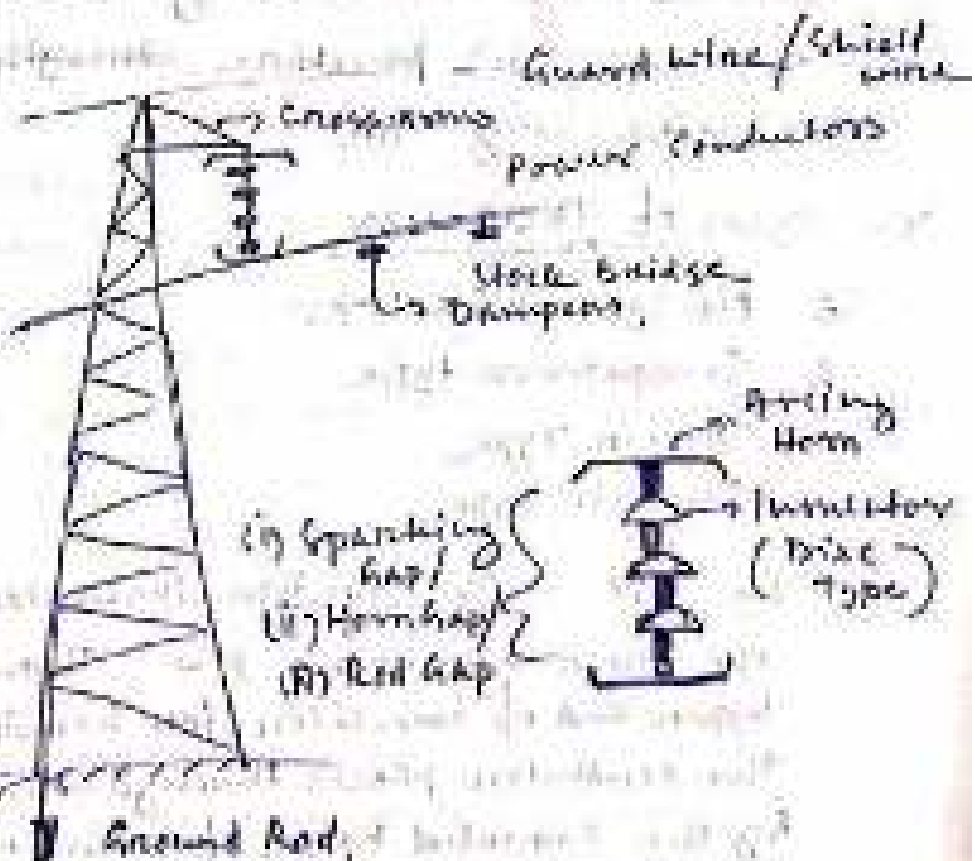
Single line RCC




Double line RCC




Steel Towers




* In hilly areas, we use Counter Poise wire for grounding.

## Insulators

The overhead line conductors should be supported on the poles or towers in such a way that current from conductors don't flow to earth through supports. For this the conductors must be insulated from supports. This is achieved by using insulators. These insulators help not to flow the leakage current to ground.

## Properties

1. High mechanical strength to withstand conductors' weight, wind load.
2. Electric resistance should be very high in order to avoid leakage current.
3. The relative permittivity must be very high to provide max. dielectric strength.
4. The insulator materials must be non-porous, free from impurities and uneven shapes, otherwise the permittivity would be very low and puncture happens.
5. The ratio b/w puncture strength and flashover must be very high.

## Types of Insulators

A. Pin type insulators
B. Suspension type
C. Strain type
D. Shackle type

**A. Pin type** :- The pin type insulators are secured to the cross-arm on the pole. There is a groove on the upper end of insulator for housing the conductor. The conductor passes through this groove and bound by the annealed wire of same material.

This can be used in transmission and distribution but voltage upto 33 kV. After that, using pin type insulators are very uneconomic.

B. Suspension Type:

This type insulators are used for more than 33 kV lines. This consists of number of porcelain discs connected in series by metal link in the form of string. The conductor is suspended at the bottom end of the string while the other end of the string is secured to the cross-arm of towers.

Each disc is designed to sustain 11 kV voltage.

Advantages of Suspension Type:

1) Cheaper than pin type.
2) The no of disc can be attached according to the voltage level.

Ex: For 66 kV → 6 no of disc
33 kV → 3 no of disc
132 kV → 9 no of disc

3) If any disc is damaged, it can be replaced, we don't need to replace the whole string.
4) More flexible, so the insulator string can be swing in any direction.
5) In case you want to increase the voltage level to manage greater voltage demand, you can easily add disc to enhance the insulation level.
6) As the conductors run below the earthed cross-arm of the tower, the arrangement provides partial protection from lightning.

C. Strain Type:

Whenever there is a dead end of line or there is a corner on sharp curve, the line undergoes greater tension. To relieve the excessive tension, strain insulators are used.

Ring
When the tension in lines is exceedingly high (at long river span) two or more strings are used in parallel.

D. Shackle Type :-
→ These are used as strain insulators. But nowadays they are used for low voltage distribution lines. This can be used in horizontal or vertical position.
→ These are bolted in tower structure and cross-arms.

E. Guy Type :- This is used along the supporting wire for safety purpose.

Q) Short Note on Conductor Spacing.
Ans:- Spacing of conductors must be such that so as to provide safety against flash-over when the wires are swinging. The proper spacing depends on:-
① Span Length.
② Voltage level.
③ Weather Condition.
↳ The use of horizontal spacing eliminates the danger caused by unequal ice loading.
↳ Light wires should be provided more space than heavy conductors.

Q) What is Galloping oscillation and what is its frequency?
Ans:- When there is wind, there will be some oscillation. If the velocity will be more, there is a chance of more oscillation and where velocity is less, the proper distance betn two conductors can manage the oscillations.
This oscillation is known as Dancing or Galloping oscillation. Its frequency is (1-2) Hz.

## 4. Sag (Dip)

The difference in level between points of supports and the lowest point on the conductor is called as Sag.


$T = T_0$ (Always)

T = Tension at support

$T_0$ = Tension at the lowest point.

→ This is an important thing to consider conductor sag and tension,

① Sag must be as less as possible to reduce the length of the conductor, cost of conductor and conducting material usage.

It will also provide sufficient "Ground Clearance" to the transmission/Distribution line.

② It is also desirable to reduce the tension level in conductor, otherwise mechanical tension on conductors as well as insulators will be very high. There will be a chance for mechanical break-down of conductors.

So in actual practice, a compromise is done between the two.

4. Sag Calculation :-

This can be done for 2 cases.

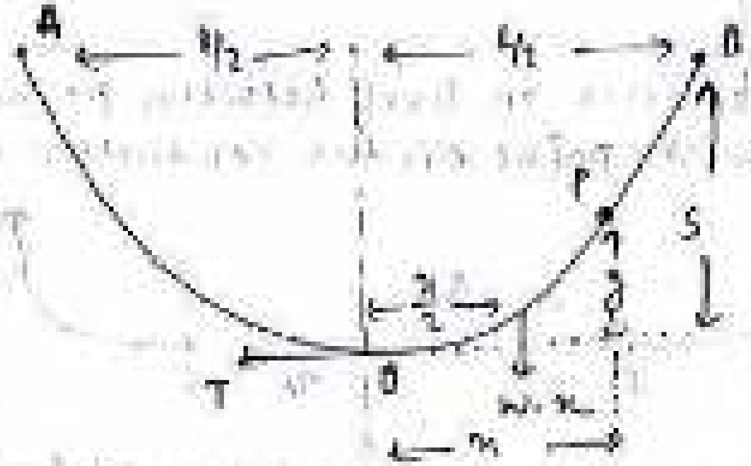
① when supports are at equal level
② when supports are at unequal level

① when supports are at equal level:-

Let consider; $l$ = length of span.

w = weight of conductor/unit length

T = tension in the conductor.




∴ The weight wx of conductor acting at a distance $\frac{x}{2}$ from O.

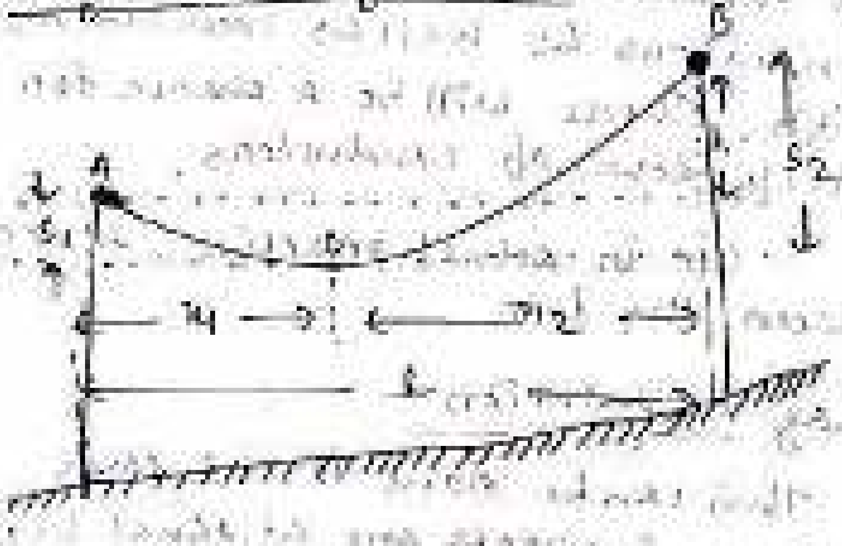
∴ The tension T acting at O.

So $Ty = wx.\frac{x}{2} \Rightarrow y = \frac{wx^2}{2T}$

If we put $x = l/2$, $y = S$.

$S = \frac{w(l/2)^2}{2T} \Rightarrow \boxed{S = \frac{wl^2}{8T}}$

(2) When supports are at unequal level :-




$l$ → Span length.

$h$ → Difference in levels betn two supports.

$x_1$ → Dist of support at lower level.

$x_2$ → Dist of support at higher level.

$T$ → Tension on conductor.

$w$ → weight/unit length of the conductor.

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

$x_1 + x_2 = L$ . —— (i)

$S_2 - S_1 = \frac{w}{2T}(x_2^2 - x_1^2) = \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$

$\Rightarrow S_2 - S_1 = \frac{wL}{2T}(x_2 - x_1)$ [As $x_2 + x_1 = L$]

$\Rightarrow x_2 - x_1 = \frac{2Th}{wL}$ (where $h = \frac{wL}{2T}(x_2 - x_1)$)

—— (ii)

So solving (i) and (ii);

$$x_1 = \frac{L}{2} - \frac{Th}{wL} \; ; \quad x_2 = \frac{L}{2} + \frac{Th}{wL}$$

After finding $x_1, x_2$, we can easily find $S_1, S_2$

c. There are two things which can affect the sag.

1. Effect of wind.
2. Ice loading.

→ In practical case, a conductor may have ice coating and simultaneously wind pressure. We know weight of conductor is acting vertically downward, so as weight of ice. But the force of wind will act horizontally.

So the resultant force will be vector sum of horizontal force and vertical force.


$t$ → Thickness of ice coating.

$d$ → Diameter of the conductor.

$w$ → weight of conductor / unit length

= material density × vol per unit length.

$w_i$ = weight of ice per unit length.

= density of ice x vol of ice per unit length.

= density of ice x $\frac{\pi}{4}((d+2t)^2 - d^2) \times l$

$w_w$ = wind force per unit length.

= wind pressure x $((d+2t) l)$

Formula

① So $\tan\theta = \frac{w_w}{w + w_i}$

② Sag (S) = $\frac{w_t l^2}{2T}$ ⇒ Slant Sag = $\frac{w_t l^2}{2T}$

③ The vertical Sag = $S\cos\theta$

Note: Slant Sag formula is S. It means the sag in a direction making an angle θ to the vertical. If not in case mention you can apply formula ②. ①

Otherwise **vertical Sag = $S\cos\theta$**

# Performance of Transmission Lines :-

## ① Voltage Regulation (VR)

When a T/L is carrying current, there is a voltage drop in line due to resistance and reactance of the line. So the sending end voltage will not be equal to the receiving end voltage. So line drop in T/L is expressed as a (%) of receiving end voltage which is called Voltage Regulation.

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

This can be calculated between conditions of no load or full load.

DO NOT WRITE IN EXAM. IT IS FOR YOUR EXTRA KNOWLEDGE

→ VR should be as low as possible.

→ VR is +ve in case of resistive and inductive load.

→ VR, in case of capacitive load, can be +ve, 0 and -ve.

| VR | Nature of load |
|---|---|
| +ve | R, R-L, R-C, R-L-C |
| 0 | R-C, R-L-C |
| -ve | R-C, R-L-C |

→ R → pf = 0

→ R-L → pf = lagging

→ R-C → pf = leading

→ R-L-C → pf = lagging if $X_L > X_C$

= leading if $X_L < X_C$

## ② Transmission Efficiency :-

The ratio b/w receiving end power to sending end power is known as Transmission efficiency of the line. Generally, due to transmission loss, receiving end power is smaller than sending end power.

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$$\% \eta = \frac{\text{Receiving end power}}{\text{Sending end power}} \times 100$$

$$\Rightarrow \boxed{\% \eta = \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100}$$

Q) What are the types of Transmission line regarding length and voltage level.

→ T/L is divided into 3 types on basis of length and voltage level.

| | Distance | | Voltage level |
|---|---|---|---|
| (a) Short T/L → | (0 – 50 km) | → | (0 – 20 kV) |
| (b) Medium T/L → | (50 – 150 km) | → | (20 – 100 kV) |
| (c) Long T/L → | (> 150 km) | → | (> 100 kV) |

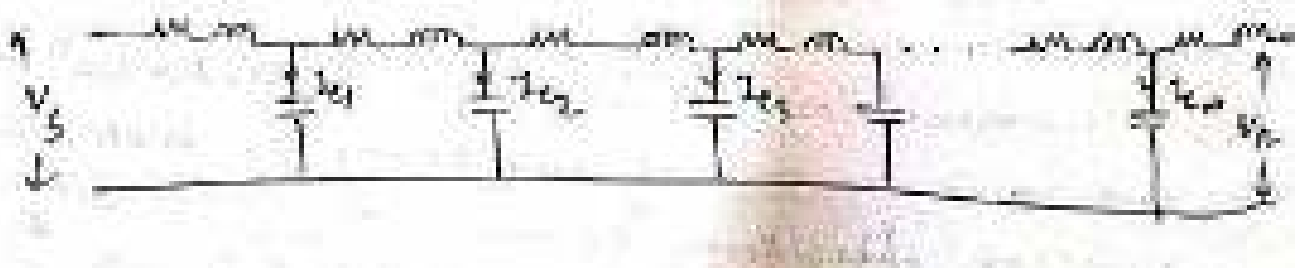
Imp

⇒ Short T/L has very smaller capacitive effect so we neglect it.

⇒ In Medium T/L, there is a significant capacitive effect. So we calculate it taking it as [Lumped parameter]. It can be lumped in 3 ways.

1. End Condensed
2. Nominal π
3. Nominal T

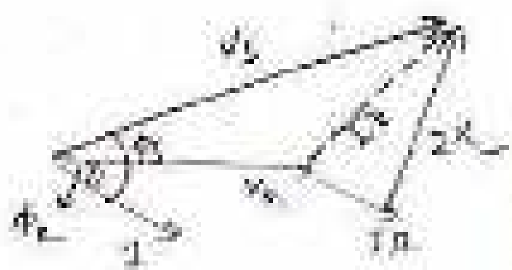
⇒ In long T/L, there is also a significant capacitive effect. But here we calculate it taking as [distributed parameter].



1. Performance of short T/L :

1-ϕ


Phasor Diagram




I = Load current

R = Resistance of conductor

$X_L$ = Inductance of conductor

$V_R$ = Receiving end voltage

$V_S$ = Sending end voltage

$\cos\phi_R$ = Receiving end P.f

$\cos\phi_S$ = Sending end P.f

→ If we are taking $\vec{V_R}$ as reference voltage.

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

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

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

$$\vec{V_S} = \vec{V_R} + \vec{I}\,\vec{Z} = (V_R + 0j) + I(\cos\phi_R - j\sin\phi_R)(R + jX_L)$$

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

$$\Rightarrow V_S^2 = (V_R + IR\cos\phi_R + IX_L\sin\phi_R)^2 + (IX_L\cos\phi_R - IR\sin\phi_R)^2$$

This value is very small. Hence neglected

$$\Rightarrow V_S = V_R + IR\cos\phi_R + IX_L\sin\phi_R$$

$$\Rightarrow V_S - V_R = IR\cos\phi_R + IX_L\sin\phi_R$$

$$\Rightarrow \frac{V_S - V_R}{V_R} = \frac{IR\cos\phi_R + IX_L\sin\phi_R}{V_R}$$

$$\Rightarrow \boxed{VR = \frac{IR\cos\phi_R + IX_L\sin\phi_R}{V_R}}$$

→ this is for lagging power factor.

→ In 3ϕ also the same result obtained, so we normally calculate in 1ϕ.

Q) What are the effect of load pf on regulation?

Ans :- We know $VR = \frac{I_R R\cos\phi_R \pm IX_L\sin\phi_R}{V_R}$

$\begin{bmatrix} + \rightarrow \text{lagging} \\ - \rightarrow \text{leading} \end{bmatrix}$

<u>Conclusions</u>

① Voltage regulation is +ve for lagging or unity or leading (in some cases) power factor. Because here;

$$\boxed{I_R R\cos\phi_R > IX_L\sin\phi_R}$$

② For a given $V_R$ and I, voltage regulation of the line increases with decrease in power factor (lagging load)

③ Voltage regulation is −ve for leading power factor (in some cases). Because here;

$$\boxed{IX_L\sin\phi_R > I_R R\cos\phi_R}$$

Here receiving end voltage is more than sending end voltage.

④ For a given $V_R$, I, voltage regulation of the line decreases with decrease in power factor for leading load.

Q) What is the effect of load pf on efficiency?

Ans :- The power delivered to the load depends on power factor. ① $P = V_R I_R\cos\phi_R$ (1ϕ)

$\Rightarrow I_R = \frac{P}{V_R\cos\phi_R}$

② $P = 3V_R I_R\cos\phi_R \Rightarrow I_R = \frac{P}{3V_R\cos\phi_R}$

(For 3ϕ)

So we can see clearly, for a const power and receiving end voltage, current is inversely proportional to power factor.

So if power factor increases, there is a decrease in line current. If I decreases, $I^2R$ loss decreases. So efficiency increases.

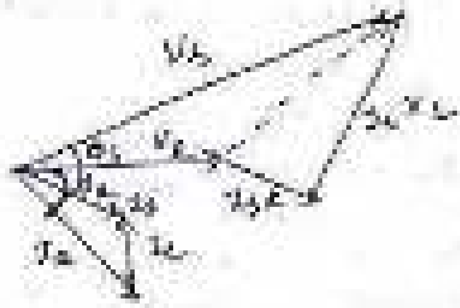
Conclusion

The efficiency of T/L ∝ power factor.

(3) Performance of Medium Length T/L;

(i) End Condensed Method :-

Phasor


$I_R$ = Load current

R = resistance

L = Inductance

C = capacitance

$V_s$ = sending end voltage

$\cos\phi_R$ = receiving end voltage

Here; $\vec{V_R}$ = receiving end voltage $= V_R + j0$

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

$$\vec{I_C} = jV_R\omega C = j2\pi fC \cdot V_R$$

↳ capacitive current / charging current

From the circuit diagram; $\vec{I_s} = \vec{I_R} + \vec{I_C}$

$$\Rightarrow \vec{I_s} = I_R\cos\phi_R + j(-I_R\sin\phi_R + 2\pi fCV_R)$$

Voltage drop $= \vec{I_s}\vec{Z} = \vec{I_s}(R + jX_L)$

So $\vec{V_s} = \vec{V_R} + \vec{I_s}Z = \vec{V_R} + \vec{I_s}(R + jX_L)$

Thus the sending end voltage can be calculated.

(45)

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

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

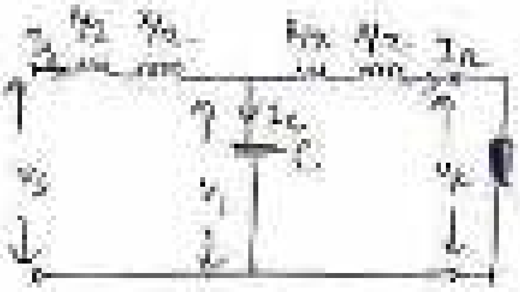
Limitations

Although this is the simplest method, but still it has some limitations.

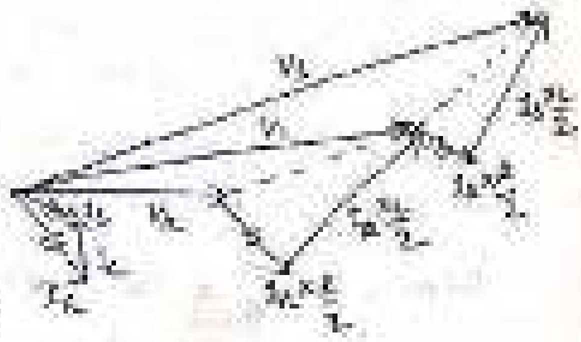
(i) There is a considerable error (about 10%) in calculation because the capacitance is taken as a lumped parameter.

(ii) This method overestimates the effects of line capacitance.

(ii) Nominal T method



Phasor Diagram



$\phi_S$ → angle b/w $V_S$ and $I_S$

$\phi_R$ → angle b/w $V_R$ and $I_R$

Receiving end voltage ; $\vec{V_R} = \vec{V_R} + j0$

Load current ; $\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

Voltage across C ; $\vec{V_1} = \vec{V_R} + \vec{I_R}\frac{Z}{2}$

$= V_R + I_R(\cos\phi_R - j\sin\phi_R)\left(\frac{R}{2} + j\frac{X}{2}\right)$

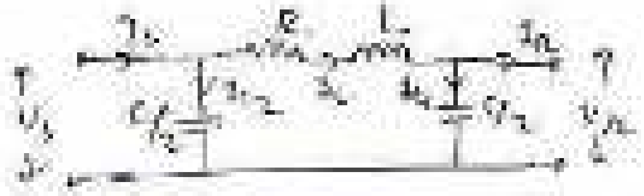
Capacitive Current ;

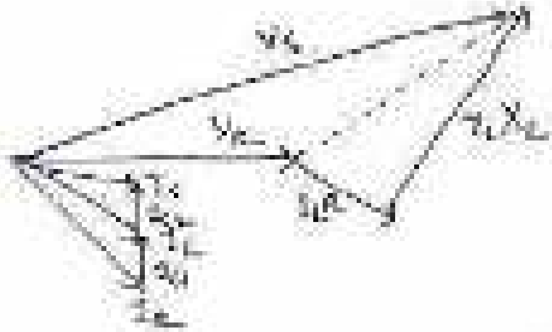
$\vec{I_C} = j\omega C\vec{V_1} = j2\pi fC\vec{V_1}$

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

Sending end voltage; $\vec{V_s} = \vec{V_1} + \vec{I_s}\frac{\vec{Z}}{2} = \vec{V_1} + \vec{I_s}\left(\frac{R}{2} + j\frac{X_L}{2}\right)$ (44)

(iii) Nominal π Method





Here; $\vec{V_R} = V_R + 0j$

$\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$ (Receiving end load current)

$\vec{I_{C_1}} = j\omega\left(\frac{C}{2}\right)\vec{V_R} = j\pi f C\vec{V_R}$ (Charging current at load end)

$\vec{I_L} = \vec{I_R} + \vec{I_{C_1}}$

Sending end voltage $= \vec{V_s} = \vec{V_R} + \vec{I_L}\vec{Z}$

$= \vec{V_R} + \vec{I_L}(R + jX_L)$

Charging current at sending end $(I_{C_2}) = j\omega\left(\frac{C}{2}\right)\vec{V_s}$

$= j\pi f C\vec{V_s}$

Sending end current $(\vec{I_s}) = \vec{I_L} + \vec{I_{C_2}}$

Points to Remember; (Not exam oriented)

- In TL $V_{ph} = \frac{V_L}{\sqrt{3}}$. But that doesn't mean TL is star connected. Always remember, TL is neither star nor delta. But as it has 3 line, to calculate phase current we apply the above formula as star.
- In balanced condition $I_L$ in each phase will be same.
- As this is an AC current or AC power sys., we have some phase angle. So all calculation will be in vector.
- In medium line, we generally used Nominal π method, because it has min error.

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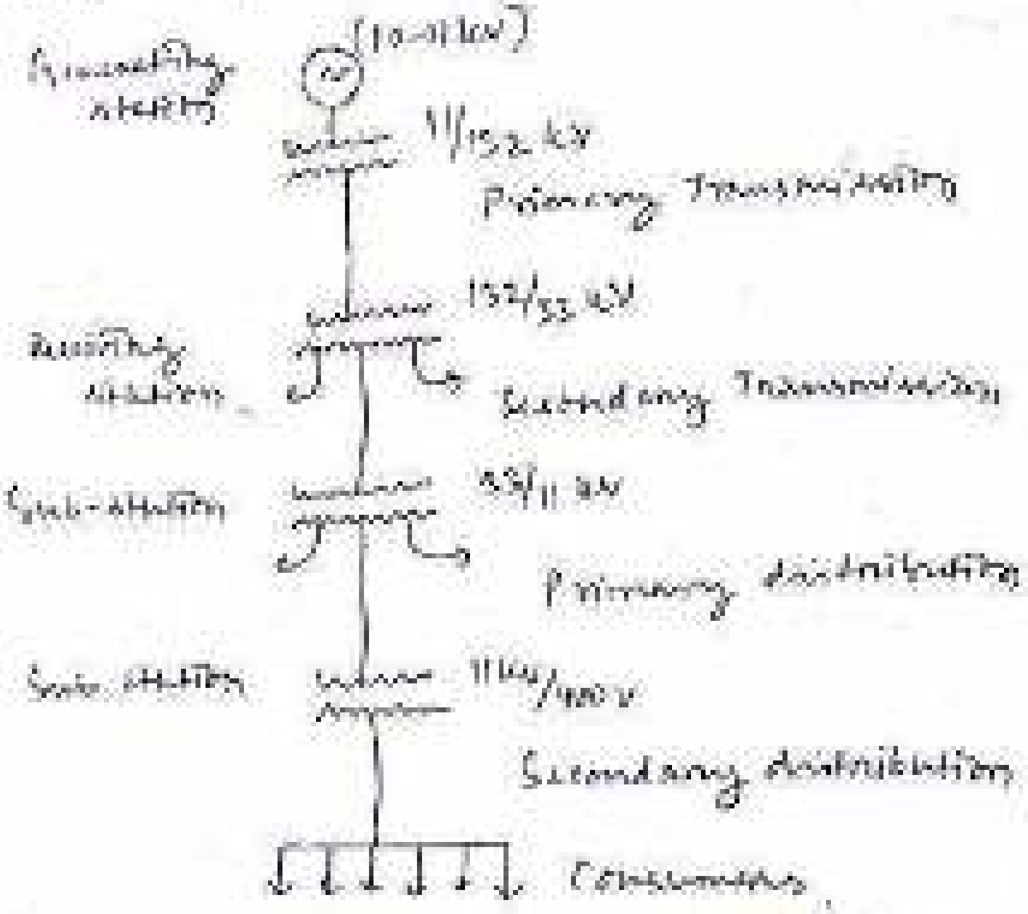
# EHV System

→ In electrical engineering, voltage level more than 33kV is known as EHV (Extra High voltage)

→ EHV system can be understood by drawing the following diagram.




① In generating station voltage can be produced at about (10-11) kV. Then it is given to transformer, which will do step up to 132kV in primary transmission.

② Then 132kV voltage will be transmitted to receiving station and step down to 33kV in secondary transmission.

③ Then the power will come to grid which will step down it to 33/11 kV and given to primary distribution.

④ Then 11kV is stepped down to 400V in secondary distribution and consumers will be provided it at their end.

⑤ All these are done in 3phase 3 line system. At distribution end there will be a T/F which is known as Distribution T/F. Its secondary is star, so here we will see a neutral point.

4) Why it is needed to transmit power at high voltage?

Ans :- See page No - (20)

you can add one more point

(iv) As voltage is very high, line drop will be less, so we can obtain better voltage regulation

$$\% \text{ line drop} = \left( \frac{3 \times \frac{IZ}{?}}{V} \times 100 \right) \%$$

$$\Rightarrow \% \text{ line drop} \propto I$$
$$\propto \frac{1}{V}.$$

5) What are the disadvantages of EHV Transmission?

Ans :- See Page No - (20)

6) What are the advantages and disadvantages of AC Transmission? [N.B → AC Transmission is different. HV AC Transmission answer is different. Similarly, DC Transmission concept is different. So Don't be confused.]

Ans :-

Advantages :-

1. Power can be generated at high voltage.
2. The maintenance of AC substations is easy, cheap.
3. This can be stepped up and stepped down using T/F with ease and efficiency. This permits to transmit power at high voltage and distribute it safely at low voltage.

Disadvantages

1. AC line requires more copper than DC because of skin effect.
2. AC line construction is more complicated than DC line.
3. Because of skin effect the effective resistance of AC is more than DC.

(4) AC line has capacitance. Therefore, there is a continuous loss of power due to charging current even when the line is open.

(5) Corona loss in AC is more than DC at very high voltage transmission.

(6) Insulation cost in AC is more than DC for a same level voltage.

(7) There is stability problem as well as synchronisation problem because it has some phase angle.

Q) What are the advantages and disadvantages of DC Transmission?

Ans:- Advantages

(1) It requires only two conductors, where AC line requires three lines.

(2) There is no L, C and phase displacement in DC.

(3) Due to absence of L, C, the inductive and capacitive drop in DC is less than AC. Because of that, DC transmission has better voltage regulation.

(4) There is no skin effect in DC. So entire cross-sectional area of the conductor is utilised.

(5) For the same working principle, insulation required in DC is less than AC.

(6) DC has less corona than AC. So induced interference in case of DC is less.

(As corona loss ∝ (f+25))

(7) High voltage DC transmission is free from the dielectric loss, particularly in the case of DC cables.

(8) In DC transmission, there is no stability and synchronisation problem.

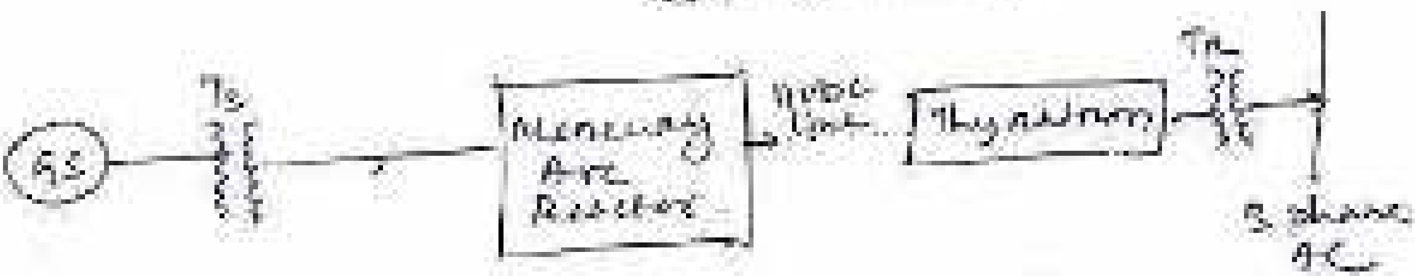
Disadvantages

1. Electric power cannot be generated at high DC voltage due to commutation problem.
2. DC voltage cannot be stepped up for transmission of power at high voltage.
3. DC switch, DC circuit breakers have their own limitations.

5) How DC Transmission line is designed ?

ans:- DC (High voltage) Transmission is superior to High voltage AC Transmission line. Although, we use HVAC more than HVDC, but there is an increasing interest for HVDC.

HVDC is made possible because of some power electronic devices, such as (1) Mercury Arc Reactor, (2) Thyratron.




First electric power is generated at Generating stations at (10-11) kV voltage. Then by using T/F, the voltage level is increased and this High voltage is fed to mercury arc reactor which converts AC to DC. Then the power is carried by HVDC line.

At receiving end voltage, the power is converted to AC from DC with the help of Thyratron. Then the AC supply is stepped down to low voltage by receiving and distribution T/F and fed to consumer end.

(58)
→ At Distribution end the level of voltage is 11kv, 6.6kv, 1.2kv, 440kv. In our house, voltage level is 230V (1 Phase) or 440V (3phase).

Q) Why voltage level is so high when we want to transmit a bulk amount of power?

Ans :- ① As we know power is to transmit through power lines or thick conductors. If the voltage level will be high then the current level will be more. If current will be more, $I^2R$ loss will be more and the efficiency will be very less.

② If current will be very high, we need thick conductors for that. If the conductors will be very thick, it will be difficult to provide that in Transmission Tower. The weight of conductor will be more. Sag will be more, hence Ground clearance will be less.

③ As we know power transfer capacity formula is

$$P = \frac{V_1 V_2}{X} \sin \delta \quad (P \propto V_1 V_2)$$

If we will enhance the voltage level, then the power transmission capacity will be very high.

Q) What are the Disadvantages of High voltage Transmission

Ans :- 1) Insulation cost will be more. As we need more thick insulation for more voltage level.
2) The switch gear and protection system also need that kind of construction to deal with High voltage.
3) We need more conductor spacing
4) We need more clearance to the ground.
5) Corona effect will be there in high voltage.

→ But still we use HV Transmission because we always give importance to efficient power system. If 30-40% of the power will be lost through $I^2R$ loss, then the power cost will be very high and it will compromise the strategy.

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# DISTRIBUTION SYSTEM :-

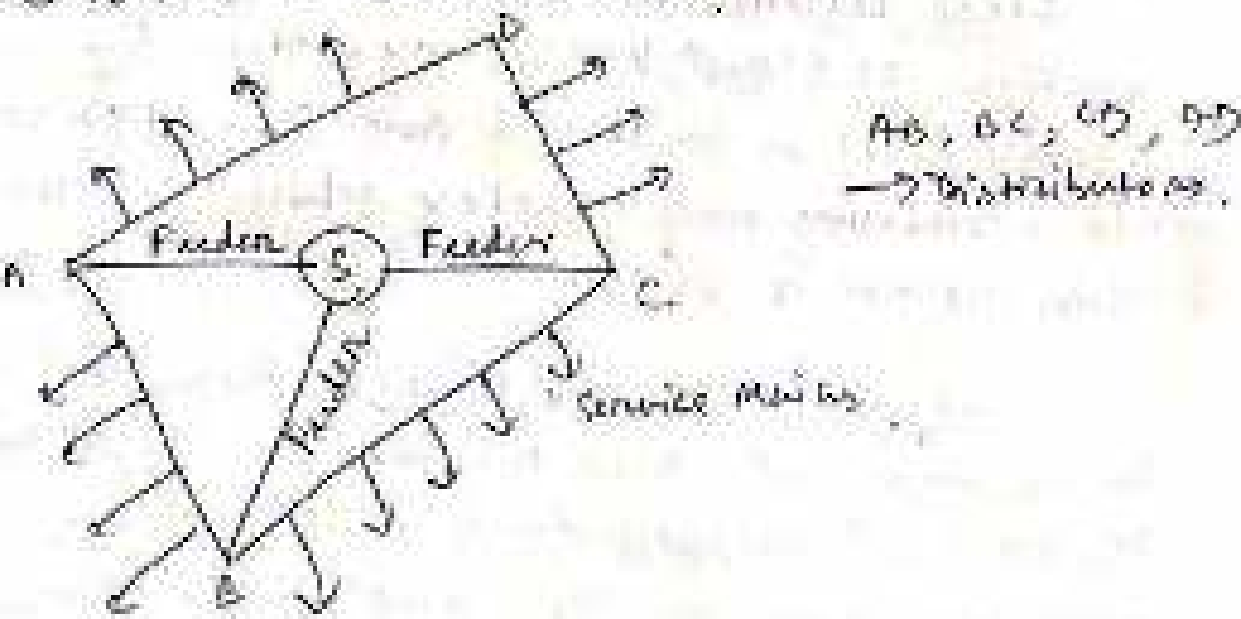
→ Distribution is a part of power system which deals with the power distribution for the local consumers and industries. Generally, this is done by the substations.

→ In substations we have a distribution T/F which helps to step down the voltage level to 33kV or 11kV. The distribution T/Fs are always Y connected in secondary. Because in star (Y), we will get a neutral.

→ Feeders :- Feeder is a conductor which connects the substation to a local area, where we want to distribute the power. No tappings are taken from the feeders, because we always want the current in it to be same throughout.

→ Distributors :- It is a conductor from which we take tappings. So current through the distributors are not same. While designing a distributor, we always take care that it has voltage drop max ± 6% of the consumer voltage.

→ Service Main :- It is a small cable which connects the distributor to the consumers end.



Classification of Distribution :-

① Nature of current :-
 ↳ AC
 ↳ DC

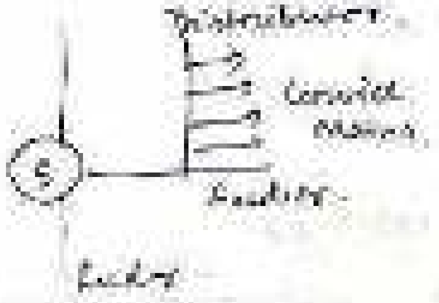
② Type of Construction :-
 ↳ Over head
 ↳ Under-ground

Over head will be (5-10) times cheaper than the UG. but UG is used where OH distribution is not feasible.

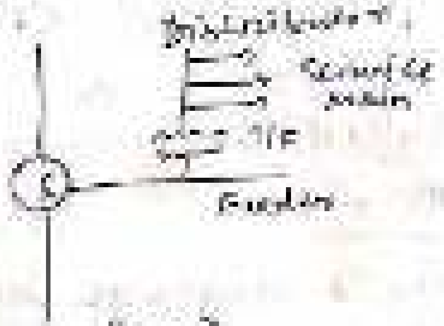
③ Scheme of Connection :-
 ↳ Radial
 ↳ Ring main
 ↳ Inter connected sys.

Connection Schemes of Distribution :-

① Radial :- In this, separate feeders radiate from a single sub-station and feed the distributors at one end only. This is employed only when power is generated at low voltage and the substations are located at centre of the load.



(DC)



(AC)

Limitations

① The end of distributor nearest to the feeder will be heavily loaded.

② All consumers depend on single feeder. So if any fault or any cut off of power occurs, all will be affected.

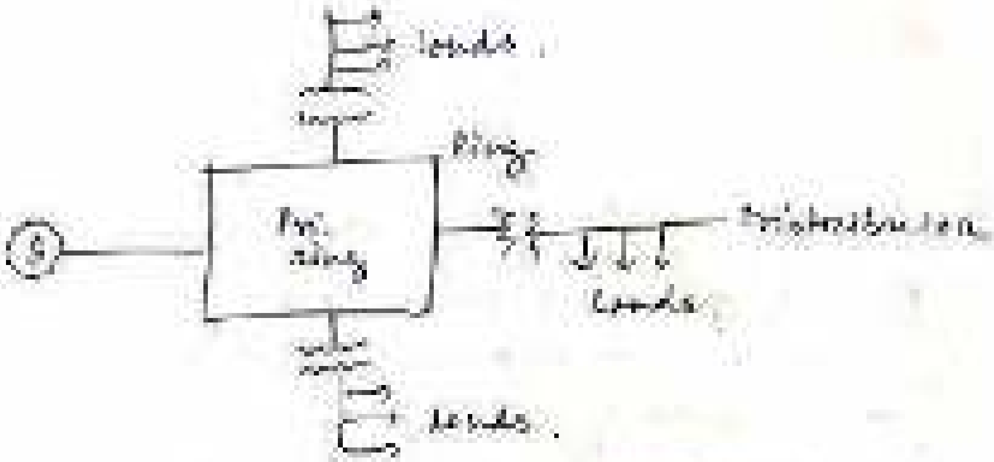
③ The consumers at the distant end of the distributor will face voltage fluctuations when the load will change

(2) Ring Main :- In this the primary of the dist. T/F form a loop. The loop circuit starts from a substation busbar, makes a loop through the area to be served and returns to the sub-station.

Advantages

(1) Less voltage fluctuations at consumer's terminal.

(2) The sys is very reliable as each distributor is fed by two feeders. If one will be out of service, the other one will keep the continuity.

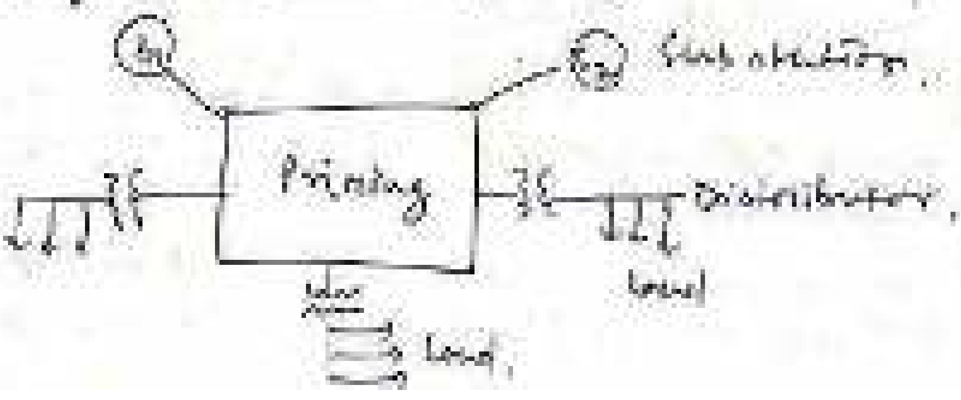



(3) Inter-connected System :- When the feeder ring is energised by two or more generators or substations, it is called inter connected sys.

Advantages

(i) It increases service reliability.

(ii) Any area fed from one generating station during peak load hours can be fed from the other. This will reduce the reserve power capacity and increase the efficiency of the total system.



Requirements of a Distribution Sys.

① Proper Voltage :- It is required to the consumer ends to have voltage (230V) constant. It is the duty of the Distribution companies to provide (230±6%) V to the consumers.

High voltage will collapse the home-appliances, where low voltage will cause insufficient light, possible burn out of motors.

② Available of power on demand :-

Power must be available to the consumer in any amount that they may require from time to time. If we want to turn on or turn off lights, fans, heaters, we should do it when we want it without giving advance notice.

③ Reliability :- In industries, plants, offices, all want electrical power. This calls for reliable service. This can't be absolute reliable, but the distribution companies must provide their best.
This can be improved by implementing
— Inter-connected sys.
— Reliable automatic control sys.
— Providing additional reserve facilities

Design considerations of Distri. Sys.

① The feeders must have enough current carrying capacity. The voltage drop in feeder is relatively unimportant, because it can be compensated by means of voltage regulating equipments.

② A distributor is designed from point of view of the voltage drop. Because according to law, the voltage drop level must be (±6%). The size and length of the distributor must be such that, voltage at consumer's terminal is within the permissible limit.

# DC Distribution

**Applications**

- Variable speed m/c (DC motors)
- Electro-chemical Industries
- Electric Traction.

**Types** — ① Distributor fed at one end.
② Distributor fed at both ends.
③ Distributor fed at the centre.
④ Ring Distributor.

**Remember**

→ As DC has no power factor, no phase displacement we can calculate it easily by means of simple arithmetic operations.

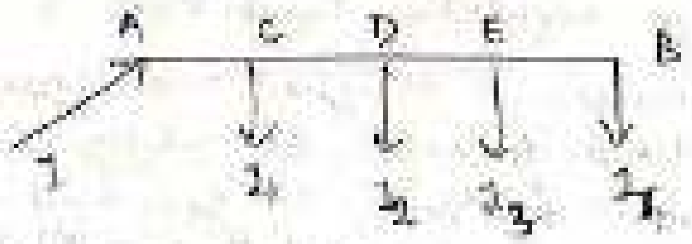
## A. Distributor fed at one end:-

- In this type of feeding, the distributor is connected to the supply mains at one end, loads are taken from different points of the distributor length.
- It is also known as "Singly fed Distributor".

→ Here the current in various section of distributor away from feeding point goes on decreasing.

→ The voltage across the loads away from the feeding point goes on decreasing. So the end point will get min voltage.

→ In case a fault occurs on any section of distributor, the whole sys will get disconnected. So the continuity of supply is interrupted.




$$I = I_1 + I_2 + I_3 + I_4$$

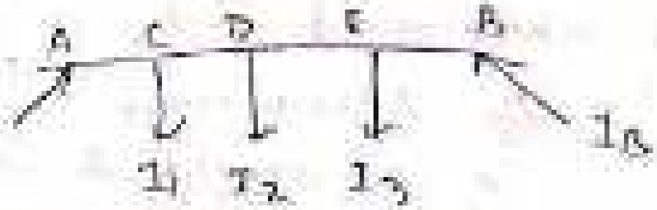
B: Distributor fed at both ends :-

- In this type, distributor is connected to the supply mains at both ends and loads are tapped off at different points along the length of the distributor.
- The voltage at feeding point may not be same.
- Here the voltage goes on decreasing as we move away from the feeding point, reaches min value and then starts increasing and reaches max value when we reach the other feeding point.
- The min voltage point goes on varying according to load.

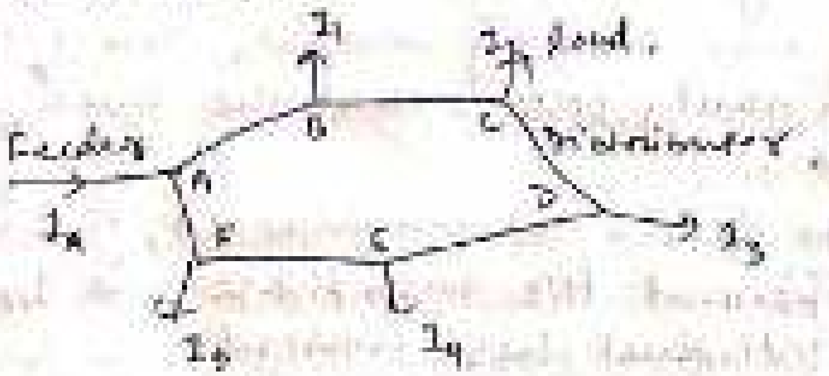
Advantages

- If fault occurs in any feeding point, the other feeding point will keep the continuity.
- If fault occurs in any section, the continuity of supply is maintained.
- The area of X-section is less.

$$I_A + I_B = I_1 + I_2 + I_3$$




C: Ring main :- In this type, the distributor is in a form of a closed loop. It is equivalent to a straight distributor fed at both ends with equal voltage, the two ends brought together to form a closed ring. Here, the feeding point may be one or more than one.



# AC Distribution

## Calculation

1. AC system has R, L, C loads so voltage drops may vary.
2. In AC s/s the addition, subtraction are done vectorially.
3. In AC, pf is taken into consideration.
4. It may refer to supply or to receive voltage as reference voltage.

## 3-ϕ Unbalanced Load :-

- The three phase load which have same impedance and power factor in each load phase is known as Balanced Load.
- But if the loads have different magnitude of impedances or power factor, we will call it as Unbalanced Load.

Ex. 1. Four wire Y-connected Unbalanced load
2. Unbalanced Δ connected load
3. Unbalanced 3 wire, Y-connected load

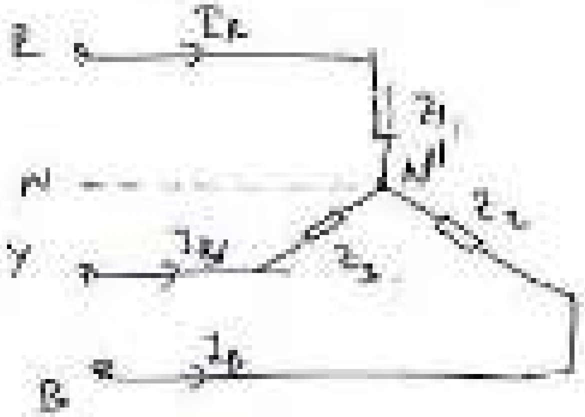
## 4-wire, Y-connected Unbalanced Load :-

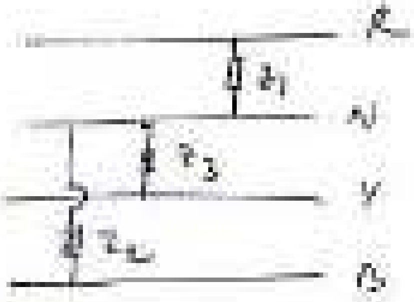
We can obtain this type load in 2 ways.

1. We may connect a 3ph, 4wire unbalanced load to 3ph, 4 wire supply. Here N must be connected to N'.
2. We may connect the single phase loads in between any line and the neutral. This is unbalanced because it is rarely possible that the three 1ϕ loads will be same.

- As the loads are unbalanced, the current will be different for each phase. So $I_N$ will be the sum of 3 individual phase current.

$$I_N = I_R + I_Y + I_B$$




Points to Remember :-

Notes

① Since, the neutral wire has negligible resistance, supply N and load N' will be at 0 potential.

② The amount of current flowing in the neutral wire will depend on the magnitude of line current and the phasor relations. $I_N \le I_{phase}$ (in normal condition).

③ In balanced load, $I_N = I_R + I_Y + I_B = 0$.

$$\Rightarrow \boxed{I_N = 0}$$

# UNDER-GROUND CABLE

→ An UG cable essentially consists of one or more conductors covered with suitable insulations and surrounded by a protecting cover.

→ The type of cable depends on working voltage and service requirements. The cable must fulfill the following necessary requirements.

(A) The conductors used should be stranded copper or aluminium of high conductivity. Stranding is necessary to make the conductor more flexible and carry more current.

(B) The size must be like that it will carry required amount of current.

(C) Proper thickness of insulation must be provided for giving high degree of safety, reliability.

(D) The cable must be provided high mechanical protection to avoid underground casualities.

(E) The materials used in cable protection must be chemically inert and physically stable.

## Construction of Cable

The several parts of UG cables are,

(A) Core of Conductor
(B) Insulations
(C) Metallic Sheath
(D) Bedding
(E) Armouring
(F) Serving.

Diagram

(Do the diagram here.)

(Page - 265)

(a) Core of conductor :- A cable may have one or more than one core depending on the type of service. It is made up of tinned copper or aluminium and is stranded to provide flexibility.

(b) Insulation :- Each core/conductor is provided with a suitable thickness of insulation. The thickness depends on voltage to be withstood by the cable. The name of some insulating materials are;
impregnated paper, varnished cambric, rubber, PVC.

(c) Metallic sheath :- To protect the cable from moisture, gases and other damaging liquid in soil and atmosphere a metallic sheath of lead / Aluminium is provided over the insulation.

(d) Bedding :- Over the metallic sheath is applied a layer of bedding which is made of fibrous material like jute, hessian, paper/tape. This will protect the metallic sheath against corrosion and mechanical injury to armouring.

(e) Armouring :- Over the bedding, armouring is provided which consists of one or two layers of galvanised steel. Its purpose is to protect the cable from mechanical injury while laying or during handling.

(f) Serving :- In order to protect the armouring from atmospheric conditions, a layer of fibrous material similar to bedding is provided over the armouring. This is known as serving.

Q) What are the properties of insulating materials ?

Ans :- (1) High insulation resistance to avoid leakage current.

(2) High dielectric strength to avoid electric breakdown.

(3) High mechanical strength to withstand mechanical handling.

(4) It should be Non-hygroscopic. It should not absorb moisture from the air/soil, else the insulation resistance will be decreased.

(5) It should be Non-inflammable.

(6) The cost should be low.

(7) The insulation must be unaffected to chemicals like acids and alkalies.

=> Name of some insulation materials and their properties.

① **Rubber** :- Rubber is made up of some oil products or it may be obtained from milky sap of tropical trees. It has relative permittivity 2-3, dielectric strength is 30kV/mm, resistivity $10^{14}$ Ω-cm.

Drawbacks :- (a) Absorbs moisture

(b) Max safe temp is low, about 38°C

(c) Soft and liable to damage due to rough handling

(d) It ages when exposed to light.

② Vulcanized India Rubber (VIR) :-

=> It is prepared by mixing pure rubber with mineral material such as Zinc Oxide (ZnO), red lead and 3-5% of sulphur. The compound formed is rolled into thin sheets.

=> It has greater mechanical strength, durability and wear resistant property than pure rubber.

=> The main drawback is, the Cu reacts with sulphur so we used tinned copper.

=> It is used for low to medium voltage applications.

Note: Vulcanization => The VIR material/rubber after production is rolled into sheets and then cut into strips. Then it is applied to the conductors and is heated upto 150°C. This process is known as Vulcanization.

③ Impregnated Paper :-

It consists of chemically pulped paper made from wood chippings and impregnated with some compound such as paraffinic / naphthenic material. It is better than the rubber insulation.

Adv: Low cost, small capacitance, high dielectric strength, high insulation resistance.

Disadvantage → The only disadvantage is that it is hygroscopic. It has tendency to absorb moisture. So the insulation resistance decreases. For this reason, paper insulated cables are always provided with some protective covering and never left unsealed.

→ It is used for low voltage level applications.

(4) Varnished Cambric :- It is a cotton cloth impregnated and coated with varnish. This type of insulation is known as [Empire Tape]. The cambric is lapped on to the conductor in the form of a tape, its surface is coated with petroleum jelly. It is also hygroscopic so it is always given metallic sheath on it.

It has dielectric strength 4 kV/mm. and permittivity of 2.5 - 3.8.

(5) Poly vinyl chloride :- (PVC)

This is a synthetic material obtained from the polymerisation of acetylene and is in the form of powder. It is compounded with certain materials known as plasticizers. It forms a gel and renders the material plastic over the desired range of temp.

Adv :- i. PVC has high insulation resistance.
ii. Good dielectric strength.
iii. Mechanical toughness.
iv. Inert to oxygen and many acids, alkalies.

→ The only limitation is, it has lower elasticity.

Use : It is used for low, medium domestic lights and power installations.

6) Classification of UG cables :-

UG cable can be classified taking the voltage level.

A. Low Tension ⟶ Upto 1000V.
B. High Tension ⟶ Upto 11000 V.
C. Super Tension ⟶ 22 - 33 kV
D. Extra - High Tension ⟶ 33 - 66 kV.
E. Extra - Super Voltage ⟶ beyond 132 kV.

## Laying of UG cable :- (18)

The reliability of UG-cable depends on the proper laying and attachment of fittings. This can be classified into 3 methods.

① Direct Method ② Draw-in-method ③ Solid method

### ① Direct Laying

(i) In this method, a trench of about 1.5m deep and 45cm wide is dug. The trench is covered with a layer of fine sand (about 10cm thickness) and the cable is laid over this sand bed. The sand prevents the entry of moisture, thus protect the cable from decaying.

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

(iii) When more than one cables are laid under the same trench, an inter axial spacing of at least 30cm is provided in order to reduce the mutual heating and also to ensure that the cable's fault does not damage the adjacent cable.

(iv) Cable should be laid in such a way that, it must have serving bituminised paper and hessian tape to provide protection against corrosion and electrolysis.

Advantages (Draw the diagram Page - 241 Fig (11.10))

(i) Simple and less costly method.
(ii) It gives the best conditions to dissipate heat
(iii) This is a clean and safe method as the cables are invisible and free from external disturbances

Disadvantages :-

(i) The extension of load is possible only by a completely new excavation which is as costly as the original work
(ii) The alteration in the cable is not easy

(iv) Maintenance is costly.
(v) Localisation of fault is difficult.
(vi) It can't be used in congested area as excavation is not feasible or expensive.

② Drawn-in System

(i) In this method, conduct or duct of glazed stone or cast iron or concrete are laid in the ground with manhole at suitable position. The cables are then kept in position from the manholes.
(ii) 3 of the ducts carry cables, where the other one will carry relay protection connection wire.
(iii) Care must be taken where the duct lines change direction. Depth, dip, offset can be made with a long radius or it will be difficult to pass the cables between the manholes.
(iv) The distance between the manholes should not be too long so as to simplify the pulling of cables.
(v)

[ Draw the Diagram Page 272 Fig (1.11) ]

Advantages

→ Repair, alteration, addition of cables are possible without opening the ground.
→ The cables to be laid in this way need not be armoured but must be provided with serving of hessian and jute.
→ As the cables are not armoured, therefore the joints become simpler and maintenance cost is less.
→ There are less chances of fault occurrence because of strong mechanical protection is provided.

Limitations

→ The initial cost is very high.
→ The current carrying capacity of the cables is reduced due to closed group of cables, so unfavourable condition for heat dissipation.

Use: This method is used at congested area where excavation is not feasible.

(3) Solid Sys.

In this method of laying, the cable is laid in open pipes or troughs dug out in earth along the cable route. This troughing is filled with cast iron, stone ware, asphalt or treated wood. After the troughing, the cables are laid and then it is filled with bituminous or asphaltic compounds.

Advantages

→ Troughing provides good mechanical protection.

Disadvantages

→ More expensive than direct laying.

→ It requires skilled labour and favourable weather conditions.

→ Due to poor heat dissipation, the current carrying capacity is very less.

## 11.5 Cables for 3-Phase Service

In practice, underground cables are generally required to deliver 3-phase power. For the purpose, either three-core cable or *three single core cables may be used. For voltages upto 66 kV, 3-core cable (*i.e.*, multi-core construction) is preferred due to economic reasons. However, for voltages beyond 66 kV, 3-core-cables become too large and unwieldy and, therefore, single-core cables are used. The following types of cables are generally used for 3-phase service :

1. Belted cables — upto 11 kV
2. Screened cables — from 22 kV to 66 kV
3. Pressure cables — beyond 66 kV.

1. **Belted cables.** These cables are used for voltages upto 11kV but in extraordinary cases their use may be extended upto 22kV. Fig. 11.3 shows the constructional details of a 3-core belted cable. The cores are insulated from each other by layers of impregnated paper. Another layer of impregnated paper tape, called *paper belt* is wound round the grouped insulated cores. The gap between the insulated cores is filled with fibrous insulating material (jute etc.) so as to give circular cross-section to the cable. The cores are generally stranded and may be of non-circular shape to make better use of available space. The belt is covered with lead sheath to protect the cable against ingress of moisture and mechanical injury. The lead sheath is covered with one or more layers of armouring with an outer serving (not shown in the figure).

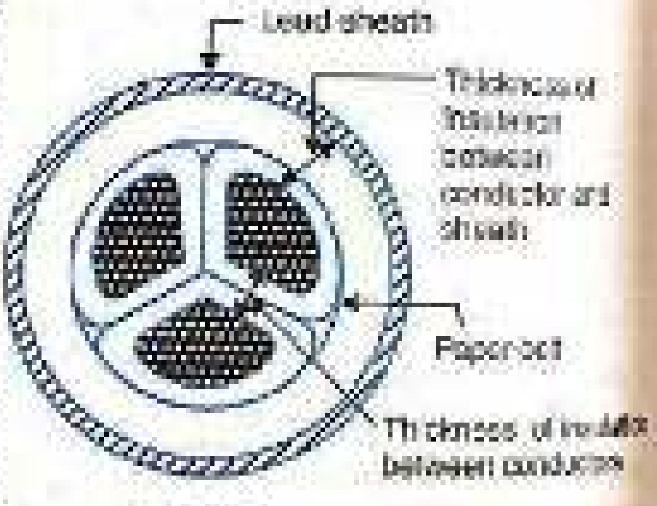


Fig. 11.3

The belted type construction is suitable only for low and medium voltages as the electrostatic stresses developed in the cables for these voltages are more or less radial *i.e.*, across the insulation. However, for high voltages (beyond 22 kV), the tangential stresses also become important. These stresses act along the layers of paper insulation. As the insulation resistance of paper is quite small along the layers, therefore, tangential stresses set up **leakage current along the layers of paper insulation. This leakage current causes local heating, resulting in the risk of breakdown of insulation at any moment. In order to overcome this difficulty, *screened cables* are used where leakage currents are conducted to earth through metallic screens.

2. **Screened cables.** These cables are meant for use upto 33 kV, but in particular cases their use may be extended to operating voltages upto 66 kV. Two principal types of screened cables are H-type cables and S.L. type cables.

(i) *H-type cables.* This type of cable was first designed by H. Hochstadter and hence the name. Fig. 11.4 shows the constructional details of a typical 3-core, *H*-type cable. Each core is insulated by layers of impregnated paper. The insulation on each core is covered with a metallic screen which usually consists of a perforated aluminium foil. The cores are laid in such a way that metallic screens

* Separate single-core cable for each phase.

** It is infact a leakage ...

make contact with one another. An additional conducting belt (copper woven fabric tape) is wrapped round the three cores. The cable has no insulating belt but lead sheath, bedding, armouring and serving follow as usual. It is easy to see that each core screen is in electrical contact with the conducting belt and the lead sheath. As all the four screens (3 core screens and one conducting belt) and the lead sheath are at †earth potential, therefore, the electrical stresses are purely radial and consequently dielectric losses are reduced.

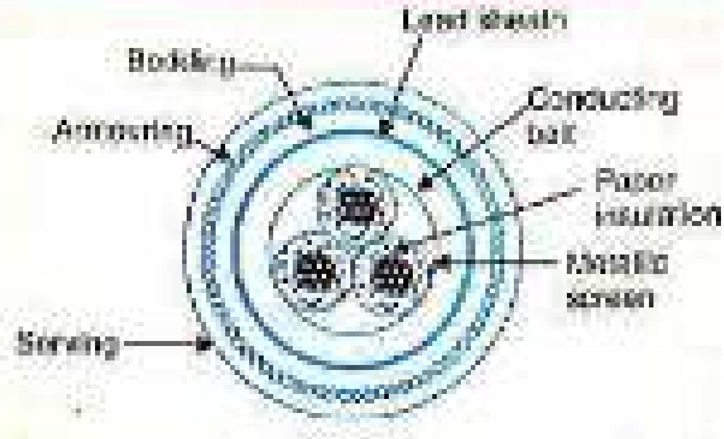
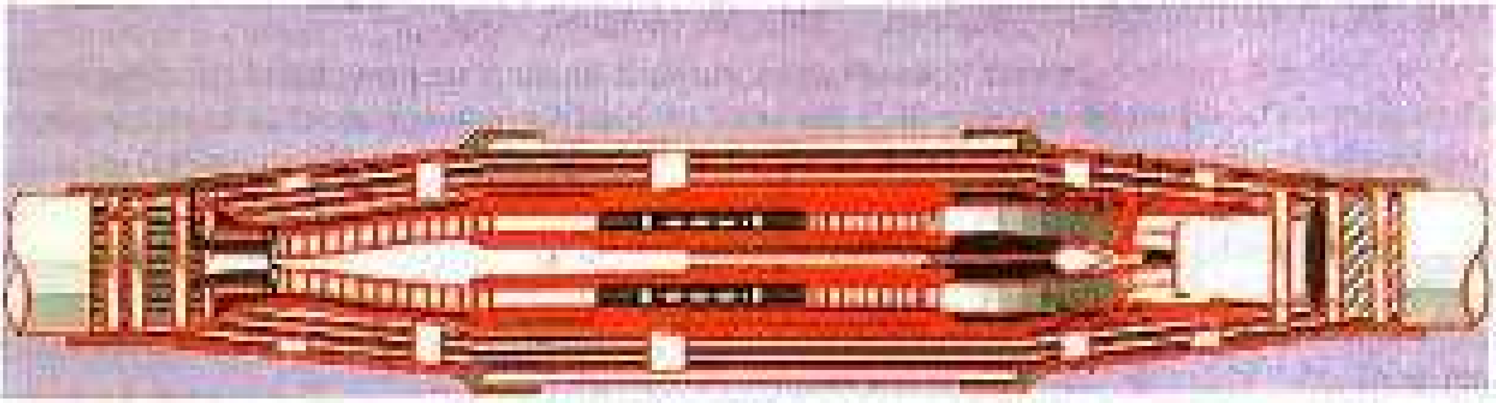


Fig. 11.4

Two principal advantages are claimed for *H* type cables. Firstly, the perforations in the metallic screens assist in the complete impregnation of the cable with the compound and thus the possibility of air pockets or voids (vacuous spaces) in the dielectric is eliminated. The voids if present tend to reduce the breakdown strength of the cable and may cause considerable damage to the paper insulation. Secondly, the metallic screens increase the heat dissipating power of the cable.


H-Type Cables

(ii) *S.L. type cables.* Fig. 11.5 shows the constructional details of a 3-core *S.L. (separate lead) type cable. It is basically *H*-type cable but the screen round each core insulation is covered by its own lead sheath. There is no overall lead sheath but only armouring and serving are provided. The S.L. type cables have two main advantages over *H*-type cables. Firstly, the separate sheaths minimise the possibility of core-to-core breakdown. Secondly, bending of cables becomes easy due to the elimination of overall lead sheath. However, the disadvantage is that the three lead sheaths of S.L. cable are much thinner than the single sheath of *H*-cable and, therefore, call for greater care in manufacture.

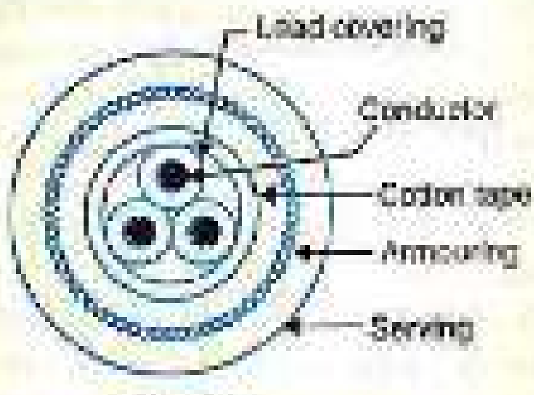


Fig. 11.5

**Limitations of solid type cables.** All the cables of above construction are referred to as solid type cables because solid insulation is used and no gas or oil circulates in the cable sheath. The voltage limit for solid type cables is 66 kV due to the following reasons :

(i) As a solid cable carries the load, its conductor temperature increases and the cable compound (*i.e.*, insulating compound over paper) expands. This action stretches the lead sheath which may be damaged.

(*b*) When the load on the cable decreases, the conductor cools and a partial vacuum is formed within the cable sheath. If the pinholes are present in the lead sheath, moist air may be drawn into the cable. The moisture reduces the dielectric strength of insulation and may eventually cause the breakdown of the cable.

(*c*) In practice, †voids are always present in the insulation of a cable. Modern techniques of manufacturing have resulted in void free cables. However, under operating conditions, the voids are formed as a result of the differential expansion and contraction of the sheath and impregnated compound. The breakdown strength of voids is considerably less than that of the insulation. If the void is small enough, the electrostatic stress across it may cause its breakdown. The voids nearest to the conductor are the first to break down, the chemical and thermal effects of ionisation causing permanent damage to the paper insulation.

3. **Pressure cables** For voltages beyond 66 kV, solid type cables are unreliable because there is a danger of breakdown of insulation due to the presence of voids. When the operating voltages are greater than 66 kV, *pressure cables* are used. In such cables, voids are eliminated by increasing the pressure of compound and for this reason they are called pressure cables. Two types of pressure cables *viz* oil-filled cables and gas pressure cables are commonly used.

(*i*) *Oil-filled cables.* In such types of cables, channels or ducts are provided in the cable for oil circulation. The oil under pressure (it is the same oil used for impregnation) is kept constantly supplied to the channel by means of external reservoirs placed at suitable distances (say 500 m) along the route of the cable. Oil under pressure compresses the layers of paper insulation and is forced into any voids that may have formed between the layers. Due to the elimination of voids, oil-filled cables can be used for higher voltages, the range being from 66 kV upto 230 kV. Oil-filled cables are of three types *viz.*, single-core conductor channel, single-core sheath channel and three-core filler-space channels.

Fig. 11.6 shows the constructional details of a single-core conductor channel, oil filled cable. The oil channel is formed at the centre by stranding the conductor wire around a hollow cylindrical steel spiral tape. The oil under pressure is supplied to the channel by means of external reservoir. As the channel is made of spiral steel tape, it allows the oil to percolate between copper strands to the wrapped insulation. The oil pressure compresses the layers of paper insulation and prevents the possibility of void formation. The system is so designed that when the oil gets expanded due to increase in cable temperature, the extra oil collects in the reservoir. However, when the cable temperature falls during light load conditions, the oil from the reservoir flows to the channel. The disadvantage of this type of cable is that the channel is at the middle of the cable and is at full voltage *w.r.t.* earth, so that a very complicated system of joints is necessary.

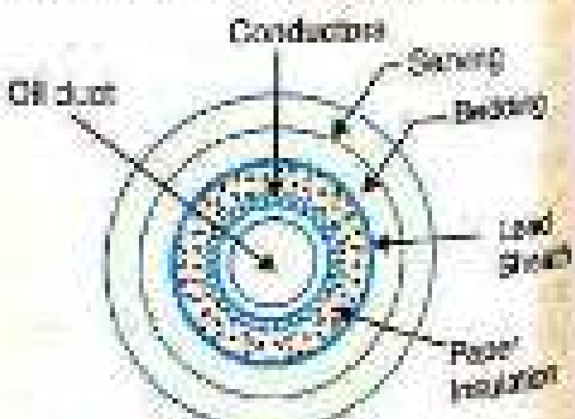


Fig. 11.6 Single-core conductor channel, oil-filled cable

Fig. 11.7 shows the constructional details of a single-core sheath channel oil-filled cable. In this type of cable, the conductor is solid similar to that of solid cable and is paper insulated. However, oil ducts are provided in the metallic sheath as shown. In the 3-core oil-filler cable shown in Fig. 11.8, the oil ducts are located in the filler spaces. These channels are composed of perforated metal-ribbon tubing and are at earth potential.

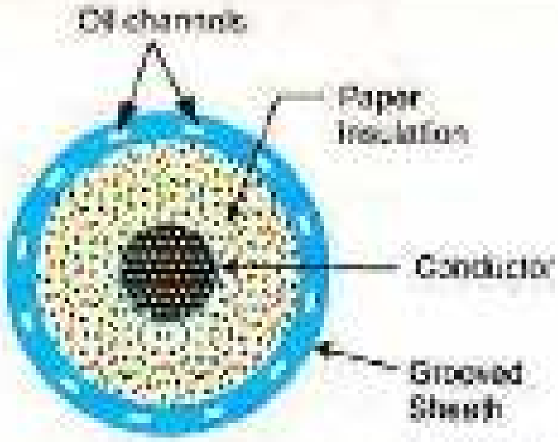



Fig. 11.7

*Oil-filled cables*

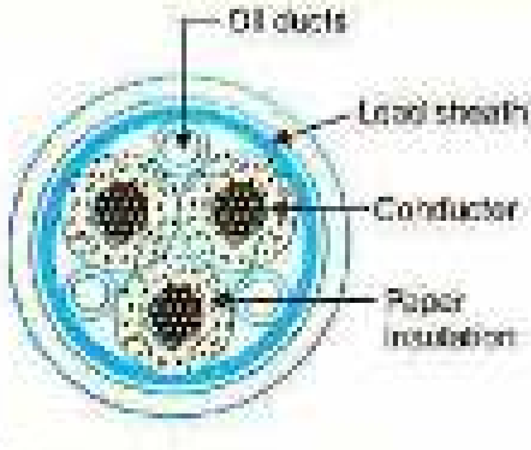



Fig. 11.8

The oil-filled cables have three principal advantages. Firstly, formation of voids and ionisation are avoided. Secondly, allowable temperature range and dielectric strength are increased. Thirdly, if there is leakage, the defect in the lead sheath is at once indicated and the possibility of earth faults is decreased. However, their major disadvantages are the high initial cost and complicated system of laying.

*(ii) Gas pressure cables.* The voltage required to set up ionisation inside a void increases as the pressure is increased. Therefore, if ordinary cable is subjected to a sufficiently high pressure, the ionisation can be altogether eliminated. At the same time, the increased pressure produces radial compression which tends to close any voids. This is the underlying principle of gas pressure cables.

Fig. 11.9 shows the section of external pressure cable designed by Hochstadter, Vogal and Bowden. The construction of the cable is similar to that of an ordinary solid type except that it is of triangular shape and thickness of lead sheath is 75% that of solid cable. The triangular section reduces the weight and gives low thermal resistance but the main reason for triangular shape is that the lead sheath acts as a pressure membrane. The sheath is protected by a thin metal tape. The cable is laid in a gas-tight steel pipe. The pipe is filled with dry nitrogen gas at 12 to 15 atmospheres. The gas pressure produces radial compression and closes the voids that may have formed between the layers of paper insulation. Such cables can carry more load current and operate at higher voltages than a normal cable. Moreover, maintenance cost is small and the nitrogen gas helps in quenching any flame. However, it has the disadvantage that the overall cost is very high.

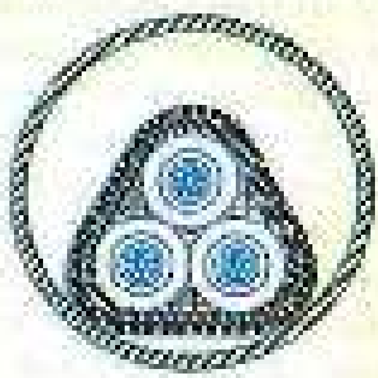


Fig. 11.9

Types of cable fault

We can classify the cable faults in three parts,

(1) Open circuit fault :- When there is a break in the conductors cable, it is called as open circuit fault. It is checked by × megger.

Process: For this, three conductors of the three core cable at the far end are shorted and earthed. Then the resistance between each conductors and earth is measured by the megger. If it indicates 0, then there is no fault. And if there is a fault, the megger will indicate ∞ resistance.

(2) Short circuit fault :- When two conductors of a multi-core cable come in electrical contact with each other because of insulation failure, it is short circuit fault.

To check it again megger is used. And the process is same as the above.

(3) Earth fault :- When the conductor of a cable comes in contact with earth, it is called earth fault or ground fault.

To identify this we use megger. The process is again the same as the above.

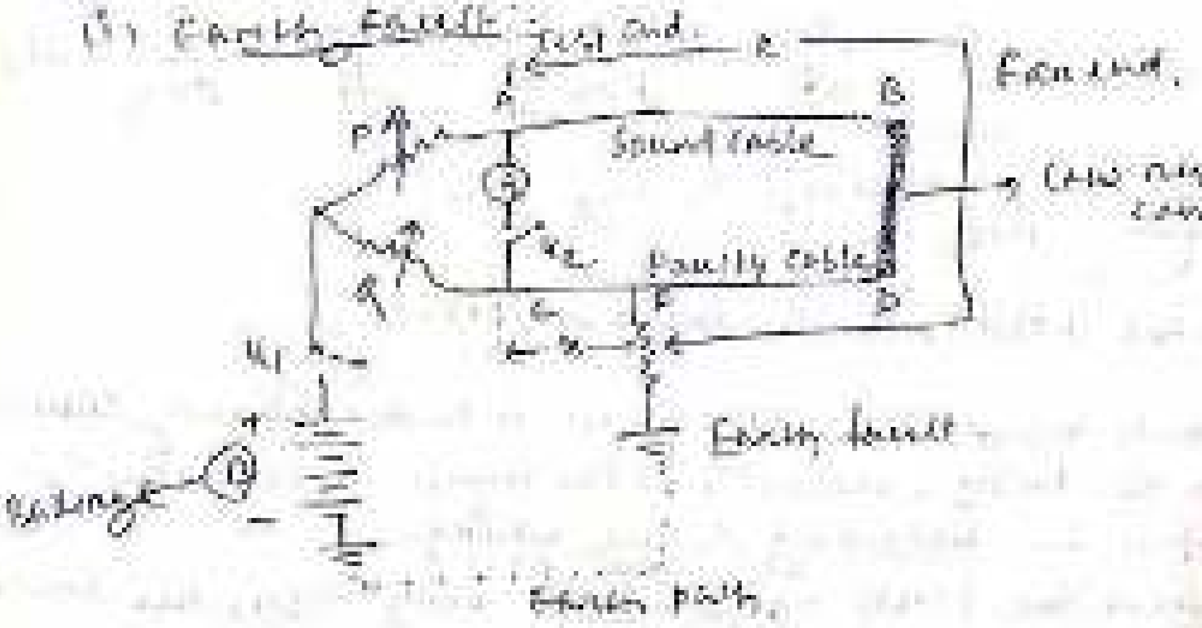
⇒ Loop Tests for Location of Faults in UG cable :-

i. Murray loop test
ii. Varley loop test.

→ Both tests employ the principle of Wheatstone Bridge for fault location.

(A) Murray loop test

(i) Earth fault :




Here, P, Q → variable resistors
K1, K2 → 2 switches.
G → Galvanometer
R → Resistance of conductor loop from fault location to test end.
X → Resistance of the other end of the loop.
AB → Sound cable  CD → faulty cable.

If we will take P, Q, R, X as the four arms of the wheatstone bridge, where P, Q → are variable.
Let all are in balanced condition, by varying P and Q to suitable position that the G is at 0.

$$\Rightarrow \frac{P}{Q} = \frac{R}{X}$$

$$\Rightarrow \frac{P}{Q}+1 = \frac{R}{X}+1$$

$$\Rightarrow \frac{P+Q}{Q} = \frac{R+X}{X}$$

If $r$ is the resistance of each cable, then $R+X = 2r$

$$\frac{P+Q}{Q} = \frac{2r}{X} \Rightarrow X = \frac{Q}{P+Q} \times 2r$$

If $l$ is the length of the cable in meter, then the resistance/meter length of cable $= \frac{r}{l}$

∴ Distance of fault point from the test end;

$$d = \frac{X}{r/l} = \frac{Q}{P+Q} \times 2r \times \frac{l}{r} = \frac{Q}{P+Q} \times 2l$$

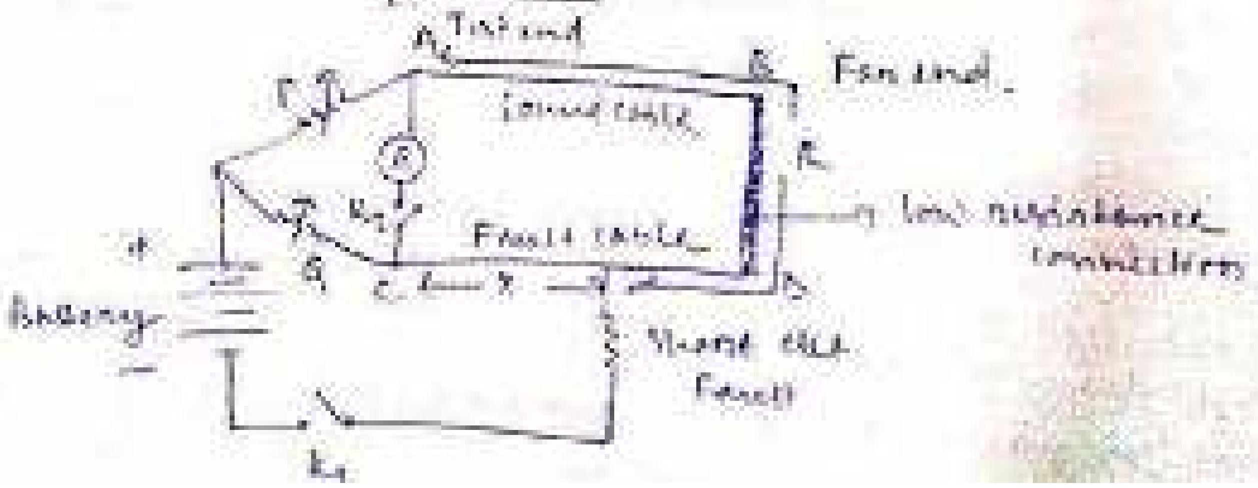
$$\Rightarrow \boxed{d = \frac{Q}{P+Q} \times (\text{loop length})} \text{ (in m)}$$

Thus the position of the fault is located.

Note – Fault resistance of the fault is in the battery circuit and not in the bridge circuit. So the fault resistance does not affect the balancing of the bridge.

However the fault resistance is very high, the battery will be the sensitivity.

(ii) Short Circuit Fault :-



(iv) Here also P, Q, R, X are the 4 arms of the wheatstone bridge.

(v) The fault resistance is in the battery circuit and not in the bridge circuit. The bridge is balanced by adjusting P, Q.

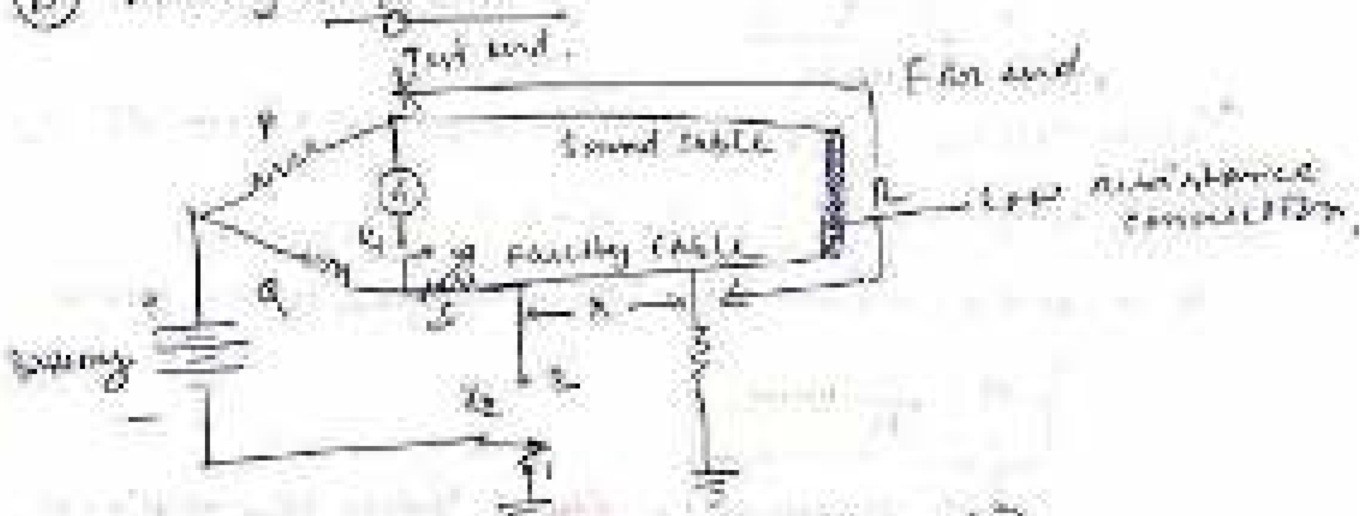
$$\frac{P}{Q} = \frac{R}{X} \Rightarrow \frac{P+Q}{Q} = \frac{R+X}{X} = \frac{2L}{X}$$

$$\Rightarrow X = \frac{Q}{P+Q} \times 2L$$

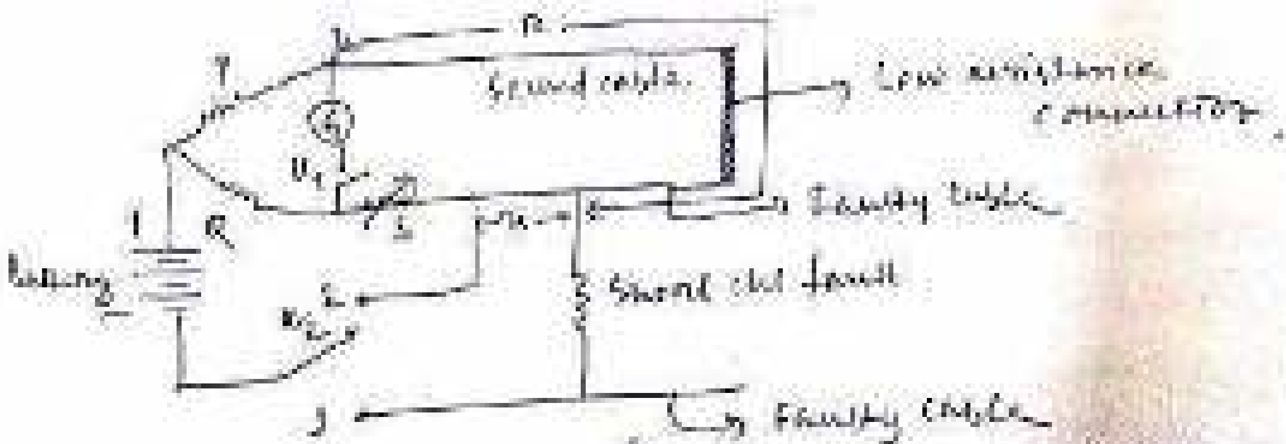
$$\Rightarrow \boxed{X = \frac{Q}{P+Q} \times (\text{loop length})} \ (\text{in m})$$

Then the position of the fault is located.

(B) Varley Loop Test :-




(Test for Earth Fault) ($K_2$ is at 1).




(Test for short circuit fault) ($K_2$ is at 2)

For earth fault or short circuit fault, the key $K_2$ (77)
is first thrown to position 1. The value of $S$ is varied
till the bridge is balanced. Let the resistance $S_1$.

$$\frac{P}{Q} = \frac{R}{X+S_1} \Rightarrow \frac{P}{Q}+1 = \frac{R}{X+S_1}+1$$

$$\Rightarrow \frac{P+Q}{Q} = \frac{R+X+S_1}{X+S_1} \Rightarrow X = \frac{Q(R+X)-PS_1}{P+Q} \quad \text{—— (1)}$$

Now, $K_2$ is thrown to pos$^n$ 2, then the bridge is
balanced. the new resistance is $S_2$.

$$\frac{P}{Q} = \frac{R+X}{S_2} \Rightarrow (R+X)Q = PS_2 \quad \text{—— (2)}$$

From eq (1) and (2),

$$X = \frac{P(S_2-S_1)}{P+Q}$$

Since $P, Q, S_1, S_2$ are known, the value of $X$,

$$\text{Loop resistance} = R+X = \frac{P}{Q}S_2$$

If $r$ is the resistance of the cable/meter then,

$$d = \frac{X}{r} \text{ meter}$$

→ Distance of fault from the test end

—o—

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# POWER FACTOR IMPROVEMENT

→ Power factor –

★ This is the cosine angle between voltage and current in an AC circuit

OR

This is the ratio between the active power and the apparent power

OR

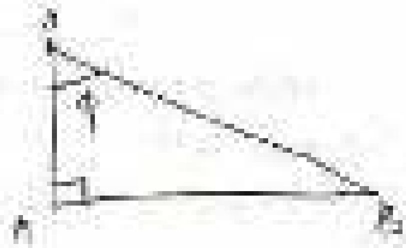
This is the ratio between the resistance to the impedance offered by the ckt.

★ Power factor is $\cos\phi$
where $\phi$ = power factor angle

→ Power Triangle

If we consider each side of the right angle triangle to the different types of power, then that triangle is known as **POWER TRIANGLE**

OA = Active power
OB = Apparent power
AB = Reactive power




We know that,

$(OA)^2 + (AB)^2 = (OB)^2$

$\Rightarrow (kW)^2 + (kVAR)^2 = (kVA)^2$

power factor $(\cos\phi) = \dfrac{kW}{kVA} = \dfrac{\text{Active power}}{\text{Apparent power}}$

$\Rightarrow$ **$kW = kVA \times \cos\phi$**

Note

★ Power factor should be as high as possible. That means power factor angle ($\phi$) should be as low as possible.

★ In practical case, pf cannot be 1, or $\phi \neq 0$

## Disadvantages of low pf

(A) As we know, $P = V_L I_L \cos\phi$ (1φ)

$P = \sqrt{3} V_L I_L \cos\phi$ (3φ)

So, $I_L = \dfrac{P}{\sqrt{3} V_L \cos\phi}$.

So for a constant power and rated voltage,

$$I_L \propto \frac{1}{\cos\phi}$$

So, with low cos φ, $I_L$ will be more. So we need to use more cross-sectional area of conductors which is uneconomical.

(B) If conductor size will be more then weight will be more. If weight will be more, sag will be more and clearance will be less.

(C) We know, $kVA = \dfrac{kW}{\cos\phi}$

$$\Rightarrow kVA \propto \frac{1}{\cos\phi}$$

Low pf means large kVA rating of the machine. So the size of the equipment/machine will be more. It will be unnecessarily expensive.

(D) If $I_L$ will be more, $I_L^2 R$ loss will be more, efficiency will be less.

(E) Large current at low lagging pf will increase the voltage drop in alternator, T/F, T/L and D/L. This will decrease the voltage supply, hence poor voltage regulation occurs.

To keep the voltage at ±6% range, we need extra equipment to regulate the voltage.

(F) With less pf, Reactive power will be more, so the handling capacity of the system will be less.

## Causes of low pf

Low pf is always undesirable. Normally in power system we want to keep the power factor in between 0.8 to 0.9. The causes of low power factor:

(a) Most of the ac m/c are induction type (1φ and 3φ induction motors). Normally they work at a power factor of 0.2 to 0.3 at light load and 0.8 to 0.9 at full load.

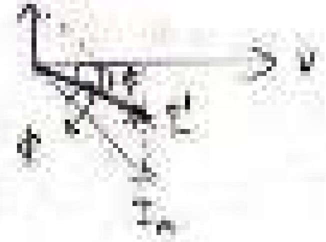
(b) All arc lamps, electric discharge lamps, industrial heating furnaces operate at low lagging pf.

(c) The load on power system is varying. It is high during morning to evening and less at night hours. So during low load time, it draws high magnetising current. This causes low pf.

## Principle of pf improvement

The reason for low pf is mainly the use of inductive load. We know inductive load is lagging power factor. So it takes lagging current. So in order to improve pf, we need to connect a leading load in parallel. We all know capacitance is an element which will take leading current. It will partly or completely neutralise the lagging power factor or reactive power of load current. So it improves the power factor.

phasor




Q) How can we improve pf ?
or
What are the equipments we use to improve the pf ?

Ans :- Normally, the pf of the whole load is about 0.8 to 0.9. But sometimes it is lower and in such cases it is generally advised to take special steps to improve power factor. This can be achieved by the following

Equipments
1. Static capacitor
2. Synchronous condenser.
3. Phase advancer.

1. Static capacitor → The power factor can be improved by connecting capacitors in parallel with the equipment in lagging power factor. This is known as static capacitor which draws a leading current, thus partly or completely neutralise the lagging reactive component. This decreases the pf angle and increases the power factor.

Uses → It is used in factories, grids.

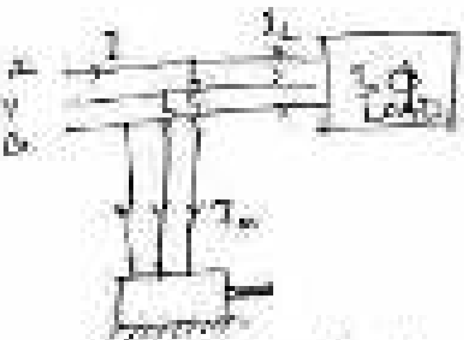
Advantages
→ Less loss.
→ They require little maintenance as it has no rotating part.
→ They can be easily installed as they are light and require no foundation.
→ They can work under ordinary atmospheric condition.

Limitations
→ They have short service period of 8-10 years.
→ They are easily damaged, if voltage exceeds rated value.
→ Once the capacitors are damaged, their repair will be uneconomical.

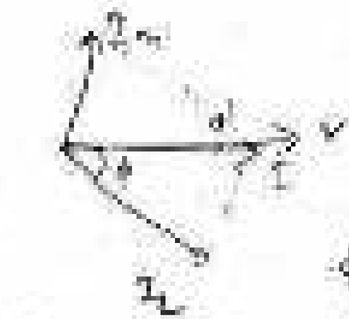
Diagram :- [Do from page 85 (Fig - 6.9)]

## ③ Synchronous Condenser (77)

A syn motor draws leading current when it will be at over excited condition. So it behaves as a capacitor. An syn motor (over excited cond^n) running at no load is known as **Synchronous condenser**. When this m/c is connected in parallel with the supply, it takes the leading current and partly neutralises the lagging reactive power. Thus P.f is improved.




3φ syn. motor




$I = I_L + I_m$    φ → V and $I_L$    φ' → V and I

So pf improved by using syn motor at over excited condition.

Advantages

→ By varying the field excitation, we can control the the current drawn by motor.
→ The motor winding has high thermal stability to short circuit current.
→ The fault can be removed easily.

Disadvantages :-

→ There are considerable losses in motor.
→ The maintenance cost is very high.
→ It produces the noise.
→ Over 500KVA, it can be used, else its cost is more than static capacitor under 500KVA.
→ Syn motor is not self-starting. So it needs an auxiliary equipment to start it.

(3) Phase Advancer :-

It is used to improve the pf of induction motor. The pf of induction motor is due to the fact that the stator winding draws exciting current which lags behind the supply voltage by 90°.

So if we will provide excitation ampere turns to AC source, then the stator winding will be relieved of excitation current and power factor can be improved. This is done by phase advancer which is simply an AC exciter. The phase advancer is mounted on the same shaft as main motor and connected in rotor circuit. By providing more ampere turns than required, the induction motor is operated at leading power factor. Thus it improves pf.

Advantage

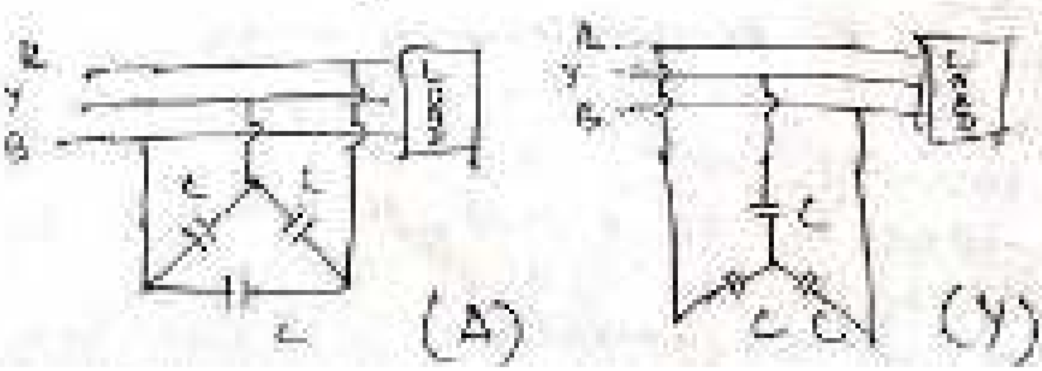
→ excitation ampere turns are supplied at slip freq so lagging VAR will be reduced.

→ It can be used where we cannot use syn. condenser.

Disadvantage → Not economical for motors below 200HP.

Note: 1HP = 746W

Static Capacitor figure



Some calculation formula for pf improvement Qs.

Imp

$V = I_c X_c \Rightarrow V = I_c \times \frac{1}{\omega C}$

$\Rightarrow \omega C = \frac{I_c}{V} \Rightarrow C = \frac{I_c}{V \times \omega} \Rightarrow \boxed{C = \frac{I_c}{2\pi f V}}$ F.

Imp

If KVAR value is given;

$KVAR = \frac{V^2}{X_c} = \frac{V^2}{\omega C} = \frac{V^2}{2\pi f C}$

$= \frac{V^2}{\frac{1}{\omega C}} = V^2 \omega C = V^2 2\pi f C$

$\Rightarrow \boxed{C = \frac{KVAR}{V^2 \times 2\pi f}}$

Imp

$KVAR = KVA \times \sin\phi$

$KW = KVA \times \cos\phi$

$KVA = \sqrt{(KW)^2 + (KVAR)^2}$

Imp.

Leading KVAR supplied when pf correction equipment is used;

$KVAR = KW (\tan\phi_1 - \tan\phi_2)$

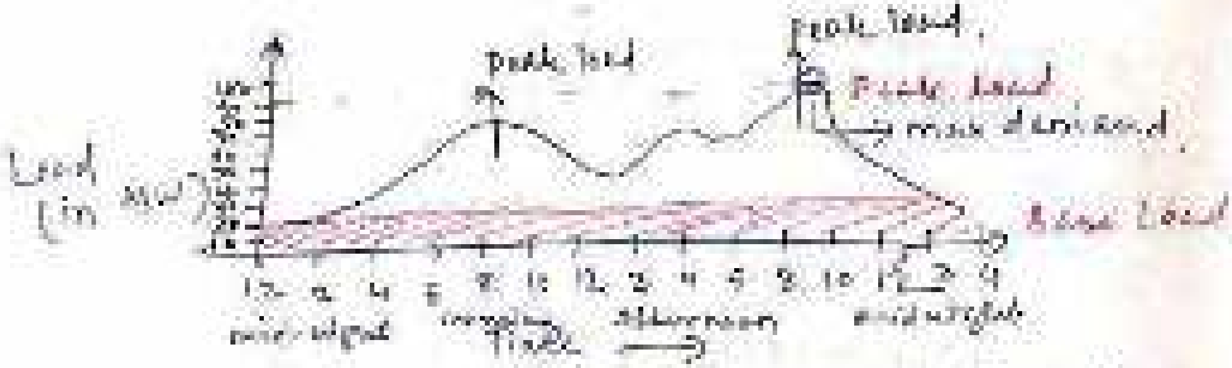
$\phi_1$ = pf angle before improvement.

$\phi_2$ = pf angle after improvement.

# Some Important Terms and Factors

## → Load Curve

The curve showing the variation of load on power station with respect to time is known as Load curve. This can be done in daily, weekly, monthly, yearly basis. It can be known from load curve, we can find out the general characteristics of load that is being imposed on the plant. Such a clear representation cannot be obtained from other tabulate figures.




We can find out the energy consumed from the area under the curve.

→ Power Sys Load

We can divide the load on power station into two types: (1) Base load (2) peak load.

→ Base Load :- The unvarying load which occurs almost the whole day on the station is known as Base load. From the figure above, we can say the base load is 20 MW.

→ Base load is provided by the Thermal, nuclear power stations.

(31)

iii) Peak load :- The various peak demand of load over and above the base load is known as peak load. This is a small part of the total load and it may occur throughout the day.

⇒ This is generally provided by the hydro power plant when necessary.

5) What do you mean by Ferranti Effect?
or
Write a short note on Ferranti Effect?

Ans:- Ferranti Effect

Under no load or light load condition, the receiving end voltage of T/L is greater than the sending end voltage. This phenomenon is known as **Ferranti effect**

Reason

Under no load condition, the T/L will have a reactive ... But there is no use of that reactive power. But there ... the load is either zero or reactive power as the load is ... negligible. So the capacitive effect of the T/L will enhance the receiving end voltage and thus there is a chance of fault, when the current will start to flow from receiving end to sending end.

~~What are the effects of Ferranti effect :-~~

Some points to write

1) Ferranti Effect happens because of both L, C of T/L
2) It happens in long T/L. Ferranti effect is proportional to the $(\text{length})^2$.
3) We can reduce Ferranti effect by using shunt inductive compensation.

Q) What are the importance of Load Curve :-

1) It will show variation of load on power station during a particular time on a whole day, week, month or year.

2) The area under the curve will show the total energy consumed, or the total energy a power station can produced.

3) The highest point will show **max demand**

4) The area under the curve divided by the total no of hours will give **Average Load**

5) The ratio of average load and max demand will give **Load factor**

6) The load curve will help to select the size and no of generating units.

7) The load curves helps to prepare operation schedule of the station.

→ Some Important Terms and Factors

1) Connected Load :- It is the sum of continuous ratings of all the equipments connected to supply system.

2) max demand :- It is the greatest demand of load on power system during a given period.
   → It helps to determine installed capacity of the station. The station must be capable of meeting the max. demand.

3) Demand Factor :- It is the ratio of max demand on power system to the connected load

$$D.F = \frac{\text{Max demand}}{\text{Connected Load}} \quad (\text{Always} < 1)$$

→ It is required to determine the capacity of the plant equipments.

4) Average Load :- The average load occurring on the power station in a given period is known as average load / Average demand.

- Daily Average Load = $\frac{\text{No of generated (kWh) units in a day}}{24 \text{ hrs}}$

- Monthly Avg Load

$$= \frac{\text{No of units generated (kWh) in a month}}{24 \times \text{Days in a month}}$$

- Yearly Avg Load

$$= \frac{\text{No of units generated (kWh) in a year}}{24 \times 365}$$

5) Load Factor :- (Always < 1)

This is the ratio of average load to the max load / max demand.

$$\text{Load Factor (LF)} = \frac{\text{Average Load}}{\text{Max Demand}}$$

If it is operated for T hrs ;

$$LF = \frac{\text{Avg Load} \times T}{\text{max demand} \times T}$$

$$= \frac{\text{Units generated in T hrs}}{\text{max demand in T hrs}}$$

6) Diversity Factor (Always > 1)

⇒ This is the ratio between sum of individual max demand to the max demand on power sys.

⇒ This is always greater than 1

$$\text{Diversity Factor} = \frac{\text{Sum of individual max demand}}{\text{max demand}}$$

7) Plant Capacity Factor :-

This is the ratio of actual energy produced to max possible energy that could have been produced in a given time period

Plant Cap. Factor = $\frac{\text{Avg energy produced}}{\text{Max energy that could have been produced}}$

$= \frac{\text{Avg Demand} \times T}{\text{Plant capacity} \times T}$

$= \frac{\text{Avg Demand}}{\text{Plant capacity}}$

⇐ Annual plant Cap. factor

$= \frac{\text{Annual kwh output}}{\text{Plant capacity} \times 8760}$

not in course (but you should know)

8) Reserve Capacity

Plant cap − max demand.

9) Plant Use Factor

$\frac{\text{station o/p in kwh}}{\text{Plant capacity} \times \text{hours of use}}$

# TARIFF

- The rate at which electrical energy is supplied to the consumers is known as tariff.

## Objectives of Tariff :-

A. Recovery of production cost of electrical energy at power station.

B. Recovery of capital investment in T and D line. (Transmission and Dist. line)

C. Recovery of cost of operation and maintenance of supply of electrical energy.

D. A reasonable profit on capital investment.

## Desirable Characteristics of Tariff :-

A. Proper return :- The tariff must be like that it ensures the proper return from each consumer. In other word, total collection from consumers must be same as cost of production, supplying of energy and profit.

B. Fairness :- The tariff must be fair so that diff. types of consumers are satisfied with rate of charge of electrical energy.

(i) Big consumers should be charged less than small consumers. Because increased electrical energy consumption spreads the fixed charge when we no of units will be more. So per unit rate (production) will be less.

(ii) The consumers whose load don't deviate much should be provided energy in less rate than the consumers who use variable load.

C. Simplicity :- The tariff calculation must be so simple that an ordinary man can understand it.

b. Reasonable profit :- The profit element in the tariff must be reasonable. An electrical supply company is a public unit and enjoys the benefits of monopoly. So they are free from competition and thus their profit margin is restricted to 8-10%.

c. Attractive :- The tariff must be attractive that a large number of consumers are encouraged to use electrical energy.

The payment of bill must be done in an easy way.

Q) What are the types of Tariff ?

Ans:- (1) Simple tariff
(2) Flat Rate Tariff
(3) Block Rate Tariff
(4) Two-part Tariff
(5) Three-part Tariff
(6) Demand Factor Tariff
(7) Power Factor Tariff.

Q) What do you mean by Flat rate Tariff ? What are the advantage and disadvantage of this.

Ans:- Flat Rate Tariff :- when different types of consumers are charged at different uniform per unit rates, it is called a flat rate tariff.

In this type, consumers are grouped into different classes, each class of consumers is charged at a different uniform rate.

Like, for lighting load the rate/kwh is 60p, where for power load it is 50p/kwh. So different classes of consumers are made taking their diversity and load factors.

Advantage → It is more fair to different types of consumers.

→ This is a simple calculation tariff.

Disadvantages

→ Separate meters are required for different load so it makes it complicated, expensive and the maintenance cost is more.

→ A particular class of people is charged at same level irrespective of the magnitude of energy consumed. However, big consumers should be charged at a lower rate as in his case, the fixed charges/kwh are reduced.

Q) What do you mean by Block rate tariff?

Ans:- When a given block of energy is charged at a specific rate and the succeeding blocks of energy are charged at progressively reduced rate, it is called Block Rate Tariff.

In this the total unit will be divided into some blocks. Each block will have some specified rate/kwh.

Ex:- If the tariff is;

1st 50 units → ₹1.70

then 50-100 units → ₹ 2.50.

then >100 units → ₹ 3.50.

Then the total bill of 120 units will be

₹ (50×1.70 + 50×2.50 + 20×3.50) = ₹ 285.00

Advantage

→ Consumers will get incentive to consume more electrical energy.

→ It increases the load factor of the system, hence cost of generation will be reduced.

Application:

It is used in residential areas and small commercial consumers.

⇒ The only disadvantage is that it lacks a measure of the consumer's demand.

Q) Write a short note on 2-part tariff.

Ans :- Two part Tariff

When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed, it is called 2-part tariff.

Here, total charge is made from the consumer is split into two components:

① ~~Fixed~~ Fixed charge

② Running charge.

Fixed charge depends on max demand of the consumer.

Running charge depends on no of units consumed by the consumers.

So the bill will be, ₹ (b × kW + c × kWh)

where b = charge/kW of max demand.

c = charge/kWh of energy consumed

Application ⇒ It is used in Industrial area.

Advantages ⇒ 1) Easy to understand.

2) It recovers the fixed charge which depends on the max demand and independent of energy consumed.

Disadvantages ⇒

1) The consumer has to pay fix charge irrespective of the fact that he has consumed it or not.

2) There is always error is occuring while calculating max demand.

# Question Bank

## 10 marks

1. Draw the schematic diagram of Steam power plant / Thermal power plant. Explain the different parts of the power plant. (3+7)
2. Draw the schematic diagram of Hydro power plant and explain the components, it has. (3+7)
3. Draw the schematic diagram of Nuclear power plant and explain its components briefly. (3+7)
4. What do you mean by Corona? Write the factors affecting corona. What are the advantages, disadvantages of Corona? How can corona be reduced? (2+3+1½+1½+2)
5. Define Kelvin's Law of most economical conductors. Derive its expression. Write its advantage and disadvantages. (2+5+1+2)
6. What are the materials we used to construct conductors. Write about those materials briefly. (10)
7. What are the types of conductors we use in electrical applications. Write briefly about each. (10)
8. What are the characteristics of good supports in electrical engineering? What are the types of supports we use and write about those briefly. (3+7)
9. What do you mean by insulators? What are the different types of insulators we use in OHTL (Overhead T/L). Write about each and their applications. (2+8)
10. What do you mean by Sag? Derive the formulae for calculating Sag for equal level and unequal level. (2+4+4)
11. Name the types of T/L considering voltage level and distance. Explain how to calculate voltage regulation in each case with phasor diagram. (2+8)

12. How DC T/L is designed? Draw its block diagram. Write the advantages and disadvantages of DC T/L. (3+2+3+2

13. What are the different scheme of ~~DC~~ Distribution line. Explain them with the diagram and write the advantages ~~and disadvantages~~ of each. (1+3+3+3

14. What are the types of DC Distribution? Explain about each with their advantages. (1+3+3+3

15. Draw a diagram of UG cable showing its several parts. Explain all of its parts. (4+6

16. What are the properties of good insulations using in UG cable: Write the types of insulating materials and write about them with their advantages (2+8

17. Write short notes on different types of cable laying with their advantages. (4+4+2

18. Explain how to locate UG cable faults in Murray loop test. (10

19. Explain how to locate UG cable faults in Varley loop test (5+5

20. What do you mean by power factor? What are the reasons of low pf and what are the disadvantages of low power factor (1+4+5

21. How can we improve the pf? What are the methods of low power factor improvement, explain them. (2+3+3+2

22. What are the different types of tariff? Write about all. (10
 1) Flat rate
 2) Block rate
 3) 2-part tariff.

23. Why we transmit power in high voltage? What are the disadvantages of AC high voltage transmission (4+6