

GENERATION TRANSMISSION AND DISTRIBUTION
ELECTRICAL ENGINEERING
4TH SEMESTER

→ The above increasing use of electric power for domestic, industrial & commercial purposes necessitates to provide electric power economically or bulk power with help of power generating unit/power plants

● → ~~This~~ The selection, placing power generating equipment should be such that a maximum will ~~write~~ minimum expenditure

→ The operation of the plant should be so as to provide ~~chief~~ reliable and continuous service.

● operation of a power plant

→ A generating station essentially employs a prime mover coupled to an alternator to provide electric power

→ The prime mover converts energy ~~from~~ ^{some} other source ^{from} ~~some~~ ^{some} other ^{form} ~~form~~ ^{form} to mechanical energy.

→ The alternator converter convert mechanical energy to electrical energy.

→ The electrical energy produce by these generating station is transmitted & distribution for the help of conductor.

→ The generating station are classified as

- 1) steam power station (Thermal)
- 2) Hydroelectric power station.
- 3) Diesel power station.

4) Nuclear power station.

Steam power station

→ A generating station which convert heat energy of coal combustion into electrical energy. It is called steam power station

→ It works as Rankin cycle

→ The steam is produced in the boiler by utilizing the heat of coal combustion

→ The steam is expanded by ~~steam~~ prime mover (steam turbine) and condensed in condenser to be fed to the boiler again

→ The steam turbine drives the alternator which convert mechanical energy to electric

energy

→ This type of power station is suitable where coal and water are available in abundance and where large amount of electric power is generated.

Advantages of steam power station

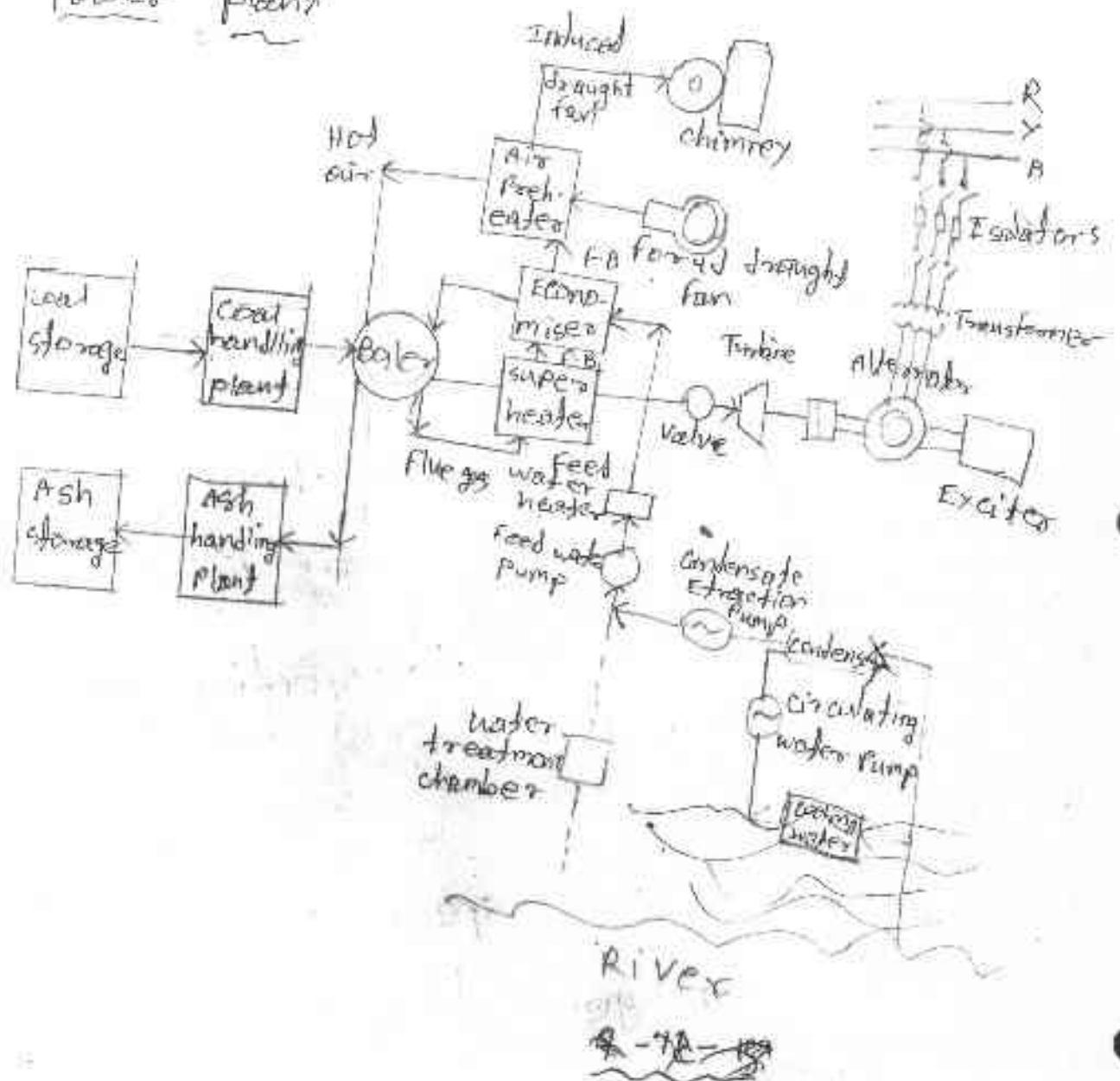
- The fuel used is quite cheap.
- Less initial cost as compare to other generation station.
- It can be installed irrespective of the existence of coal. The coal can be transported to the site.
- It required less space compare to hydraulic power station.
- The cost of generation is less than Diesel power station.

Disadvantages

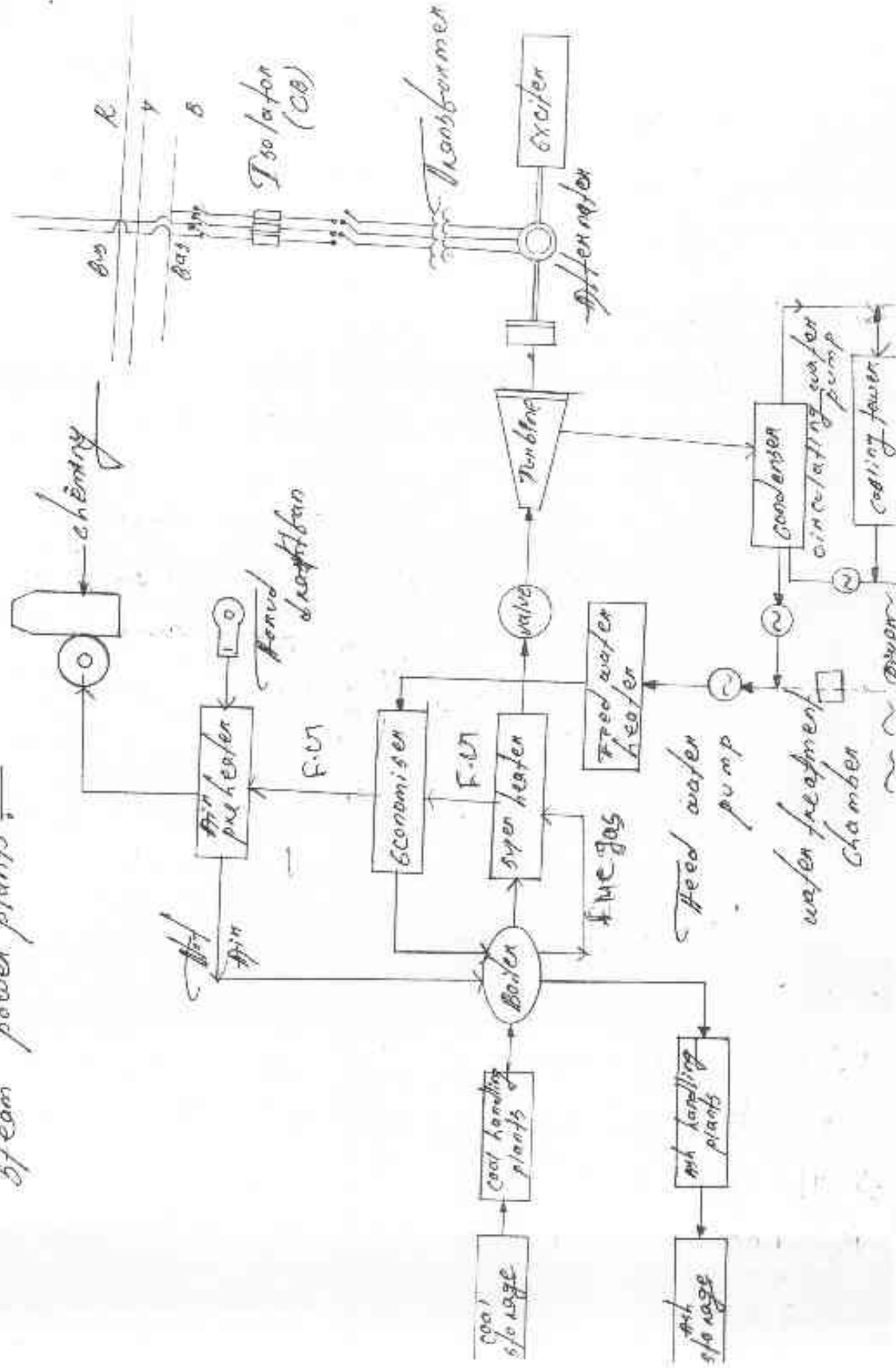
- It pollute the atmosphere due to the production of large amount of smoke and fumes.
- It is costly in running cost as compare to hydroelectric plant.
- It provided soil pollution/degradation.

Schematic diagram of steam power plant

5-12-15



Schematic diagram of steam power plants :-



Arrangement of steam power station 7-12-15

- Coal and Ash handling arrangements
- steam generating plant.
- steam turbines / Prime mover.
- 1 - Alternator necessary
- 5 - feed water
- 5 - cooling arrangement

Coal and Ash handling arrangement. 8-12-15

The coal is transported to the power station by road or rail and it ~~store~~^{stored} in a coal ~~hand~~ storage plant. From the coal storage plant coal is delivered to coal handling plant where it is pulverised (crushed in to small pieces) in order to increase the surface exposure.

→ Then the pulverised coal is fed to the boiler by belt conveyors.

→ The coal is burned to the boiler and ash produced after complete combustion of coal is removed the ash handling plant for disposal.

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

2. steam generating plant.

(a) boiler

The steam generating plant consists of a boiler. The heat of coal combustion is utilized to convert water into steam at high temperature & pressure. The flue gases produced are ~~exhausted~~ ^{exhausted} by chimney exhausted to atmosphere.

(b) Super heater.

The steam produced in boiler is wet and it is passed through the super heater where it is dried and super heated by the flue gas on the way to chimney.

Benifits of -

- (1) To increase the overall efficiency.
- (2) Too much condensation of turbine is avoided.
- (3) The super heated steam from super heater is fed to steam turbine through main valve.

(c) Economiser.

- An economiser is essentially a feed water heater and derives heat from the flue gases.
- The economiser extracts a part of flue gas to increase the feed water temperature.

(d) Air preheater

An air preheater increases the temperature of the air supplied for coal burning. By deriving heat from the flue gases, air is drawn from the atmosphere by a forced draught fan and is passed through an air preheater before supplying to boiler furnace. The air preheater extracts heat from the

and increases it temp to air used for coal combustion.

9-12-15

2 steam turbines.

The dry and super heated steam from the super heater is feed to the steam turbines by the main valve. The heat energy of the steam when passing over the blades of turbine is converted into mechanical energy after giving heat energy to turbine the steam is exhausted to the condenser.

Alternator ✓

The steam turbine is connect a alternator the alternator convert mechanical energy to power to electrical energy or power.

Feed water

The condensate from the condenser is used as feed water to the boiler.

→ The feed water on its way to the boiler is heated by water heaters & economiser for raise the overall efficiency.

Cooling arrangement:

- To improve the efficiency of a plant the steam exhausted from turbine is condensed by mix a condenser.
 - The circulating water takes of the heat of the exhausted steam and itself becomes hot & it is discharge down the river.
 - In case of non availability of water the source of supply (cooling tower ~~towers~~ are used)
- choices of site.

- supply of fuel
- water availability of water.
- water transportation facility.
- cost. type of land.
- nearer to road centre.
- distance from polluted area.

Efficiency of a steam power plant.

- The over all efficiency of a steam power plant is very low about (29%) due to
- (a) large amount of heat is lost in condenser.
- (b) Heat losses that occur in various stages
- Thermal efficiency.

The ratio of heat equivalent of mechanical energy

Transmit to the turbine shaft to the heat of combustion of coal is called thermal efficiency

• Thermal efficiency,

$$\eta_{\text{thermal}} = \frac{\text{Heat equivalent to mechanical energy}}{\text{Heat of coal combustion}}$$

• Thermal efficiency is about (30%)

• The overall efficiency is $\gg$ than thermal efficiency

The ratio of heat equivalent of electrical energy to the heat of coal combustion is called overall η

$$\eta_{\text{overall}} = \frac{\text{Heat equivalent of electrical energy}}{\text{Heat of coal combustion}}$$

$$\text{overall } \eta = \text{thermal } \eta \times \text{electrical } \eta$$

Q) (1) A steam power station has overall efficiency of 20%. If 0.6 kg of coal is burned per kWh of electrical energy generated calculate the calorific value of fuel

Data given

$$\eta_{\text{overall}} = 0.2 / 20\%$$

0.6 kg of coal

To find

calorific value of fuel

fuel be

Let, the calorific value of x kcal/kg

$$0.6 \text{ kg} = 0.6 \times x \text{ kcal}$$

$$\eta_{\text{overall}} = \frac{\text{Heat eqy. of electrical app}}{\text{Heat of coal combustion}}$$

$$\Rightarrow 0.2 = \frac{860}{0.6x}$$

$$\Rightarrow x = \frac{860}{0.6(0.2)} = 7166.66 \text{ kcal}$$

Q) A thermal station has max^m demand 2000 kW, load factor 40%, boiler efficiency 85%, turbine efficiency 90%, coal consumption 0.9 per kWh, cost of 1 ton of coal = 300 Rs determine.

(i) thermal efficiency

(ii) coal bill per annum/year

Given Data

max^m demand 20000 kW

$$\eta_{\text{turbine}} = 90\% = 0.90$$

Coal combustion 0.9 per kWh.

$$\text{load factor} = 40\% = 0.40$$

$$\eta_{\text{boiler}} = 85\% = 0.85$$

Cost of 1 ton of coal is Rupees 300
Required.

(i) Thermal efficiency

(ii) Coal bill per year.

Soln (i) Thermal efficiency

~~Overall thermal efficiency = $\eta_{\text{thermal}} \times \eta_{\text{boiler}} \times \eta_{\text{turbine}}$~~

$$\eta_{\text{thermal}} = \eta_{\text{boiler}} \times \eta_{\text{turbine}}$$

$$= 0.85 \times 0.90$$

$$= 0.766 \times 100$$

$$= \boxed{76.6\%}$$

Unit generated / annum

$$= \text{max}^m \text{ demand} \times \text{load factor} \times \text{Hours in a year}$$

$$= 20000 \times 0.40 \times 8760$$

$$= 7008 \times 10^4 \text{ kWh}$$

$$\begin{aligned}
 \text{Coal consumption/annum} &= 0.9 \times 7008 \times 10^4 \\
 &= \frac{63072000}{1000} \\
 &= 63072 \text{ tons.}
 \end{aligned}$$

Coal ~~per~~ bill per year.

$$\begin{aligned}
 &63072 \times 300 \\
 &= \boxed{18921600 \text{ Rs}}
 \end{aligned}$$

Q) A 100 MW steam station uses coal of calorific value 6400 KCal/kg. Thermal efficiency of station is 30% and electrical efficiency is 92%. Calculate the coal combustion per hour when the station is delivering it's full output.
Given

steam station uses - 100 MW
 calorific value = 6400 KCal/kg.

$$\eta_{\text{thermal}} = 30\% = 0.3$$

$$\eta_{\text{electrical}} = 92\%$$

* Coal combustion per hour ?

$$\eta_{\text{overall}} = \eta_{\text{thermal}} \times \eta_{\text{electrical}}$$

$$\begin{aligned}
 &= 0.3 \times 0.92 = 0.276 \quad \left(\begin{aligned} &= 0.276 \times 100 \\ &= 27.6\% \end{aligned} \right)
 \end{aligned}$$

unit generate per hour.

$$100 \times 10^6 \times 1 = 10^8 \text{ kWh}$$

$$\text{heat produced per hour } H = \frac{\text{Elect. o/p in heat unit}}{\eta_{\text{overall}}}$$

The turbine drive the alternator which converts mechanical energy to electrical energy.

→ hydroelectric power stations are popular because the reserves that is coal & oil are depleting day by day.

→ They have the added importance for flood control storage of water for irrigation and water for drinking purposes.

Advantages.

- It requires no fuel, as water is used for the generation of electrical energy.
- It is quite neat & clean as no smoke or ash is not produced.
- It requires very small running charges because water is the source of energy which is available free of cost.
- It is comparatively simple in construction and requires less maintenance.
- It doesn't require long starting time like a steam power station, such plant can be put in to service instantly.
- It is robust and has a longer life.
- Such plant serves many purposes. In addition to the generation of electrical energy they also help in irrigation and controlling floods.

→ Although such plants required attention of highly skilled ~~person~~ person.

Disadvantages.

→ It involve high capital cost due to construction of dam.

→ There is uncertainty about the availability of use amount of water due to dependence on weather conditions.

→ ~~scared~~ skilled and experience hands are required to build the plant.

→ It required high cost of transmission lines as the plant is located in hilly areas which is quit away from the consumer.

$$\underline{17+12+15}$$

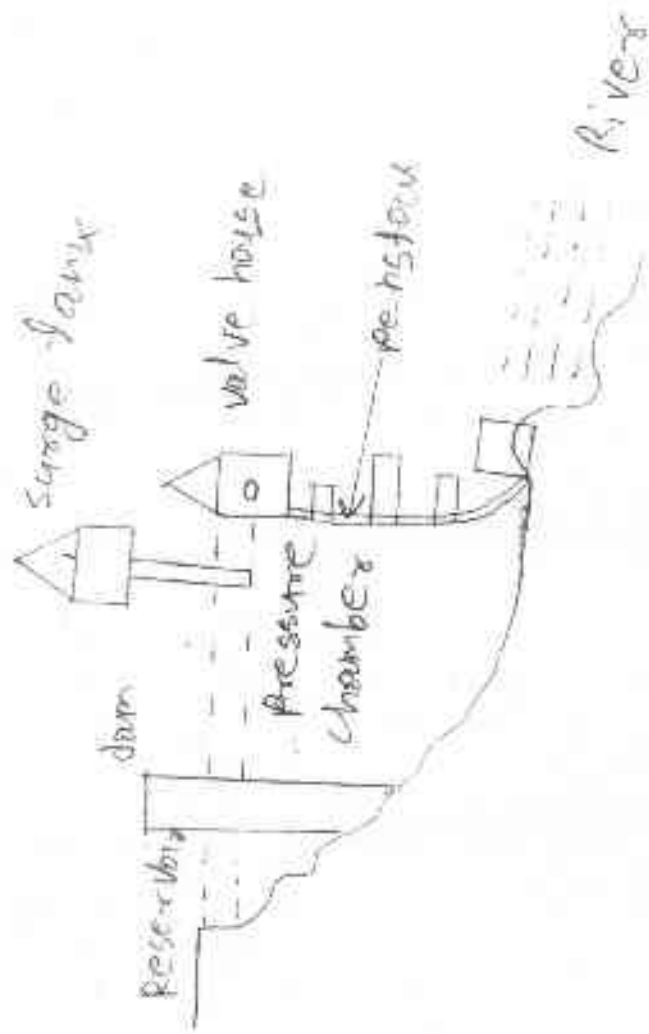
Schematic arrangement of

17-12-15

Hydroelectric power station

simple

Although a hydroelectric power station involve the conversion of hydroelectric energy into electrical energy, yet it requires many arrangements for proper working & efficiency.



→ The dam is constructed across a river or lake and water from catchment area collects at the back of the dam to form a reservoir.

→ A pressure tunnel is taken off from the reservoir and water is brought to the valve house at the start of the penstock.

→ The valve house contains sluice valve or automatic isolating valve. The former controls the ~~water~~ water flow to the power house and the latter cuts off ~~water~~ the supply of water when the penstock bursts.

→ From the valve house water is taken to the water turbine through a use steel pipe known as penstock.

→ The water turbine converts ~~hydro~~ hydraulic energy to mechanical energy.

→ The turbine drives the alternator which converts mechanical energy to electrical energy.

→ A surge tank is built before the valve house.

→ ~~its~~ surge tank ~~fun~~ is to protect the penstock from bursting in case the turbine gate is suddenly closed.

→

choices of site for hydroelectric power station.

- availability of water
- storage of water.
- cost & type of land
- where transportation facilities

Constituents of Hydroelectric plant.

→ Constituents of hydroelectric plant are.

- Hydraulic structure.
- water turbines.
- Electrical equipments.

Hydraulic structure.

→ Hydraulic structure is a hydroelectric power station include Dam, spillways, head works, surge tank, penstock

Dam.

→ A dam is a ^{barrier} which stores water and creates water head.

Spillways.

Some times the river flow exceeds the storage capacity of the reservoir. such a situation arises during heavy rain fall in catchment area. In order to discharge the surplus water from the storage reserves into the river

Head works

17-12-15

→ The head works consists of the diversion structure at the head of intake. They generally include slyices ~~to~~ for by passing segments and valves for controlling flow of water to the turbine. To avoid head losses and cavitation surge tank.

A surge tank is a small reserve or tank (open at the top) in which water level rises or falls to reduce pressure swings in the conduit/process.

It is located near the beginning of the conduit. when the turbine is running at a steady load there is no surge in the flow of water i.e. the quantity of water flowing in to conduit is just sufficient to meet the turbine requirement.

→ when load on turbine decreases the governor closes the gates of turbine reducing water supply to the turbine.
→ on the other hand when load on the turbine increase additional water is drawn

from the surge tank to meet the increased load requirement penstock.

Penstock are open or closed conduits which carry water to the turbine

• They are made of concrete or steel

* Concrete is suitable for low heads ($< 30m$) and the steel is designed any. head water turbines.

Water turbines are used to convert the energy of falling water into mechanical energy

→ The principle types of water turbines are
1) Impulse turbines.

2) Reaction "

1. Impulse turbine.

Impulse turbine are used for high head in impulse turbine the entire pressure of water is converted into kinetic energy in a nozzle and the velocity of jet drives the wheel (Ex- Pelton wheel)

→ It consists of a wheel fitted with elliptical buckets along its periphery

Reaction turbine

→ These are used for low and medium head.

→ The importance type of reaction turbines are,

(a) Francis turbine.

(b) Kaplan turbine.

Problems

A hydroelectric power station is supplied from a reservoir of capacity 5×10^6 cubic meter at a head of 200 meter find the total energy available in kWh if the overall efficiency is 75%.

Given

Capacity - 5×10^6 ~~for~~ cubic m.

head, $h = 200$ m.

~~weight~~ -

over all eff. 75 or 0.75

weight of the water available

= Volume of the water $\times$ density.

$$= 5 \times 10^6 \times 1000 = 5 \times 10^9 \text{ kg.}$$

$$= 5 \times 10^9 \times 9.81 = 4.905 \times 10^{10} \text{ N.}$$

Electrical energy available =

weight of water $\times$ overall efficiency.

$$= 4.905 \times 10^{10} \times 200 \times 0.75 = 7.35 \times 10^{12} \text{ JWS}$$

$$7.35 \times 10^{12} \div 3600 = 5677.0833 \times 1000 = 5.677 \text{ kWh}$$

2) water from a hydroelectric station is obtained from a reservoir with a head of 100 m calculate the electrical energy generated per cubic meter of water. If the hydraulic eff. be 0.86 & the electrical eff. 0.92

Given

$$H = 100$$

$$\text{Discharge } Q = 1 \text{ m}^3/\text{s}$$

$$\eta_{\text{hydraulic}} = 0.86$$

$$\eta_{\text{el.}} = 0.92$$

$$\eta_{\text{overall}} = 0.92 \times 0.86 = 0.7912$$

weight of water available per second

$$W = Q \times 100 \times 9.81$$

=

Nuclear power plant.

18-12-15

A generating station in which nuclear energy convert in to elect. energy is called Nuclear power plant.

→ In nuclear power plant having elements such as Uranium ($^{235}_{92}\text{U}$) & Thorium ($^{232}_{90}\text{Th}$) are subjected to nuclear fission in a special apparatus called Reactor.

→ The heat energy thus release is utilized in raising steam at high tempⁿ & Pressure.

The steam runs the steam turbine which converts the steam energy in to mechanical energy. The turbine drives the alternator which converts mechanical energy to electrical energy.

The most important features of a nuclear power station is the huge amount of electrical energy can be produced from a relatively small amount of nuclear fuel as compared to others.

Advantages of nuclear power station.

- Amount of fuel required is very small
- There is considerable saving in the cost of fuel
- It required very less space as compare to other station

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

→ This type of plant is very economical for producing bulk ~~extra~~ amount of elect. power.

→ It can be located near the load centres because it doesn't require large quantity of ^{water} ~~water~~ and need not be placed near ~~coal~~ ^{coal} mines. The cost of primary distribution is reduced.

→ There are large deposits of nuclear fuel all over the world. Such plant can ensure continuous supply of electrical energy for 1000 of years.

→ It ensures reliability of operation.

Disadvantages.

→ The fuel used is expensive and difficult to recover.

→ The capital cost on a nuclear plant is very high.

→ Erection and commissioning of the plants require greater technical knowhow.

→ The fission by products are generally ~~radio~~ radio active and may cause a dangerous amount of radioactive pollution.

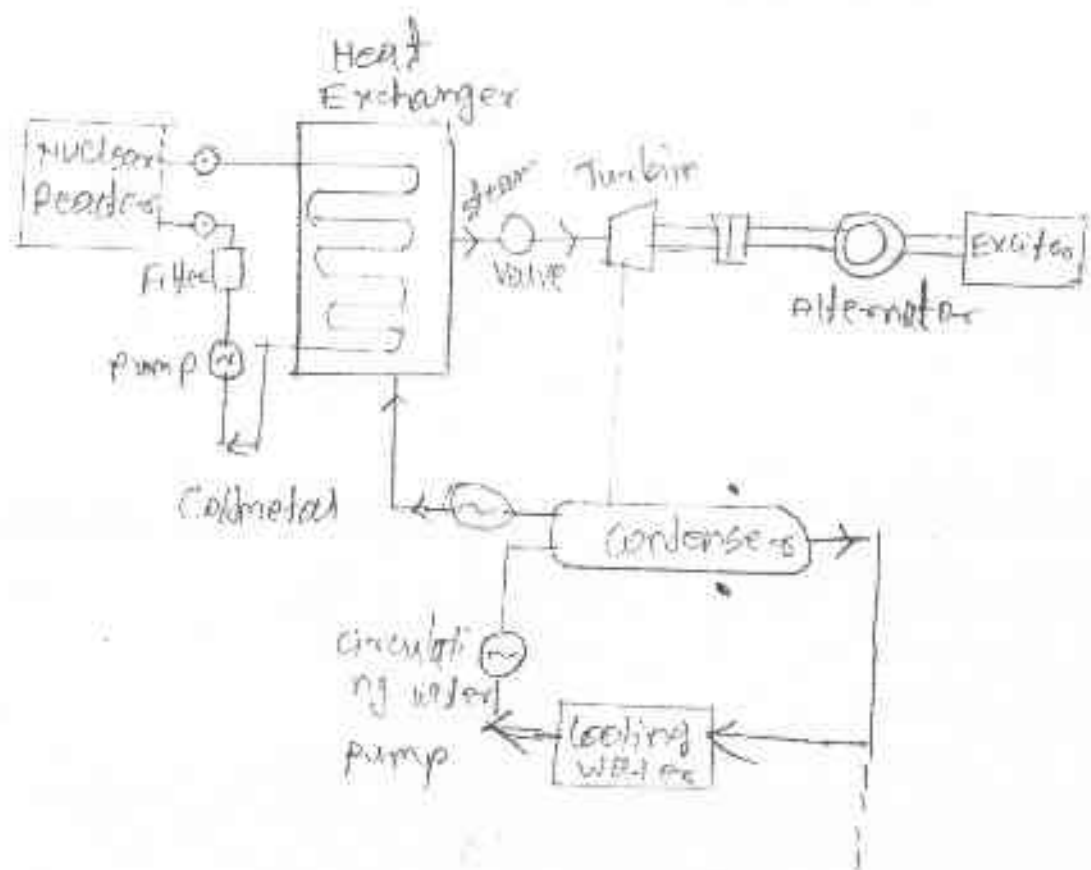
→ maintenance ^{charges} are high due to ~~standard~~ standardization.

→ Not well suited for varying loads.

→ The disposal of the byproducts which

the reactor is a big problem

schematic diagram



P. 15 - 6

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Transmission of electrical power.

Electric supply system.

The conveyance of electric power from a power station to consumer's premises is called electric supply system.

→ It can be broadly classified into 2 type.

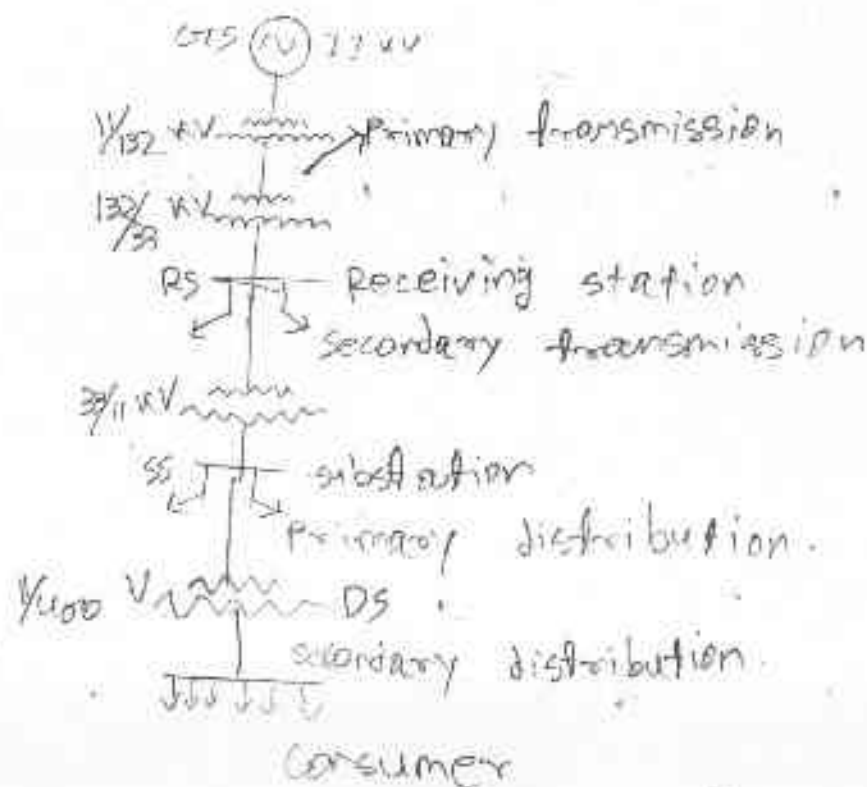
(1) DC & AC system.

(2) overhead or underground system.

Now and as three phase three wire AC system is adopted for generation & transmission of electric power. The large network of conductor is broadly divided into 2 parts.

(1) Transmission system.

(2) Distribution "



Generating station (G.S)

The figure 'G.S' represents the generating station where electrical power is produced by three phase alternator operating parallel.

→ The usually generation station 11 kV

→ For economy in the transmission of electric power the generation voltage is stepped in to 132 kV at the generating station with the help of 3-phase transformer.

→ Generally the primary transmission is carried at 66 kV or 132 kV or 220 kV or 400 kV

Primary transmission

The electric power at 132 kV is transmitted by 3-phase 3 wire overhead system to the outskirts of the city. This forms the primary transmission.

Secondary transmission

The primary transmission line terminates at the receiving station (R.S) which usually lies at the outskirts of the city.

→ At the receiving end the voltage is reduced at 33 kV by stepdown transformer. From this station electrical power is transmitted at 33 kV by three phase 3-wire overhead system to various substations (S.S) located at the strategic points in the city. This forms the secondary transmission.

Primary distribution

The secondary ^{transmission} line end to the substation where voltage reduces from 33 kV to 11 kV, three phase three wire.

→ The 11 kV lines run along the important road side of the city. This forms the primary distribution.

→ It may be noted that being consumer are generally supplied power at 11 kV for further handling with their own substations.

secondary distribution

The electric power from primary distribution line (11 kV) is delivered to distribution substations.

→ These substations are located near the consumer localities and step down the voltage to 400 V, and ~~3 phase~~ 3 phase, 4 wire for secondary distribution.

Elements of a transmission line.

5-1-2016.

- a) conductor.
- b) stepup & stepdown transformers.
- c) line insulators.
- d) supports.
- e) protective devices.
- f) voltage regulating devices.

Economics of power transmission.

- a) Economic choice of conductor size.
- b) " " of transmission voltage.

Economic choice of conductor size.

The determination of proper size of conductor for the line is of vital importance. The most economical area of conductor is that for which the total annual cost of transmission line is minimum. This is called Kelvin's Law.

→ The total annual cost of transmission line can be divided into two parts.

- a) annual charge on capital outlay
- b) " cost of energy wasted in conduction.

1). Annual charge or expense

The annual charge on an overhead transmission line can be expressed as

$$\text{Annual charge } \cancel{P_1 + P_2} \quad P_1 + P_2 a$$

where,

P_1 & P_2 are constant's and 'a' is the cross-section of the conductor.

2- Annual cost of energy wasted.

The energy loss is mainly due to I^2R loss in the conductors.

→ Annual cost of energy wasted

$$= \frac{T_3}{a}$$

where,

T_3 is a constant

$$\rightarrow \text{Total annual cost, } c = P_1 + P_2 a + \frac{T_3}{a} \quad \left/ \quad \frac{P_1 + P_2 a + T_3}{a} \right.$$

~~Here~~ In the above expression the only variable 'a' (cross-section)

Therefore the total annual cost of transmission line will be minimum is the differentiation of 'c' with respect to 'a'

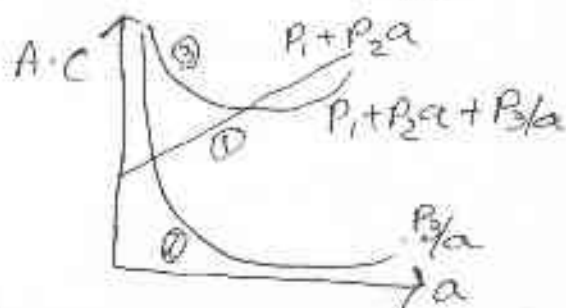
$$= \frac{dc}{da} = 0 \quad = \frac{d}{da} (P_1 + P_2 a + P_3/a) = 0$$

$$= P_2 + \left(-\frac{P_3}{a^2}\right) = 0 \quad P_2 = \frac{P_3}{a^2}$$

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

That is variable part of annual charge is equal to annual cost of energy wasted

Therefore, the ~~total~~ most economical area of conductor is that for which the variable part of ~~the~~ annual charge is equal to the cost of ~~the~~ energy loss of per year.



Limitation of Kelvins law.

- It is not easy to estimate the energy loss in the line. Without actual load curve, which are not available at the time of estimation.
- The assumption that annual cost of account of interest & depreciation on the capital out lay is in the form $P_1 + P_2 a$ is not true.
- The law doesn't take in to account various factors like self current density, mech. strength, Corona losses.
- The conductor size determined by this law may not always be practicable because it may be

for small or for the case varying of current.
→ Interest & depreciation on the capital outlay can't be determined accurately.

Economic choice of transmission voltage.

The transmission voltage for which the cost of conductors, cost of insulators, transformers, switch gear and other terminal apparatus is minimum is called economical transmission voltage.

→ The economic voltage betⁿ lines in 3-phase AC

● system is

$$V = 5.5 \sqrt{0.62L + 3P/150}$$

where,

V is the line voltage in kV

P = max^m kW per phase to be delivered to single cut.

L = Distance of transmission line in km.

● CORONA

6-1-2016

→ When the applied voltage ~~exceeds~~ ^{exceeds} a certain value called critical disruptive voltage, the conductors are surrounded by a faint violet glow called corona.

→ The phenomenon of corona is accompanied by a hissing sound, production of ozone, power loss and radio interference.

→ The higher the voltage is raised the greater

are the sound and the power loss

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

→ If the conductors are smooth the Corona glow will be uniform throughout of the conductor

Factor affecting Corona

a) Atmosphere

1) Conductor size

2) spacing betⁿ the conductors

3) line voltage

Critical Disruptive voltage

→ It is the minimum phase neutral voltage at which Corona occurs.

$$C.D.V, V_c = \frac{m_o g r \log \frac{d}{r}}{\delta} \text{ kV/phase}$$

where, m_o = Irregularity factor
 $m_o = 1$ for smooth conductors

= 0.98 to 0.92 (for dirty conductors)

= 0.87 to 0.8 (for stranded ")

δ = air density factor.

$$= \frac{3.926}{273 + t}$$

$$273 + t$$

g_0 = potential gradient

The value of g_0 is directly proportional to air density

Visual critical voltage

→ It is the minimum phase neutral voltage at which corona glow appears ^{the} along conductors.

$$\rightarrow V_v = m_v g_0 \delta r \left(\frac{140.2}{\sqrt{r}} \right)$$

Power loss due to corona

Formation of corona is always accompanied by energy loss which is dissipated in the form of light, heat, sound & chemical action.

→ The power loss due to corona is given by

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

where f is the frequency in hertz

V is the phase neutral voltage

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

V_c = disruptive voltage (rms per phase)

ADVANTAGES OF CORONA.

7-1-2016.

Due to corona formation the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increase thereby reduces the electrostatic stresses on the conductors.
→ corona reduces the effects of transient ^{surges} produced by surges.

Disadvantages

- Corona is accompanied by loss of energy.
- This effects in transmission efficiency of the line.
- Ozone is produced by corona therefore ~~corrosion~~ corrosion of the conductors may occur due to chemical action.
- The current drawn by the line due to corona is non sinusoidal and hence non-sinusoidal voltage occurs in the line.

Methods of reducing ^{corona} current:-

1→ By increasing conductor size.

→ By increasing conductor size the voltage at which corona occurs is raised and hence corona effects are reduced.

23 By increasing spacing.

→ By increasing the spacing betⁿ conductors the volts at which corona occurs is raised and hence the corona effect can be neglected.

Problem's

Q) A 3-phase line has conductors 2 cm ~~in~~ diameter spaced equilaterally one meter apart if the dielectric strength of air is 30 kV/cm find the disruptive critical voltage for the line?

Take air density factor $\sigma = 0.952$ and irregular

factor $m_0 = 0.9$.

Soⁿ

we know Given D.

find.

3-phase line.

disruptive voltage.

(g) diel. strength = $\frac{30 \text{ kV}}{\text{cm}} = 22.21$

(d) spacing = $1 \text{ m} = \frac{1}{\sqrt{3}} \times 100 \text{ cm}$

(r) = $1 \text{ cm} = \frac{2}{\sqrt{3}} \text{ m}$

① critical disruptive voltage →

$$V_c = m_0 g_0 \sigma r \log_e \frac{d}{r}$$

$$= \frac{0.9 \times 30 \times 0.952 \times 1 \times \log \frac{100}{1}}{\sqrt{3}}$$

$$= 0.9 \times 22.21 \times 0.952 \log_e \frac{100}{1} = 83.68 \text{ kV/phase}$$

② line voltage = $83.68 \times \sqrt{3} = 144.93$

CH-3 DESIGN OF OVER HEAD LINE.

Main component of
over head lines

conductor which carry

Conductor which carry electric power from sending end station to receiving end station.

① Support's

Support's which may be poles & tower & keep the conductors at suitable level above the ground.

② Insulator's

Insulator's which are attach to support and insulate the conductors from the ground.

③ Cross arms.

Cross arms which provide support to the insulators.

④ Miscellaneous items

Miscellaneous items ^{are} phase plate, danger plates, lightning arrester, wires etc.

Conductor's materials.

The conductor is one of the important items, so the proper choice of material and size of the conductor is an considerable importance.

The conductor material used for transmission & distribution should have.

- (1) high electrical conductivity
- (2) high tensile stress. to withstand mechanical stress
- (3) low cost so that it can be used for long distances.
- (4) low specific gravity

The most commonly used conductor materials are copper, aluminium, steel ~~and~~ ^{coating} aluminium, cadmium copper, galvanised steel

Line supports

The supporting structure for overhead line conductors are various type of poles and towers called line supports

→ The line supports must have the following properties.

are (1) high mechanic strength to withstand the weight of conductors.

(2) light in weight without the loss of mechanical strength

(3) cheap in cost and economical ^{to} maintain

(4) longer life

(5) Easy accessibility of conductor for maintains

The line supports used for transmission and distribution of electric power are of various type.

- ① wooden poles
- ② steel poles
- ③ RCC poles
- ④ lattice steel towers

Insulators.

08-01-2016

The over head line conductors should be supported on the poles or towers in such a way that current from the conductor do not flow to earth through supports.

Line conductors must be properly insulated from supports. this is achieve by sequencing line conductors to support with the help of insulator.

The insulator provide necessary insulation both the line conductors & support and thus prevent any linkage from conductors to earth.

- The insulators should have the following properties
- 1) High mechanical strength to withstand conduct load, wind load.
 - 2) High electrical resistance in order to avoid leakage current to earth.
 - 3) High relative permittivity of insulator material so that dielectric strength is high
 - 4) The insulator material should be free from impurities and cracks otherwise the permittivity

→ High ratio of puncture strength to flash over, the most commonly used material for insulators of overhead line is porcelain, steelite, glass are also used

Types of insulators

① Pin type insulators.

② Suspension " "

③ strain " "

④ shackle " "

Causes of insulator failure

→ Insulators are required to withstand both mechanical and electrical stress. The latter type is primarily due to line voltage and may cause breakdown of insulator. The electrical breakdown of insulator can occur either by flash over or puncture.

In flash over an arc occurs between the line conductor and the arc and the discharge jumps across the air gap. In case of flash over the insulator will continue to act in its proper capacity unless, extreme heat produced by the arc destroys the insulator.

* safety factor of insulator = $\frac{\text{puncture strength}}{\text{flash over voltage}}$

→ suspension type insulators are low cost than pin type insulators for voltages beyond 33 kV.

→ The ~~desired no. of disc~~ desired no. of disc can be connected in series. If any one disc is damaged the damaged disc can be replaced.

It provides greater flexibility to the line

→ The suspension type insulators are generally used with steel towers. As the conductor hangs below the cross arm of the tower,

Therefore this arrangement provides partial protection from lightning.

Sag in overhead line.

19-01-2016

The difference in level betⁿ point of supports and the lowest point on the conductor is called sag.



The lowest point on the conductor is 'O' and the sag is 's'. The following point may be noted.

- * when the conductor is suspended betⁿ 2 supports at the same level it takes the shape of a parabola.
- * The tension at any point on the conductor acts tangentially.
- * Thus tension T_0 at the lowest point 'O' acts horizontally.
- * The horizontal component of the tension is constant throughout the length of the wire.
- * The tension at supports is approximately equal to the horizontal tension acting at any

part on the wire.

Calculation of sag

→ low conductor tension and minimum sag are not possible
→ It is because low sag means a tight wire and high tension.

→ We will now calculate sag and tension of a conductor when.

- 1 → supports at equal levels.
- 2 → " " " different " "

● I. when supports are at equal levels

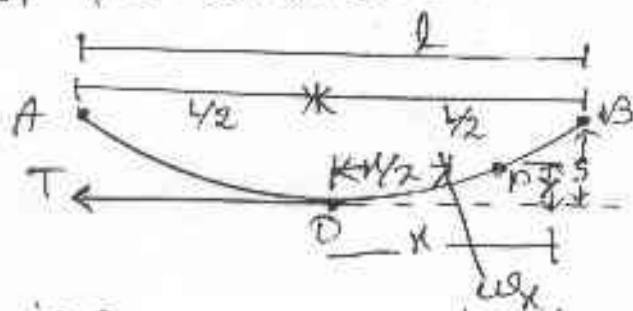
Consider a conductor betⁿ two equilevel supports A & B, with 'O' as the lowest point

Let,

L , is the length of the span

w , weight of unit length of conductor.

T , Tension of the conductor.



~~Let,~~

Let us consider a point 'P' on the conductor.

Let the co-ordinate of point 'P' be x & y .

* The two forces acting on the portion O, P of the conductor are

a) The weight w_x of the conductor acting

At a distance $x/2$ from 'O'

↳ The tension acting at 'O'

The equaling moments of ~~at~~ above two forces about point 'O' we get

$$Ty = wx + \frac{x^2}{2}$$

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

The maximum sag is represented by the value of y at either of supports A & B

At support 'A' = $x = l/2$

and ' y ' = s

$$\therefore \text{sag}(s) = \frac{w(l/2)^2}{2T}$$

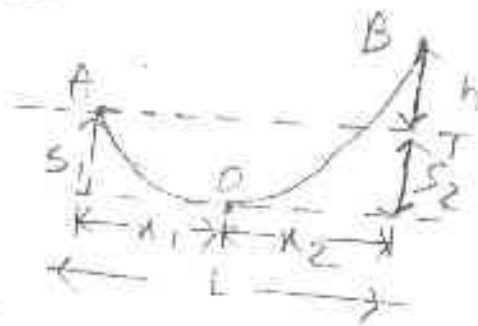
$$Ty = wx + \frac{x^2}{2}$$

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

$$s = \frac{w(l/2)^2}{2T} = \frac{wl^2/4}{2T}$$

$$= \frac{wl^2}{8T} = \frac{wl^2}{8T}$$

2. when supports at different level



$$s_1 = \frac{wx_1^2}{2T}$$

$$s_2 = \frac{wx_2^2}{2T}$$

again $x_1 + x_2 = l$

$$s_2 - s_1 = \frac{w}{2T} (x_2^2 - x_1^2)$$

where, h is difference in level betⁿ 2 support

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

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

But $s_2 - s_1 = h$

$$x_2 - x_1 = \frac{2Th}{wl}$$

~~$x_1 + x_2$~~ $x_1 + x_2 = l$ — (1)

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

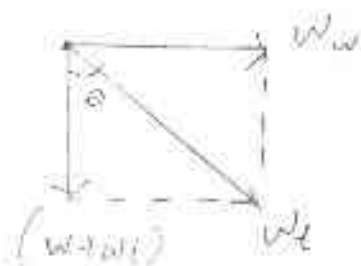
on solving eqn (1) & eqn (2) we get.

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

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

Effect of Ice and wind loading

20-1-2016



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

where, w = weight of the conductor per unit length

* w_i = " " " " ice " " "

$$\therefore \text{Density of ice} \times \frac{\pi}{4} [(d+2t)^2 - d^2] \times l$$

$$= \text{Density of ice} \times \pi t (d+t)$$

* w_w = wind force per unit length

$$= \text{wind pressure} [(d+2t) \times l]$$

When the conductor has wind & ice loading

the following points may be noted.

1 $\rightarrow$ The conductor sets itself at an angle θ to the vertical

where,

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

2) The sag of conductor is given by .

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

3) The vertical sag = $5 \cos \theta$

Problem

weight of the conductor 680 kg/km, length of the span 260 m, tension 1550 kg, ground clearance required is 10 meters. Calculate the height above the ground at which the conductors should be supported.

Solⁿ

$$w = 680 \text{ kg/km} = \frac{680}{1000} = 0.68 \text{ kg/m}$$

$$l = 260 \text{ m}$$

$$T = 1550 \text{ kg}$$

$$s = \frac{w(l/2)^2}{2T} = \frac{0.68(260/2)^2}{2 \times 1550} = 3.70 \text{ m}$$

Conductors will be supported at height of
 $10 + 3.70 = 13.70 \text{ m}$ above the ground.

9) Q1-D

span length (l) = 150 m

working tension (T) = 2000 kg

wind force per meter length (w_w) = 1.5 kg

weight of the conductor per meter length (w) = 1.98 kg

calculate the sag (s) = ?

Find the vertical sag : ?

$$\begin{aligned} \text{iv)} \quad s &= \frac{w \left(\frac{l}{2} \right)^2}{2T} \\ &= \frac{2.48 \left(\frac{150}{2} \right)^2}{2 \times 2000} = 3.48 \text{ m} \end{aligned}$$

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

$$\text{Then } \theta = \frac{w_w}{w} = \frac{1.5}{1.98} = 0.75$$

$$\theta = \tan^{-1} 0.75$$

$$\theta = 36.86^\circ$$

CH-3 performance of Transmission lines

21-1-16

Classification of overhead transmission lines

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

→ The resistance and inductance form the series impedance.

→ The capacitance existing between conductors for single phase line or from a conductor to neutral for a three phase line forms a shunt path throughout the length of the line.

→ The overhead transmission lines are classified as -

a → short transmission lines.

b → medium " "

c → long " "

* (a) short transmission lines :-

The length of the short transm is up to about 50 km and the line voltage is comparatively low.

→ Due to smaller length and lower voltage the capacitance effect can be small.

and only resistance & inductance of the line are taken in to account

medium transmission line

The length of the MT is about 50 to 100 km and the line voltage is moderately high / just high. Due to sufficient length and high voltage the effect of capacitance is taken in to account

c. long transmission lines

The length of the long T.L's is more than 150 km and the line voltage is very high ($> 100 \text{ kV}$)

voltage regulation

When a transmission line is carrying current there is a voltage drop due to resistance & inductance of the line. So the receiving end voltage (V_R) is generally less than sending end voltage (V_S)

* voltage drop = ~~sending end voltage~~ / ~~receiving end voltage~~ = $\frac{V_S}{V_R}$ $(\frac{V_S - V_R}{V_R})$

and is expressed as a percentage of receiving end voltage V_R and is called voltage regulation.

The difference in voltage at the receiving end of a transmission line betⁿ conditions of

no load & full load is called voltage regulation

and is expressed as a percentage of the receiving end voltage.

mathematically % voltage regulation

$$= \frac{V_s - V_r}{V_r} \times 100$$

Transmission efficiency

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

* Percentage transmission efficiency

$$\Rightarrow \eta_T = \frac{\text{Receiving end power}}{\text{Sending end power}} \times 100$$

$$= \frac{V_R I_R \cos \phi_R}{V_S I_S \cos \phi_S} \times 100$$

where,

$V_R, I_R \cos \phi_R$ are receiving end voltage.

I_R " " current.

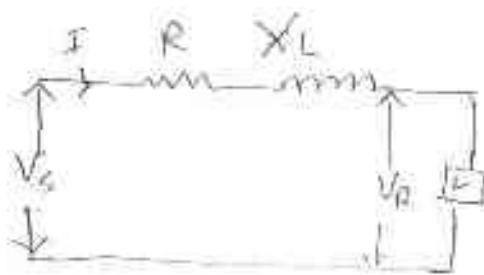
$\cos \phi_R$ " " end at power factor.

V_S = sending end voltage.

I_S = " " current.

$\cos \phi_S$ = " " end at power factor.

Performance of single phase short transmission lines



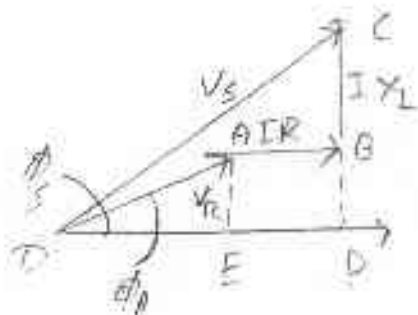
Let I = load current.

R = Resistance of both conductors.

X_L = Reactance

V_s = sending voltage

V_R = Receiving voltage



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

From the rightangle triangle, ODC we get

$$OC^2 = OD^2 + CD^2$$

$$V_s^2 = (OE + ED)^2 + (DB + CB)^2$$

$$V_s^2 = (V_R \cos \phi_R + IR)^2 + (V_R \sin \phi_R + IX_L)^2$$

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

Percentage voltage regulation = $\frac{V_S - V_R}{V_R} \times 100$

+ sending end power factor $\cos \phi_S = \frac{P_{OC}}{V_S I} = \frac{V_R \cos \phi_R + I R}{V_S}$

* Power delivered $P = V_R I \cos \phi_R$
 $= V_R I R \cos \phi_R$

line losses = $I^2 R$

Power sent out = $V_R I R \cos \phi_R + I^2 R$

% transmission $\eta = \frac{\text{Power delivered}}{\text{Power sent out}} \times 100$

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

Soln in complex notation

$$\vec{V}_S = \vec{V}_R + \vec{I} \times \vec{Z}$$

$$= (V_R + j0) + I(\cos \phi_R - j \sin \phi_R)(R + jX_L)$$

$$= (V_R + I R \cos \phi_R + I X_L \sin \phi_R) + j(I X_L \cos \phi_R - I R \sin \phi_R)$$

~~Therefore~~ $V_S =$

Therefore $V_S = \sqrt{(V_R + I R \cos \phi_R + I X_L \sin \phi_R)^2 + (I X_L \cos \phi_R - I R \sin \phi_R)^2}$

The second term is quite small and can be neglected

Therefore V_S becomes

$$V_S \approx V_R + I R \cos \phi_R + I X_L \sin \phi_R$$

The following points may be noted

1) The approximate formula for V_s gives fairly correct result for lagging power factor. Now error is caused for leading power factors.

Therefore approximate expression for V_s should be used for lagging power factor only

Q) A single phase overhead transmission line delivers 1100 kW at 33 kV at 0.8 power factor lagging. The total resistance and inductive reactance of the line are 10Ω and 15Ω respectively. Determine.

- (1) sending end voltage
- (2) sending end power factor
- (3) Transmission efficiency.

V.V.V. important

Solⁿ

Load power factor $\cos \phi_R = 0.8$ (lagging)

Total line impedance $\vec{Z} = R + jX_L$
 $= 10 + j15 \Omega$

Receiving end voltage $V_R = 33000 \text{ V}$

$$\begin{aligned} \text{Line current (I)} &= \frac{1100 \times 10^3}{V_R \cos \phi_R} \\ &= \frac{1100 \times 10^3}{33000 \times 0.8} = 41.66 \text{ A.} \end{aligned}$$

$$(\cos \phi = 0.8) \Rightarrow \phi = \cos^{-1}(0.8) = 36.86^\circ$$

$$\sin \phi = \sin(36.86) = 0.6$$

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

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

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

$$= 33.336 - j25$$

$$\vec{V}_S = \vec{V}_R + \vec{I} \vec{Z}$$

$$= 33000 + (33.33 - j25)(10 + j15)$$

$$= 33000 + 333.3 - j250 + j500 = 33708.3 + j250$$

$$\Rightarrow 33708.3 + j250$$

$$V_S = \sqrt{(33708.3)^2 + (250)^2} = 33709 \text{ V}$$

$$\text{angle bet}^n \vec{V}_R \text{ and } \vec{V}_S = (\alpha) = \tan^{-1} \frac{250}{33708.3} = 0.42^\circ$$

$$\phi_S = \phi_R + \alpha$$

$$= 36.86 + 0.42 = 37.28^\circ$$

$$\text{sending end power factor angle} = 37.28^\circ$$

$$\cos \phi_S = \cos(37.28)$$

$$= 0.795 (\text{lagging})$$

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

$$= (41.67)^2 \times 10 = 17364 \text{ W}$$

$$\text{output} = 1100000 + 17364 \text{ W}$$

$$= 1117364 \text{ W or } 1117.364 \text{ kW}$$

Transmission efficiency.

$$= \frac{1100}{1117.364} \times 100 = 98.44 \%$$

Q) An overhead 3ϕ transmission line delivers 5000 kW at 22 kV at 0.8 power factor lagging. The resistance and reactance of each conductor is 4Ω & 6Ω . Determine.

1. sending end voltage.
2. Percentage Regulation.
3. Transmission efficiency

Solⁿ

Load power factor $\cos \phi_R = 0.8$

total $V_L = 22 \text{ kV} = 22000$

$$V_R = \frac{V_L}{\sqrt{3}} = \frac{22000}{\sqrt{3}} = 12701 \text{ V}$$

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

$$= 4 + j6$$

Line current $I = \frac{P}{V \cos \phi} = \frac{5000 \times 10^3}{3 \times 12701 \times 0.8} = 164.04 \text{ A}$

$$(\cos \phi = 0.8 \Rightarrow \phi = \cos^{-1}(0.8) = 36.86^\circ$$

$$\sin \phi = \sin(36.86) = 0.6$$

$$\vec{V}_R = V_R + j0 = 12701 \angle 0^\circ$$

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

$$= 164.04 (0.8 - j0.6)$$

$$= 131.232 - j98.424$$

$$\vec{V}_S = \vec{V}_R + \vec{I}^* \vec{Z}^T$$

$$= 12700 + (131.2 - j98.4) (4 + j6)$$

$$= 12700 + 524.8 + 1787.2 - j393.6 + 576.4$$

$$= 13815.2 + j393.6$$

Answer any two

Internal

1) (a) what is thermal eff. & over all eff. (2)

b) why surge tank is provided in hydroelectric power station.

c) Draw the schematic arrangement of thermal power station.

2) (a) what is corona.

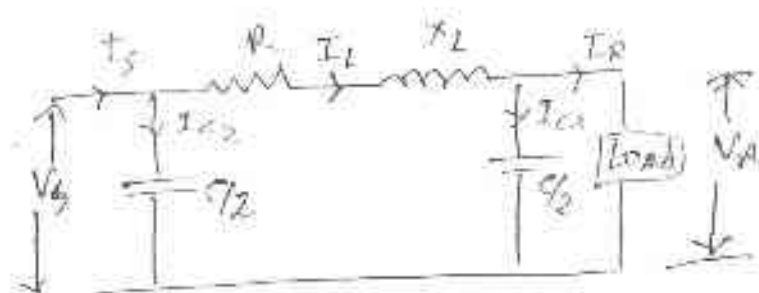
b) what are the factor affecting corona

c) Derive the sag when the support are in equal level

3) (a) Explain the principle of working of a nuclear power plant

b) Draw and explain the lay out of transmission and distribution ~~and~~ scheme

c) Derive the expression for Kelvin's law for economic size of conductors.



Let I_R is the load current

R is the resistance

X_L inductive reactance

C capacitance

$\cos \phi_R$ receiving end power factor

V_s sending end voltage

we know,

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

$$\text{load current } \vec{I}_R = I_R (\cos \phi_R + j \sin \phi_R)$$

$$\text{charging current at load end } \vec{I}_{C1} = j\omega C/2 \vec{V}_R$$

$$\text{line current } \vec{I}_L = \vec{I}_R + \vec{I}_{C1}$$

$$\text{sending end voltage, } \vec{V}_s = \vec{V}_R + \vec{I}_L \times Z$$

$$\text{i.e. } \vec{V}_R + \vec{I}_L (R + jX_L)$$

$$\text{charging current at the sending end } \vec{I}_{C2} = j\omega C/2 \times \vec{V}_s$$

$$= j(\pi f) C \times \vec{V}_s = j\pi f C \vec{V}_s$$

$$\text{sending end current} = \vec{I}_L + \vec{I}_{C2}$$

→ In this method the capacitance of each conductor is divided in to two half

1) one half ~~of~~ present ^{at} the sending end.

and the other half at the receiving end.

2) The capacitance at the sending end has no effect on the line draw.

Problem

A three phase 50 hertz 150 km line has a resistance inductive reactance and capacitive sub admittance of 0.1Ω , 0.5Ω & $3 \cdot 10^{-6} S$ per km per phase if the line delivers 50 MW at 110 kV and 0.8 power factor lagging. Determine the sending end voltage and current assume a nominal π cut for the line

Ans

Soln

$$R = 0.1 \Omega$$

Total resistance per phase = $0.1 \times 150 = 15 \Omega$

Total reactance per phase = $0.5 \times 150 = 75 \Omega$

Capacitive admittance = $3 \times 10^{-6} \times 150 = 45 \times 10^{-5} S$

Receiving end voltage per phase $V_R = \frac{110 \times 10^3}{\sqrt{3}} = 63508 V$

Load current $I_R = \frac{P}{\sqrt{3} V_R \cos \phi} = \frac{50 \times 10^6}{\sqrt{3} \cdot 110 \times 10^3 \times 0.8} = 32803 A$ or $\frac{50 \times 10^6}{63508 \times 0.8} = 32803 A$

$$\cos \phi_R = 0.8$$

$$\Rightarrow \phi_R = \cos^{-1}(0.8)$$

$$\Rightarrow \phi_R = 36.86^\circ$$

$$\sin \phi_R = \sin 36.86^\circ = 0.59 \sim 0.6$$

$$V_p = V_R + I_0$$

$$= 63508 \text{ V}$$

$$\vec{I}_R = I_R (\cos \phi_R + j \sin \phi_R)$$

$$= 328.03 (0.8 + j 0.6)$$

$$= 262.4 - j 196.82$$

$$\text{Charging current at load end } \vec{I}_C = \vec{V}_R \frac{j \omega C}{2}$$

$$= 63508 \cdot j \frac{4.5 \times 10^{-5}}{2} = j 14.3$$

$$\text{Line current, } \vec{I}_L = \vec{I}_R + \vec{I}_C$$

$$= 262.4 - j 196.82 + j 14.3$$

$$= 262.4 - j 182.52$$

$$\text{Sending voltage, } \vec{V}_S = \vec{V}_R + \vec{I}_L \vec{Z}$$

$$= 63508 + (262.4 - j 182.52) \times (81.5 + j 75)$$

$$= 63508 + 3936 + j 19680 - j 2737.5 + 13687.5$$

$$= 63508 + 3936 + j 19680 - j 2737.5 + 13687.5 \quad [\because j^2 = -1]$$

$$= 81131.5 + j 16942.5$$

$$V_S = \sqrt{a^2 + b^2}$$

$$= \sqrt{(81131.5)^2 + (16942.5)^2}$$

$$= 82881.65 \text{ V}$$

Line to line sending voltage.

$$= \sqrt{3} \times 82881.65 = 143555.22, V_L = 143.55 \text{ kV}$$

charging current at sending end. $I_{C2} = \frac{V_S}{V_S} \frac{j\gamma}{2}$

$$81131.5 + j16942.5 + j \frac{45710.5}{2}$$

$$= -3.81 + j18.25$$

sending end current, $\vec{I}_S = \vec{I}_L + \vec{I}_{C2}$

$$= (262.4 - j182.52) + (-3.81 + j18.25)$$

$$= 258.59 - j164.27$$

Therefore, the magnitude of sending end current =

$$= \sqrt{a^2 + b^2}$$

$$= \sqrt{(258.59)^2 + (-164.27)^2}$$

The angle = 306.35° A per

$$= \tan^{-1}(306.35) = 89.81$$

V.V.V.V.V. ipot

Q) A 100 km long 3 phase 50 Hz transmission line has the following line constants resistance per phase, per km = 0.01Ω , reactance per phase, per km = 0.5Ω , susceptance per phase per km = $10 \times 10^{-6} \text{ S}$

if the line supplies load of 20 MW at 0.9 power factor lagging at 66 kV at the receiving end,

calculate by nominal π method

- (1) sending end power factor, 0.9
- (2) regulation
- (3) Transmission efficiency

$$\text{Resistance per phase} = 100 \times 0.1 = 10 \Omega$$

$$\text{Reactance per phase} = 100 \times 0.5 = 50 \Omega$$

$$\text{total} = 100 \times 0.5 = 50 \Omega$$

$$\text{susceptance per phase}$$

$$= 100 \times 10 \times 10^{-6} = 10^{-3} S$$

$$\text{Receiving end voltage phase} = \frac{66 \times 10^3}{\sqrt{3}} = 3810.5 V$$

$$\text{load current } I_a = \frac{20 \times 10^6}{\sqrt{3} \times 3810.5} = 195 A$$

$$\cos \phi_R = 0.9$$

$$\Rightarrow \phi_R = \cos^{-1} 0.9 = 25.84$$

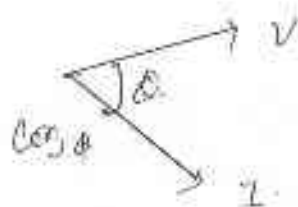
$$\sin \phi_R = \sin(25.84) = 0.435$$

$$I_L =$$

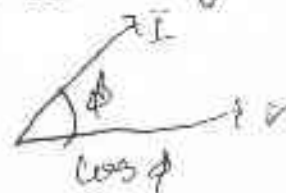
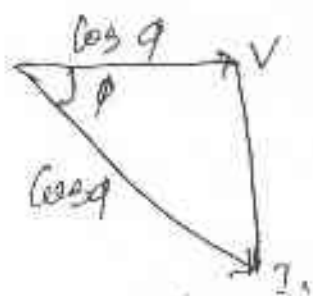
Power factor improvement.Power factor.

The cosine of the angle betⁿ voltage and current in an A.C. ckt is known as power factor.

The term $\cos \phi$ is called the power factor of the ckt. if the ckt is inductive the current lags behind the voltage and the power factor is referred to as lagging.



How ever in capacitive ckt the current leads the voltage and the power factor is said to be leading



The current ' I ' can be resolved into two rectangular components.

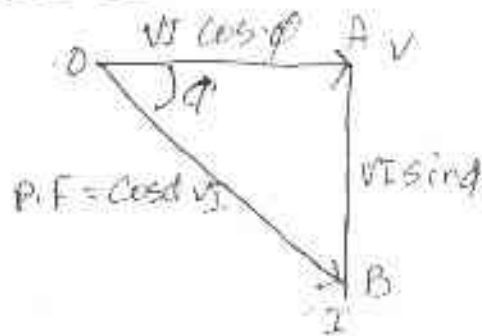
- $I \cos \phi$ in phase with voltage (V)
- $I \sin \phi$ - 90 out of phase voltage

→ The component $I \cos \phi$ is known as active or wattful component.

→ The component $I \sin \phi$ is called the reactive or wattless

- If the reactive component is small the phase angle ' ϕ ' is small and hence $\cos \phi$ will be high and vice versa.
- The value of power factor can never be more than unity.

→ Power Triangle



- OA $VI \cos \phi$ and represent in active power in watts or kW.
- AB $VI \sin \phi$ and represent in reactive power in VAR and kVAR.
- OB VI and represent the apparent power in VA or kVA.

The following points may be noted.

$$\rightarrow OB^2 = OA^2 + AB^2$$

or

$$\text{Apparent power}^2 = \text{active power}^2 + \text{reactive power}^2$$

$$\rightarrow \text{power factor, } \cos \phi = \frac{b}{h}$$

$$\cos \phi = \frac{OA}{OB} = \frac{\text{Active Power}}{\text{Reactive Power}}$$

Thus the power factor of a ckt is the ratio of active power to apparent power

$$\rightarrow \text{kVAR} = \text{kVA} \sin \phi$$

→ power factor $\cos\phi$ = cosine of the angle
betn V & I

$$\text{Power factor} = \frac{R}{Z} = \frac{\text{Resistance}}{\text{impedance}}$$

$$\text{Power factor} = \frac{V_L \cos\phi}{V_L} = \frac{\text{Active Power}}{\text{apparent power}}$$

D.A. of low power factor -

- large kVA rating of equipment.
- greater conductor size
- large copper losses
- core voltage regulation.
- Reduce handling capacity of system.

Causes of low power factor. U.2.16

* Most of the AC motors are induction type which have low lagging power factor. These motors work at power factor which is extremely small at light load and raises to 0.8 or 0.9 at full load.

* Arcs lamps, electric discharge lamps industrial furnaces operate at low power factor

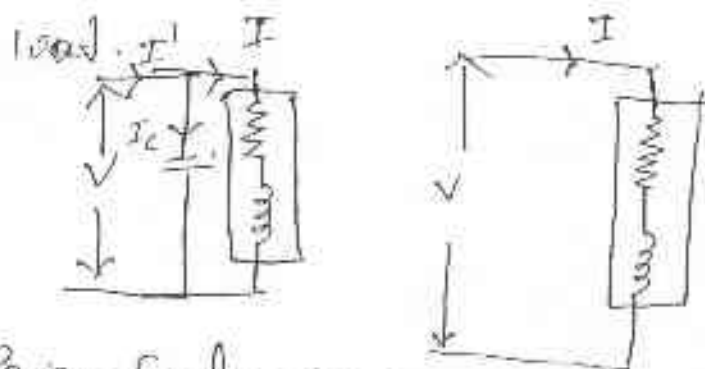
* The load on power system is varying. During low load period, supply voltage is increased which increases magnetisation current.

This results in decreased power factor.

4.2.16

Power factor Improvement

In order to improve the power factor, some device having leading power should be connected in parallel with the load. one of such devices is a capacitor. The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of total load current. This raises raises the power factor of the



Power factor improvement equipment.

The power factor can be improved by the following equipments

1. static capacitor
2. Synchronous Condensers
3. phase advancers

1. static capacitor.

The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (static) draws a leading current and partly & completely neutralizes the lagging reactive component of load current.

Advantages

They have low losses.

* required little maintenance.

* can be easily installed.

* can work under ordinary atmospheric conditions

Disadvantages

* short service life

* Easily damaged

* If capacitor is damaged the repair is uneconomical

2 Synchronous Condenser

A synchronous motor takes a leading current when over excited and behaves as a capacitor.

An over excited synchronous motor running on no load is called synchronous condenser.

Advantages

* By varying the field excitation, the magnitude of the current drawn by the motor can be changed.

* The motor windings have high thermal stability to short cut currents.

* fault can be removed easily

Disadvantages :- * There are considerable losses in motor. maintenance cost is high

* It produces noise

* As synchronous motor has no starting torque.

an auxiliary equipment has to be provided
phase ~~advance~~ - advances

phase advances are used to improve power factor of induction motor. If exciting ampere turns can be provided from some other AC source, the starter winding is relieved of exciting current and the power factor of the motor can be increased.

Advantages:

- * Lagging kVAR drawn by the motor are reduced.
- * It can be used where the use of synchronous motor is inadmissible.

Disadvantages:

They are not economical for motors below 250 H.P.

09-02-2016

11-02-2016.

Important terms & factors:-

1. Connected load.

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

2. Max^m demand.

* It is the greatest demand of load on the power station during a given period.

* The station must be capable of meeting the max^m demand.

* The max^m demand is generally less than

the connected load.

3. Demand factor

It is the ratio of max^m demand on the power station to its connected load

Demand factor = $\frac{\text{Max}^m \text{ demand}}{\text{Connected load}}$

* The value of demand factor is usually less than one because the max^m demand is less than connected load.

* The knowledge of demand factor is vital in determining the capacity of plant equipment

1. Average load

The average of loads occurring on the power station in a given period is called average load or average demand

Daily average load

Number of units

Daily average load = $\frac{\text{number of units generated in a day}}{24 \text{ hour}}$

~~monthly average load = $\frac{\text{No. of unit generated}}{3}$~~

~~no. of day in a month = 30 day~~

monthly average load = $\frac{\text{no. of units generated in a month}}{\text{no. of days} \times 24 \text{ in month}}$

yearly average load
$$= \frac{\text{no. of unit generated in a year.}}{8760 \text{ hours.}}$$

Load factor.

It is the ratio of average load to the max^m demand during a given period.

$$L.F = \frac{\text{Average load.}}{\text{max}^m \text{ demand.}}$$

- * Load factor is always less than one because average load is smaller than max^m demand.
- * It is used to determine the overall cost per unit generated.

Diversity Factor

The ratio the some of individual max^m demand to the max^m demand on the power station is known as diversity factor

$$\text{Diversity factor} = \frac{\text{some of individual max}^m \text{ demands.}}{\text{max}^m \text{ demand on power station.}}$$

- * The max^m demand on the power station is always less than the some of individual max demands

plant capacity factor

It is the ratio of actual energy produced to the max^m energy that could have been produced during a given period.

$$\text{plant capacity factor} = \frac{\text{Actual energy produced}}{\text{Max}^m \text{ energy that could have been produced}}$$

* i.e. = average demand by plant capacity

$$\text{* Annual plant capacity factor} = \frac{\text{Annual kWh op}}{\text{plant capacity} \times 8760}$$

* The plant capacity factor is an indication of the reserve capacitive plant.

$$\text{Reserve capacity} = \text{plant capacity} - \text{max}^m \text{ demand}$$

plant use factor

It is the ratio of kWh generated to the product of plant capacity and the no. of hours for which the plant was in operation

$$\text{plant use factor} = \frac{\text{op in kWh}}{\text{plant capacity} \times \text{hours of use}}$$

The curve showing the variation of load on the power station with respect to time is called a load curve.

The load on a power station varies from time to time. The load variation during the ~~the~~ whole day ^{or half} ^{as recorded} hourly or hourly and are plotted in a graph against the time the curve obtained is known as daily load curve.

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

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

Importance

The daily load curve has a greater importance in generation as they give the following information.

→ The daily load curve shows the variation of the load on the power station during different hours of the day.

→ The area under the daily load curve gives the no. of units generated in the day.

units generated per day.

= Area (in kWh) under daily load curve

→ The highest point on the daily load curve represents the max^m demand on that day.

→ The area under the daily load curve divided by the total no. of hour gives the average load on that day.

→ The ratio of the area under the load curve to the total area of rectangle in which it is contained gives the load factor

$$\text{Load factor} = \frac{\text{average load}}{\text{max}^m \text{ demand}}$$

→ The load curve helps in selecting the size and number of generating units

→ The load curve helps in preparing the operation schedule of the station

① $\text{max}^m \text{ demand} = 100 \text{ MW}$

$\text{annual load factor} = 40\% = 0.4$

Calculate energy generated in a year.

Solⁿ

Energy generated per year.

$$= \frac{\text{max}^m \text{ demand} \times \text{load factor} \times \text{hours in a year.}}{}$$

$$100 \times 10^6 \times 0.4 \times 8760 = 3.5 \times 10^{11}$$

② Connected load = 43 MW.

$\text{max}^m \text{ demand} = 20 \text{ MW}$

units generated = $61.5 \times 10^6 \text{ per annum.}$

① Calculate demand factor.

② Load factor.

Solⁿ

① Demand factor = $\frac{\text{max}^m \text{ demand.}}{\text{Connected load.}}$

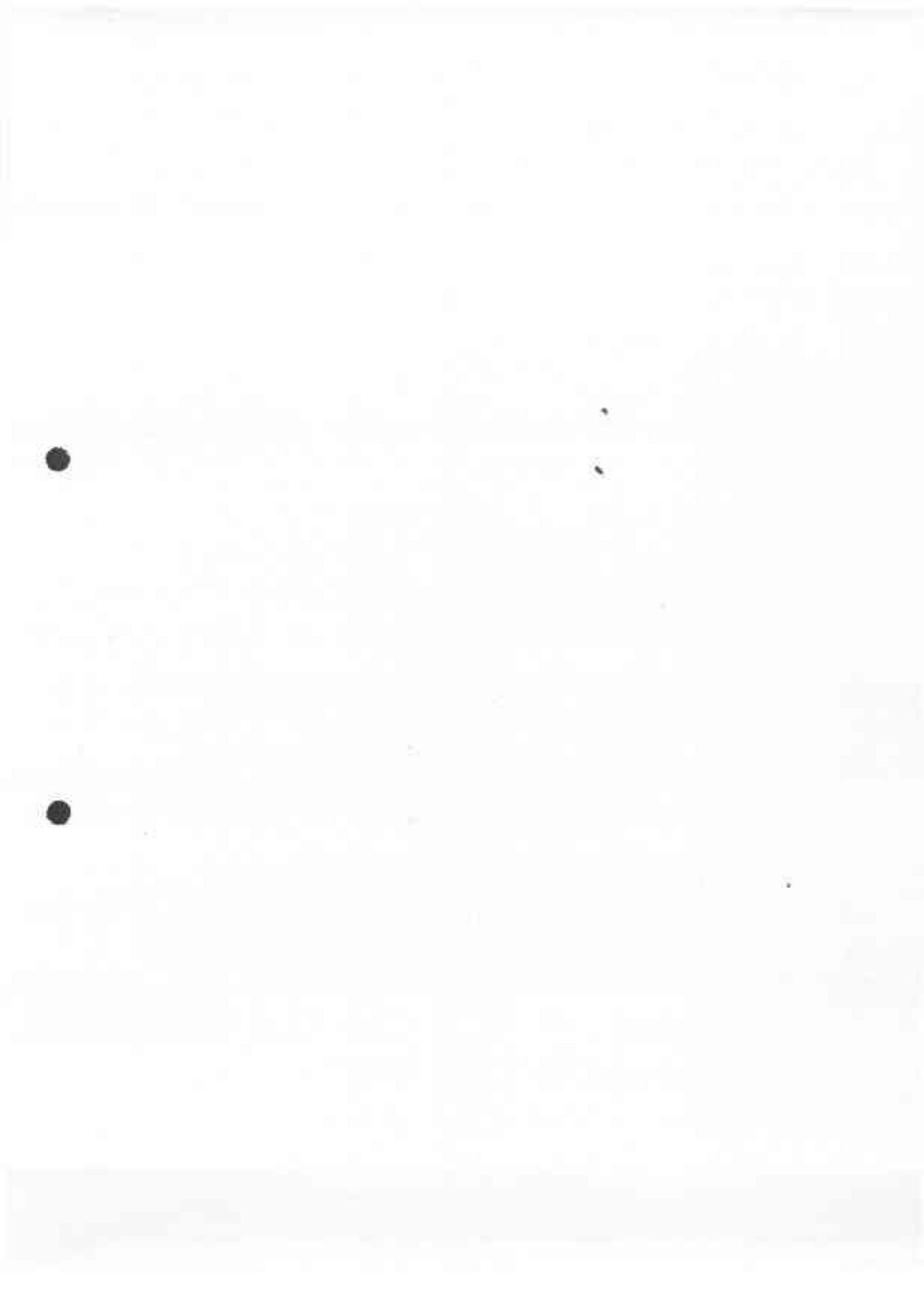
$$\frac{20}{43} = 0.465$$

② Load factor = $\frac{\text{Average demand.}}{\text{max}^m \text{ demand.}}$

Average load = $\frac{\text{Unit generated.}}{\text{no. of hours in year.}} = \frac{61.5 \times 10^6}{8760}$

= 7020 MW

load factor = $\frac{7020}{20} = 0.0351$



CH -
Distribution system.

23-02-2016

* The part of power station which distribute electrical power for local use for local use is called as distribution system

* It generally consists of feeders, distributors and service mains

Feeder.

A feeder is a conductor which connects the substation to the area where power is to be distributed. & generally no tappings are taken from the feeder so that current in it remains the same.

Distributors.

A distributor is a conductor from which tappings are taken for supply of consumer

* The current through a distributor is not constant because tappings are taken at various places

Service main.

A service mains is generally a small cable which connects the distributors to the consumer terminals.

Classification of distribution.

A distribution system can be classified according to

- 1- The nature of current.
- 2- types of construction.
3. scheme of connection

1- Nature of current.

According to the ~~nature~~ nature of current distribution system can be ~~classified into~~ as AC distribution system & DC dist. system.

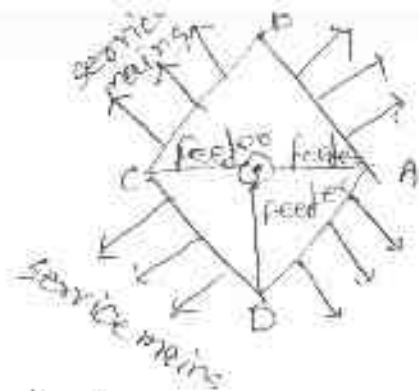
* It is universally adopted for distion of electrical power.

2- Types of Construction.

According to the type of construction distribution system can be classified as overhead & under ground distribution system.

3- scheme of connection.

According to the scheme of connection the dist. system can be classified as radial system, ring main system & interconnected system.



AC Distribution.

The AC dist. system is classified into .

- ① Primary distribution system.
- ② secondary " "

1- Primary Distribution system.

It is the part of AC distribution system which operates at voltage some what higher than general utilization and handles large electrical energy.

* The voltage used for primary distribution depend upon the amount of power to be fed and the distance of substation.

* The most commonly used primary distribution voltage are 11 KV, 33 KV & 6.6 KV

* Primary distribution is carried out by 3 phase 3 wire system.

2- secondary distribution system.

It is a part of AC distribution system system which includes voltages at which the ultimate consumer utilizes the electrical energy delivered.

The secondary distribution employs $400/230\text{ V}$
3 phase 4 wire system

Dc Distribution.

for certain applications Dc supply is absolutely necessary for this purpose Ac power is converted into Dc power by rectifier, inverter converter and motor generator sets.

* The Dc supply from the substation may be obtained in the form of two wire, 3 wire for ~~2~~ distribution

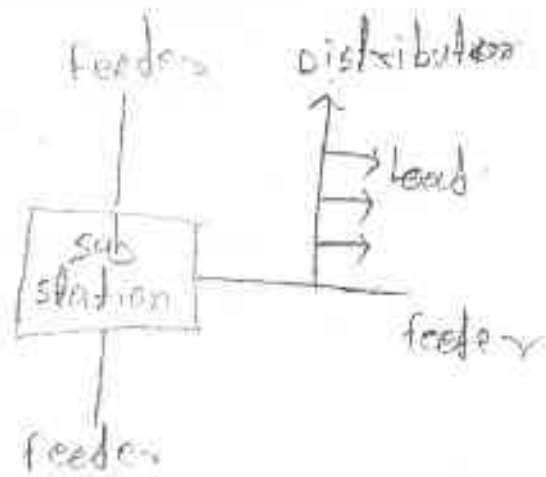
Connection schemes of Distribution system.

25-02-2021

* All distribution of electrical energy is done by constant voltage system. The following distribution cut are generally used-

① Radial system $\rightarrow$

In this system separate feeders radiate from a single substation and feed the distributors at one end only



The radial system is employed only when power is generated at low voltage and the sub station is located at the centre of the load

* This is the simplex distribution circuit and has lower initial cost

Disadvantages -

* The end of the distributor nearer to the feed point will be heavily loaded.

* The consumers are dependents on a single feed and a single distributor. Any fault on the feeder or distributor cuts off supply to the consumer

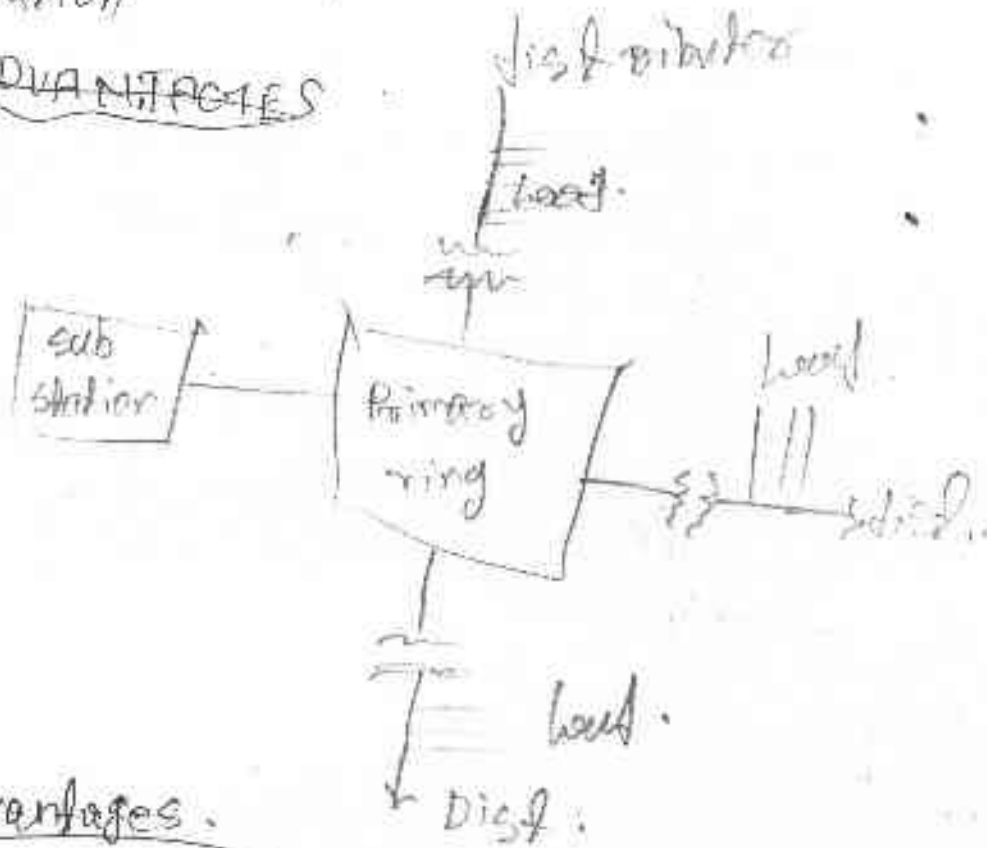
* The consumers at distant end of the distributor, there would be serious voltage ~~fluctuation~~ fluctuations when the load on the changes

Note - Due to this disadvantages this system is used for short distances only

Ring main system.

* In this system the primaries of distribution transformer form a loop. The loop cut starts from the substation bus bars, makes a loop through the area to be served and returns to the substation.

ADVANTAGES



advantages.

- * There are less voltage fluctuation and Consistent performance.
- * The system is very reliable as each distributor is fed by two feeders. In the even of fault of the feeders, the Continuity of supply is maintained.

Inter Connected system.

when the feeder ring is energised ^{fed from} ~~the~~ more than ^{two} generating system or substation then it is called inter connected system.

Advantages.

- * It increases the system reliability.
- * It reduces reserve power capacity & increase efficiency of the system.

Requirement of a distribution system.

- * Proper voltage
- * Availability of power on demand.
- * Reliability.

DC distribution.

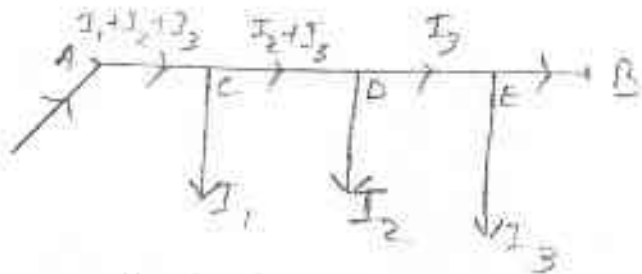
Types of DC Distributors.

- Distributor ^{fed} ~~fed~~ at one end.

DC distribution

Types of distribution

1) Distributor feed at one end:



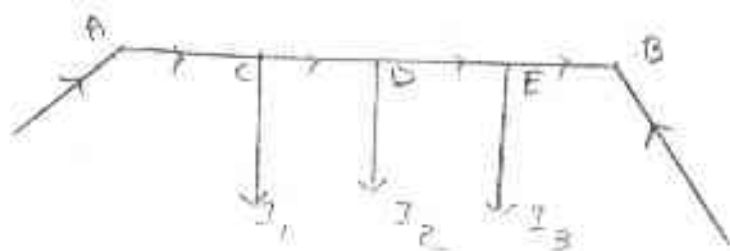
- In this type of feeding the distributor is connected to the supply at one end and loads are taken at different points along the length of the distributor.
- * It is also called singly fed distributor.

Disadvantages

- * The current in various sections goes on decreasing.
- * The voltage across the load goes on decreasing.
- * In case of a fault the whole distributor is disconnected from the supply mains. Therefore continuity of supply is interrupted.

2) Dis.

2) Distributor feed at both end :-



In this type of feeding the distributor is connected to the supply mains at both end & loads are tapped off at different points along the distributor.

ADVANTAGE.

* If a fault occurs, the continuity of supply is maintain from other feeding point.

* The area of X-section required for a doubly feed distributor is much less than that of a single feed distributor.

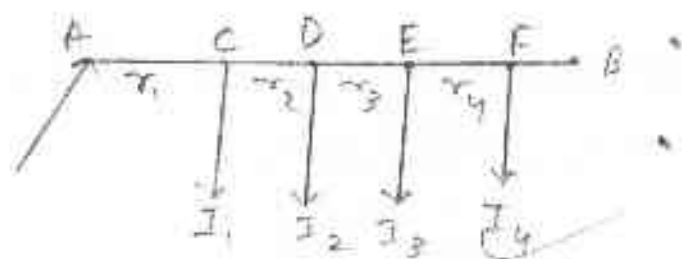
3) Distributor feed at a center :-



* In this type of feeding the centre of the distributor is connected to the supply mains.

v) Ring mains — :

* In this type of the distributor is in the form of a closed ring. The distributor ring may be fed at one or more than one point.
DC distributor fed at one end.



Let

r_1, r_2, r_3, r_4 be the resistances of both wires of the section ABC, CBD, DDE, EFF, FBB

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

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

" " " CBD = $I_2 + I_3 + I_4$

" " " DDE = $I_3 + I_4$

" " " EFF = I_4

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

" " " " CBD = $r_2 (I_2 + I_3 + I_4)$

" " " " DDE = $r_3 (I_3 + I_4)$

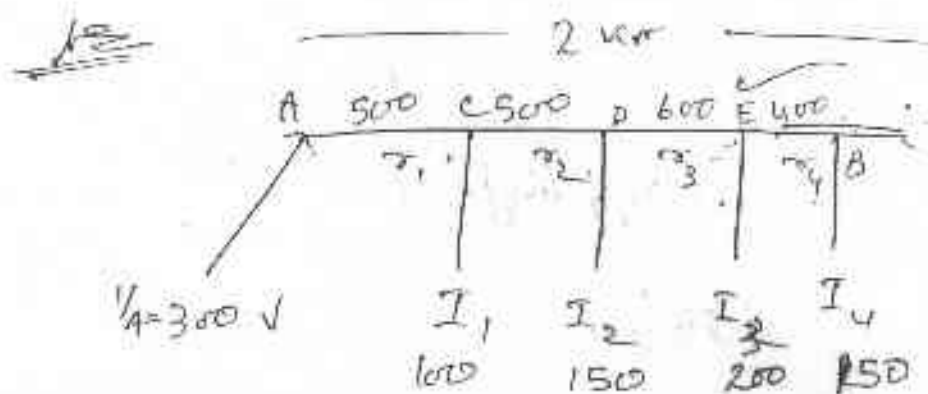
" " " " EFF = $r_4 (I_4)$

Total voltage drop of the distribution.

$$r_1(I_1 + I_2 + I_3 + I_4) + r_2(I_2 + I_3 + I_4) + r_3(I_3 + I_4)$$

Q) A two wire DC distributor cable A, B is 2 km long & supplies loads of 100A, 150A, 200A, 150A

loads situated 500m, 1000m, 1600m & 2000m from the feeding point A. Each conductor has a resistance of 0.01 Ω per 1000 m. Calculate P.D at each load point if a P.D of 300V is maintained at point A.



Current in sec. A-B = $100 + 150 + 200 + 150 = 500$

C-D = $150 + 200 + 150 = 500$

D-E = $200 + 150 = 350$ A.

E-B = 150 A.

Resistance in sec. AC = $500 = \frac{0.01}{1000} \times 500 = 0.005 \Omega$

$V_C = V_A - I_{AC} \times R_{AC} = 300 - (500 \times 0.005) = 297.5V$

"

Resistance in sec. CD = 0.005Ω

$V_D = 297.5 - (500 \times 0.005) = 295.5V$

$$R_E = 0.006 \Omega$$

$$V_E = 295.5 - (250 \times 0.006) = 293.5$$

$$R_B = 0.004 \Omega$$

$$V_B = 293.5 - (50 \times 0.004) = 293.3 \text{ V}$$

EC

27.02.2016

- 3) (a) at what condition the η of a T-F is max
 b) Derive the emf eqn of a single phase T-F with usual notation.

(c) The no load current of a TF is 4A and 0.25 power factor when supplied at 250 V at 50 Hz. The no. of turns the primary winding is 200. Calculate,

(1) Flux in the core

(2) Core loss

2) (a) In DC shunt motor if the field terminals are reversed then what happens to its speed.

b) Derive torque eqn of a DC motor with usual notation

(c) The η of a 250 V of DC shunt motor is 11% at no load current is ~~5~~ 5 A., no load speed

150 rpm armature resistance 0.5Ω & armature field resistance is 10Ω . Calculate.

① The torque developed.

② The speed at full load.

3) (a) write two important causes for which DC shunt generator may not build up its voltage.

(b) Derive the emf eqn of a DC generator.

(c) A 25 kW 250 V DC shunt generator has an armature & field resistance of 0.6Ω and 100Ω respectively. Determine total developed power developed when running

① As a generator, delivering 25 kW

② As a motor taking 25 kW

12 Resistance per wire

$$1000 \text{ m} = 0.01 \Omega$$

$$\text{Total resistance} = 2 \times 0.01 \Omega$$

$$1000 \text{ m} = 0.02 \Omega$$

$$\text{Current in section AC} = 100 + 150 + 200 + 50 = 500 \text{ A}$$

$$\text{CD} = 400 \text{ A}$$

$$\text{DE} = 250 \text{ A}$$

$$\text{EB} = 50 \text{ A}$$

Resistance is $\text{sec. AC} = \frac{0.02}{1000} \times 500 = 0.01 \Omega$

N // //

$$CD = 0.01$$

$$DE = 0.012$$

$$EB = 0.008 \Omega$$

$$V_C = V_A - (500 \times 0.01) = 300 - 5 = 295$$

$$V_D = V_C - (400 \times 0.01) = 295 - 4 = 291 \text{ V}$$

$$V_E = V_D - (250 \times 0.012) = 291 - 3 = 288 \text{ V}$$

$$V_B = V_E - (50 \times 0.008) = 288 - 0.4 = 287.6 \text{ V}$$

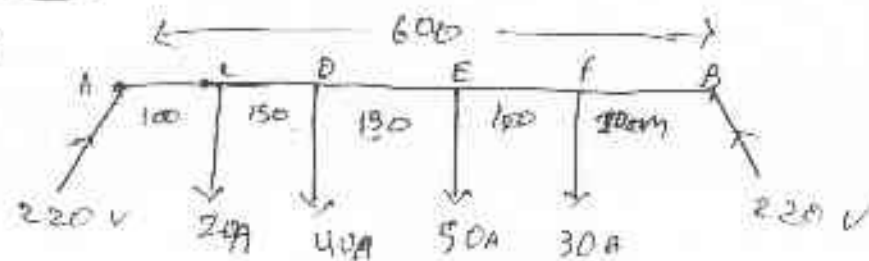
Distributor fed at both ends.

→ Two ends fed with equal voltages.

A two wire DC street main AB 600 m long is fed from both the ends at 220 V. load of 20, 40, 50, 30 A are tapped at distance of 100 m, 250 m, 400 m, 500 m. If the area of x-section of distributor

conductor is 1 cm^2 Find the minimum consumer voltage

Take $\rho = 1.7 \times 10^{-6} \Omega \text{ cm}$



Current in sec. AC = $(I_A - 20) \text{ A}$

// // CD = $(I_A - 60) \text{ A}$

// // EF = $(I_A - 110) \text{ A}$

// // // FB = $(I_A - 140) \text{ A}$

we know that

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

$$l = 2 \text{ m} = 100 \text{ cm}$$

$$\rho = 1.7 \times 10^{-6} \Omega \cdot \text{cm}$$

$$a = 1 \text{ cm}^2$$

$$R = 1.7 \times 10^{-6} \times \frac{100 \text{ cm}}{1 \text{ cm}^2}$$

$$= 1.7 \times 10^{-4}$$

$$\text{Total resistance} = 2 \times 1.7 \times 10^{-4}$$

$$= 3.4 \times 10^{-4} \Omega$$

$$AC = 3.4 \times 10^{-4} \Omega = 0.034$$

$$CD = (3.4 \times 10^{-4} \times 150) = 0.051$$

$$DE = (3.4 \times 10^{-4} \times 150) = 0.051$$

$$EF = (3.4 \times 10^{-4} \times 150) = 0.051$$

$$FB = 3.4 \times 10^{-4} \Omega = 0.034$$

$$V_B = V_A - I_A (0.034) - (I_A - 20) 0.051 - (I_A - 60) 0.051 - (I_A - 110) 0.051 - (I_A - 140) 0.034$$

$$V_B = V_A - I_A [0.034 + 20 \times 0.051 + 60 \times 0.051 + 110 \times 0.051 + 140 \times 0.034]$$

$$\Rightarrow 2.20 - I_A (12.55)$$

$$0.204 I_A = 12.55 \Rightarrow I_A = \frac{12.55}{0.204} = 61.51$$

$V_E = \text{Current } AC = I_A = 61.51 \text{ A}$

27-02-2016

$$CD = I_A - 20 = 61.51 - 20 = 41.51$$

$$DE = 61.51 - 60 = 1.51$$

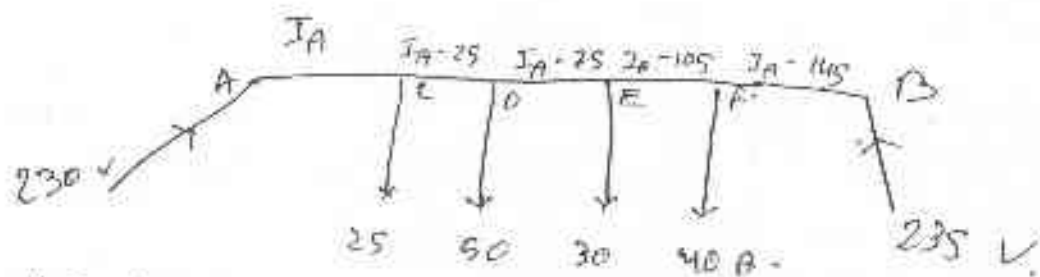
$$ED = 61.51 - 110 = -48.49$$

$$FB = 61.51 - 140 = -78.49$$

$$V_E = V_A - (0.034)(61.7) - (0.051)(41.7) - (0.057)(1.7)$$

$$= 220 - 4.31$$

$$= 215.69 \text{ V}$$



$$R = 0.6 \Omega / 1000 \text{ m}$$

Resistance for sec. $AC = \frac{0.6}{1000} \times 50 = 0.03 \Omega$

" " " $CD = \frac{0.6}{40} = 0.015 \Omega$

$$DE = 0.015$$

$$EF = 0.03$$

$$FB = 0.03$$

~~Current for sec. AC = $(I_A - 25) \times$~~

~~$V_B = V_A - I_A \times (0.03)$~~

$$I_A = 33.34 \text{ A}$$

current at section DC = 33.34

" " " " CD = 8.34 A

" " " " DE = $I_A - 75 = -41.66$

EF = $I_A - 105 = -71.66$ A

FB = -111.66 A

$$V_B = 230 - (33.34)(0.03) - (8.34)(0.015) \\ = 228.875 \text{ V}$$

Total power loss

$$I_A^2 R = (33.34)^2 \times 0.03 + (8.34)^2 \times 0.015 + \dots$$

AC Distribution.

03-03-2016

ac distribution calculation differ from those of dc distribution in the following respect —

- * In case of dc system the voltage drop is due to resistance only. However in ac system it depends on inductance, resistance & capacitance
- * In dc system the addition and subtraction of voltages and current are done numerically. But in case of ac system it is done vectorially
- * In dc system the power factor is not taken into account.
- * But in an ac system the power factor is taken into account.

Method of solving ac distribution problem.

In ac distribution calculation, power factor of various load current have to be considered since

Current will be the vector sum & not the arithmetic sum. The power of load current may be given —
 $1 \div$ with the respect to ~~send~~ receiving or sending end voltage
 $2 \div$ " " " load voltage if self
Power factor refer to ^{receiving} end voltage.



Let's
 Consider an AC distributor A B C
 with concentrated load of I_1 & I_2 tapped off at
 point B & C respectively. Taking the receiving end
 voltage V_c as the reference vector, let lagging
 power factor at B & C be $\cos \phi_1$ & $\cos \phi_2$ with r.c. to V_B
 Let R_1, X_1 & R_2, X_2 be the resistance & reactance
 of section AB & BC respectively.

Impedance of se. AB, $\vec{Z}_{AB} = R_1 + jX_1$
 " " " BC, $\vec{Z}_{BC} = R_2 + jX_2$

load current at point B, $\vec{I}_1 = I_1 (\cos \phi_1 - j \sin \phi_1)$
 " " " " C, $\vec{I}_2 = I_2 (\cos \phi_2 - j \sin \phi_2)$

current in sec. BC, $\vec{I}_{BC} = \vec{I}_2 = I_2 (\cos \phi_2 - j \sin \phi_2)$

" " " " AB, $\vec{I}_{AB} = \vec{I}_1 + \vec{I}_2 = I_1 (\cos \phi_1 - j \sin \phi_1) + I_2 (\cos \phi_2 - j \sin \phi_2)$

voltage drop in sec. BC, $\vec{V}_{BC} = \vec{I}_2 \vec{Z}_{BC}$

$= \vec{I}_2 (R_2 + jX_2)$

" " " " AB, $\vec{V}_{AB} = (\vec{I}_1 + \vec{I}_2) \vec{Z}_{AB}$

sending end voltage, $\vec{V}_A = \vec{V}_C + \vec{V}_{BC} + \vec{V}_{AB}$

" " current, $\vec{I}_A = \vec{I}_1 + \vec{I}_2$

2) Power factors refer to respective load voltages.

Let,

ϕ_1 be the phase angle betⁿ V_B & $\vec{I}_1$ and ϕ_2 is the phase angle betⁿ V_C & $\vec{I}_2$

voltage drop in section BC, $\vec{V}_{BC} = \vec{I}_2 \vec{Z}_{BC}$

" at point, C = $\vec{V}_C$ + drop in sec. BC

~~voltage at~~ $\vec{V}_C$ = $V_B \angle \alpha$

Now $\vec{I}_1 = I_1 \angle -\phi_1$ with respect to voltage V_B

$\vec{I}_1 = I_1 \angle -(\phi_1 - \alpha)$ with respect to voltage V_C

$\vec{I}_1 = I_1 [\cos(\phi_1 - \alpha) - j \sin(\phi_1 - \alpha)]$

$\vec{I}_{AB} = \vec{I}_1 + \vec{I}_2$

voltage drop in sec. AB = $\vec{I}_{AB} \vec{Z}_{AB}$

$\therefore$ voltage at point A = V_C + drop in BC + drop in AB

CHAPTER-

23.02.2016

UNDER GROUND CABLE

An under ground cable essentially consist of one or more conductor covered with suitable insulation and surrounded by protecting cover.

* A cable must fulfill the necessary requirements —

i → It should be sinned stranded copper or aluminium of high conductivity

ii → The conductor size should be such that the cable carries the current without over heating and causes voltage drop within limits

iii → The cable must have proper thickness of insulation in order to give high safety and reliability

iv → The cable must be provided with suitable protection so that it may withstand the rough use in laying heat.

v → The materials used for the manufacturing of the cables should be complete chemical & physical stability

Construction of cable.

A) ~~Cable~~ Cores or Conductors :-

A cable may have one or more than one core depending up on the type of service.

→ ~~The~~ Cable

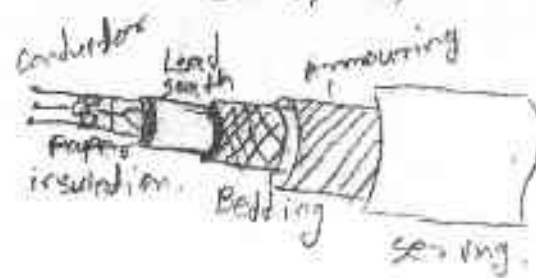
B) Insulation :-

Each core is provided with suitable thickness of insulation, depending upon the voltage to be with stood by the cable.

Ex - paper, wood, rubber

C) Metallic sheath :-

In order to protect the cable from moisture gasses or other daymasing liquid in the soil and atmosphere a metallic sheath is provided over the insulation.



Bedding

In order to over the metallic sheath is applied a layer of bedding which consist of material like Jute. The purpose of bedding is to protect the metallic sheath from ~~corrosive~~ corrosion.

Armouring over the bedding.

- Armouring is provided to protect the cable from mechanical injury.

It consist of one or two layers of galvanised steel wire or steel tape.

Serving

In order to protect the armouring from the atmospheric condition a layer of material like Jute is provided over the armouring. This is called serving.

Insulating materials for Cable.

1) Rubber

1) Vulcanised india rubber (VIR)

2) Impregnated paper

3) Varnished cambric

4) Polyvinyl chlorid. (PVC)

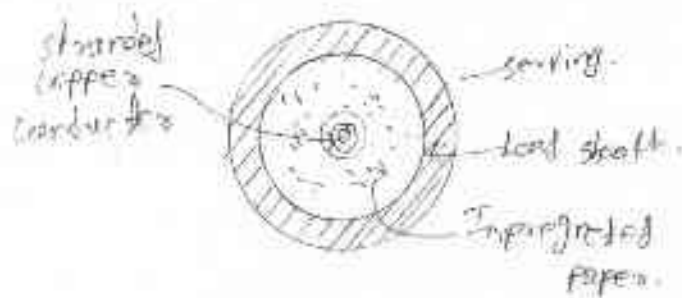
Classifications of Cable

04-03-2016

The cables can be classified as follows -

- 1) Low tension (LT) cables, range 1000 V.
- 2) High tension (HT) " " 11 kV to 11 kV
- 3) Super tension (ST) " " 22 kV / 33 kV.
- 4) Extra high tension (EHT) " " 33 kV / 66 kV.
- 5) Extra super voltage (ESV) " beyond 132 kV.

1. Low Tension Cable (LT)



It consists of one circular core of tinned stranded copper insulated by Impregnated paper. The insulation is surrounded by lead sheath. Finally serving is provided over lead sheath to protect the lead sheath from corrosion.

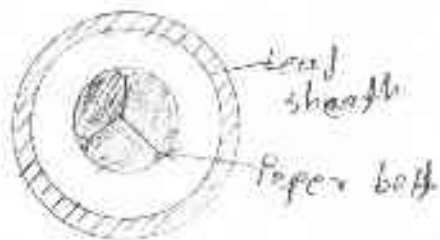
2 HT cable.

under ground cables are generally required to deliver 3 ϕ power for the purpose either 3 core cable or 3 single core cables may be used.

The following types of cable are generally used for ~~are generally used~~ 3 ϕ service

- 1- Belted. cable up to 11 kV.
- 2- Screened " " 22 kV / 66 kV.
- 3- pressure " beyond 66 kV.

Belted Cables.



These Cables are used for voltages up to 11 kV.

These core are ^{insulated by} each other by layers of impregnated paper. Another layer of Impregnated paper tape, called paper belt is wound round the cores.

→ The belted types cables is suitable for low and medium voltages

laying of under ground cable.

- * Direct laying :- This method of laying under ground cables is simple and cheap.
 - In this method a trench about 1.5 m deep and 2.5 cm wide is dug. The trench is covered with a layer of sand and the cable is laid over the sand bed. The sand prevents the entry of moisture from the ground.

Advantages.

- It is simple and less costly.
 - It gives the best conditions for dissipating the heat generated in the cables.
 - It is clean and safe method, and free from external disturbances.

Disadvantages.

- The maintenance cost is very high.
 - Localization of fault is difficult.
 - It can't be used in congested area because excavation is expensive and inconvenient.
 - The alteration in the cable network is

difficult.

Draw In system.

In this method ~~Ground~~ Conduit or duct of glassed stone or cast iron or concrete are laid in the ground with main holes.

The cables are then pulled in to position from main hole.

Advantages.

Repairs, alterations or addition to the cable network can be made without opening the ground.

* As the cables are not armoured, therefore joint becomes ant maintenance cost is reduced.

* There are very less chances of fault occurrence due to strong mechanical protection.

Disadvantages.

→ The initial cost is very high.

* The current carrying capacity of the cables is reduced.

Solid system

* In this method of laying, the cable is laid in open pipes or through dug out in earth along the cable route.

Disadvantages

- It is more expensive
- It required shielded cables.
- Due to poor heat dissipation the current carrying capacity is reduced.

Types of cable fault

The following are the fault most likely to occur in underground cable

1- open cut fault :-

when there is a break in the conductor of a cable it is called an open cut fault.

* The ~~off~~ open cut fault can be checked by a megger

2- short cut fault

when two conductors of a multi core cable come in electrical contact with each other due to insulation failure it is called short cut fault.

for this purpose the 2 terminals of the megger are connected to any two conductors

3- Earth fault.

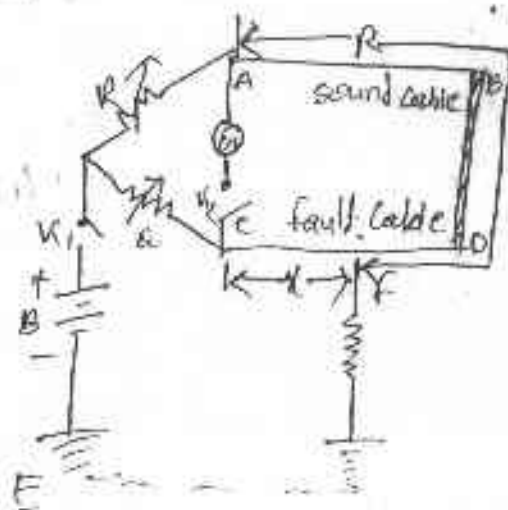
when the conductor of a cable comes in contact with earth it is called earth fault or ground fault. To identify this fault one terminal of the megger is connected to the conductor and the other terminal to the earth.

Loop test for location of fault.

In underground cables.

1- Murray loop test :-

i) Earth fault.



Let R = resistance of the conductor loop up to the fault from the test end

x = resistance of the other length of the loop.

In the balanced position of the bridge,

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

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

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

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

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

If l is the length of each cable, then resistance
per meter length of cable
 $= x/l$

$\therefore$ distance of fault from test end.

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

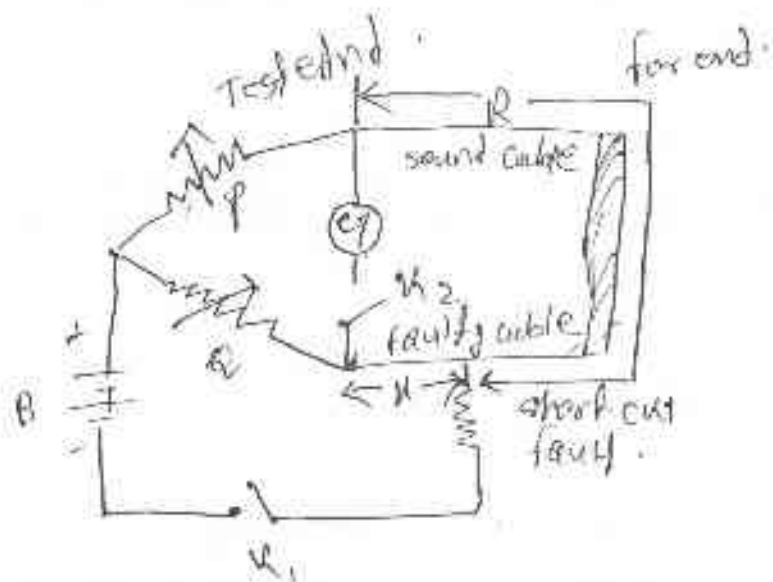
$$= \frac{Q}{P+Q} \times 2l$$

$$= \frac{Q}{P+Q} \times \text{loop length}$$

08-03-2018

(ii) short circuit fault.

25-03-2016.



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

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

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

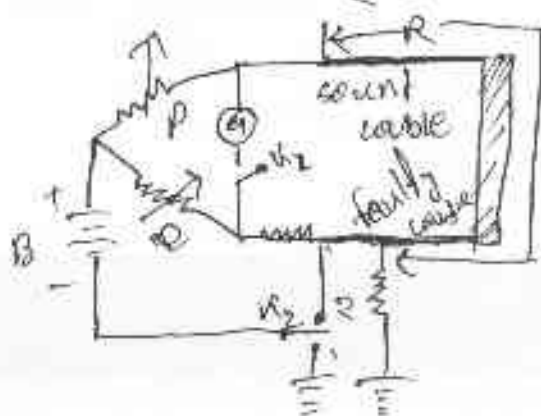
$$\Rightarrow \frac{P+Q}{R} = \frac{2X}{X}$$

$$\Rightarrow X = \frac{a}{P+Q} (2R)$$

$$\Rightarrow \frac{a}{P} \text{ (loop length) in meters.}$$

Thus the position of the located.

Wheeler loop test.



$$\frac{P}{Q} = \frac{R}{X+S_1} \quad (\text{Add 1})$$

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

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

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

It is happen, when K_2 is thrown in to posⁿ (1)

K_2 is thrown to posⁿ (2)

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

$$\Rightarrow (R+X)Q = PS_2 \quad \text{--- (2)}$$

~~$X = PS_2$~~
from equⁿ 1 & 2, we get.

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

Since the values of P, Q, S_1, S_2 are known, the value of X can be determine

Loop resistance, $R+X$

$$= \frac{P}{Q} S_2$$

if R is the resistance is the cable per meter length the distance of the fault from the line 1.

$$d = \frac{x}{y} m$$

a) murray loop test is performed on a faulty cable 300 m long. At balance, the resistance connected to the faulty core was set at 15Ω and the resistance of the resistor connected to the sound core was 45Ω . Calculate the distance of the fault from the test end.

$$R = 45 \Omega$$

$$Q = 15 \Omega$$

$$x = 300 m$$

We know that

$$\text{distance } d = \frac{Q}{P+Q} (2x)$$

$$= \frac{15}{45+15} (2 \times 300) = 150 m.$$

a) In a test by murray loop for ground fault on 500 m cable. having a resistance of $1.6 \Omega/km$ the faulty cable is loop with a sound cable of the same length and area of cross-section. If the ratio of the other two arms of the testing network at balance is 3:1, find the distance of the fault from the testing end. of the cable.

OM

Given

$$r = 500$$

$$\frac{p}{a} = \frac{3}{p}$$

$$\text{So } \frac{p+1}{a} = 3+1$$

$$\Rightarrow \frac{p+a}{a} = 4$$

$$\text{So } d = \frac{a}{p+a} (2r)$$

$$\Rightarrow d = \frac{1}{4} \times 2 \times 500 \left[\frac{p+a}{a} = 4, \text{ so } \frac{a}{p+a} = \frac{1}{4} \right]$$
$$= 250 \text{ m}$$

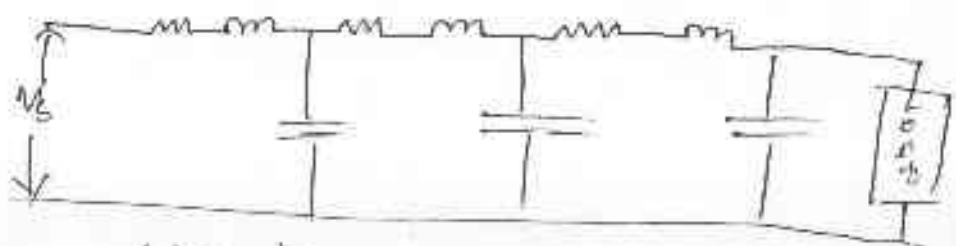
Chapter-5

5-3-16.

Extra high voltage EHV Transmission lines.

Generally the voltages of 300 kV - 765 kV are considered as extra high voltage transmission line.

* Generally E.H.V. AC lines are selected for long distances 150 km or above and high power of 500 mega watt or above.



Line diagram of E.H.V. Transmission line.

surge impedance $Z = \sqrt{\frac{L}{C}}$ Ω

Surge impedance is the square root of the ratio of the line inductance and the line capacitance.

Reasons for adoption of EHV Transmission line.

for a given amount of power to be transmitted over a given distance, the transmission efficiency increases as the transmission voltage is increased.

* In the EHV lines the per unit resistance drop decreases and volume of the conductor material decreases.

* The line ~~installation~~ ^{installation} cost per MW per km decreases with increase in voltage.

* The power transmitting capacity of a transmission line at the EHV range increases suddenly as the transmission capacity is proportional to the square of the transmission voltage.

Surge impedance loading.

If the surge impedance is equal to the load impedance then it is called surge impedance loading.

$$SIL = \frac{V^2}{Z_0}$$

where Z_0 = surge impedance.

Problems Involved in EHV Transmission Lines

(i) Corona loss & radio-interference

→ The corona loss in EHV transmission line is more and hence greatly interference with T.V. and radio signals.

* To reduce the corona loss the spacing betⁿ the conductors are increased, hence the cost of support will be increased.

* The diameter of the conductor increases by using hollow conductor but the manufacturing of hollow conductor is very difficult.

B. Line support

EHV lines have large mechanical loading in towers.

* The transmission tower with fabricated steel members are mostly being used.

* The cost of steel tower varies from 20% to 30% of the total cost of the line for voltages up to 500 kV.

* The ~~terific~~ wind pressure during storms & cyclones causes heavy damage to towers, conductors and insulators.

c. Erection difficulty.

The erection of EHV line possess the wide range ~~of~~ ^{of} requiring extremely high standard maintenance.

Insulation requirement.

The magnitude of voltage surges determines the required line insulation level.

* This surges may be due to internal causes (switching operation) or due to external causes (lightning).

e. power station & sub-station equipment.

* The design and manufacturing of sub power sub-station equipment also undergoes so revolutionary changes occurs.

High Voltage DC transmission line.

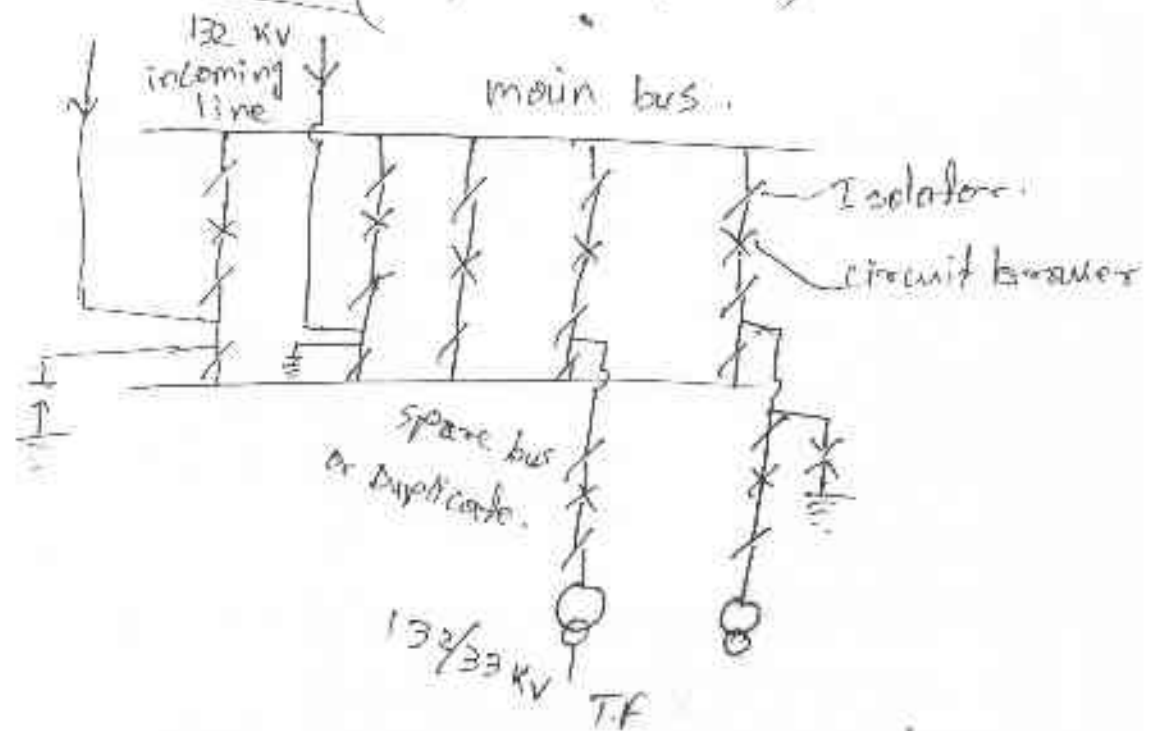
The principle of HV DC transmission system consist of one rectifier station at the sending end side and one inverter station

at the receiving end side.

* The two stations are interconnected by a DC Transmission line.

* The Varying the firing angle of the thyristor in the Converter the DC output voltage magnitude is controlled.

Way out
of E.H.T sub station. ($132/33$ or $132/16$ kV)



Substation Earthing.

The ^{the} parts of earthing system includes a metallic solid conductor betⁿ earthed points and the under-ground earth mat.

- The earth points are held near earth potential by low resistance conductor connection with earth mat called the earthing grid.
- several identical earth electrodes are driven vertically in to the soil and welded to the earthing rods of the under ground mesh.
- Earthing ~~con~~ Connections are galvanised steel strips or electrolytic copper flats or flexible cable.

The substation earthing system is provided for the following purposes.

1. Safety of operational and maintenance staff
2. Discharge of electrical charges to the ground
3. Electromagnetic interference.

Earthing of Transmission line.

In transmission line a conductor placed on top of the tower having comparatively smaller diameter than other conductors (line conductor) is provided for earthing purpose, this conductor is known as ~~→~~ this earthing conductor.

→ Purpose of Earthing -

- To ensure that no current carrying conductor raise to a greater potential than its design insulation

- To ensure that the potential of non-current carrying metal work doesn't raise to a value such that a person may get shock on touching it

short type.

- 1) what is sub-station & types?

2)

$$\underline{1 \text{ kWh} = 860 \text{ units}}$$