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

July/August,2023 | **Electrical and Electronics Engineering**

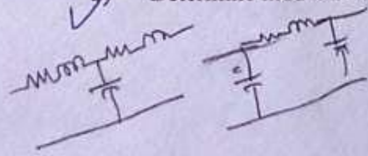
Fourth Semester | **Generation and Transmission**

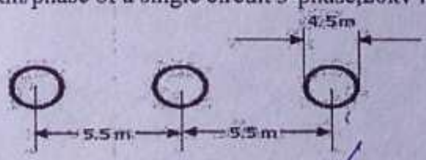
Time: Three Hours | **Maximum: 70 Marks**

Answer question 1 compulsory. (14X1 = 14Marks)

Answer one question from each unit. (4X14=56 Marks)

			CO	BL	M
1	a)	Define tariff.	CO1	L1	1
	b)	List any three causes of low power factor?	CO1	L1	1
	c)	Define plant use factor.	CO1	L1	1
	d)	List any three disadvantages of a thermal power plant?	CO2	L1	1
	e)	Define Nuclear Fission.	CO2	L1	1
	f)	What are main Components in Wind Power plants.	CO2	L1	1
	g)	Draw equivalent T network.	CO3	L1	1
	h)	Define voltage regulation.	CO3	L1	1
	i)	What is sag?	CO4	L1	1
	j)	List any one advantage of corona loss.	CO4	L1	1
	k)	Define string efficiency.	CO4	L1	1
	l)	List the Types of power stations.	CO1	L1	1
	m)	List the types of types of boilers in Thermal power plants.	CO2	L1	1
	n)	Define GMD.	CO3	L1	1
		Unit-I			
2	a)	i) Explain different types of tariff's. ii) A supply is offered on the basis of fixed charges of Rs 30 per annum plus 3 paise per unit or alternatively, at the rate of 6 paise per unit for the first 400 units per annum and 5 paise per unit for all the additional units. Find the number of units taken per annum for which the cost under the two tariffs becomes the same.	CO1	L2	7M
	b)	Discuss the various methods for power factor improvement	CO1	L2	7M
		(OR)			
3	a)	What do you understand by the load curve? What information's are conveyed by a load curve ?	CO1	L3	7M
	b)	Explain the terms load factor and divesity factor. How do these factors influence the cost of generation?	CO1	L2	7M
		Unit-II			
4	a)	Draw a general layout of a modern thermal power plant and explain the working of different circuits.	CO2	L4	7M
	b)	Explain the I-V and P-V characteristics of PV panels.	CO2	L2	7M
		(OR)			
5	a)	Enumerate & explain essential components of a nuclear reactor	CO2	L2	7M
	b)	Draw a neat schematic diagram of a hydro-electric plant and explain the functions of various components.	CO2	L4	7M
		Unit-III			
6	a)	Derive an expression for capacitances of a single phase transmission system and discuss the effect of earth on capacitance with suitable equation.	CO3	L3	7M
	b)	Derive expression for surge impedance. And also Explain the Ferranti effect in long transmission lines.	CO3	L3	7M
		(OR)			
7	a)	Derive the expression for ABCD parameters of medium transmission lines by π- method draw the vector diagram.	CO3	L3	7M
	b)	Determine inductance /km/phase of a single circuit 3-phase,20kv line shown below figure	CO3	L4	7M





			CO	BL	M
		Unit-IV			
8	a)	Discuss various methods for improving the string efficiency in a string of insulators.	CO4	L3	7M
	b)	Show how the sag of an overhead line can be calculated in case of supports at different levels.	CO4	L2	7M
		(OR)			
9	a)	Describe the phenomenon of corona? How can the corona loss is minimized in transmission lines.	CO4	L2	7M
	b)	Derive the expression for wave equation of a travelling wave.	CO4	L4	7M

II/IV B.Tech (Supplementary) DEGREE EXAMINATION

July/August, 2023 **Electrical & Electronics Engineering**

Fourth Semester **Genaratiom and Transmission**

Time: Three Hours **Maximum:** 70 Marks

Scheme of Evaluation

Answer Question No.1 compulsorily. (14X1 = 14 Marks)

1.

a)Define tariff.

Tariff is defined as the rate at which electrical energy is supplied to a consumer is known as tariff.

b)List any three causes of low power factor?

The three causes of low power factor are:-

1.Most of the a.c motors are of induction type which have low lagging power factor. These motors work at a power factor which is extremely small on light load(0.2 to 0.3) and rises to 0.8 or 0.9 at full load.

2.Arc lamps, electric discharge lamps, and industrial heating furnaces operates at low lagging power factor.

3.The load on the power system is varying; being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetisation current. This results in the decreased power factor.

c) Define plant use factor. .

Plant use factor is defined as the ratio of KWH generated to the product of plant capacity and the number of hours for which the plant was in operation.

d) List any three disadvantages of a thermal power plant?

The three disadvantages of thermal power plant is:-

1.It pollutes the atmosphere due to the production of large amount of smoke and fumes.

2 .It is costlier in running cost as compared to hydroelectric power plant.

3.A large water source is required to convert water into steam.

e) Define Nuclear Fission

Nuclear fission is defined as a nuclear reaction in which a heavy nucleus splits spontaneously or on impact with another particle, with the release of energy.

f) What are main components in Wind power plants.

The main components in Wind power plants are:-

1.Foundation

2. The tower

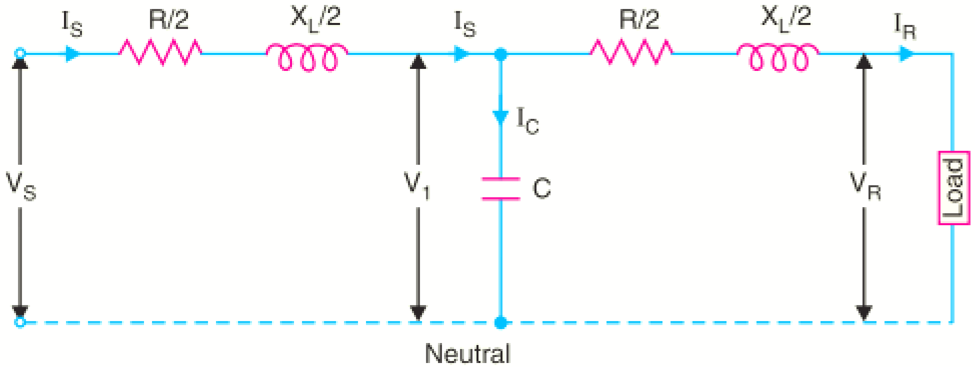
3. The rotor and hub (including three blades)

4.The nacelle

5. Generator.

g) Draw equivalent T-network. .

The equivalent T-network is



h)Define voltage regulation.

The difference in voltage at the receiving end of a transmission line **between conditions of no load and full load is called voltage regulation and is expressed as a percentage of the receiving end voltage.

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

i)What is sag?

Sag is defined as the difference in level between points of supports of poles and the lowest point of the conductor is called "sag".

j) List any one advantage of corona loss

The one advantage of corona loss is reducing the effect of transients that are produced by voltage surges.

k) Define string efficiency.

String efficiency is defined as the ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as string efficiency i.e.,

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

l) List the types of power station?

The types of power stations are

1.Steam or Thermal power station

2.Hydal power station

3.Nuclear power palnt

4.Diesel power plant

5.Gas Turbine power plant

6.Solar power plant

7.Wind power plant

m) List the types of boilers in Thermal power plants.

The types of boilers used in Thermal power plant are

1.Water tube boilers

2.Fire tube boilers

n) Define GMD.

The GMD is the geometrical mean of the distances from one conductor to the other and, therefore, must be between the largest and smallest such distance.

Unit – I

2 **7M**

a)i) Explain different types of tariff's. **4M**

There are several types of tariff. However, the following are the commonly used types of tariff :

1. Simple tariff.:-When there is a fixed rate per unit of energy consumed, it is called a simple tariff or uniform rate tariff. In this type of tariff, the price charged per unit is constant i.e., it does not vary with increase or decrease in number of units consumed. The consumption of electrical energy at the consumer's terminals is recorded by means of an energy meter. This is the simplest of all tariffs and is readily understood by the consumers.

Disadvantages :-

There is no discrimination between different types of consumers since every consumer has to pay equitably for the fixed* charges.

(ii) The cost per unit delivered is high.

(iii) It does not encourage the use of electricity.

2. 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 of tariff, the consumers are grouped into different classes and each class of consumers is charged at a different uniform rate. For instance, the flat rate per kWh for lighting load may be 60 paise, whereas it may be slightly less† (say 55 paise per kWh) for power load. The different classes of consumers are made taking into account their diversity and load factors. The advantage of such a tariff is that it is more fair to different types of consumers and is quite simple in calculations.

Disadvantages

(i)Since the flat rate tariff varies according to the way the supply is used, separate meters are required for lighting load, power load etc. This makes the application of such a tariff expensive and complicated.

(ii) A particular class of consumers is charged at the same rate irrespective of the magnitude of energy consumed. However, a big consumer should be charged at a lower rate as in his case the fixed charges per unit are reduced

3. Block rate tariff.:-When a given block of energy is charged at a specified rate and the succeeding blocks of energy are charged at progressively reduced rates, it is called a block rate tariff.

In block rate tariff, the energy consumption is divided into blocks and the price per unit is fixed in each block. The price per unit in the first block is the highest** and it is progressively reduced for the succeeding blocks of energy. For example, the first 30 units may be charged at the rate of 60 paise per unit ; the next 25 units at the rate of 55 paise per unit and the remaining additional units may be charged at the rate of 30 paise per unit.

The advantage of such a tariff is that the consumer gets an incentive to consume more electrical energy. This increases the load factor of the system and hence the cost of generation is reduced. However, its principal defect is that it lacks a measure of the consumer’s demand. This type of tariff is being used for majority of residential and small commercial consumers.

4. 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 a two-part tariff. In two-part tariff, the total charge to be made from the consumer is split into two components viz., fixed charges and running charges. The fixed charges depend upon the maximum demand of the consumer while the running charges depend upon the number of units consumed by the consumer. Thus, the consumer is charged at a certain amount per kW of maximum†† demand plus a certain amount per kWh of energy consumed i.e.,

$$\text{Total charges} = \text{Rs } (b \times \text{kW} + c \times \text{kWh})$$

where,

b = charge per kW of maximum demand

c = charge per kWh of energy consumed

This type of tariff is mostly applicable to industrial consumers who have appreciable maximum demand.

Advantages

(i)It is easily understood by the consumers.

(ii) It recovers the fixed charges which depend upon the maximum demand of the consumer but are independent of the units consumed.

Disadvantages

(i) The consumer has to pay the fixed charges irrespective of the fact whether he has consumed or not consumed the electrical energy.

(ii) There is always error in assessing the maximum demand of the consumer.

5. Maximum demand tariff:- It is similar to two-part tariff with the only difference that the maximum demand is actually measured by installing maximum demand meter in the premises of the consumer. This removes the objection of two-part tariff where the maximum demand is assessed merely on the basis of the rateable value. This type of tariff is mostly applied to big consumers. However, it is not suitable for a small consumer (e.g., residential consumer) as a separate maximum demand meter is required.

6. Power factor tariff:- The tariff in which power factor of the consumer's load is taken into consideration is known as power factor tariff.

In an a.c. system, power factor plays an important role. A low* power factor increases the rating of station equipment and line losses. Therefore, a consumer having low power factor must be penalised. The following are the important types of power factor tariff :

(i)k VA maximum demand tariff : It is a modified form of two-part tariff. In this case, the fixed charges are made on the basis of maximum demand in kVA and not in kW. As kVA is inversely proportional to power factor, therefore, a consumer having low power factor has to contribute more towards the fixed charges. This type of tariff has the advantage that it encourages the consumers to operate their appliances and machinery at improved power factor.

(ii) Sliding scale tariff : This is also know as average power factor tariff. In this case, an average power factor, say 0·8 lagging, is taken as the reference. If the power factor of the consumer falls below this factor, suitable additional charges are made. On the other hand, if the power factor is above the reference, a discount is allowed to the consumer.

(iii) kW and kVAR tariff : In this type, both active power (kW) and reactive power (kVAR) supplied are charged separately. A consumer having low power factor will draw more reactive power and hence shall have to pay more charges.

7. Three-part tariff. When the total charge to be made from the consumer is split into three parts viz., fixed charge, semi-fixed charge and running charge, it is known as a three-part tariff. i.e.,

$$\text{Total charge} = \text{Rs } (a + b \times \text{kW} + c \times \text{kWh})$$

Where

a = fixed charge made during each billing period. It includes interest and depreciation on the cost of secondary distribution and labour cost of collecting revenues,

b = charge per kW of maximum demand,

c = charge per kWh of energy consumed

ii) A supply is offered on the basis of fixed charges of Rs 30 per annum plus 3 paise per unit or alternatively, at the rate of 6 paise per unit for the first 400 units per annum and 5 paise per unit for all the additional units. Find the number of units taken per annum for which the cost under the two tariffs becomes the same. 3M

Sol:- Let x (> 400) be the number of units taken per annum for which the annual charges due to both tariffs become equal.

$$\text{Annual charges due to first tariff} = \text{Rs}\,(30 + 0{\cdot}03x)$$

$$\text{Annual charges due to second tariff} = \text{Rs}\,[(0{\cdot}06 \times 400) + (x - 400) \times 0{\cdot}05]$$

$$= \text{Rs}\,(4 + 0{\cdot}05x)$$

As the charges in both cases are equal,

$$\therefore \quad 30 + 0{\cdot}03x = 4 + 0{\cdot}05x$$

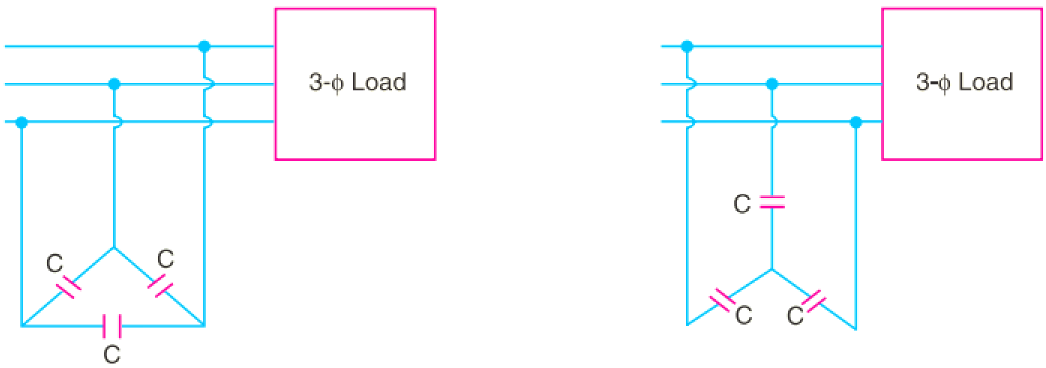
$$\text{or} \quad x = \frac{30 - 4}{0{\cdot}05 - 0{\cdot}03} = \mathbf{1300\ kWh}$$

2.b) Discuss the various methods for power factor improvement. **7M**

Diagrams: 4M Explanation: 3M

The various methods for power factor improvement are :

1. Static capacitors.
2. Synchronous condenser.
3. Phase advancers.



(*i*) (*ii*)

1. Static capacitor.:-The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static**capacitor) draws a leading current and partly or completely neutralises the lagging reactive component of load current. This raises the power factor of the load. For three-phase loads, the capacitors can be connected in delta or star as shown in Fig. Static capacitors are invariably used for power factor improvement in factories.

Advantages

(i)They have low losses.

(ii) They require little maintenance as there are no rotating parts.

(iii) They can be easily installed as they are light and require no foundation.

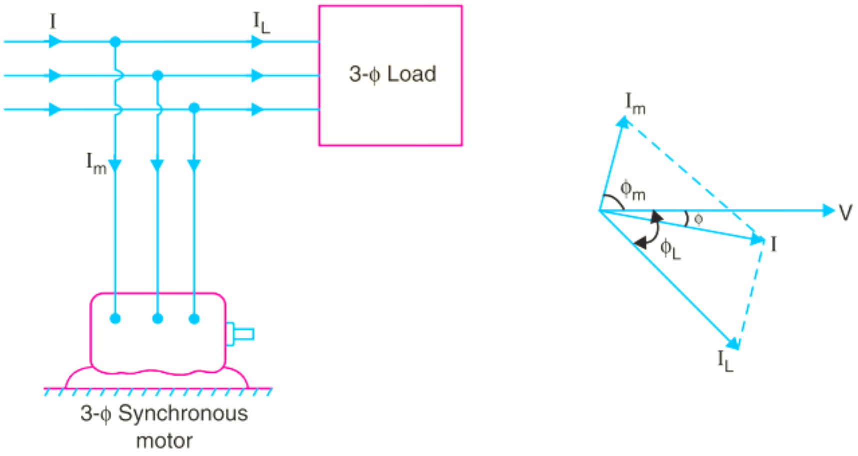
(iv) They can work under ordinary atmospheric conditions.

Disadvantages

(i) They have short service life ranging from 8 to 10 years.
(ii) They are easily damaged if the voltage exceeds the rated value.
(iii) Once the capacitors are damaged, their repair is uneconomical.

2. Synchronous condenser:- A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as synchronous condenser. When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralises the lagging reactive component of the load. Thus the power factor is improved.

The following figure shows the power factor improvement by synchronous condenser method. The 3φ load takes current IL at low lagging power factor cos φL. The synchronous condenser takes a current Im which leads the voltage by an angle φm*. The resultant current I is the phasor sum of Im and IL and lags behind the voltage by an angle φ. It is clear that φ is less than φL so that cos φ is greater than cos φL. Thus the power factor is increased from cos φL to cos φ. Synchronous condensers are generally used at major bulk supply substations for power factor improvement.



Advantages

(i)By varying the field excitation, the magnitude of current drawn by the motor can be changed by any amount. This helps in achieving stepless † control of power factor.

(ii) The motor windings have high thermal stability to short circuit currents.

(iii) The faults can be removed easily.

Disadvantages

(i) There are considerable losses in the motor.

(ii) The maintenance cost is high.

(iii) It produces noise.

(iv) Except in sizes above 500 kVA, the cost is greater than that of static capacitors of the same rating.

(v) As a synchronous motor has no self-starting torque, therefore, an auxiliary equipment has to be provided for this purpose.

(OR)

3.a) What do you understand by the load curve? What information's are conveyed by a load curve? 7M

Concept: 3M Explanation: 4M

A load curve, also known as a demand curve or load profile, is a graphical representation of the variation in electrical power consumption or demand over a specific period of time. It shows how the electricity demand changes throughout the day, week, month, or year for a particular region, facility, or system. Load curves are important tools in the field of electrical engineering and energy management as they provide valuable insights into consumer behaviour, energy usage patterns, and system planning.

Load curves convey several important pieces of information:

1. Peak Demand: The highest point on the load curve represents the peak demand, which is the maximum amount of power required by consumers during a specific period. This information is crucial for power utilities and grid operators to size their infrastructure, such as power plants, transmission lines, and transformers, to ensure they can meet the highest demand levels.

2. Off-Peak and Shoulder Periods: Load curves also highlight periods of low demand, known as off-peak times, and intermediate demand, referred to as shoulder periods. These times are important for grid management and energy pricing strategies. Off-peak periods can be used for maintenance of power plants and equipment, while shoulder periods might influence pricing structures to encourage energy consumption when demand is lower.

3. Load Distribution: The shape of the load curve provides insights into the distribution of electricity demand throughout the day. This information can help grid operators anticipate when demand is likely to be high or low, allowing them to adjust their operations accordingly. For example, they might ramp up generation during peak hours or reduce it during low-demand periods.

4. Capacity Planning: Load curves are crucial for capacity planning, allowing utilities and power providers to determine how much generation capacity is needed to ensure a reliable power supply. They assist in selecting the appropriate mix of power plants (e.g., coal, natural gas, renewable sources) and help in planning for future infrastructure expansions.

5. Demand Response: Load curves help identify opportunities for demand response programs, where consumers are encouraged to reduce their electricity consumption during peak periods in exchange for incentives. This can help alleviate stress on the grid during high-demand times.

6. Energy Efficiency Strategies: By analyzing load curves, energy managers can identify patterns of energy usage and target energy-saving measures to specific times when consumption is high. This can lead to more effective energy efficiency initiatives.

In summary, load curves provide a visual representation of how electricity demand fluctuates over time. They offer valuable information for grid management, capacity planning, pricing strategies, demand response programs, and energy efficiency initiatives, ultimately contributing to the stable and efficient operation of the electrical grid.

3.b) Explain the terms load factor and diversity factor, How do these factors influence the cost of generation? 7M

Explanation: 4M Factors influencing cost of Generation: 3M

Load Factor and Diversity Factor are important concepts in the field of electrical engineering and power system analysis. They both play a role in determining the efficiency of power generation and distribution systems, as well as their associated costs.

1. Load Factor:

The load factor is a measure of how effectively electrical power is being used over a specific period of time, typically a day, month, or year. It is the ratio of the average power demand to the peak power demand during that time period. Mathematically, it can be expressed as:

Load Factor = (Average Power Demand) / (Peak Power Demand)

A high load factor indicates that the power system is being utilized efficiently because the average demand is closer to the peak demand. This means that power generation resources are being used more consistently throughout the day, leading to more stable operations.

Influence on Cost of Generation: A higher load factor implies that power plants are operating closer to their full capacity for longer durations, resulting in better utilization of resources and lower per-unit generation costs. Power plants are capital-intensive, and their costs are spread out more effectively when they run at higher load factors. This can help reduce the cost of generation and make electricity production more economical.

2. Diversity Factor:

The diversity factor represents the ratio of the sum of individual maximum demands to the peak demand of a group of consumers or loads. In other words, it quantifies the extent to which the sum of individual peak demands is less than the overall system's peak demand. Mathematically, it can be expressed as:

Diversity Factor = (Sum of Individual Maximum Demands) / (System Peak Demand)

A high diversity factor implies that the individual peak demands do not occur simultaneously, allowing for a reduction in the total capacity required to meet those peaks.

3M

Influence on Cost of Generation: The diversity factor is crucial for sizing power generation and distribution infrastructure. When individual loads or consumers have diverse patterns of electricity usage, the combined peak demand is lower than if all loads peaked simultaneously. This means that power generation plants and equipment can be designed with lower overall capacity, leading to cost savings in terms of investment and maintenance.

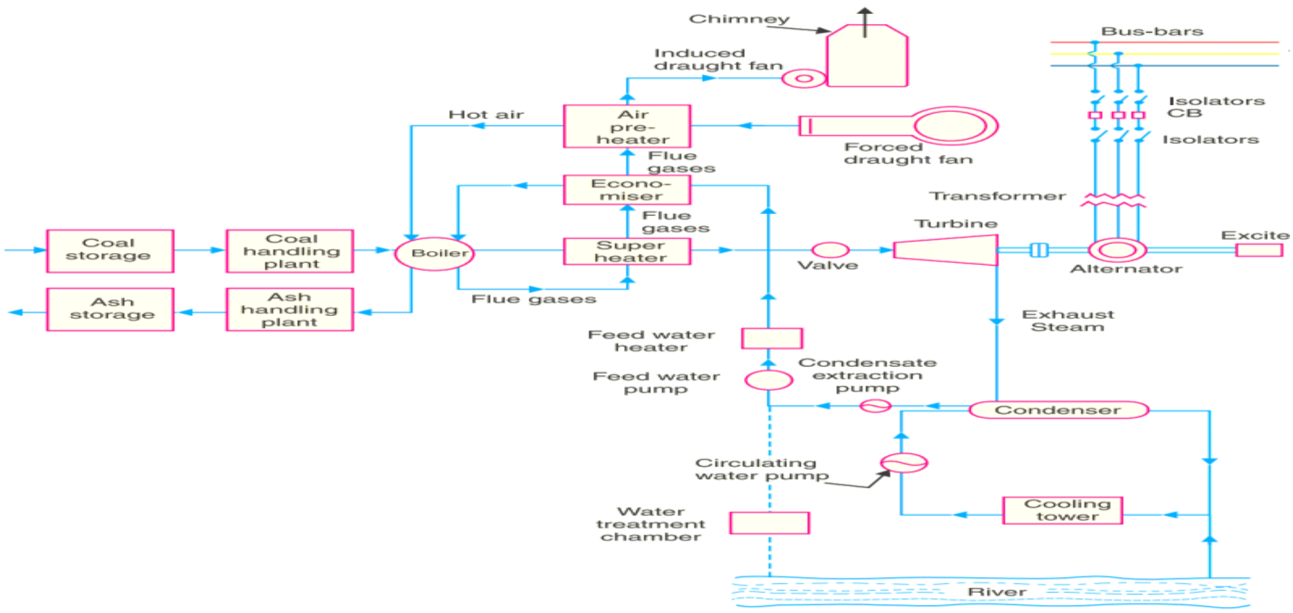
Relationship Between Load Factor and Diversity Factor:

Load factor and diversity factor are related in the sense that a higher diversity factor can contribute to a higher load factor. When loads are diverse and don't peak all at once, the power system can maintain a higher average demand compared to the peak demand, resulting in a higher load factor.

In summary, the load factor and diversity factor are key indicators that influence the efficiency and cost of power generation and distribution. A higher load factor indicates better resource utilization and lower generation costs, while a higher diversity factor allows for the reduction of peak capacity requirements, leading to cost savings in infrastructure .

Unit – II

4.a) Draw a general layout of a modern thermal plant and explain the working of different circuits. 7M Layout: 4M Explanation: 3M



Schematic arrangement of Steam Power Station

The schematic arrangement of a modern steam power station is shown in Fig The whole arrangement can be divided into the following stages for the sake of simplicity **:**

1. Coal and ash handling arrangement
2. Steam generating plant
3. Steam turbine
4. Alternator
5. Feed water
6. Cooling arrangement

1. Coal and ash handling plant. The coal is transported to the power station by road or rail and is stored in the coal storage plant. Storage of coal is primarily a matter of protection against coal strikes, failure of transportation system and general coal shortages. From the coal storage plant, coal is delivered to the coal handling plant where it is pulverised (i.e., crushed into small pieces) in order to increase its surface exposure, thus promoting rapid combustion without using large quantity of excess air. The pulverised coal is fed to the boiler by belt conveyors. The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant and then delivered to the ash storage plant for disposal. The removal of the ash from the boiler furnace is necessary for proper burning of coal.

It is worthwhile to give a passing reference to the amount of coal burnt and ash produced in a modern thermal power station. A 100 MW station operating at 50% load factor may burn about 20,000 tons of coal per month and ash produced may be to the tune of 10% to 15% of coal fired i.e., 2,000 to 3,000 tons. In fact, in a thermal station, about 50% to 60% of the total operating cost consists of fuel purchasing and its handling.

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

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

(ii) Superheater. The steam produced in the boiler is wet and is passed through a superheater where it is dried and superheated (i.e., steam temperature increased above that of boiling point of water) by the flue gases on their way to chimney. Superheating provides two principal benefits. Firstly, the overall efficiency is increased. Secondly, too much condensation in the last stages of turbine (which would cause blade corrosion) is avoided. The superheated steam from the superheater is fed to steam turbine through the main valve.

(iii) Economiser. An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of heat of flue gases to increase the feed water temperature.

(iv) Air preheater. An air preheater increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air preheater before supplying to the boiler furnace. The air preheater extracts heat from flue gases and increases the temperature of air used for coal combustion. The principal benefits of preheating the air are : increased thermal efficiency and increased steam capacity per square metre of boiler surface.

3. Steam turbine. The dry and superheated steam from the superheater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy. After giving heat energy to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation.

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

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

6. Cooling arrangement. In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed* by means of a condenser. Water is drawn from a natural source of supply such as a river, canal or lake and is circulated through the condenser. The circulating water takes up the heat of the exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river. In case the availability of water from the source of supply is not assured throughout the year, cooling towers are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

4.b) Explain the I-V and P-V characteristics of PV panels. 7M

I-V characteristics – 4M P-V characteristics of PV panels- 3M

Photovoltaic (PV) panels, also known as solar panels, are devices that convert sunlight directly into electricity using the photovoltaic effect. The I-V (current-voltage) and P-V (power-voltage) characteristics of PV panels are important graphical representations that illustrate how the panels behave in terms of current, voltage, and power output under different conditions.

I-V Characteristics (Current-Voltage):

The I-V curve of a PV panel shows the relationship between the generated current and the voltage across the panel's terminals. It provides insights into how the current output of the panel changes as the voltage across its terminals varies. The general shape of the I-V curve for a PV panel is as follows:

- Initially, at zero voltage (short circuit condition), the panel generates its maximum current, known as the short-circuit current (Isc). This is the current that flows when the terminals of the panel are directly connected without any load.
- As the voltage increases, the current generated by the panel decreases. This is because the higher voltage creates a driving force for the generated current to flow externally through a load rather than directly through the panel.
- At a certain voltage known as the open-circuit voltage (Voc), the current becomes zero (open circuit condition). Voc is the maximum voltage the panel can generate when there is no load connected.
- The I-V curve represents the panel's capability to deliver current at various voltages, and its shape is influenced by factors such as temperature, shading, and the characteristics of the panel materials.

P-V Characteristics (Power-Voltage):

The P-V curve of a PV panel illustrates the relationship between the power output and the voltage across the panel's terminals. It provides information about the panel's efficiency and optimal operating points. The P-V curve is derived from the I-V curve and can be obtained by multiplying current and voltage values at different points.

- The curve has a characteristic shape resembling a bell or hump.

- The point on the curve where the product of current and voltage is maximized corresponds to the maximum power point (MPP). The voltage and current at the MPP are denoted as Vmpp and Impp, respectively.

- At the short-circuit condition (zero voltage), the power is zero since the voltage is zero.

- At the open-circuit condition (zero current), the power is again zero since the current is zero.

- The efficiency of the panel is highest at the MPP, where it can produce the maximum amount of power output for a given set of conditions.

Understanding the I-V and P-V characteristics of PV panels is crucial for system design, installation, and optimization. Engineers and solar energy professionals use this information to determine the ideal conditions for connecting panels in series or parallel, selecting appropriate power converters, and designing systems that maximize energy production based on the available sunlight and temperature conditions.

(OR)

5.a) Enumerate & explain essential components of a nuclear reactor. 7M

A nuclear reactor is a complex system designed to initiate and control nuclear reactions for the purpose of generating heat that can be converted into electricity. Essential components of a nuclear reactor include:

1. Fuel Assemblies: Fuel assemblies are composed of fuel rods containing nuclear fuel pellets, typically uranium or plutonium isotopes. These fuel pellets undergo controlled nuclear fission, releasing energy in the form of heat.

2. Control Rods: Control rods are made of materials that absorb neutrons and slow down or stop the nuclear fission chain reaction. By adjusting the position of control rods within the reactor core, operators can control the rate of reaction and maintain a stable, controlled release of energy.

3. Moderator: The moderator is a material, often water or graphite, that slows down fast neutrons produced during fission reactions, allowing them to interact more effectively with other fissile nuclei, promoting sustained chain reactions.

4. Coolant: The coolant, usually water or a specialized coolant like heavy water (deuterium oxide) or liquid sodium, serves to transfer heat from the reactor core to a heat exchanger. It also helps in maintaining the core temperature and ensuring the safety of the reactor.

5. Reactor Core: The reactor core contains the fuel assemblies, control rods, and moderator. It's where the nuclear fission reactions occur, generating heat. The core's design and configuration influence the reactor's efficiency and safety.

6. Pressure Vessel: The pressure vessel is a robust containment structure that holds the reactor core and coolant under high pressure and temperature. It ensures that the coolant remains in a liquid state even at high temperatures, preventing boiling.

7. Steam Generator: In pressurized water reactors (PWRs), a steam generator transfers heat from the reactor coolant to a separate loop of water, turning it into steam that drives turbines connected to generators for electricity production.

8. Turbines and Generators: The steam produced by the reactor's heat drives turbines, which are connected to generators that produce electricity.

9. Containment Building: The containment building is a massive structure made of reinforced concrete that encloses the reactor and auxiliary systems. It provides an additional layer of safety by preventing the release of radioactive materials into the environment in case of accidents.

10. Emergency Cooling and Shutdown Systems: These systems are designed to rapidly cool down the reactor and shut it down in case of abnormal conditions or emergencies. They include backup coolant systems, emergency coolant injection, and emergency core cooling systems.

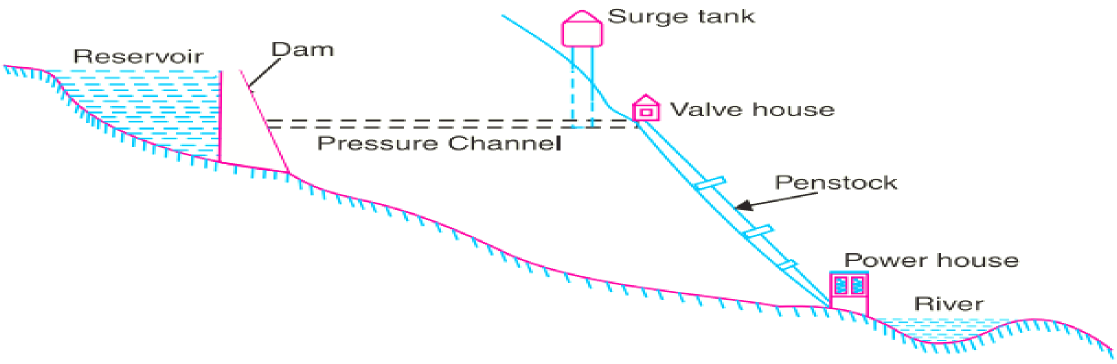
11. Reactor Pressure Relief System: This system is designed to safely release pressure from the reactor in case of overpressure scenarios, preventing the rupture of the pressure vessel.

12.Instrumentation and Control Systems: Modern reactors have sophisticated instrumentation and control systems that monitor and regulate various parameters such as temperature, pressure, and neutron flux. These systems ensure safe and efficient reactor operation.

These essential components work together to enable controlled nuclear reactions and convert the resulting heat into electricity, all while maintaining the safety and stability of the reactor system. Different types of reactors might have variations in these components, but the fundamental principles of nuclear fission and heat conversion remain consistent.

5.b) Draw a neat schematic diagram of a hydro-electric plant and explain the functions of various components. 7M

Diagram- 4M Functions: 3M



Schematic arrangement of a Hydro-electric plant

The constituents of a hydro-electric plant are (1) hydraulic structures (2) water turbines and (3) electrical equipment. We shall discuss these items in turn.

1. Hydraulic structures. Hydraulic structures in a hydro-electric power station include dam, spillways, headworks, surge tank, penstock and accessory works.

(i) Dam. A dam is a barrier which stores water and creates water head. Dams are built of concrete or stone masonary, earth or rock fill. The type and arrangement depends upon the topography of the site. A masonary dam may be built in a narrow canyon. An earth dam may be best suited for a wide valley. The type of dam also depends upon the foundation conditions, local materials and transportation available, occurrence of earthquakes and other hazards. At most of sites, more than one type of dam may be suitable and the one which is most economical is chosen.

(ii) Spillways. There are times when the river flow exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area. In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spillways are used. Spillways are constructed of concrete piers on the top of the dam. Gates are provided between these piers and surplus water is discharged over the crest of the dam by opening these gates.

(iii) Headworks. The headworks consists of the diversion structures at the head of an intake. They generally include booms and racks for diverting floating debris, sluices for by-passing debris and sediments and valves for controlling the flow of water to the turbine. The flow of water into and through headworks should be as smooth as possible to avoid head loss and cavitation. For this purpose, it is necessary to avoid sharp corners and abrupt contractions or enlargements.

(iv) Surge tank. Open conduits leading water to the turbine require no* protection. However, when closed conduits are used, protection becomes necessary to limit the abnormal pressure in the conduit. For this reason, closed conduits are always provided with a surge tank. A surge tank is a small reservoir or tank (open at the top) in which water level rises or falls to reduce the pressure swings in the conduit. A surge tank is located near the beginning of the conduit. When the turbine is running at a steady load, there are no surges in the flow of water through the conduit i.e., the quantity of water flowing in the conduit is just sufficient to meet the turbine requirements. However, when the load on the turbine decreases, the governor closes the gates of turbine, reducing water supply to the turbine. The excess water at the lower end of the conduit rushes back to the surge tank and increases its water level. Thus the conduit is prevented from bursting. On the other hand, when load on the turbine increases, additional water is drawn from the surge tank to meet the increased load requirement. Hence, a surge tank overcomes the abnormal pressure in the conduit when load on the turbine falls and acts as a reservoir during increase of load on the turbine.

(v) Penstocks. Penstocks are open or closed conduits which carry water to the turbines. They are generally made of reinforced concrete or steel. Concrete penstocks are suitable for low heads (< 30 m) as greater pressure causes rapid deterioration of concrete. The steel penstocks can be designed for any head; the thickness of the penstock increases with the head or working pressure.

Various devices such as automatic butterfly valve, air valve and surge tank (See Fig. 2.3) are provided for the protection of penstocks. Automatic butterfly valve shuts off water flow through the penstock promptly if it ruptures. Air valve maintains the air pressure inside the penstock equal to outside atmospheric pressure. When water runs out of a penstock faster than it enters, a vacuum is created which may cause the penstock to collapse. Under such situations, air valve opens and admits air in the penstock to maintain inside air pressure equal to the outside air pressure.

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

(i) Impulse turbines (ii) Reaction turbines

(i) Impulse turbines. Such turbines are used for high heads. In an impulse turbine, the entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the jet drives the wheel. The example of this type of turbine is the Pelton wheel (See Fig. 2.4). It consists of a wheel fitted with elliptical buckets along its periphery. The force of water jet striking the buckets on the wheel drives the turbine. The quantity of water jet falling on the turbine is controlled by means of a needle or spear (not shown in the figure) placed in the tip of the nozzle. The movement of the needle is controlled by the governor. If the load on the turbine decreases, the governor pushes the needle into the nozzle, thereby reducing the quantity of water striking the buckets. Reverse action takes place if the load on the turbine increases.

(ii) Reaction turbines. Reaction turbines are used for low and medium heads. In a reaction turbine, water enters the runner partly with pressure energy and partly with velocity head. The important types of reaction turbines are :

(a) Francis turbines (b) Kaplan turbines.

A Francis turbine is used for low to medium heads. It consists of an outer ring of stationary guide blades fixed to the turbine casing and an inner ring of rotating blades forming the runner. The guide blades control the flow of water to the turbine. Water flows radially inwards and changes to a downward direction while passing through the runner. As the water passes over the "rotating blades" of the runner, both pressure and velocity of water are reduced. This causes a reaction force which drives the turbine.

A Kaplan turbine is used for low heads and large quantities of water. It is similar to Francis turbine except that the runner of Kaplan turbine receives water axially. Water flows radially inwards through regulating gates all around the sides, changing direction in the runner to axial flow. This causes a reaction force which drives the turbine.

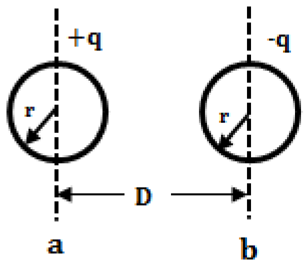
3. Electrical equipment. The electrical equipment of a hydro-electric power station includes alternators, transformers, circuit breakers and other switching and protective devices.

Unit – III

6.a) Derive an expression for capacitances of a single phase transmission system and discuss the effect of earth of capacitance with suitable equation. 7M

Derivation: 4M Effect of Earth on Capacitance: 3M

Consider a single-phase line consisting of two solid round conductors a and b of radius r meters and spaced at D meters as shown in the figure below.



Let us assume that r << D. So the charge density will be uniform throughout the length of the conductors as the charge on one conductor does not affect the charge on the other. Let a charge Q coulombs exist on conductor a. Since it is a single-phase line, the other conductor acts as a return conductor, so the charge on conductor b will be -q coulombs.

Now, the potential difference between conductor a and neutral point n at infinity is,

$$V_{an} = \int_{r}^{\infty} \frac{+q}{2\pi \in_o} . \frac{dx}{x} + \int_{D}^{\infty} \frac{-q}{2\pi \in_o} . \frac{dx}{x}$$

$$V_{an} = \frac{q}{2\pi \in_o} [[\log x]_r^{\infty} - [\log x]_D^{\infty}]$$

$$V_{an} = \frac{q}{2\pi \in_o} \log\left(\frac{D}{r}\right) V$$

Similarly, the potential difference between conductor b and neutral point n is,

$$V_{bn} = \frac{-q}{2\pi \in_o} \log\left(\frac{D}{r}\right) V$$

Therefore, the potential difference between conductors a and b is,

$$V_{ab} = V_{an} - V_{bn}$$

$$= \frac{q}{2\pi \in_o} \log\left(\frac{D}{r}\right) + \frac{q}{2\pi \in_o} \log\left(\frac{D}{r}\right)$$

$$= \frac{q}{\pi \in_o} \log\left(\frac{D}{r}\right)$$

The capacitance between two transmission lines is the charge on the conductors per unit of potential difference between them i.e.,

$$C = \frac{q}{V} = \frac{q}{V_{ab}} = \frac{q}{\frac{q}{\pi \in_o} \log\left(\frac{D}{r}\right)}$$

$$C = \frac{\pi \in_o}{\log\left(\frac{D}{r}\right)} F/m \ or \ C = \frac{\pi \in_o}{\log\left(\frac{D}{r}\right)} \times 1000 \ F/Km$$

Effect of Earth on Capacitance:

When transmission lines are installed above the ground, the earth also plays a role in affecting the capacitance. The earth acts as a third conductor, providing an additional path for electric field lines and affecting the distribution of electric charges.

The presence of the earth introduces what is known as "ground capacitance." Ground capacitance increases the effective capacitance of the transmission line system.

$$\mathbf{C = 2\pi\xi_0 / \ln [(D_{aa'} / D_{ab'}) (D_{ab} / r)]}$$

Since $D_{aa'} / D_{ab'} < 1$, therefore from the above expression we can say that the value of capacitance has increased due to the effect of earth. However as the distance of separation between the conductors i.e. Dab is very much small when compared to height of conductor above ground level, therefore for all practical calculation $(D_{aa'} / D_{ab'}) \approx 1$. Thus the effect of earth on capacitance of transmission line may be neglected.

The capacitance to the ground can be further affected by factors such as the distance between the conductors and the ground and the characteristics of the ground itself. It can be estimated using complex mathematical models that consider the geometry of the conductors and the ground plane.

In summary, the capacitance of a single-phase transmission line is influenced by the arrangement of the conductors and the surrounding medium, such as air and the ground. The presence of the earth increases the effective capacitance of the system due to the additional capacitance between the conductors and the ground. This increased capacitance can have implications for the behavior and performance of the transmission line in terms of its impedance, voltage distribution, and power losses.

6.b) Derive expression for surge impedance. And also explain the Ferranti effect in long transmission lines. Derivation: 4M Ferranti Effect: 3M

Derivation of Surge Impedance:

From the rigorous solution of a long transmission line we get the following equation for voltage and current at any point on the line at a distance x from the receiving end

$$V_x = \left[\frac{V_R + Z_C I_R}{2}\right] e^{\delta x} + \left[\frac{V_R - Z_C I_R}{2}\right] e^{-\delta x}$$

$$I_x = \left[\frac{\frac{V_R}{Z_C} + I_R}{2}\right] e^{\delta x} - \left[\frac{\frac{V_R}{Z_C} - I_R}{2}\right] e^{-\delta x}$$

Where, V_x and I_x = Voltage and Current at point x ; V_R and I_R = Voltage and Current at receiving end Z_c = Characteristic Impedance ; δ = Propagation Constant. Z = Series impedance per unit length per phase; Y = Shunt admittance per unit length per phase

$$Z_C = \sqrt{\frac{Z}{Y}}$$

$$\delta = \sqrt{YZ} = \alpha + j\beta$$

We observe that the instantaneous voltage consists of two terms each of which is a function of time and distance. Thus they represent two travelling waves. The first one is the positive exponential part representing a wave travelling towards receiving end and is hence called the incident wave. While the other part with negative exponential represents the reflected wave. At any point along the line, the voltage is the sum of both the waves. The same is true for current waves also.

Now, if suppose the load impedance (Z_L) is chosen such that $Z_L = Z_c$, and we know $Z_L = V_R / I_R$

$$\frac{V_R}{I_R} = Z_C \;\; i.e. V_R - Z_C I_R = 0$$

Hence the reflected wave vanishes. Such a line is termed as infinite line. It appears to the source that the line has no end because it receives no reflected wave. Hence, such an impedance which renders the line as infinite line is known as surge impedance. It has a value of about 400 ohms and phase angle varying from 0 to –15 degree for overhead lines and around 40 ohms for underground cables.

Ferranti Effect in Long Transmission Lines:

The Ferranti effect, also known as the Ferranti effect phenomenon, is observed in long high-voltage transmission lines. It refers to the phenomenon where the receiving end voltage of a lightly loaded transmission line is higher than the sending end voltage, despite the absence of any significant load at the receiving end.

This effect is primarily due to the capacitance of the transmission line. When a transmission line is energized, the line's capacitance causes charging current to flow, charging up the line capacitance and creating a voltage drop across the line. This voltage drop can be substantial for long transmission lines with high voltage levels.

During periods of light load or no load at the receiving end, there is less current drawn from the line. As a result, the charging current becomes a more significant portion of the total current flowing through the line. Since the charging current lags behind the voltage by 90 degrees (due to the capacitive nature of the current), the line's voltage drop due to the charging current becomes more pronounced.

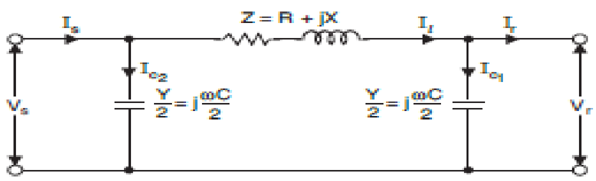
The combination of the voltage drop due to charging current and the lagging phase of charging current results in a higher voltage at the receiving end compared to the sending end. This effect can be significant in long transmission lines with high voltages and low loads, and it can potentially lead to overvoltages and operational challenges.

To mitigate the Ferranti effect, reactive power compensation, voltage regulation equipment, and proper line design are employed. This ensures that the voltage profile along the transmission line remains within acceptable limits and prevents excessive voltage rise at the receiving end.

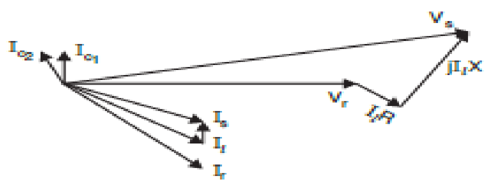
(OR)

7.a)Derive the expression for ABCD parameters of medium transmission lines by pi method draw the vector diagram. Vector Diagram : 4M Derivation : 3M

The circuit and its vector diagrams are shown in Figs.
For nominal-π it is desirable to take receiving end voltage as the reference vector. Refer to Fig. for calculating V_s.



Nominal-π.



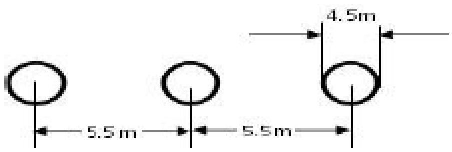
Phasor diagram for nominal-π.

To determine A, B, C, D constants for nominal-π

$$I_{c_1} = V_r \frac{Y}{2}$$
$$I_l = I_r + I_{c_1} = I_r + V_r \frac{Y}{2}$$
$$V_s = V_r + I_l Z = V_r + \left(I_r + V_r \frac{Y}{2}\right) Z$$
$$= \left(1 + \frac{YZ}{2}\right) V_r + Z I_r$$
$$I_s = I_l + I_{c_2} = I_l + V_s \frac{Y}{2} = I_r + V_r \frac{Y}{2} + \left\{V_r\left(1+\frac{YZ}{2}\right) + Z I_r\right\} \frac{Y}{2}$$
$$= V_r\left(Y + \frac{Y^2 Z}{4}\right) + \left(1 + \frac{YZ}{2}\right) I_r$$

$$A = 1 + \frac{YZ}{2}$$
$$B = Z$$
$$C = Y\left(1 + \frac{YZ}{4}\right)$$
$$D = \left(1 + \frac{YZ}{2}\right)$$

7.b)Determine inductance/km/phase of a single circuit 3-phase ,20kv line shown below figure.



Formulae: 2M Procedure and Solution: 5M

Equivalent equilateral spacing, Deq $=\sqrt[3]{5.5 * 5.5 * 11} = 6.94$ m

The conductor radius r = 4.5/2 = 2.25 m.

Inductance/phase/m = 10^{-7} (0·5 + 2 loge D_{eq}/r) H

$=10^{-7}(0.5+2\log 6.94/2025)$H

$=2.75*10^{-7}$

Inductance/phase/km $=2.75*10^{-7}*1000$

$=275.27\mu$H

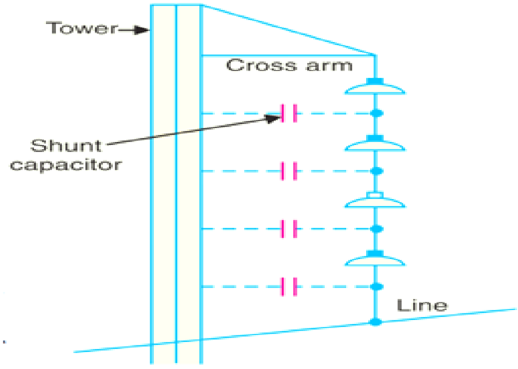
Unit – IV

8.a)Discuss various methods for improving the string efficiency in a string of insulators. 7M

Diagrams: 3M Explanation: 4M

Methods of improving string efficiency:-

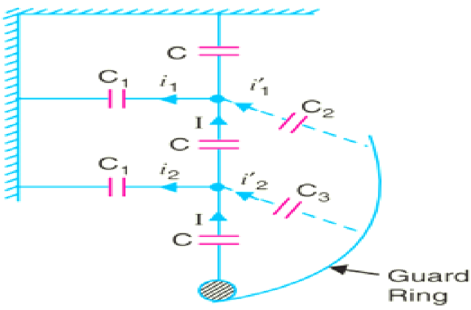
It has been seen above that potential distribution in a string of suspension insulators is not uniform. The maximum voltage appears across the insulator nearest to the line conductor and decreases progressively as the crossarm is approached. If the insulation of the highest stressed insulator (i.e. nearest to conductor) breaks down or flash over takes place, the breakdown of other units will take place in succession. This necessitates to equalise the potential across the various units of the string i.e. to improve the string efficiency. The various methods for this purpose are :



(i)By using longer cross-arms. The value of string efficiency depends upon the value of K i.e., ratio of shunt capacitance to mutual capacitance. The lesser the value of K, the greater is the string efficiency and more uniform is the voltage distribution. The value of K can be decreased by reducing the shunt capacitance. In order to reduce shunt capacitance, the distance of conductor from tower must be increased i.e., longer cross-arms should be used. However, limitations of cost and strength of tower do not allow the use of very long cross-arms. In practice, K = 0·1 is the limit that can be achieved by this method.

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

(iii) By using a guard ring. The potential across each unit in a string can be equalised by using a guard ring which is a metal ring electrically connected to the conductor and surrounding the bottom insulator as shown in the Fig. 8.13. The guard ring introduces capacitance be-tween metal fittings and the line conductor. The guard ring is contoured in such a way that shunt capacitance currents i 1, i 2 etc. are equal to metal fitting line capacitance currents i′ 1, i′ 2 etc. The result is that same charging current I flows through each unit of string. Consequently, there will be uniform potential distribution across the units.



8.b) **Show how the sag of an overhead line can be calculated incase of supports at different levels.** **7M**

When poles are at different levels:- When supports are at unequal levels. In hilly areas, we generally come across conductors suspended between supports at unequal levels. The lowest point on the conductor is O.

Let

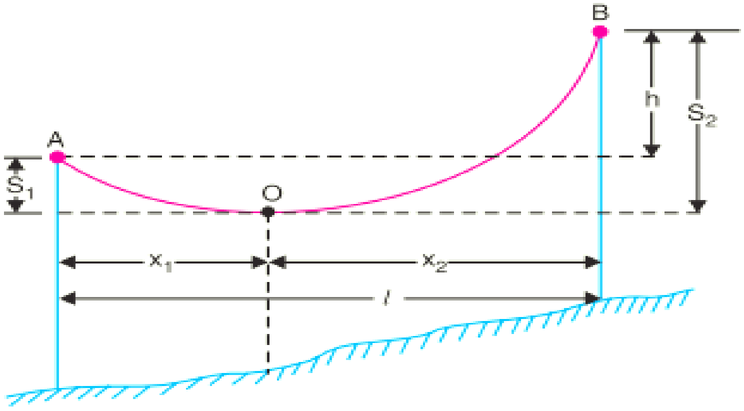
l = Span length

h = Difference in levels between two supports

x_1 = Distance of support at lower level (*i.e.*, A) from O

x_2 = Distance of support at higher level (*i.e.* B) from O

T = Tension in the conductor



If w is the weight per unit length of the conductor, then,

$$\text{Sag } S_1 = \frac{w\,x_1^{2*}}{2T}$$

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

Also $$x_1 + x_2 = l$$

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

$\therefore$ $$S_2 - S_1 = \frac{w\,l}{2T}(x_2 - x_1) \qquad [\because x_1 + x_2 = l]$$

But $$S_2 - S_1 = h$$

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

or $$x_2 - x_1 = \frac{2\,Th}{w\,l} \qquad \ldots(ii)$$

Solving exps. (*i*) and (*ii*), we get,

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

$$x_2 = \frac{l}{2} + \frac{T\,h}{w\,l}$$

Having found x_1 and x_2, values of S_1 and S_2 can be easily calculated.

(OR)

9. a)Describe the phenomenon of corona? How can the corona losses is minimized in transmission lines. 7M

Phenomenon of corona:- 3M Loss Minimization : 4M

When an alternating potential difference is applied across two conductors whose spacing is large as compared to their diameters, there is no apparent change in the condition of atmospheric air surrounding the wires if the applied voltage is low. However, when the applied voltage exceeds a certain value, called *critical disruptive voltage,* the conductors are surrounded by a faint violet glow called corona.

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 larger and higher the luminous envelope becomes, and greater are the sound, the power loss and the radio noise. If the applied voltage is increased to breakdown value, a flash-over will occur between the conductors due to the breakdown of air insulation.

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

If the conductors are polished and smooth, the corona glow will be uniform throughout the length of the conductors, otherwise the rough points will appear brighter. With d.c. voltage, there is difference in the appearance of the two wires. The positive wire has uniform glow about it, while the negative conductor has spotty glow.

Theory of corona formation. Some ionisation is always present in air due to cosmic rays, ultra-violet radiations and radioactivity. Therefore, under normal conditions, the air around the conductors contains some ionised particles (*i.e.,* free electrons and +ve ions) and neutral molecules. When p.d. is applied between the conductors, potential gradient is set up in the air which will have maximum value at the conductor surfaces. Under the influence of potential gradient, the existing free electrons acquire greater velocities. The greater the applied voltage, the greater the potential gradient and more is the velocity of free electrons.

When the potential gradient at the conductor surface reaches about 30 kV per cm (max. value), the velocity acquired by the free electrons is sufficient to strike a neutral molecule with enough force to dislodge one or more electrons from it. This produces another ion and one or more free electrons, which is turn are accelerated until they collide with other neutral molecules, thus producing other ions. Thus, the process of ionisation is cummulative. The result of this ionisation is that either corona is formed or spark takes place between the conductors.

Factors Affecting Corona

The phenomenon of corona is affected by the physical state of the atmosphere as well as by the conditions of the line. The following are the factors upon which corona depends :

(i) *Atmosphere.* As corona is formed due to ionsiation of air surrounding the conductors, therefore, it is affected by the physical state of atmosphere. In the stormy weather, the number of ions is more than normal and as such corona occurs at much less voltage as compared with fair weather.

(ii) *Conductor size.* The corona effect depends upon the shape and conditions of the conductors. The rough and irregular surface will give rise to more corona because unevenness of the surface decreases the value of breakdown voltage. Thus a stranded conductor has irregular surface and hence gives rise to more corona that a solid conductor.

(iii) *Spacing between conductors.* If the spacing between the conductors is made very large as compared to their diameters, there may not be any corona effect. It is because larger distance between conductors reduces the electro-static stresses at the conductor surface, thus avoiding corona formation.

(iv) *Line voltage.* The line voltage greatly affects corona. If it is low, there is no change in the condition of air surrounding the conductors and hence no corona is formed. However, if the line voltage has such a value that electrostatic stresses developed at the conductor surface make the air around the conductor conducting, then corona is formed.

Advantages and Disadvantages of Corona

Corona has many advantages and disadvantages. In the correct design of a high voltage overhead line, a balance should be struck between the advantages and disadvantages.

Advantages

(*i*) Due to corona formation, the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increased diameter reduces the electrostatic stresses between the conductors.

(*ii*) Corona reduces the effects of transients produced by surges.

Disadvantages

(*i*) Corona is accompanied by a loss of energy. This affects the transmission efficiency of the line.

(*ii*) Ozone is produced by corona and may cause corrosion of the conductor due to chemical action.

(*iii*) The current drawn by the line due to corona is non-sinusoidal and hence non-sinusoidal voltage drop occurs in the line. This may cause inductive interference with neighbouring communication lines.

Methods of Reducing Corona Effect

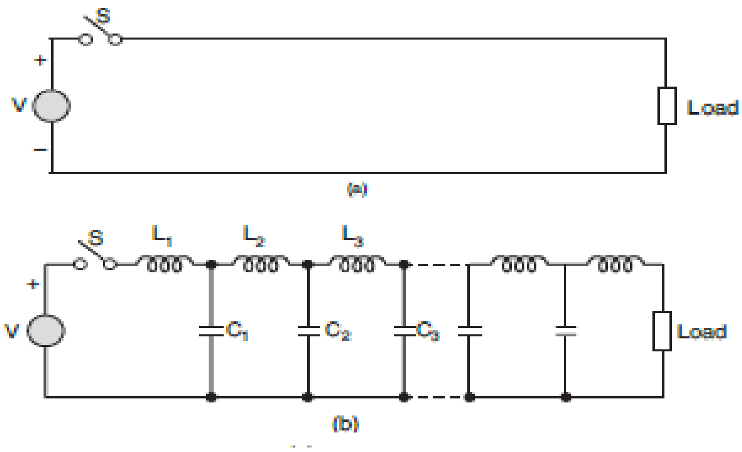
It has been seen that intense corona effects are observed at a working voltage of 33 kV or above. Therefore, careful design should be made to avoid corona on the sub-stations or bus-bars rated for 33 kV and higher voltages otherwise highly ionised air may cause flash-over in the insulators or between the phases, causing considerable damage to the equipment. The corona effects can be reduced by the following methods :

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

(*ii*) *By increasing conductor spacing.* By increasing the spacing between conductors, the voltage at which corona occurs is raised and hence corona effects can be eliminated. However, spacing cannot be increased too much otherwise the cost of supporting structure (*e.g.,* bigger cross arms and supports) may increase to a considerable extent.

9.b) Expression for wave equation of travelling wave **7M**

Diagram: 2M Explanation and Derivation: 5M



(*a*) Long transmission line, (*b*) Equivalent π-section of a long transmission line.

Suppose that the wave after time t has travelled through a distance x. Since we have assumed lossless lines whatever is the value of voltage and current waves at the start, they remain same throughout the travel. Consider a distance dx which is travelled by the waves in time dt. The electrostatic flux is associated with the voltage wave and the electromagnetic flux with the current wave. The electrostatic flux which is equal to the charge between the conductors of the line up to a distance x is given by

$$q = VCx$$

The current in the conductor is determined by the rate at which the charge flows into and out of the line.

$$I = \frac{dq}{dt} = VC\frac{dx}{dt}$$

Here dx/dt is the velocity of the travelling wave over the line conductor and let this be represented by v. Then

$$I = VCv$$

Similarly the electromagnetic flux linkages created around the conductors due to the current flowing in them up to a distance of x is given by

$$\psi = ILx$$

The voltage is the rate at which the flux linkages link around the conductor

$$V = IL\frac{dx}{dt} = ILv$$

Dividing equation (12.5) by (12.3), we get

$$\frac{V}{I} = \frac{ILv}{VCv} = \frac{I}{V}\cdot\frac{L}{C}$$

or $$\frac{V^2}{I^2} = \frac{L}{C}$$

or $$\frac{V}{I} = \sqrt{\frac{L}{C}} = Z_n$$

The expression is a ratio of voltage to current which has the dimensions of impedance and is therefore here designated as surge impedance of the line. It is also known as the natural impedance because this impedance has nothing to do with the load impedance. It is purely a characteristic of the transmission line. The value of this impedance is about 400 ohms for overhead transmission lines and 40 ohms for cables.

$$VI = VC\upsilon \cdot IL\upsilon = VILC\upsilon^2$$

or $$\upsilon^2 = \frac{1}{LC}$$

or $$\upsilon = \frac{1}{\sqrt{LC}}$$

Now expressions for L and C for overhead lines are

$$L = 2 \times 10^{-7} \ln \frac{d}{r} \text{ H/metre}$$

$$C = \frac{2\pi\varepsilon}{\ln \frac{d}{}} \text{ F/metre}$$

the velocity of propagation of the wave

$$\upsilon = \frac{}{\left(2 \times 10^{-7} \ln \frac{d}{r} \cdot \frac{2\pi\varepsilon}{\ln d/r}\right)^{1/2}}$$

$$= \frac{1}{\sqrt{4\pi\varepsilon \,.\, 10^{-7}}} = \frac{1}{\sqrt{4\pi \,.\, \frac{1}{36\pi} \times 10^{-9} \times 10^{-7}}}$$

$$= 3 \times 10^8 \text{ metres/sec.}$$

This is the velocity of light. This means the velocity of propagation of the travelling waves over the overhead transmission lines equals the velocity of light. In actual practice because of the resistance and leakance of the lines the velocity of the travelling wave is slightly less than the velocity of light. Normally a velocity of approximately 250 m/μ sec is assumed. It can be seen from the expression that the velocity of these waves over the cables will be smaller than over the overhead lines because of the permittivity term in the denominator.