**1401**

**October 2024**

# GENERATION, TRANSMISSION & SWITCHGEAR

## PART-A

### 1. Write about choice of site for locating a thermal power plant [3 marks]

- In order to reduce the transmission cost, the plant should be located near the centre of the load.
- The cost of the land should be quite reasonable.
- The bearing capacity of the ground should be adequate so that heavy equipment could be installed.
- Facilities should exist for the transport of fuel etc.
- Large Quantity of cooling water should be available for the condensers etc.
- The land should not be marsh so as to require pile foundation.

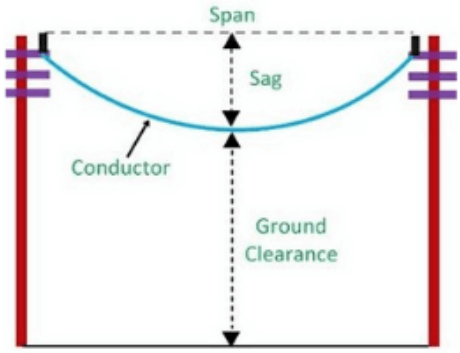
### 2. What is hybrid renewable energy system? [ 3 marks]

Hybrid power system combines solar power from a photovoltaic system with another power generating electric source.

Eg: Photovoltaic Diesel Hybrid System
Solar –wind hybrid System (PV-Wind)

### 3. What is Sag in overhead transmission lines [3 marks]

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




### 4. What is Ferranti Effect? [3 marks]

When the long transmission line having high capacitance is unloaded or is operated at light loads, it will be observed that the voltage at the receiving end is more than the sending end. This phenomenon of the rise in voltage at the receiving end is called Ferranti's Effect.

### 5. Define String Efficiency. [3 marks]

The ratio of voltage across the whole string to product of number of discs and the voltage across the disc nearest to the conductor is known as 'String Efficiency'.

$$String\ Efficiency = \frac{\text{Voltage across the string}}{\text{nX voltage across disc nearest to the conductor}}$$

Where ,n= = number of discs in the string.

## 6. Classify Underground Cables based on voltage level. [3 marks]

1) Low tension cables (L.T cables) upto 1 KV
2) High tension cables (H.T cables) upto 11 KV
3) Super tension cables (S.T cables) 22 KV to 33KV
4) Extra high tension cables (EHT cables) 33KV to 66KV
5) Oil filled cables 66 KV to 132 KV
6) Extra super voltage cables beyond 132 KV

## 7. State the essential features of Switchgear . [3 marks]

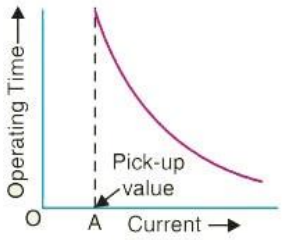
1. Complete reliability
2. Absolutely certain discrimination
3. Quick operation
4. Provision for manual control
5. Provision for Instruments

## 8. Define Re-Striking voltage ? [3 marks]

The transient voltage that appears across the contacts at the instant of arc extinction is called the "restriking voltage".

## 9.What is Inverse time relay? [3 marks]

In this type of relay, the operating time is inversely proportional to the magnitude of the actuating quantity (current or voltage).




## 10. What is the necessity of Neutral grounding [3 marks]

Neutral grounding provides protection to personal and equipment. It is because during earth fault, the current path is completed through the earthed neutral and the protective devices operate to isolate the faulty conductor from the rest of the system.

1. Protection Against Overvoltages
2. Fault Detection and Protection
3. Improved System Stability
4. Reduced Risk of Electrical Shock
5. Protection of Equipment
6. Reduction in Arcing Hazards

## PART-B

**11. (a) Draw the schematic arrangement of a Diesel power plant and explain? [14 marks]**

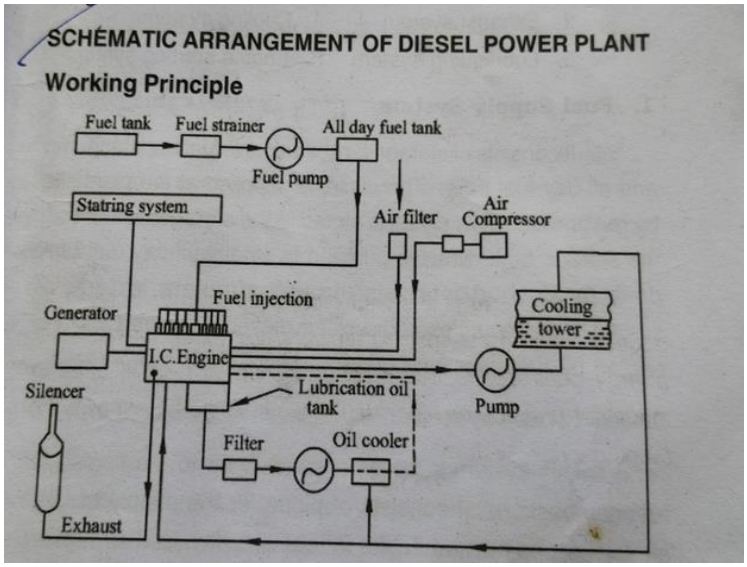
**[ Diagrams -7 marks, Explanation -7marks]**

A generating station in which diesel engine is used as the prime mover for the generation of electrical energy is known as **diesel power station**.

(The diesel bums inside the engine and the products of this combustion act as 'working fluid' to produce mechanical energy. The diesel engine drives the alternator which converts mechanical energy into electrical energy. As the generation cost is high due to high price of diesel, such power stations are only used to produce small power.

Apart from the diesel-generator set the plant has the following auxiliaries.

1. Fuel supply system
2. Air Intake system
3. Exhaust system
4. Cooling system
5. Lubricating system
6. Engine starting system




**1. Fuel Supply System**

It consists of storage tank, strainers, fuel transfer pump and all-day fuel tank. The diesel is supplied at the plant site by rail or road. This diesel is stored in the storage tank. From the storage tank diesel is pumped to smalle all-day fuel tank daily or at short intervals through strainers to remove suspended impurities. The clean diesel is injected into the engine by fuel injection pump.

**2. Air Intake system**

This system supplies necessary air to the engine for fuel combustion. It consists of pipes for the supply of fresh air to the engine manifold. Filters are provided to remove dust particles from air.

**3. Exhaust system**

This system leads the engine exhaust gas outside the building and discharges into atmosphere. A

silencer is usually incorporated in the system to reduce noise level.

**4. Cooling system**

The heat released by the burning of fuel in the engine cylinder is partially converted into work. The remaining part of heat passes through the cylinder walls, piston, rings etc., and may cause damage to the system. In order to keep the temperature of the engine parts within the safe operating limits cooling is provided. The cooling system comprises of water source, pump and cooling towers. The pump circulates water through cylinder and head jacket. The water takes away heat from the engine and itself becomes hot. The hot water is cooled by cooling towers and is re-circulated for cooling.

**5. Lubricating system**

This system minimises the wear of rubbing surfaces of the engine. It comprises of lubricating oil tank, pump, filter and oil cooler. The lubricating oil is drawn from the lubricating oil tank by the pump and is passed through filters to remove impurities. The clean lubricating oil is delivered to parts which require lubrication. The oil cooler connected in the system keeps the temperature of the oil low.

**6. Engine Starting System**

This is an arrangement to rotate the engine during starting, until the unit runs with its own power. Small sets are started manually by handles but for larger units, compressed air is used for starting.

**Advantages**

1. The design and layout of the plant are quite simple
2. It occupies less space as the number and size of the auxiliaries is small.
3. It can be located at any place.
4. It can be started quickly and can pick up load in a short time.
5. There are no stand-by losses.
6. It requires less quantity of water for cooling.
7. It requires less operating staff.

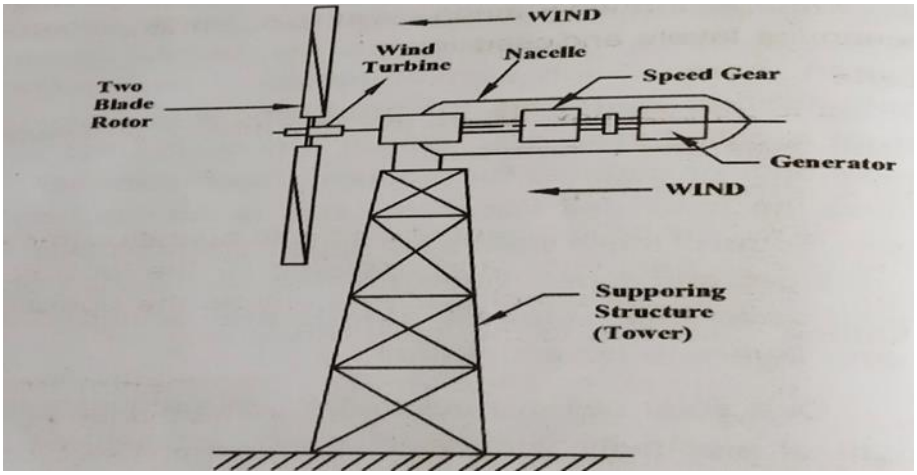
**Disadvantages**

1. The plant has high running charges as the diesel is costly.
2. The plant does not work satisfactorily under overload conditions for a longer period.
3. The plant can only generate small power.
4. The cost of lubrication is generally high
5. The maintenance charge is generally high.

## 11.(b) Explain the principle of Wind power generation. [14 marks]

**[Diagrams -7 marks, Explanation -7marks]**

Wind power is used to produce electric power with the help of multi blade turbine alternator combinations. It is the cheapest of all energies. But it requires high wind for a longer period in the same direction. The wind power station consists of towers, turbine generator assembly, gear box, control system and yawing System Wind power is used even before the development of electrical power by other sources.




**Towers**

Steel towers are provided to carry the assembly of turbine, gear box, generator in a nacelle. There are two types of towers narrow base tower and latticed steel tower. There is a staircase inside the tubular steel tower to carry out maintenance and repair works.

**Turbine**

Turbines have generally three blades. The blades convert wind energy into mechanical energy. This mechanical energy is converted into electrical energy by means of generator. The material selected for blades should be of low weight and at the same time should have high modulus of elasticity usually aluminium and fibre glass is used as blade materials. The design and construction of wind turbines depend upon the power requirement and the location .

**Generator**

When the induction machine runs at below synchronous speed, it can operate only as motor, and above synchronous speed it operates as generator and it is called induction generator. The wind force is used to run the machine above synchronous speed. An induction generator is coupled with the wind turbine with gear. It is a 3 phase generator of totally enclosed type.

**Nacelle**

It is a metal box, where the assembly of turbine gear box and generator is arranged.

**Local control system**

When the wind power station is in operation, the wind turbine will be controlled and operated by the local control system. The local control system controls the operation of the turbine according to the set points. The computer receives the information from the sensors. This information is compared with the set points. If the values differ from the limits, the wind turbine stops. The error is then displayed on the screen and registered.

**Yawing (turning of nacelle)**

Yawing is done for keeping the nacelle to face the wind direction. When the wind direction changes, the wind vane sense the wind direction and sends an error signal to the control system. The control system gives command to the yawing system to yaw the nacelle. Yawing is done by a motor or by some hydraulic system.

**Working principle**

In wind power station, the three phase induction generator is connected with the grid through 11KV/400V transformer. It the wind speed is more, the speed of the machine will be above synchronous speed. Now the machine acts as induction generator and feeds power to the grid. It the wind speed is low, the speed of machine will be below the synchronous speed. Now it draws power from the grid and runs as motor. At this time automatic provisions are made to disconnect the machine from the grid. Even when the power failure is taken place in the grid, the same automatic provisions are made to disconnect the machine from the grid system.

**Advantages**

1. The initial and running costs are very low.
2. It is a quick starting plant.
3. Wind power plant is free from pollution.
4. It requires less space.

**Disadvantages**

1. Wind power plant do not produce same amount of power at all time.
2. Maintenance cost is high.
3. Noisy in operation.

## 12.(a) State the types of supports used in overhead system and explain with necessary diagrams. . [14 marks]

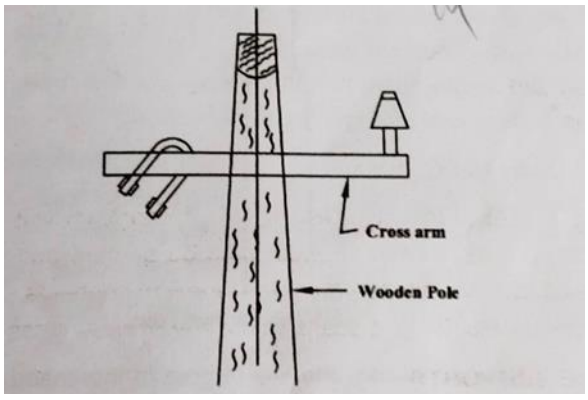
**[Diagram -7 marks, Explanation -7 marks]**

**TYPES OF LINE SUPPORTS**

1. Wooden poles
2. Tubular steel poles
3. Reinforced concrete poles
4. Latticed steel towers

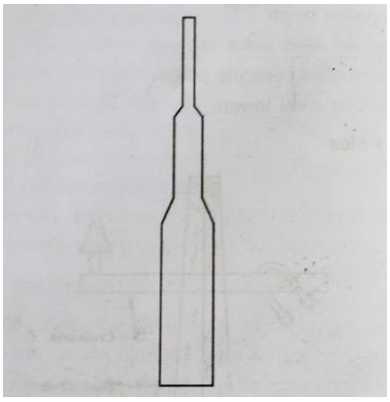
**1. Wooden poles**

The wooden poles must be straight, strong with gradual tapper and free from knots. These poles are cheap and provided with an insulating property. Generally the wooden poles tend to rot below the ground level due to improper foundation. In order to prevent this, the portion of the pole below the ground level is impregnated with preservative compounds like creosote oil. However their life is short. These poles are suitable for shorter spans upto 50 metres. Mostly these poles are used for low voltage distribution purposes. But in some cases they are used upto 11KV with less span.



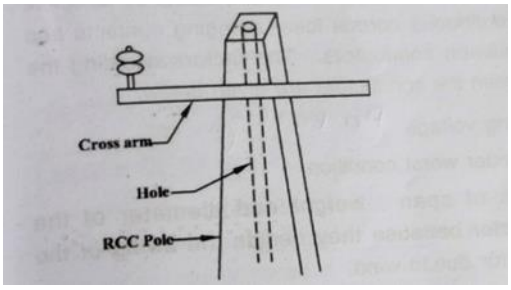
**2. Tubular Steel Poles**

These are often used as a substitute for wooden poles These are lightweight poles, and have high strength and long life and permit longer span. By galvanising, the life of pole is increased. These poles are also used for distribution purposes up to 11KV. For safety purpose they must be earthed. shows a tubular steel pole.



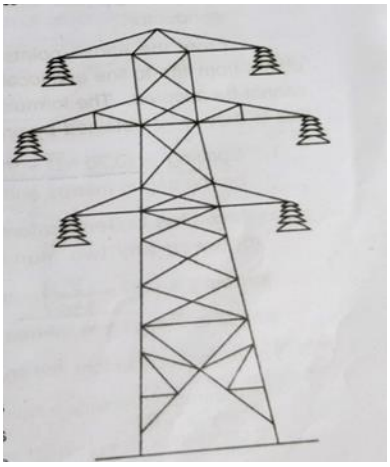
**3.Reinforced Concrete Poles (R.C.C Poles)**

In modern days, the reinforced concrete poles have almost replaced the wooden and steel tubular poles. So they are attractive to look at.They have greater mechanical strength, long life and permit longer spans. They require little maintenance and have good insulating properties. Such poles are quite heavy so the transportation cost increases. Therefore to reduce the transportation cost such poles are often manufactured at the site. shows a reinforced concrete pole.




**4.Latticed Steel Towers**

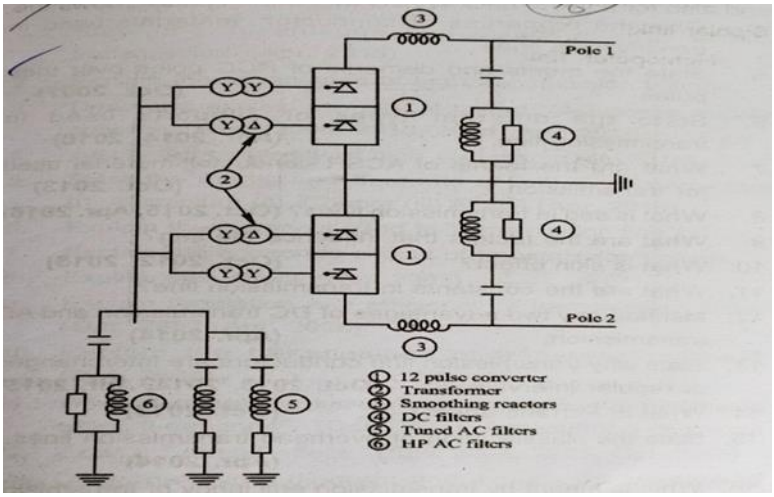
Steel towers have greater mechanical strength, longer life, and permit longer spans. Hence they are most suitable for crossing fields, valleys, railway lines. rivers etc. They withstand most severe climatic conditions. Steel towers are classified into Narrow base lattice type and Broad base towers. Narrow base steel towers are used for smaller spans and, broad base towers are used when the span is very large.



## 12.(b) Draw the schematic diagram of a HVDC converter station and explain. . [14 marks]

**[Diagram -7 marks, Explanation -7 marks]**

The image shows a schematic diagram of a typical HVDC (High Voltage Direct Current) converter station. These stations are essential components in HVDC power transmission systems, where electricity is transmitted over long distances or undersea using DC instead of AC. The major components of the station are labeled, and their functions are detailed below.




**Components and Their Functions:**

1. **12-Pulse Converter (Label 1):**

   The 12-pulse converter is the heart of the HVDC system. It converts alternating current (AC) to direct current (DC) in rectifier mode or DC to AC in inverter mode.

   - Achieves 12 pulses per cycle using two 6-pulse bridge converters in series or parallel.
   - Helps in reducing harmonics.

2. **Transformers (Label 2):**
   - Step up or step down the AC voltage as required by the HVDC system.
   - Typically, transformers are configured in star-star (Y-Y) and star-delta (Y-Δ) connections to provide phase shift for harmonic reduction.
3. **Smoothing Reactors (Label 3):**
   - Installed in the DC line to reduce ripple in the DC current and provide smoothing.
   - These are large inductors that also limit the rate of rise of fault current during DC line faults.
4. **DC Filters (Label 4):**
   - Filters out high-frequency harmonics generated by the converter station on the DC side.
   - Ensures the transmitted DC power has minimal interference with communication lines.

5. **Tuned AC Filters (Label 5):**
    - Installed on the AC side to remove harmonics created during the AC-DC conversion process.
    - Also improve the power factor of the system.
6. **High-Pass (HP) AC Filters (Label 6):**
    - Target specific high-frequency harmonics for elimination.
    - Complement the tuned AC filters to ensure the AC output is clean and within permissible harmonic limits.

**Power Flow:**

- **AC to DC Conversion:** On the sending-end converter station, the AC voltage from the power grid is stepped up or down by transformers, converted to DC using the 12-pulse converters, and then transmitted via the DC transmission lines.
- **DC to AC Conversion:** At the receiving-end station, the DC power is converted back to AC and integrated into the local grid using similar equipment in reverse operation.

**Advantages of HVDC Systems:**

1. **Reduced Power Losses:** HVDC lines have lower power losses over long distances compared to AC lines.
2. **Long-Distance Transmission:** HVDC is efficient for long-distance and undersea transmission.
3. **No Reactive Power Issues:** HVDC eliminates the problem of reactive power, which is common in AC systems.
4. **Interconnection of Grids:** HVDC allows the interconnection of asynchronous AC grids.

## 13.(a) Explain strain, shackle and stay insulators with necessary sketches. . [14 marks]

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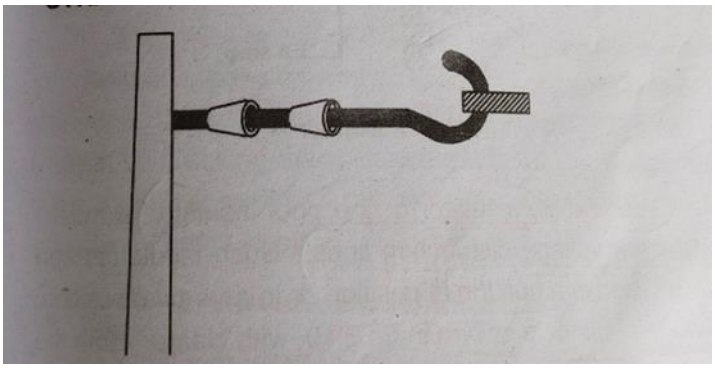
**[Diagrams -7 marks, Explanation -7 marks]**

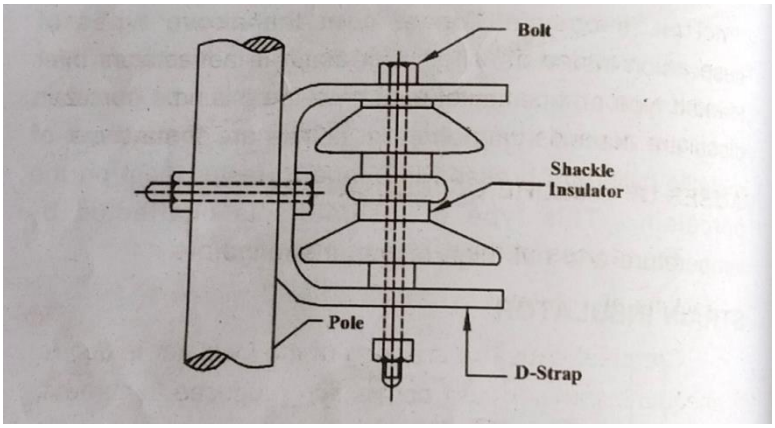
**Strain insulator**

These insulators are used in places where there is very high tensions, such as dead ends and sharp curves or there is a corner, or the line crosses the river etc. For low voltages up to 11 KV shackle insulators can be used. But for high voltage transmission lines, strain insulators are used. If the pull on the string of the suspension insulators is high such as in case of long spans across the river, under these circumstances two, three or four strings of insulators are used in series. Two or more strings of insulators in parallel may be used if the tension exceeds that for a single string .



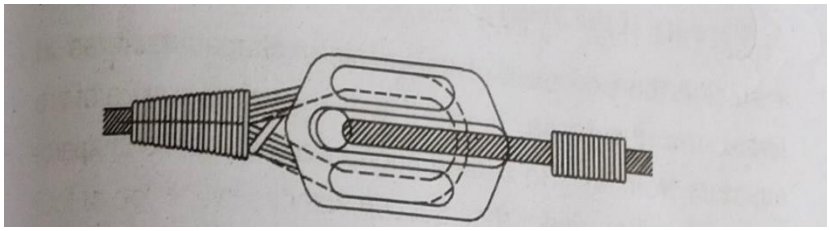
**Shackle insulator**

The shackle insulator or the pool insulator is mostly used for low voltage distribution lines. Such insulators car either be used in a horizontal position or in a vertical position. A shackle insulator is shown. with clamp. Both the low voltage conductors and the house service wires are attached to the shackle insulator. The conductor is fixed the groove by soft binding wire.




**Stay insulator**

The insulator used in the stay wire is called stay insulator. It is made of porcelain. It is used to insulate the stay wire. In the case of breakage of insulator the conductor will not fall to the ground. The stay insulator is shown. These are provided at a height of about 3 metres from the ground level for the safety of people on the ground. The size of insulator depends upon the tensile strength of stay wire.



## 13.(b) With neat diagram, explain about pressure cables. State their advantages and disadvantages. . [14 marks]

**[Diagram -7 marks , Explanation -7 marks]**

For voltages above 66 KV solid type cables are unreliable. Because there is a danger of breakdown of insulation due to presence of voids. When the operating voltages are greater than 66 KV pressure cables are used .In these cables voids are eliminated by increasing the pressure of compound. For this reason they are called pressure cables. There are two types of pressure cables

They are

1. Oil filled cables
2. Gas pressure cables

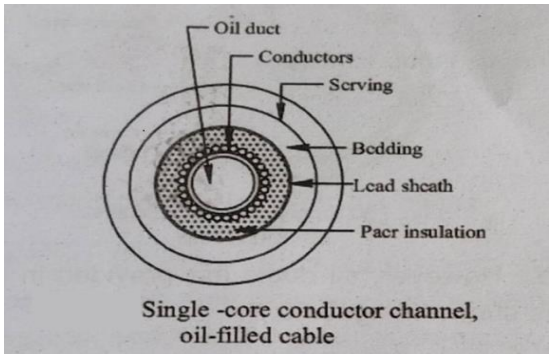
**OIL FILLED CABLES**

In oil filled cables channels of ducts are provided in the cable for oil circulation. The oil under pressure is kept constantly supplied to the channel by means of external reservoir. The reservoir is placed at a suitable distance (say 500 m) along the cable route. Oil under pressure compresses the layers of paper insulation. Hence in this types of cables voids are eliminated. Therefore this type of cables is used from 66 KV to 230 KV.

**Oil filled cables are of three types**

1. Single core conductor channel.
2. Single core sheath channel.
3. Three core filler space channel.

**1. Single core conductor channel oil filled cable**

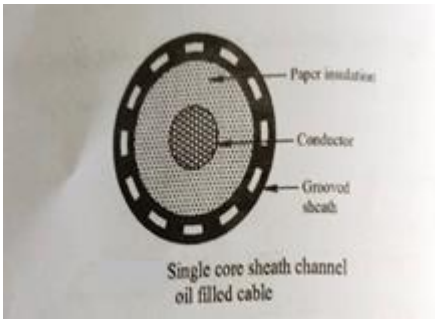


Single -core conductor channel, oil-filled cable

The oil channel is formed at the centre by stranding the conductor wire around a hollow cylindrical steel spiral tape. The oil under pressure is supplied to the channel by means of external reservoir. The oil pressure compresses the layers of paper insulation and prevents the possibility of void formation. The system is so designed that when the oil gets expanded due to increase in cable temperature, the extra oil collects in the reservoir. When the cable temperature falls during light load coditions, the oil from the reservoir flows to the channel. The disadvantage of this type of cable is that the channel is at the middle of the cable and is at full voltage with respect to earth. So joints are complicated.

**2. Single core sheath channel oil filled cable**

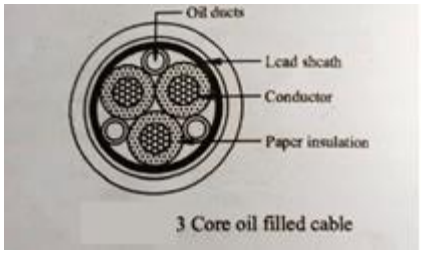
In this type of cable, the conductor is solid similar to that of solid cable and is paper insulated.However,oil ducts are provided in the metallic sheath.



Single core sheath channel oil filled cable

**3. Three core filler space channel**

In this type of cable oil ducts are located in the filler spaces as shown .The channels are made of perforated metal ribbon tubing and are at earth potential.



3 Core oil filled cable

**Advantages of oil filled cable**

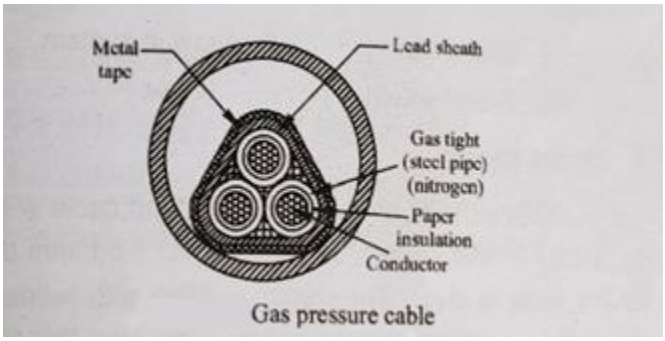
1. The formation of voids and ionisation is avoided.
2. Oil filled cable withstands high temperature.
3. Dielectric strength of the cable is increased**.**
4. A defect in the sheath will be indicated by the leakage of oil at the place.
5. The possibility of earth fault is decreased.
6. The size of cable for a given voltage and KVA rating is small.

**Disadvantages**

1. Higher cost
2. Complication in construction and laying.

**GAS PRESSURE CABLES**

In this type of cable, the gas pressure produces radial compression, which tends to close any voids. This is the principle of gas pressure cable. The construction of cable is similar to that of ordinary solid type. But it is of triangular shape and thickness of lead sheath is 75% that of solid cable. The triangular section reduces the weight and gives low thermal resistance. The main reason for triangular shape is that the lead sheath acts as a pressure membrane. The sheath is protected by a thin metal tape. The cable is laid in a gas tight steel pipe. The pipe is filled with dry nitrogen gas at 12 to 15 atmospheres. The gas pressure produces radial compression and closes the voids formed between the layers of paper insulation.



Gas pressure cable

**Advantages**

1. These cables can carry more load current and operate at higher voltage than a normal cable.
2. Maintenance cost is low.
3. The nitrogen gas helps in quenching any flame.

**Disadvantage**

1.The overall cost is very high.

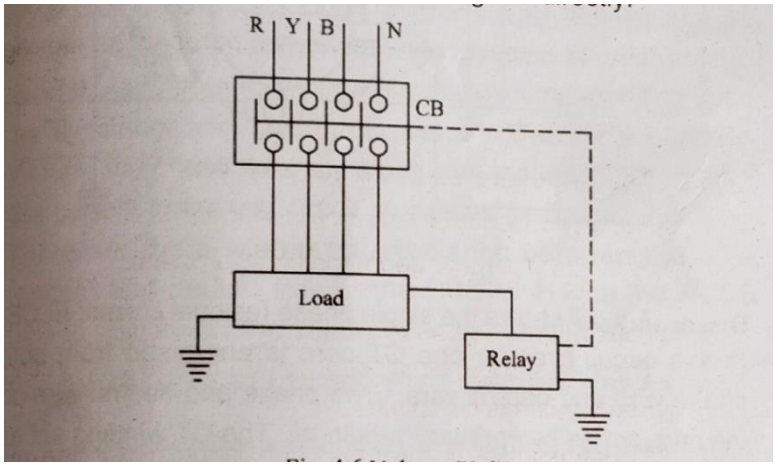
## 14 a) Explain the construction and working of Earth Leakage Circuit Breaker (E.L.C.B) with neat diagram. [14 marks]

**[Diagrams -7 marks, Explanation -7 marks]**

Current leakage from any electrical installation may results in insulation failure of the electric circuits. So it must be properly detected and prevented to avoid electric shock any one touches the installation. An earth leakage circuit breaker detects the earth leakage current and trips the power supply. There are two types of ELCB, They are

1. Voltage ELCB
2. Current ELCB (RCCB)

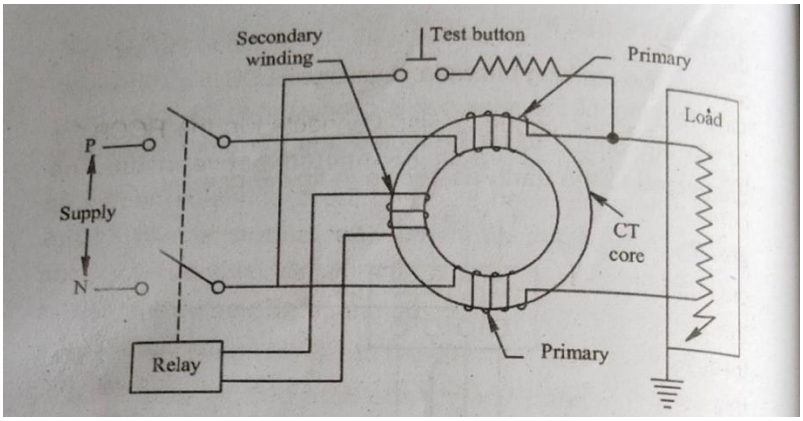
**VOLTAGE ELCB**




The working principle of voltage ELCB is quite simple. One terminal of the relay coil is connected to the metal body of the equipment to be protected and the other terminal is connected to the earth .If any insulation failure occurs or live phase wire touches the metal body of the equipment there must be a voltage difference appears across the terminal of the coil connected to the equipment and earth. If the voltage. Difference crosses a predetermined limit the current through the relay sufficient to operate the relay and hence tripping the associated circuit breaker to disconnect the power supply.

**RESIDUAL CURRENT CIRCUIT BREAKER (RCCB (OR) CURRENT ELCB**

The residual current circuit breaker is more sensitive than ELCB (Voltage ELCB). The current based ELCB is referred to as RCCB. In this circuit breaker one CT core is energised from both phase wire and neutral wire. The phase and neutral wire on the core act as two primary windings. The CT winding act as secondary and is connected across the relay as shown. The polarity of phase winding and neutral winding on the core is chosen such that in normal condition the flux of one winding opposes that of other. If no leakage current between the two lines, the current flows through phase wire will be returned via the neutral wire.




As both the currents are equal and opposite, the resultant flux produced by these currents is zero. Hence there is no current flows through the secondary winding of CT. Therefore the relay connected to the CT secondary is inoperative. When any earth leakage occurs in the equipment there may be a part of phase current passes to the earth through the leakage path instead of returning via neutral wire. Hence the magnitude of neutral current is not equal to

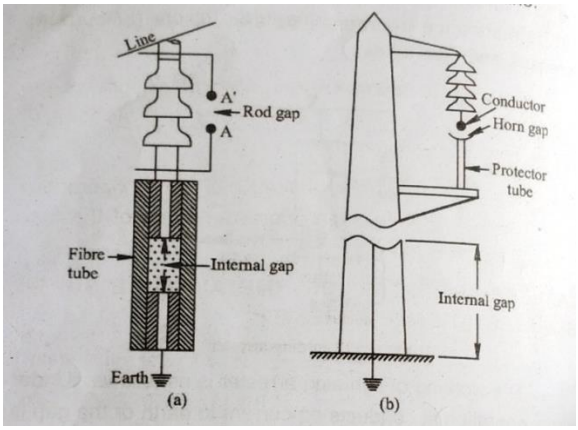
phase current. Hence a resultant flux will setup in the core. Therefore a current will be induced in the CT secondary. Hence the relay connected to the second- ary will operate and trip the circuit breaker.

The test circuit is also connected in the RCCB for testing the RCCB. It is connected between the ling conductor on the load side and the supply side neutral as shown. When the test button is pushed the current starts flowing through the test circuit depending upon the resistance provided in the circuit. This current passes through the phase side coil along with the load current. But this current in the test circuit by passes neutral side winding. Therefore there will be an unbalance between line side (phase) and neutral side of the RCCB. Hence the RCCB trips to disconnect the supply even in normal condition.

## 14. (b) Draw and explain about the expulsion type lightning arrester. State its advantages and disadvantages . [14 marks]

**[Diagrams -7 marks, Explanation -7 marks]**

**EXPULSION TYPE LIGHTNING ARRESTOR**




This type of arrestor is also called "Protector tube" and is commonly used on system operating at voltages upto 33KV shows the important parts of an expulsion type lightning arrester. It consists of a rod gap AA' in series with a second gap enclosed within the fibre tube. The gap in the fibre tube is formed by two electrodes. The upper electrode is connected to the rod gap and the lower electrode to the earth. One expulsion arrestor is placed under each line conductor.

When over voltage occurs on the line, the series gap AA' is spanned and an arc is struck between the series gap and electrodes gap in the tube. The heat of the arc vapouries some of the fibre of tube walls, resulting the production of a neutral gas. The gas builds up high pressure and is expelled through the lower electrode, which is hollow. As the gas leaves the tube violently, it carries away ionised air around the arc and thus the arc is extinguished.

**Advantages**

1. They are not very expensive.
2. They block the flow of power frequency current
3. They can be easily installed

**Disadvantages**

1. This type of arrester cannot be mounted in an enclosed equipment due to the discharge of gases during operation.
2. Due to the poor volt-amp characteristics of the arrester, it is not suitable for the protection of expensive equipment.
3. It can be used only limited number of operations because during each operation, some of the fibre material is ionised.

**15. (a) With a diagram, explain the working of differential relay.** [14 marks]

**[Diagrams -7 marks, Explanation -7 marks]**

**DIFFERENTIAL RELAYS**

A differential relay is a relay that operates when the phasor difference of two or more similar electrical quantities exceeds a predetermined value.

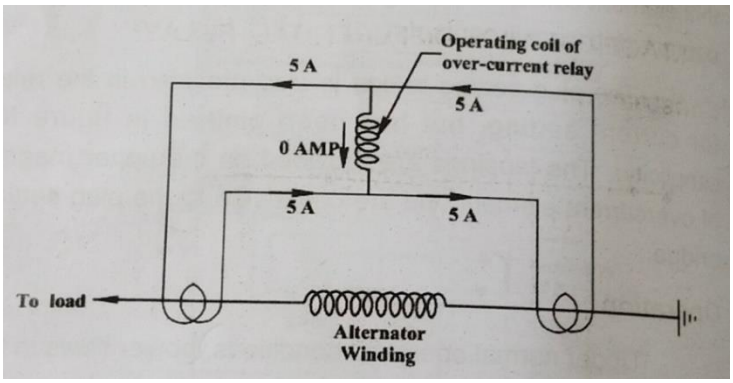
There are two types.

1. Current differential relay
2. Voltage differential relay

**CURRENT DIFFERENTIAL RELAY**

**Construction**

Two identical current transformers are fitted each on either end of the section to be protected (alternator winding in this case). The secondaries of the current transformers are connected in series in such a way that they carry the induced current in the same direction. The operating coil of the over current relay is connected across the current transformer secondary circuit. This differential relay compares the current at the two ends of the alternator winding



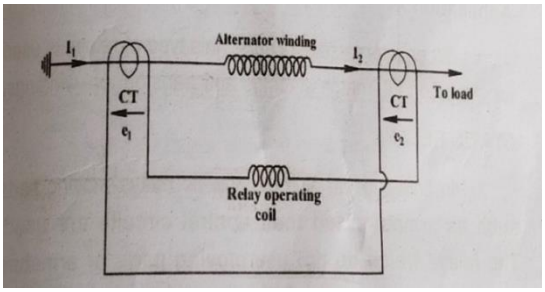

**Principle of operation**

Under normal operating condition there is no fault current. The secondary currents 1 and 2equal and there is no circulating current in the operating coil of the relay. Therefore the relay remains in operative. When a fault occurs on the alternator winding the secondary currents 1 and 2 are not equal. The difference of current i1 and flows i2 through the operating coil of the relay. Therefore relay operates and closes the trip circuit.

**VOLTAGE BALANCE DIFFERENTIAL RELAY**

**Construction**

Two similar current transformers are connected at either end of the elements to be protected (alternator winding) by means of pilot wires. The secondaries of current transformers are connected in series with a relay in such a way that under normal working conditions their induced emfs in opposition.




**Principle of operation**

Under normal working conditions, equal currents (i1=i2) flow in both primary windings. Therefore the secondary voltages of the two transformers are balanced against each other and no current will flow through the relay operating coil. When a fault occurs in the protected zone the currents in the two primaries will differ from one another (ie., i1=i2) and their secondary voltages are unbalance. This voltage difference will cause a current to flow through the operating coil of the relay. Thus relay closes the trip circuit.

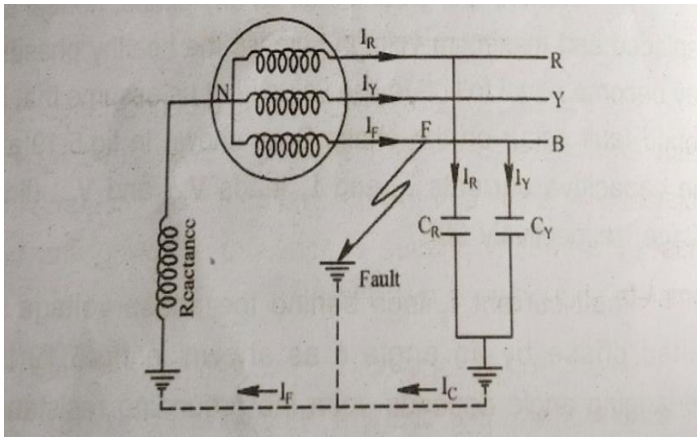
**Application**

When internal fault occurs, this type of relays is used for protecting alternator windings and transformer windings.

## 15.(b) Explain about reactance grounding with a diagram and vector diagram [14 marks]

**[Diagrams -7 marks, Explanation -7marks]**

**REACTANCE GROUNDING**




This system of earthing is similar to resistance earthing except that the resistance between the neutral and earth is replaced by a reactance of three times. This system of earthing is shown. The fault current depends upon the reactance. So by varying the reactance in the earth circuit, the magnitude of fault current can be changed. If X is very small, the system behaves as an effectively grounded system. If X is very large, there is increase in transient voltage due to arcing. Hence this system is not in common use.

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