324

APRIL 2024

GENERATION, TRANSMISSION & SWITCHGEAR

PART-A

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

- The reservoir to be constructed should have large catchment area.
- Sufficient quantity of water at a reasonable head should be available.
- There should be possibility of stream diversion during construction period.
- The distance between the power station and load centre should be minimum.
- The site should allow for strong foundations with minimum cost.

2. Name the supplementary fuels used in co-generation plants. [3 marks]

- Veg oil
- Bio methanol
- Natural gas
- Coal
- Bio mass and
- Bio gas

3. State the advantages of high transmission voltage. [3 marks]

- With increase in the transmission voltage, the size of the conductors is reduced (Cross section of the conductors are reduced as required current is carrying capacity reduced).
- As the reduction in current carrying requirement, losses are reduced which leads betterefficiency
- Due to low current, voltage drop will be less so voltage regulation improves

4. What is Span? State the factors affecting it. [3 marks]

The distance between two adjacent line supports in an overhead line is called length of span.
The length of the span depends on the

- Temperature
- Working Voltage
- Maximum Tension on the poles and the conductors
- Load
- Type of support used

5. State the advantages of Glass insulators [3 marks]

- Compared with porcelain, it has high dielectric strength.
- Its resistivity is also high.
- It has a low thermal expansion coefficient.
- Compared with porcelain insulators, it has higher tensile strength.
- Since it is transparent, it will not heat in sunlight like porcelain.
- Due to its transparency, impurities and air bubbles can be easily detected inside the glass insulator.
- Glass has a very long service life because the mechanical and electrical properties of glass are not affected by aging.
- Glass is cheaper than porcelain.

6. List the disadvantages of UG cables. [3 marks]

- Since the electrical field in the three core cables is tangential, the paper insulation and the fibrous materials are subjected to the tangential electrical stresses. This stresses weakens the fibrous material as well as the resistance and dielectric strength for the insulation along the tangential path.
- The weakening of the insulation may lead to the formation of air spaces in the insulation. Under high voltages the air may be ionized and cause deterioration and breakdown of insulation. For this reason, the belted cables are only suitable for voltages up to 11KVa and not higher.
- Due to the large diameter of the paper belt, bending the cable may lead to the formation of wrinkles and gaps.

7. Define Short time rating. [3 marks]

- It is defined as the time period for which the circuit breaker is capable of carrying high currents or faulty current safely in a closed position.
- This happens in case of momentary fault like bird age on the transmission lines and the fault is automatically cleared and persists only for 1 or 2 seconds.

8. Classify fuses. [3 marks]

Fuses are generally classified into two:

- Low voltage fuses
- High voltage fuses

Low Voltage Fuses

Low Voltage Fuses are of two types

- Semi Enclosed Rewritable Fuse
- High Rupturing Capacity (HRC) Cartridge Fuses

9. State the fundamental requirements of protective relaying. [3 marks]

The principal function of protective relaying is to cause the prompt removal from service of any element of the power system when it starts to operate in an abnormal manner or interfere with the effective operation of the rest of the system. The fundamental requirements are

1. Selectivity
2. Speed
3. Sensitivity
4. Reliability
5. Simplicity
6. Economy

10. What is system grounding? [3 marks]

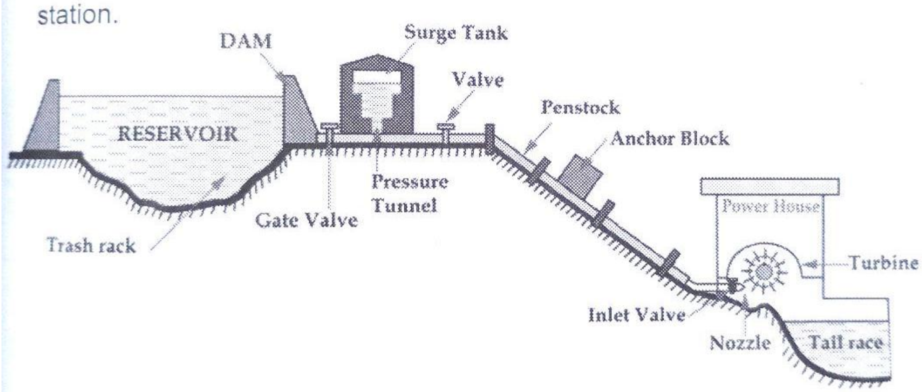
The process of connecting some electrical part of the power system (e.g. neutral point of a star connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil) iscalled **system grounding.**

PART-B

11.(a) Draw the schematic of a Hydro power plant and explain. [14 marks]

[Diagrams -7 marks, Explanation -7marks]

A generating station which uses the potential energy of stored water for the generation of electrical energy is known as hydel power station.



Dam and Reservoir:

- The dam is constructed on a large river in hilly areas to ensure sufficient water storage at height. The dam forms a large reservoir behind it.
- The height of water level (called as water head) in the reservoir determines how much of potential energy is stored in it.

Control Gate:

- Water from the reservoir is allowed to flow through the penstock to the turbine. The amount of water which is to be released in the penstock can be controlled by a control gate.

Penstock:

- A penstock is a huge steel pipe which carries water from the reservoir to the turbine. Potential energy of the water is converted into kinetic energy as it flows down through the penstock due to gravity.

Water Turbine:

- Water from the penstock is taken into the water turbine. The turbine is mechanically coupled to an electric generator.
- There are two main types of water turbine; (i) Impulse turbine and (ii) Reaction turbine. Impulse turbines are used for large heads and reaction turbines are used for low and medium heads.

Surge Tank:

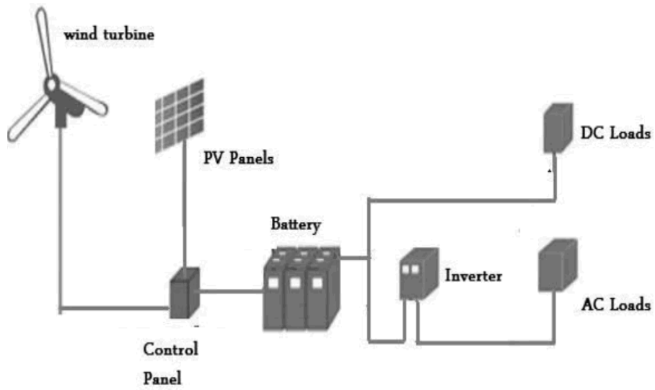
- Surge tanks are usually provided in high or medium head power plants when considerably long penstock is required.
- A surge tank is a small reservoir or tank which is open at the top. It is fitted between the reservoir and the power house.
- The water level in the surge tank rises or falls to reduce the pressure swings in the penstock. When there is sudden reduction in load on the turbine, the governor closes the gates of the turbine to reduce the water flow.

Generator:

- A generator is mounted in the power house and it is mechanically coupled to the turbine shaft.
- When the turbine blades are rotated, it drives the generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

11.(b) Explain any one type of renewable energy systems. [14marks]

[Diagrams -7 marks, Explanation -7marks]



- **Hybrid system** are the combination of two different power generation system, they are solar PV and another power generating energy source.
- Intermittent energy resources and energy resources unbalance are the most important reason to install a hybrid energy supply system.
- The Solar PV and wind hybrid system suits to conditions where sunlight and wind has seasonal shifts. As the wind does not blow throughout the day and the sun does not shine for the entire day, using a single source will not be a suitable choice.
- A hybrid arrangement of combining the power harnessed from both the wind and the sun and stored in a battery can be a much more reliable and realistic power source.
- The load can still be powered using the stored energy in the batteries even when there is no sun or wind.
- Hybrid systems are usually built for design of systems with lowest possible cost and also with maximum reliability.
- Battery system is needed to store solar and wind energy produced during the day time. During night time, the presence of wind is an added advantage, which increases the reliability of the system. In the monsoon seasons, the effect of sun is less at the siteand thus it is apt to use a hybrid wind solar system.

Photovoltaic solar power

- PV (Photo-voltaic) cells are made up from semiconductor structures as in the computer technologies.
- Sun rays are absorbed with this material and electrons are emitted from the atoms .This release activates a current.
- Solar power is converted into the electric power by a common principle called photo electric effect.
- The solar cell array or panel consists of an appropriate number of solar cell modules connected in series or parallel based on the required current and voltage.

Wind Power

- The wind energy is a renewable source of energy. Wind turbines are used to convert the wind power into electric power. Electric generator inside the turbine converts the mechanical power into the electric power.
- Wind turbine systems are available ranging from 50W to 3-4 MW. The energy production by wind turbines depends on the wind velocity acting on the turbine.

Batteries

- The batteries in the system provide to store the electricity that is generated from the wind or the solar power. Any required capacity can be obtained by serial or parallel connections of the batteries.

Inverter

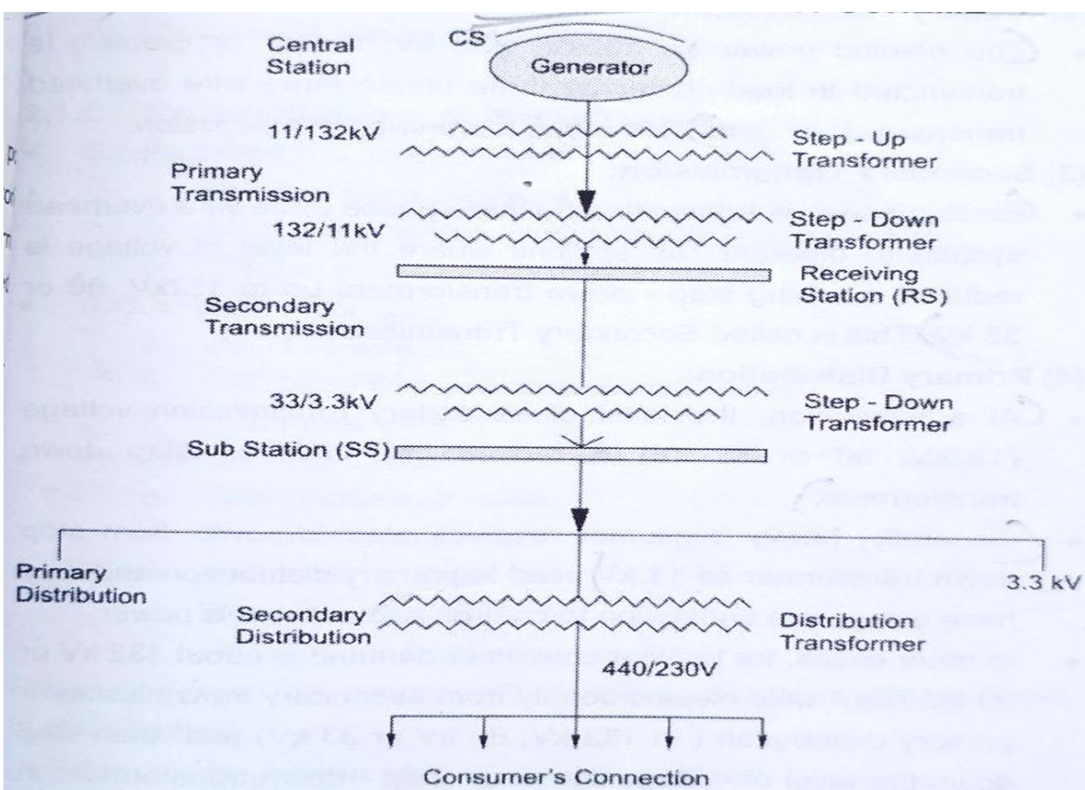
- Energy stored in the battery is drawn by electrical loads through the inverter, which converts DC power into AC power.
- The inverter has in-built protection for Short-Circuit, Reverse Polarity, Low Battery Voltage and Over Load.

Microcontroller

- The microcontroller compares the input of both Power system and gives the signal to the particular relay and charges the DC Battery.
- The DC voltage is converted into AC Supply by Inverter Circuit. The MOSFET is connected to the Secondary of the centre tapped transformer.
- By triggering of MOSFET alternatively, the current flow in the Primary winding is also alternative in nature and we get the AC supply in the primary winding of the transformer.

12.(a) Draw the typical layout of AC power supply scheme.

[Diagram -7 marks, Explanation -7 marks]



Layout of AC power system has two components:

- **Transmission System**
- **Distribution System**

We can explore these systems in more categories such as Primary transmission and secondary transmission. Similarly primary distribution and secondary distribution.

1. Generating Station
2. Primary transmission
3. Secondary transmission
4. Primary Distribution
5. Secondary Distribution

Generating Station:

The place where electric power produced by the parallel connected three phase alternators/generators is called Generating Station.

The Ordinary power plant capacity and generating voltage may be 11kV, 11.5 kV 12kV or 13kV. But economically, it is good to step up the produced voltage from (11kV, 11.5kV Or 12 kV) to 132kV, 220kV or 500kV or greater by Step up transformer (power Transformer).

Primary Transmission:

The electric supply (in 132kV, 220 kV, 500kV or greater) is transmitted to load center by three phase three wire (3 Phase – 3 Wires) overhead transmission system.

Secondary Transmission:

- We have been connected with receiving station by line is called Secondary transmission.
- At receiving station, the level of voltage is reduced by step-down transformers up to 132kV, 66 or 33 kV, and Electric power is transmitted by three phase three wire (3 Phase – 3 Wires) overhead system to different sub stations. This is called Secondary Transmission.

Primary Distribution:

- At a substation, the level of secondary transmission voltage is (132kV, 66 or 33 kV) reduced to 11kV by step down transformers.
- Generally, heavy consumer receives from step down transformer as 11 kV used in primary distribution (in three phase three wire overhead system) and they have a separate substation to control and utilize this power.
- For heavier consumer (at large scale) their demand is about 132 kV or 33 kV. they take electric supply from secondary transmission or primary distribution (in 132 kV, 66kV or 33kV) and then step down the level of voltage by step-down transformers in their own sub station for utilization.

Secondary Distribution:

- Electric power is transferred from Primary distribution i.e.11kV to secondary distribution substation. This substation is located nearby consumers areas where the level of voltage reduced by step down 440V by Step down transformers.
- These transformers called Distribution transformers, three phase four wire system is used ((3 Phase – 4 Wires)). So 400 Volts is available (Three Phase Supply System) between any two phases and 230 Volts (Single Phase Supply) between a neutral and phase (live) wires.

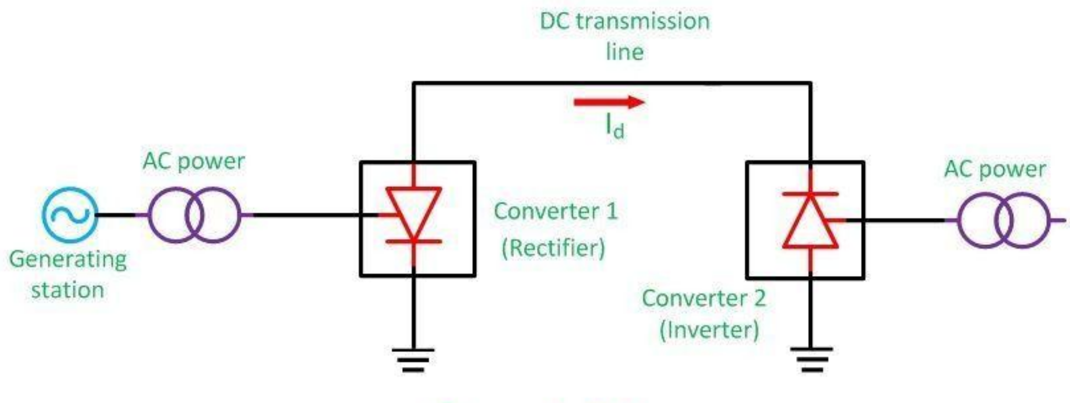
12. (b) Draw and explain any two D.C. link configurations.

[Diagram -7 marks, Explanation -7 marks]

HVDC links are classified into three type. These links are explained below;

Monopolar link :

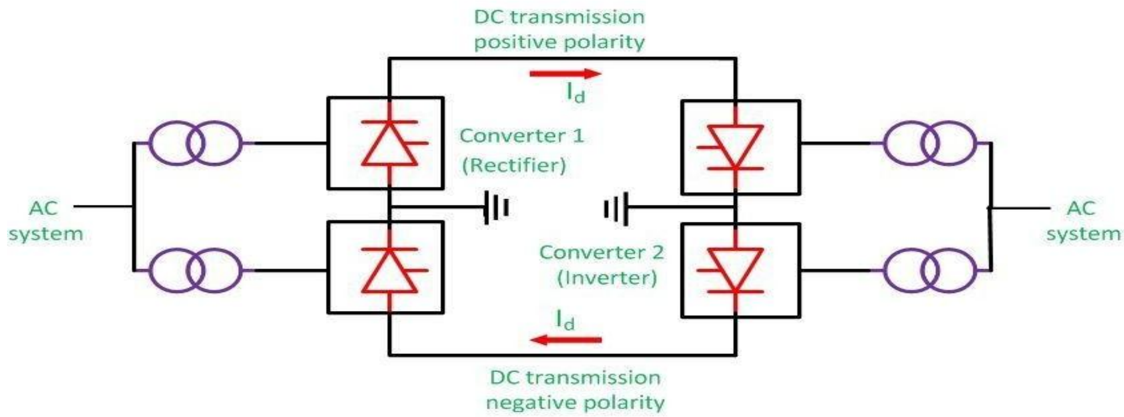
- It has a single conductor of negative polarity and uses earth or sea for the return path of current. Sometimes the metallic return is also used.
- In Monopolar link, two converters are placed at theend of each pole. Earthing of poles is done by earth electrodes placed about 15 to 55 km away from the respective terminal stations.
- But this link has several disadvantages because it uses earth as a return path. Monopolar link is not much in use nowadays.



Monopolar link

Bipolar link

- A bipolar link has two conductors, one positive and the other negative with respect to earth. The midpoints of converters at each terminal station are earthed via electrode lines.
- The voltage between the conductors is equal to two times the voltages between either of the two conductors and ground.
- Since one conductor is at the positive polarity with respect to earth and other is at negative polarity with respect to earth.
- In bipolar link when one pole goes out of operation, the system may be changed to the monopolar mode with the ground return.
- Thus, the system continues to supply the half rated power. Bipolar links are most commonly used in all high power HVDC systems.

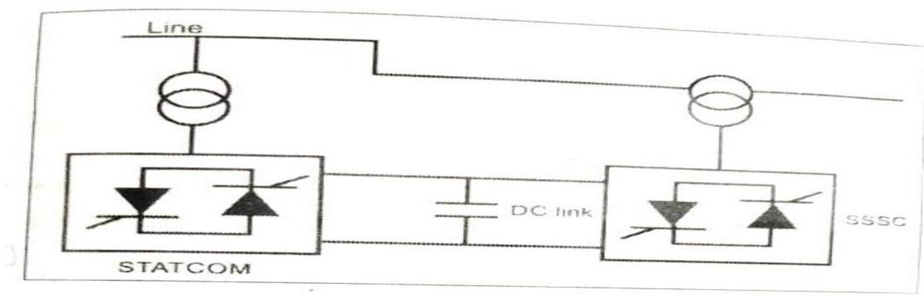


Bipolar link

13.(a) Draw and explain UPFC Facts controller with a block diagram.

[Diagrams -7 marks, Explanation -7 marks]

- UPFC is the combination of STATCOM and SSSC which are coupled by via a common DC link. It can exhibit the characteristics of both SSSC with series voltage injection and STATCOM with shunt current injection , with added features.
- Its function is to allow bi-directional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM.
- Also, these can be controlled to provide concurrent reactive and real power series lines compensation without use of an external source.
- In the above UPFC, SSSC injects a voltage with controllable magnitude and phase angle in series with line through a series transformer. The function of STATCOM is to absorb or supply the reactive power demanded by SSSC at the common DC link.
- It can also supply or absorb the controllable reactive power to the transmission line to provide independent shunt reactive compensation.



Advantages:

- They help in obtaining optimal system operation by reducing power losses and improving voltage profile.
- Fast controllability of FACTS controllers, the power carrying capacity of lines can be increased up to thermal limits.
- The transient stability limit is increased thereby improving the dynamic security of the system.

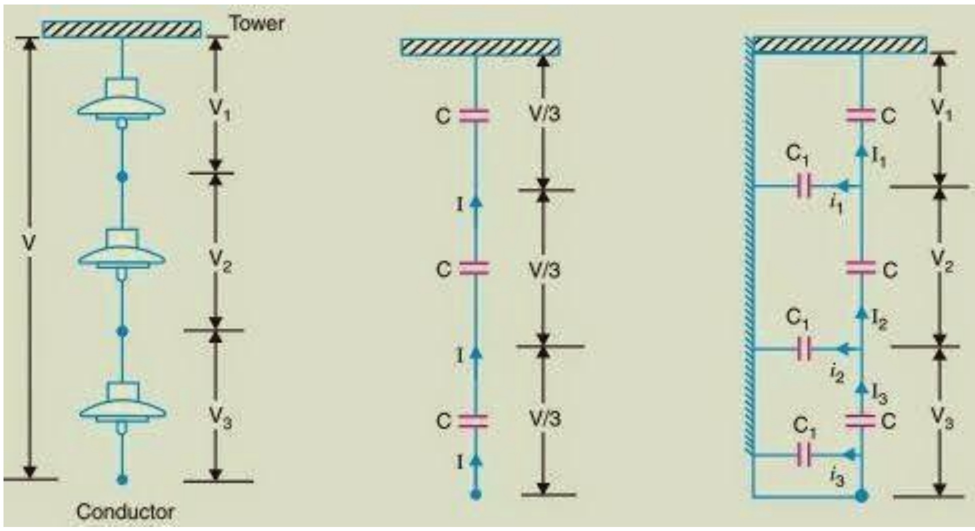
Applications of FACTS:

- Voltage control using shunt connected controllers.
- Controlled power flow using series connected controllers.
- UPFC can controlled both voltage and power flow.

13. b)Derive an expression for voltage across a string of three suspension insulators. Also define string efficiency

[Diagram and Derivation -12marks, Definition of string efficiency-02 marks]

A string of suspension insulators consists of a number of porcelain discs connected in series through metallic links.



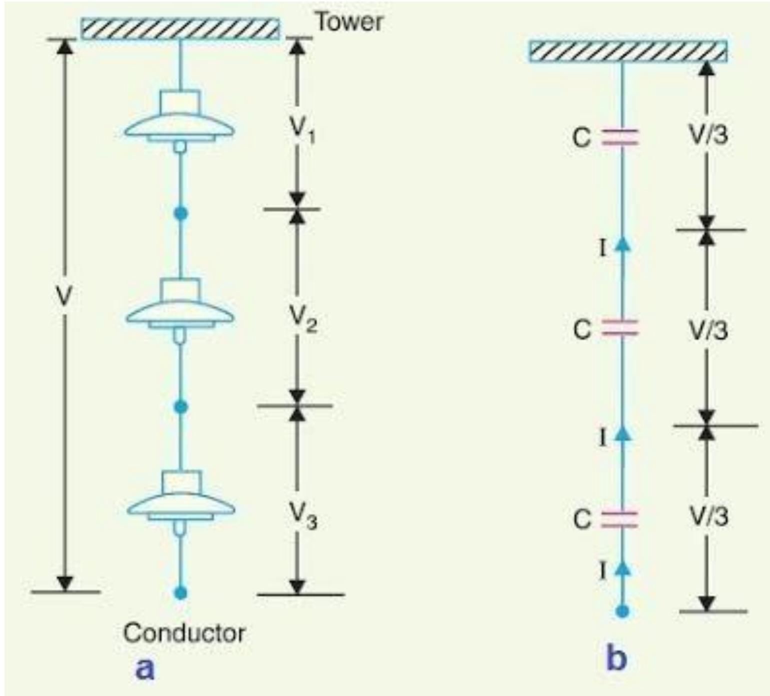
The following points may be noted regarding the potential distribution over a string of suspension insulators :

(i) The voltage impressed on a string of suspension insulators does not distribute itself uniformly acrossthe individual discs due to the presence of shunt capacitance.
(ii) The disc nearest to the conductor has maximum voltage across it. As we move towards the cross-arm,the voltage across each disc goes on decreasing.
(iii) The unit nearest to the conductor is under maximum electrical stress and is likely to be punctured. Therefore, means must be provided to equalize the potential across each unit.
(iv) If the voltage impressed across the string were D.C., then voltage across each unit would be the same.It is because insulator capacitances are ineffective for d.c.

To find voltage

Figure below shows the equivalent circuit for a 3-disc string. Let us suppose that self capacitanceof each disc is C. Let us further assume that shunt capacitance C1 is some fraction K of self capacitance i.e., C_1 = KC. Starting from the cross-arm or tower, the voltage across each unit is V_1,V_2 andV_3 respectively as shown.

Applying Kirchhoff's current law to node A, we get,



$$I_2 = I_1 + i_1$$

or $$V_2\omega C = V_1\omega C + V_1\omega C_1$$

or $$V_2\omega C = V_1\omega C + V_1\omega KC$$

$$\therefore V_2 = V_1(1 + K) \quad ...(i)$$

Applying Kirchhoff's current law to node B, we get,

$$I_3 = I_2 + i_2$$

$$V_3\omega C = V_2\omega C + (V_1 + V_2)\,\omega C_1$$

or $$V_3\omega C = V_2\omega C + (V_1 + V_2)\,\omega K C$$

or $$V_3 = V_2 + (V_1 + V_2)K$$

$$= KV_1 + V_2(1 + K)$$

$$= KV_1 + V_1(1 + K)^2$$

$$= V_1[K + (1 + K)^2]$$

$$V_3 = V_1[1 + 3K + K^2]$$

$$V = V_1 + V_2 + V_3$$

$$= V_1 + V_1(1 + K) + V_1(1 + 3K + K^2)$$

$$= V_1(3 + 4K + K^2)$$

$$V = V_1(1 + K)(3 + K)$$

String efficiency:

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

string efficiency = $\frac{\text{voltage across string}}{\text{n x voltage across disc nearest conductor}}$

Where n = number of discs in the string.

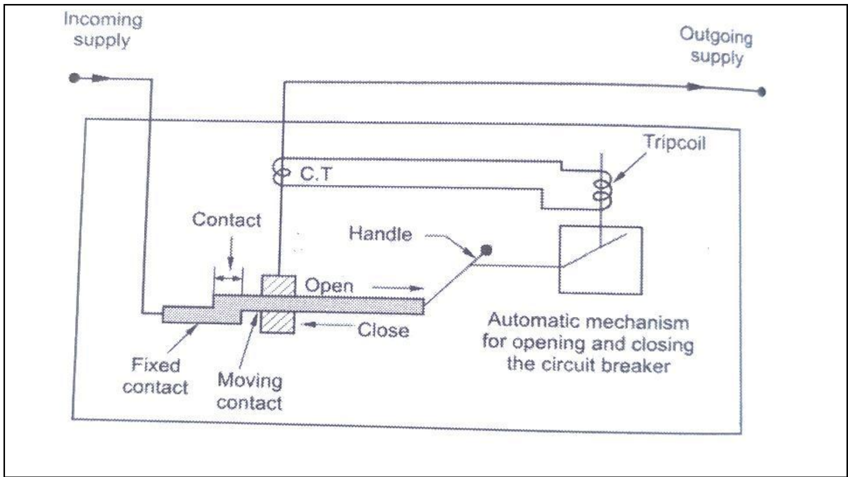
14.(a) Explain the principle of working of Circuit breaker with neat sketch .[14 marks]

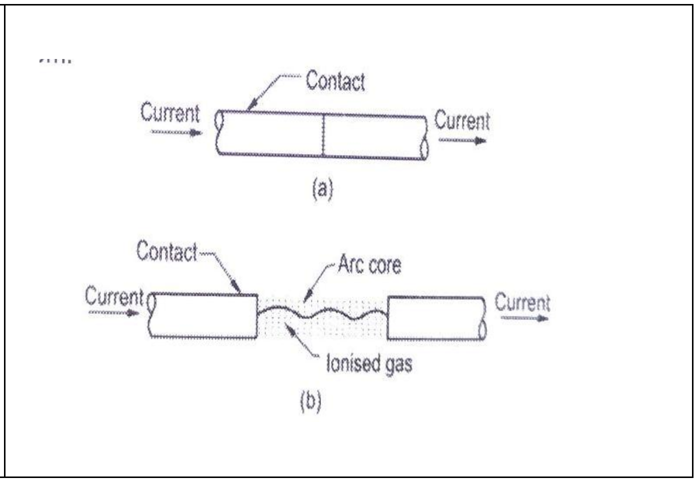
[Diagrams -7 marks, Explanation -7 marks]

A circuit breaker essentially consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until andunless the system becomes faulty.

- The contacts can be opened manually or by remote control whenever desired.
- When a fault occurs on anypart of the system, the trip coils of the breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuit**.**

Operating principle of Circuit Breaker





- When the contacts of a circuit breaker are separated under fault conditions, an arc is struck between them.
- The current is thus able to continue until the discharge ceases. The production of arc not only delays the current interruption process but it also generates enormous heat which may cause damageto the system or to the breaker itself.
- Therefore, the main problem in a circuit breaker is to extinguish thearc within the shortest possible time so that heat generated by it may not reach a dangerous value.

14.(b) Explain the harmful effects of lightning. List the types of lightning arrestors.

[Explanation- 12 marks , types- 2 marks]

- The foregoing discussion concentrated on the principles of lightning strikes and how their effects can be mitigated.
- However, lightning strikes on electrical lines or substations are those that cause problems in the distribution network which come right into our residences and offices.
- A direct lightning strike on a conductor of a power line causes extremely high voltage pulses at the strike point, which are propagated as traveling waves in either direction from the point of strike. The crest of the pulse can be calculated as:

  - $V = I \times Z$

- *Where:*

  V is the crest voltage
  I is the peak lightning current
  Z is the impedance seen by the pulse along the direction of travel.

- It is therefore necessary that no direct strike must be permitted on the overhead power lines phaseconductors.
- The clearance between the phase conductors and the shield wire must be selected so that air space between them does not breakdown by the high impulse voltage generated in the shield wires. This is easily achievable in systems of 66 kV and higher.
- Even when protected in the above manner, the flow of the pulse of lightning current in the shield wire causes an induced voltage pulse in the phase conductors. These being much smaller in value than thedirect pulse safely pass along the line without causing any insulation failure.
- To protect the equipment at the termination point of the overhead lines (such as circuit breakers, transformers, measuring devices, etc.), lightning surge arrestors are provided at the point of termination. These arrestors absorb any surges in the line and prevent them from traveling into the substation equipment.

Types of Lightning arrestors:

1. Road Gap Arrester
2. Sphere Gap Arrester
3. Horn Gap Arrester
4. Multiple-Gap Arrester
5. Impulse Protective Gap
6. Electrolytic Arrester
7. Expulsion Type Lightning Arrester
8. Valve Type Lightning Arresters

9. Thyrite Lightning Arrester

10. Auto valve Arrester

11. Oxide Film Arrester

12.Metal Oxide Lightning Arresters

15.(a) Classify relays based on timing characteristics and explain.

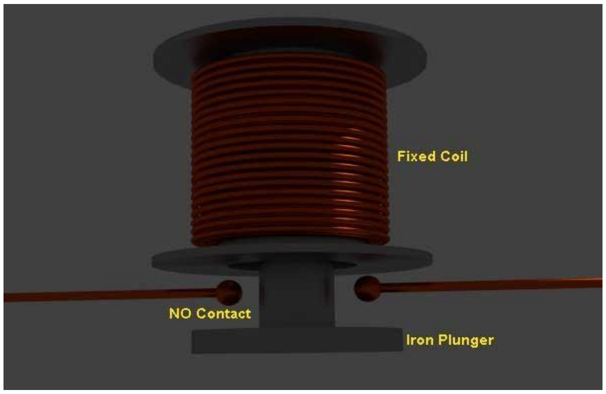
[Diagrams -7 marks, Explanation -7 marks]

Classification:

- Instantaneous Relay
- Inverse Time relay
- Definite Time lag relay
- Over load Inverse time/ Inverse Definite Minimum Timelag(IDMT) relay

Instantaneous Relay

An instantaneous relay is one in which there is no time delay provided intentionally. More specifically ideally there is no time required to operate the relay. Although there is some time delaywhich can not be avoided.

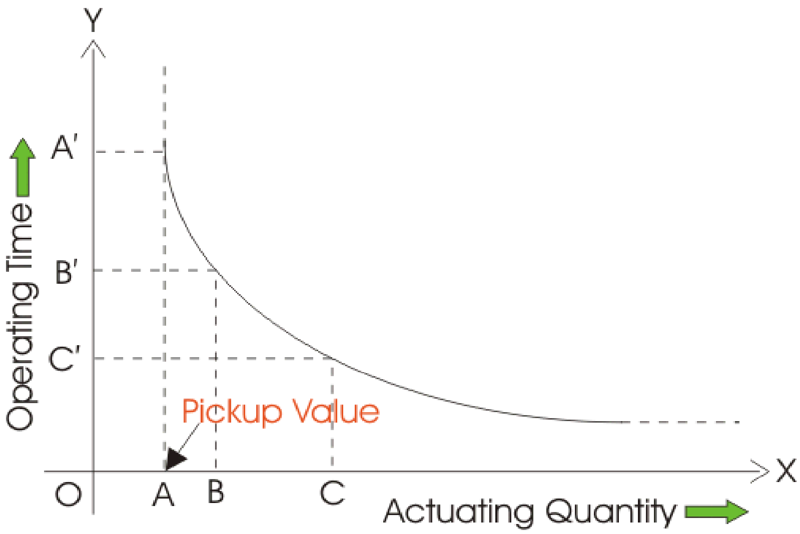


Inverse Time Relay

In this type of relays, the time of operation depends upon the magnitude of actuating quantity.

If the magnitude of actuating quantity is very high, the relay operation is very fast.

The relayoperating time that is time delay in the relay is inversely proportional to the magnitude of actuating quantity.



- Here, in the graph it is clear that, when, actuating quantity is OA, the operating time of the relay is OA', when actuating quantity is OB, the relay operating time is OB' and when actuating quantity is OC,the relay operating quantity is OC'.
- In the graph above, it is also observed that, when actuating quantity is less than OA, the relay operating time becomes infinity, that means for actuating quantity less than OA, the relay does not at allactuate.

- "**The inverse time relay, where the actuating quantity is current, is known as inverse <u>current</u> relay. "**

Definite Time Lag Relay

Definite time lag relays are those which operate after a specific time.

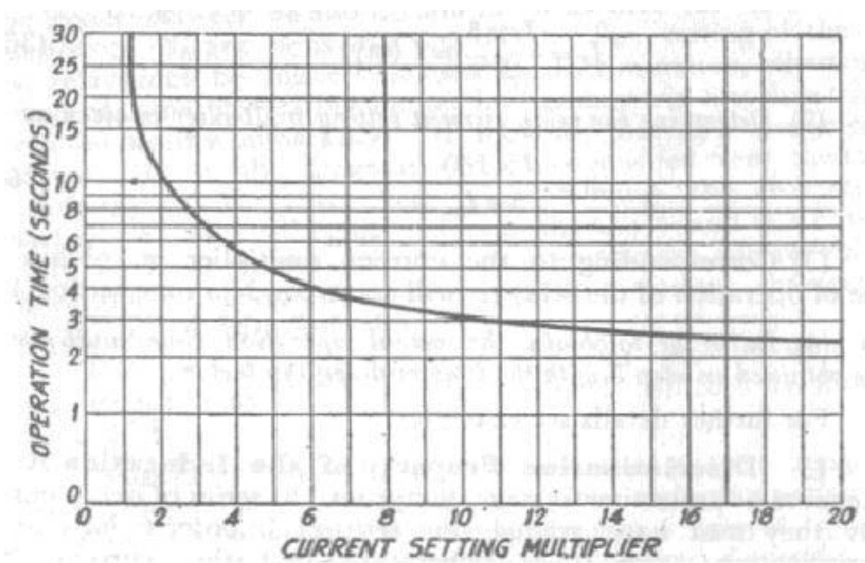
The time lag between instant when the actuating current crosses the pickup level and the instant when relay contacts finally closed, is constant.

This delay does not depend up on magnitude of actuating quantity. For all actuating quantity, above pick up values,the relay operating time is constant.

Inverse definite minimum time

IDMT relays are protection relays. They are used on transmission lines to see to that the linecurrent doesn't exceed safe values and if it does, triggers the circuit breaker.

IDMT means **inverse definite minimum time. So** as the current keeps increases, the relay takes **minimum time** to trip thecircuit.



- ` The current time characteristics of the relay have been illustrated in Fig.
- It represents the time required to close the trip contacts for different values of over current.
- Its horizontal scale is marked interms of current-setting multipliers i.e. number of times the relay current is in excess of current setting .

15.(b) Explain methods of neutral grounding.

[Diagrams -7 marks, Explanation -7 marks]

Neutral Grounding

- The process of connecting neutral point of 3-phase system to earth (i.e. soil) either directly orthrough some circuit element (e.g. resistance, reactance etc.) is called **neutral grounding.**
- 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 (e.g. a fuse etc.) operate to isolate the faulty conductor from the rest of the system.

Methods of Neutral Grounding

The methods commonly used for grounding the neutral point of a 3-phase system are :

- Solid or effective grounding
- Resistance grounding
- Reactance grounding
- Peterson-coil grounding

Solid Grounding

When the neutral point of a 3-phase system (e.g. 3- phase generator, 3-phase transformer etc.) is directly connected to earth (i.e. soil) through a wire of negligible resistance and reactance, it is called **solid grounding** or **effective grounding**.

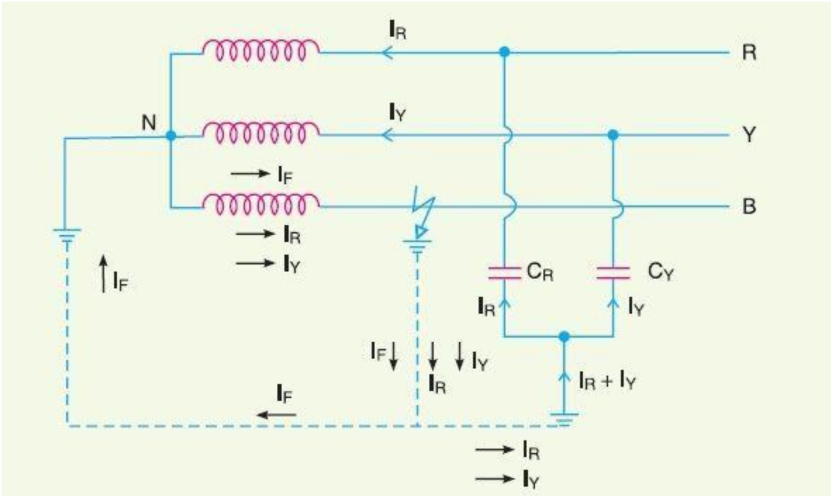


Fig. 5.26. shows the solid grounding of the neutral point.

- **Since the neutral point is directly connected to earth through a wire, the neutral point is held at earth potential under all conditions.**
- Therefore, under faultconditions, the voltage of any conductor to earth will not exceed the normal phase voltage of the system.

Resistance Grounding

- In order to limit the magnitude of earth fault current, it is a common practice to connect theneutral point of a 3-phase system to earth through a resistor. This is called resistance grounding.

- When the neutral point of a 3-phase system (e.g. 3-phase generator, 3-phase transformer etc.)is connected to earth (i.e. soil) through a resistor, it is called **resistance grounding.**

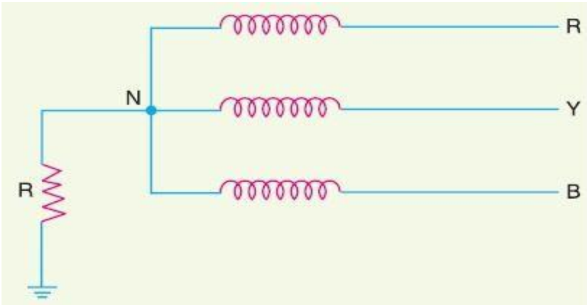


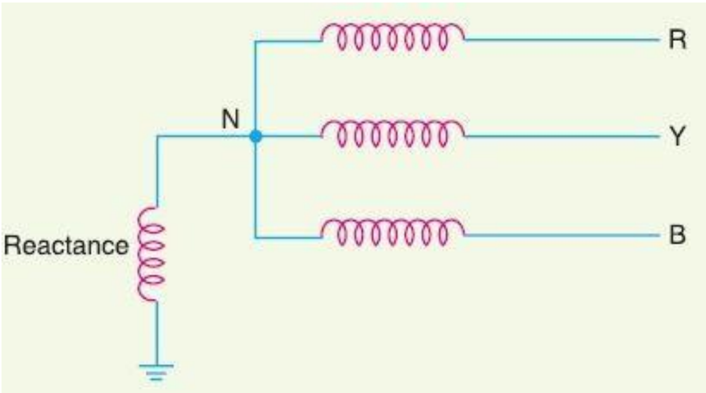
Fig.shows the grounding of neutral point through a resistor *R*. **The value of *R* should neither be verylow nor very high.** If **the value of earthing resistance *R* is very low, the earth fault current will be large and the system becomes similar to the solid grounding system.**

If the earthing resistance *R* is very high, the system conditions become similar to ungrounded neutral system.

The value of *R* is so chosen such that the earth fault current is limited to safe value but still sufficient to permit the operation of earth fault protection system.

In practice, that value of *R* is selected that limits the earth fault current to 2 times the normal full load current of the earthed generatoror transformer.

Reactance Grounding



- **In this system, a reactance is inserted between the neutral and ground .**
- Thepurpose of reactance is to limit the earth fault current.
- By changing the earthing reactance, the earth faultcurrent can to change to obtain the conditions similar to that of solid grounding.

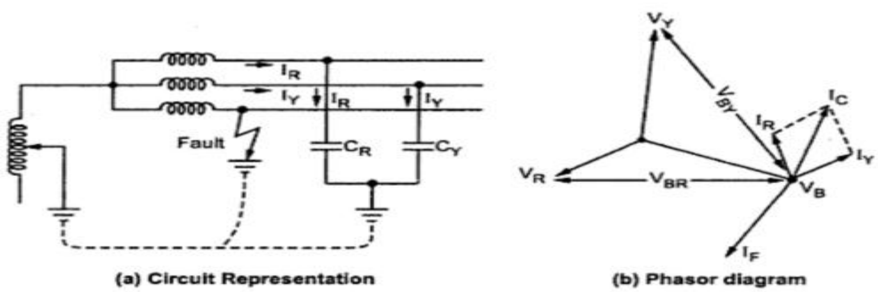
This method is not used these days because of the following disadvantages:

- In this system, the fault current required to operate the protective device is higher than that of resistance grounding for the same fault conditions.
- High transient voltages appear under fault conditions.

Resonant Grounding

This system is also referred as arc suppression coil grounding.

- It consists of a coil called Peterson coil or Ground fault neutralizer or arc supre ssion coil whose function is to make arcing earth faults self extinguishing and in the case of sustained faults to reduce the earth current to low value so that system can supply power with one line earthed.
- This system works on the principle that when inductance and capacitance are connected in parallel, resonance takes place between them and because of the characteristics of resonance, the fault current isreduced or can be neutralized.



Resonant grounding

An arc supression coil is an iron-cored reactor similar to oil immersed transformer connected between neutral of system and earth.

This coil is provided with number of tappings so that it can be tuned with the capacitance which may vary due to varying operational conditions.

As the system operation is similar to isolated neutral system, the phase to earth voltage of healthy phase is times the normal phase voltage and the resultant capacitive current is √3 times the normal charging current of one phase.

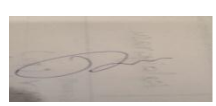
The resultant capacitive current will lead by with faulty phase voltage while the fault current lags by with faulty phase voltage.

Now we have, $I_F = I_C$ at resonance

$I_F = V_{ph}/X_L$; $I_C = 3V_{ph}/X_C$

This method of neutral grounding is used in medium voltage overhead transmission line which are connected to system generators through intermediate power transformers.

Answer Key Prepared By



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