CAPITAL UNIVERSITY - KODERMA

POWER SYSTEM ASSIGNMENT

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1. State the significance of double line fault.

In double line-to-ground fault, the two lines contact with each other along with the ground. The probability of such types of faults is nearly 10 %. The symmetrical and unsymmetrical fault mainly occurs in the terminal of the generator, and the open circuit and short circuit fault occur on the distribution system. It is an important consideration in power system planning, protection equipment selection, and overall system reliability assessment. At the heart of today's power generation and distribution are high-voltage transmission and distribution networks. When a fault (e.g., a short circuit) occurs at some point in the network, the normal operating conditions of the system are upset; if the fault is persistent severe loss of load, property damage due to fire or explosion, and steep eco-nomic losses can arise as undesirable consequences. Therefore, the correct modeling of components and the correct fault analysis in power systems are critical to ensuring safety and reliability. In this chapter fault analysis is illustrated via spreadsheets. Spreadsheets are widely accessible and the ease of programming is the hallmark feature that renders them appealing to many users. This simple tool is employed to analyze both symmetrical and unsymmetrical faults in PowerSystems.

2. Define negative sequence component.

Negative sequence is a balanced three-phase system with the opposite phase sequence as the original sequence. which means the set of the three phases are equal in magnitude, spaced 120° apart from each other & having the phase sequence opposite to that of the original phases.

3. State the different types of faults.

Electrical faults in three-phase power system mainly classified into two types, namely open and short circuit faults. Also, the faults can be symmetrical or unsymmetrical faults.

Open circuit fault: The most common causes of these faults include joint failures of cables and overhead lines, and failure of one or more phase of circuit breaker and also due to melting of a fuse or conductor in one or more phases. Open circuit faults are also called as series faults. These are unsymmetrical or unbalanced type of faults except three phase open fault.

Short circuit fault: These are the most common and severe kind of faults, resulting in the flow of abnormal high currents through the equipment or transmission lines. If these faults are allowed to persist even for a short period, it leads to the extensive damage to the equipment. Short circuit faults are also called as shunt faults. These faults are caused due to the insulation failure between phase conductors or between earth and phase conductors or both.

4. State the various types of unsymmetrical faults.

The most common faults that occur in the power system network are unsymmetrical faults. This kind of fault gives rise to unsymmetrical fault currents (having different magnitudes with unequal phase displacement). These faults are also called as unbalanced faults as it causes unbalanced currents in the system. A single line-to-ground (LG) fault is one of the most common faults and experiences show that 70-80 percent of the faults that occur in power system are of this type. This forms a short circuit path between the line and ground. These are very less severe faults compared to other faults.

A line-to-line fault occurs when a live conductor gets in contact with another live conductor. Heavy winds are the major cause for this fault during which swinging of overhead conductors may touch together. These are less severe faults and its occurrence range may be between 15-20%.

In double line to ground faults, two lines come into the contact with each other as well as with ground. These are severe faults and the occurrence these faults are about 10% when compared with total system faults.

Unsymmetrical faults are analyzed using methods of unsymmetrical components in order to determine the voltage and currents in all parts of the system. The analysis of these faults is more difficult compared to symmetrical faults.

5. Mention the withstanding current in our human body.

The minimum current a human can feel depends on the current type (AC or DC) and frequency. A person can feel at least 1 mA of AC at 50-60 Hz, while at least 5 mA for DC. The current may, if it is high enough, cause tissue damage or fibrillation which leads to cardiac arrest.

6. State the various types of earthing.

There are mainly 4 types of Earthing Systems in India, Plate Earthing, Pipe Earthing, Mat Earthing, and Rod Earthing.

Pipe Earthing
Pipe earthing is a common form of earthing in India that uses a steel pipe to connect with the earth's electrical conductors. The size of the iron pipe depends on the soil moisture and the magnitude of the current. The soil's moisture will decide the depth for the placement of the steel pipe.

Plate Earthing
Plate earthing is where a copper plate is distanced at 3 meters from the earth and vertically placed in the ground pit.

Mat Earthing
Mat earthing connects vertical and horizontal electrodes – a horizontal electrode represses the current generated due to a massive fault while the vertical electrode dissipates the current into the earth.

Marconite Earthing
Marconite earthing is the safest earthing technology that uses low-resistant copper earth electrodes that are specially manufactured to deliver a premium quality earthing system for solar power plants. It is a dark grey material that is mixed with cement and water to produce safe and secure earthing system.

7. What are the causes of faults?

There is a number of causes for the occurrence of a fault in the power system. Some of the possible causes of faults are,

Overvoltage due to switching surges, severe lightning strokes, aging of conductor, heavy wind, rains, and snowfall, falling trees on the transmission line, excessive internal and external stresses on the conductors, high changes in atmospheric temperatures, accident of vehicle with towers or poles of transmission line, perching of birds on the lines.

8. Name the different kinds of over current relays.

Based on the relay operating characteristics , overcurrent relays can be classified into three groups

- Definite current or instantaneous
- Definite time
- Inverse time

9. Define operating time of a relay.

The operating time is the time from when the rated voltage is applied to the coil, until the time when the contacts operate. With Relays that have multiple pairs of contacts, if there are no other conditions, then the operating time is the time required for the slowest pair of contacts to operate.

10. Define resetting time of a relay.

The time which elapses between the instant when the actuating quantity becomes less than the reset value to the instant when the relay contacts return to its normal position.

11. What are over and under current relays?

An undercurrent relays which operates whenever the current in a circuit drops below a predetermined value.

An overcurrent relay is a type of protective relay which operates when the load current exceeds a pickup value.

12. Mention any two applications of differential relay.

Protection of the generator, protection of generator transformer unit.
Protection of transformer.
Protection of feeder (transmission line) by pilot wire differential protection.
Protection of transmission line by phase comparison carrier current protection.
Protection of large motor.
Bus-zone protection.

13. What is an under-frequency relay?

Under frequency relays are used to shed automatically certain portion of load whenever the system frequently falls to such a low level as to threaten the stability of the power system. In this paper a very simple digital frequency relay is proposed for this purpose.

14. What are the features of directional relay?

Directional relays must have the following features:

- high speed of operation;
- high sensitivity;
- ability to operate with low values of voltage;
- adequate short-time thermal rating;
- burden must not be excessive; and.
- there should be no voltage creep and current creep.

15. What is static relay?

a static relay is a type of relay, an electrically operated switch, that has no moving parts. Static relays are contrasted with electromechanical relays, which use moving parts to create a switching action.

9. What are the advantages of static relay over electromagnetic relay?

Advantages of static relay over electromagnetic relay

- No moving contacts; hence associated problems of arcing, contact bounce, erosion, replacement of contacts
- Low power consumption as low as 1mW
- No gravity effect on operation of static relays. Hence can be used in vessels ie, ships, aircrafts etc.
- A single relay can perform several functions like over current, under voltage, single phasing protection by incorporating respective functional blocks. This is not possible in electromagnetic relays
- Static relay is compact
- Superior operating characteristics and accuracy
- Static relay can think, programmable operation is possible with static relay
- Effect of vibration is nil, hence can be used in earthquake-prone areas o Simplified testing and servicing. Can convert even non-electrical quantities to electrical in conjunction with transducers.

16. Define a over current relay.

The overcurrent relay is defined as the relay, which operates only when the value of the current is greater than the relay setting time. It protects the equipment of the power system from the fault current.

17. Define an undercurrent relay?
An undercurrent relays which operates whenever the current in a circuit drops below a predetermined value.

18. What are the various faults that would affect an alternator?

Some of the Important Faults which may occur on Alternator are Overvoltage, Overspeed, Overcurrent, Failure of Prime mover, Unbalanced Loading, Failure of Field and Stator winding fault (which includes Line to Ground Fault, Line to Line Fault, Double Line to Ground Fault, three phase Fault and Inter turn Fault).

19. Why neutral resistor is added between neutral and earth of an alternator?

In order to limit the flow of current through neutral and earth a resistor is introduced between them.

20. What is the backup protection available for an alternator?

Overcurrent and earth fault protection is the backup protections used for alternator.

21. What are faults associated with an alternator?

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22. What are the main safety devices available with transformer?

The following discusses protection devices typically delivered as a part of the power transformer delivery.

- Buchholz (Gas) Relay.
- Pressure Relay.
- Oil Level Monitor Device.
- Winding Thermometer.

23. What are the limitations of Buchholz relay?

Only fault below the oil level is detected. Mercury switch setting should be very accurate, otherwise even for vibration, there can be a false operation. The relay is of slow operating type, which is unsatisfactory.

24. What are the problems arising in differential protection in power transformer and how are they overcome?

Difference in lengths of pilot wires on either side of the relay. This is overcome by connecting adjustable resistors to pilot wires to get equipotential points on the pilot wires.

Difference in CT ratio error difference at high values of short circuit currents that makes the relay to operate even for external or through faults. This is overcome by introducing bias coil.

Tap changing alters the ratio of voltage and currents between HV and LV sides and the relay will sense this and act. Bias coil will solve this.

Magnetizing inrush current appears wherever a transformer is energized on its primary side producing harmonics. No current will be seen by the secondary. CT's as there is no load in the circuit. This difference in current will actuate the differential relay. A harmonic restraining unit is added to the relay which will block it when the transformer is energized.

25. What is REF relay?

Fault detection is confined to the zone between the two CTs hence the name 'Restricted Earth Fault'. REF protection is fast and can isolate winding faults extremely quickly, thereby limiting damage and consequent repair costs.

REF relay will not be actuated for external earth fault. But during an internal fault, the neutral current transformer only carries the unbalance fault current and operation of Restricted Earth Fault Relay takes place.

26. What is over fluxing protection in transformer?

The over fluxing protection operates when the ratio of the terminal voltage to frequency exceeds a predetermined setting and resets when the ratio falls below 95 to 98% of the operating ratio. By adjustment of a potentiometer, the setting is calibrated from 1 to 1.25 times the ratio of rated volts to rated frequency.

27. Why bus bar protection is needed?

This scheme of protection cannot discriminate the faulty section of the busbar. Now days, electrical power system deals with huge amount of power. Hence any interruption in total bus system causes big loss to the company. So, it becomes essential to isolate only faulty section of busbar during bus fault.

28. What are the causes of bus zone faults?

The bus zone fault occurs because of various reasons likes failure of support insulators, failure of circuit breakers, foreign object accidentally falling across the bus bar, etc., For removing the bus fault, all the circuits connecting to the faulty section needs to be open.

29. Mention the short comings of Merz Price scheme of protection applied toa power transformer.

n a power transformer, currents in the primary and secondary are to be compared. As these two currents are usually different, the use of identical transformers will give differential current, and operate the relay under no-load condition. Also, there is usually a phase difference between the primary and secondary currents of three phase transformers. Even CTs of proper turn-ratio are used, the differential current may flow through the relay under normal condition.

30. What are the various faults to which a turbo alternator is likely to be subjected?

Failure of steam supply; failure of speed; overcurrent; over voltage; unbalanced loading; stator winding fault.

31. Define the term pilot with reference to power line protection.

The term 'pilot' refers to a communication channel between two or more ends of a transmission line to provide instantaneous clearing over 100% of the line. Communication channels typically used include power line carrier, microwave, fiber optic, and communication cable.

32. Mention any two disadvantage of carrier current scheme for transmission line only.

The program time (i.e., the time taken by the carrier to reach the other end-up to .1% mile); the response time of band pass filter; capacitance phase-shift of the transmission line .

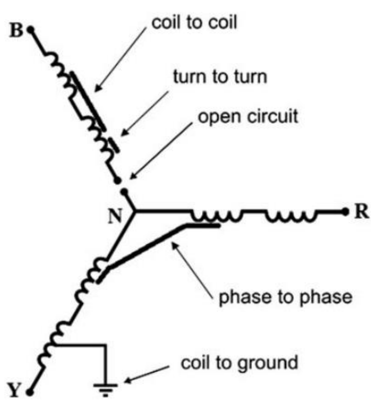
33. What are the causes of over speed and how alternators are protected from it?

What are the causes of over speed and how alternators are protected from it? Sudden loss of all or major part of the load causes over-speeding in alternators.

Modern alternators are provided with mechanical centrifugal devices mounted on their driving shafts to trip the main valve of the prime mover when a dangerous over-speed occurs.

34. What are the main types of stator winding faults?

Different types of stator winding faults are: (i) short circuit between two turns of same phase called turn-to-turn fault, (ii) short circuit between two coils of same phase called coil to coil fault, (iii) short circuit between turns of two phases called phase to phase fault, (iv) short circuit between turns of all three phases, (v) short circuit between winding conductors and the stator core called coil to ground fault, and



(vi) open-circuit fault when winding gets break

1. (a) What are the causes of over voltage on a power system?

(b) Why is it necessary to protect the lines and other equipment of the power system against over Voltages?

(c) What are the methods to reduce this resistance?

Ans: (a) Increase in voltage for the very short time in power system is called as the over voltage. it is also known as the voltage surge or voltage transients. The voltage stress caused by over voltage can damage the lines and equipment's connected to the system, There are two types of causes of over voltage in power system. 1. Over voltage due to external causes 2. Over voltage due to internal causes Transient over voltages can be generated at high frequency (load switching and lightning), medium frequency (capacitor energizing), or low frequency. This cause of over voltage in power system is the lightning strokes in the cloud.

(b) Without effective protection, the overvoltage's destroy sensitive electronic components in the circuits of the connected appliances. Overvoltage's can be caused, for example, by switching impulses of powerful engines, welding equipment or other large electric appliances.

(c) Methods to reduce resistance

- Higher transmission voltages

The line drops in a transmission line depend on the length (l), voltage (v), current density (J) and resistivity (ρ) by the following relationship:

Line drops = [Jρl]/V

J, ρ, and l remain constant for any line factors. The lines drops can be reduced by raising the temperature to a higher level.

- Power Factor Improvement

The power factor of a system explains the relationship between real and reactive power. Lower power factor results in a larger capacity of generators as well as a large number of drops in transmission lines. Line power losses can be considerably reduced by improving the power factor.

- By Reducing Resistance

The resistance of transmission line is a major design factor which is one of the most important causes of power loss. Mathematically: $R = \rho * l / a$

- By Using Bundled Conductors

An LV power line carries electrical power without corona losses. However, in case of HV voltages, significant coronas result in power losses. These power losses can be avoided by using Bundled conductors which are the multiple conductors per phase.

- Conductor Maintenance

The cleanliness of transmission line conductors is greatly influenced by External environmental conditions, pollutants, dust particles, and industrial chemicals coming from factories. Such pollutants contaminate the body of conductors, as well as they, reduce the efficiency of transmission lines. Proper maintenance of conductor improves transmission line efficiency and increases the lifetime of conductors.

- Reduction of Skin effect

The concentration of ac current near the surface conductor is known as skin effect. Skin effect reduces the effective cross-sectional area for current flow. The skin effect is less in stranded conductors as compared to solid conductors. It can also be reduced by decreasing the diameter of the wire

3, (a) what is necessity of protecting electrical equipment against traveling waves?

(b)Describe in brief the protective devices used for protection of equipment against such waves?

Ans: (a) All the electrical equipment must be protected from severe damage due to the lightning strokes. The problem of protection of power systems against lightning can be studied under the following : - 1. Protection of power stations and substations from direct lightning strokes 2. Protection of overhead transmission lines from direct lightning strokes 3. Protection of electrical equipment from travelling waves.

1. Protection of Power Stations and Substations from Direct Lightning Strokes:

Power stations are usually indoor while substations may be indoor or outdoor. For protection of a structure from direct strokes there are three requirements which are to be fulfilled. These requirements are interception, conduction and dissipation.

These requirements involve:

(i) An object in good electrical connection with the earth so that the leader stroke may get attracted,

(ii) A low impedance path joining this object to earth so that the discharge follows it in preference to any other path,

(iii) A low resistance connection with the earth body.

For 1, the upper portion of a metal structure may be employed. Alternatively, a separate metallic system, often called the shield, either mounted on the structure or near to and above it may be provided. A particular shield configuration in the form of masts or overhead ground wires is considered to provide good shielding.

2. Protection of Overhead Transmission Lines from Direct Lightning Strokes:

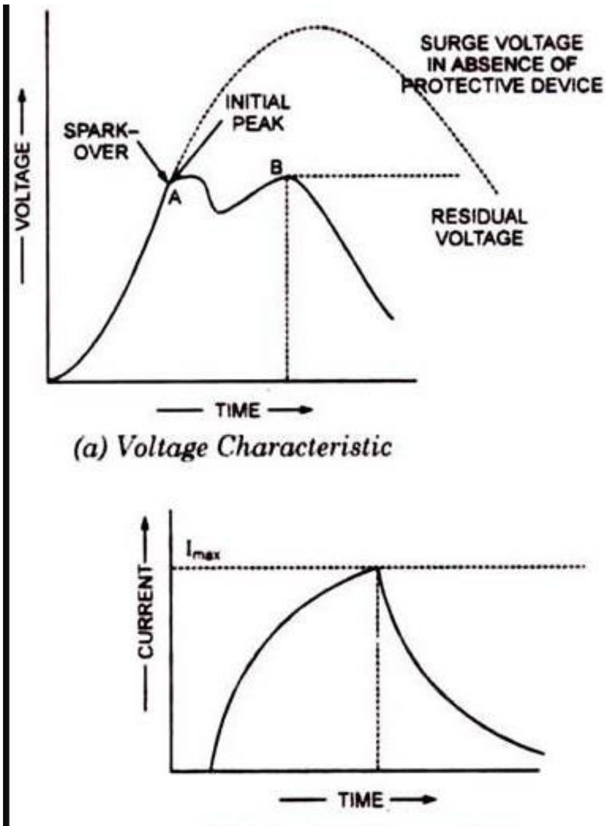
The two methods of protecting overhead transmission lines against lightning strokes are:

(i) Overhead ground wires and

(ii) Expulsion protector tubes.

(b) The most common devices used for protection of equipment at the substations against travelling waves are lightning arresters or surge diverters.

A surge diverter is a device that is connected between line and earth, i.e., in parallel with the equipment to be protected at the substation.



(a) Voltage Characteristic

(b) Current Characteristic
Voltage and Current Characteristics of Surge Diverters

Fig. 9.17

When a travelling wave reaches the diverter, it sparks-over at a certain prefixed voltage as illustrated by point A in the figure, and provides a conducting path of relatively low impedance between the line and ground.

The surge impedance of the line restricts the amplitude of current flowing to ground. This is necessary in order to protect the insulation of the equipment. Fig. 9.17 shows the shape of voltage and of current at the diverter terminals.

It should, however, be noted that the surge diverter should provide a path of low impedance only when the travelling surge reaches the surge diverter, neither before it nor after it.

4. Describe the protection of stations and sub-stations against direct lightning stroke.

Power stations are usually indoor while substations may be indoor or outdoor. For protection of a structure from direct strokes there are three requirements which are to be fulfilled. These requirements are interception, conduction and dissipation.

These requirements involve:

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For 1, the upper portion of a metal structure may be employed. Alternatively a separate metallic system, often called the shield, either mounted on the structure or near to and above it may be provided. A particular shield configuration in the form of masts or overhead ground wires is considered to provide good shielding.

For 2, the requirements are:

(i) Low resistance (i.e., adequate conductivity and cross- section, properly bounded joints, free from possible corrosion),

(ii) Low reactance (i.e., absence of sharp bends, or loops and short conductors),

(iii) And sufficient clearance from any other conducting objects that might provide separate uncontrolled path to ground.

Outdoor substations have much of equipment carried on metal gantries and the interconnection of the upper portion of these will screen the apparatus. Usually, there is suitable grounding provided.

Shielding of the station and the incoming lines (about 0.8 km out from the station) to restrict the severity of the waves that can enter the station through the lines is a desirable supplement, particularly in the case of hv lines (66 kV and above) to the lightning arrester located in the station.

Where overhead ground wires cannot be provided on the incoming lines due to existing structure/construction, additional protection of the station equipment against direct lightning strokes can be provided by equipping each line with protector tubes at the entrance to the structure of the station and at each tower for a distance of about 0.8 km out from the station. However, shielding of the power station/substation is the only way of eliminating direct strokes to the station itself.

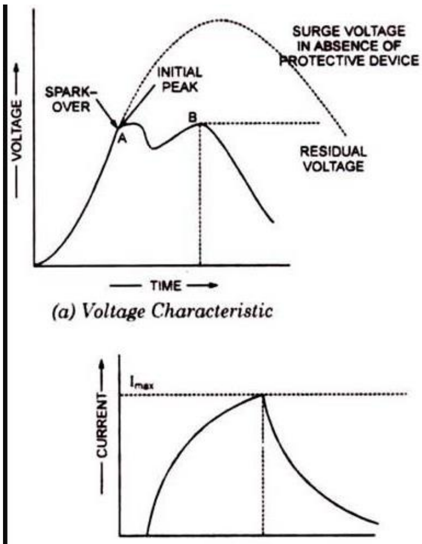
5. Describe the construction and principle of operation of

(i) Expulsion type lightning arrester

(ii) Value type lightning arrester.

Ans: Expulsion type lightning arrester is also known as a protector tube. It consists of – (i) a tube made of fiber which is very effective gas-evolving material (ii) an isolating spark gap (or external series gap) and (iii) an interrupting spark gap inside the fiber tube.

During operation arc due to the impulse spark-over inside the fibrous tube causes some fibrous material of the tube volatized in the form of gas, which is expelled through a vent from the bottom of the tube, thus extinguishing the arc just like in circuit breakers. Since the gases generated have to be expelled, one of the electrodes is hollow and the diverter is open at its lower end.



(a) Voltage Characteristic

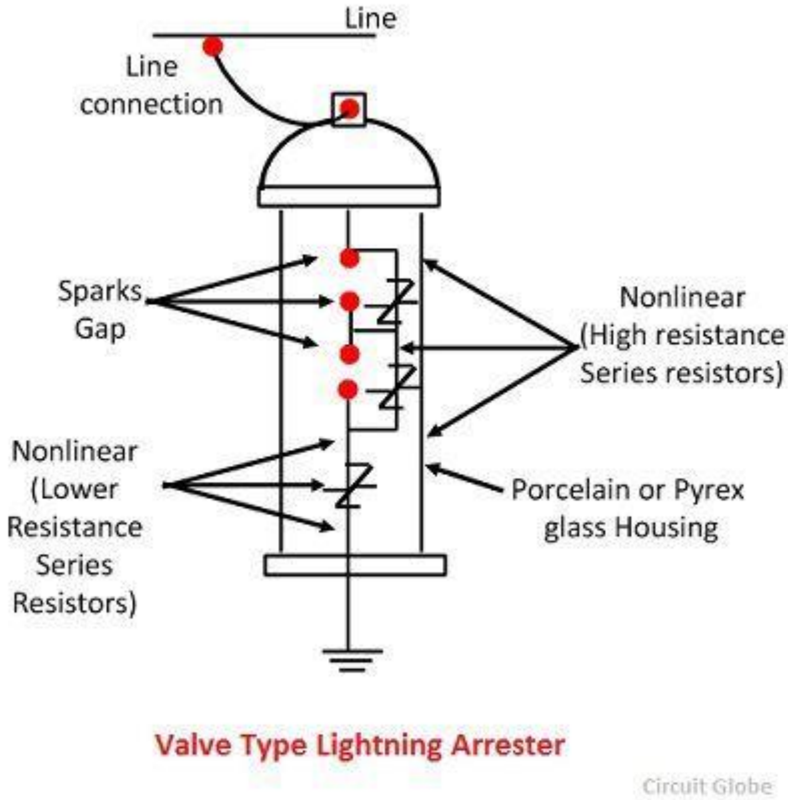
(b) Current Characteristic
Voltage and Current Characteristics of Surge Diverters

Fig. 9.17

(2) The lightning arrester which consists the single or multi-gaps connected in series with the current controlling element, such type of arrester is known as the lightning arrester. The gap between the electrodes intercepts the flow of current through the arrester except when the voltage across the gap raises beyond the critical gap flashover. The valve type arrester is also known as gap surge diverter or silicon carbide surge diverter with a series gap.

Construction of Valve Type Lightning Arrester

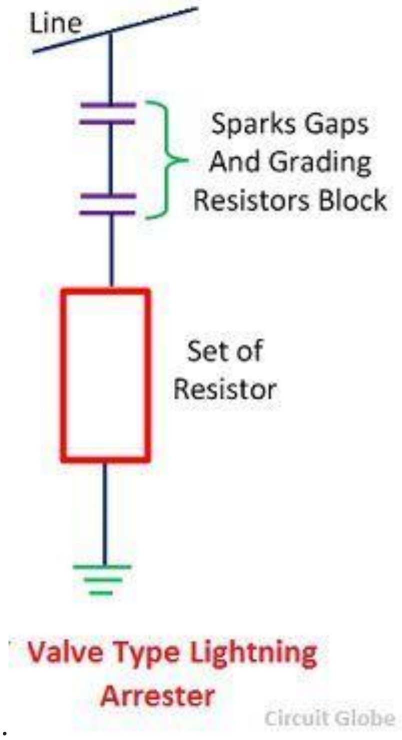
The valve type arrester consists of a multiple spark gap assembly in series with the resistor of nonlinear element. The each spark gap has two elements. For non-uniform distribution between the gap, the nonlinear resistors are connected in parallel across the each gap.



The resistor elements are made up of silicon carbide with inorganic binders. The whole arrangement is enclosed in a sealed porcelain housing filled with nitrogen gas or SF6 gas.

Working of Valve Type Lightning Arrester

For low voltage, there is no spark-over across the gaps due to the effect of parallel resistor. The slow changes in applied voltage are not injurious to the system. But when the rapid changes in voltage occur across the terminal of the arrester the air gap spark of the current is discharged to ground through the



non-linear resistor which offers very small resistance.

After the passage of the surge, the impressed voltage across the arrester falls, and the arrester resistance increases until the normal voltage restores. When the surge diverter disappears, a small current at low power frequency flow in the path produced by the flash over. This current is known as the power follow current.

The magnitude of the power follows current decreases to the value which can be interrupted by the spark gap as they recover their dielectric strength. The power follow current is extinguished at the first current and the supply remains uninterrupted. The arrester is ready for the normal operation. This is called resealing of the lightning arrester.

6. What is Peterson coil?

What protective functions are performed by this device?

Peterson coil is an iron cored inductor used to connect the neutral of the three-phase system to the earth. In other words, the neutral of the three-phase system is grounded through the Peterson coil. This also eliminates the arcing ground, so it is also called an Arc suppression coil.

In a power system, the capacitive fault current returns to the system through the fault. Likewise, any added component of the fault current coming from other admittances between system and ground will return through the fault. The resultant fault current will be the superposition of the various components. If two fault currents of equal magnitude and opposite sign merge at the fault, they neutralize each other.

An essential feature of Petersen's invention is that it adds an inductive current of appropriate magnitude to neutralize the capacitive fault current.

The neutralizing current may come from any source as long as the correct amount passes through the fault. A first approach may be connecting a three-phase reactor in parallel with the capacitance to ground of each conductor. When there is a ground-fault in one phase, the rated-frequency capacitance current flowing between the unfaulted phases and earth (the charging current), will be substantially equal to the rated frequency current flowing in the grounding reactors. These components will be 180° out of phase at the fault location, and the neutralizing effect is apparent.

The voltage of the neutral raised to the phase-to-neutral voltage of the faulty conductor and line-to-line voltage appears throughout the system between the ground and the two unfaulted lines (73% increase).

7. Write short notes on the following. (i) klydonograph and magnetic link (ii) Rod gap (iii) Arcing horns

The **Klydonograph** is a device that records a surge in electrical voltage on a sulphur-dusted photographic film. The device is credited to John F. Peters, who pursued the idea as a means of investigating the effects of lightning on electric power lines. The resulting graphic varies in size and shape as a function of the potential, polarity, and wave shape of the captured lightning discharge.

A rod gap may be used to measure the peak value of power frequency and impulse voltages.

rod gap may be used to measure the peak value of power frequency and impulse voltages. The gap usually consists of two 1.27 cm square rod electrodes square in section at their end and are mounted on insulating stands so that a length of rod equal to or greater than one half of the gap spacing overhangs the inner edge of the support.

Arcing horns (sometimes **arc-horns**) are projecting conductors used to protect insulators or switch hardware on high voltage electric power transmission systems from damage during flashover. Overvoltages on transmission lines, due to atmospheric electricity, lightning strikes, or electrical faults, can cause arcs across insulators (flashovers) that can damage them. Alternately, atmospheric conditions or transients that occur during switching can cause an arc to form in the breaking path of a switch during its operation. Arcing horns provide a path for flashover to occur that bypasses the surface of the protected device.

8. What are the requirements of a ground wire for protecting power conductors against direct lightning stroke? Explain how they are achieved in practice

The basic requirements for the design of a line to safeguard it against direct lightning strokes are-

1. The ground wire used should be mechanically strong and should be so located that they provide sufficient shielding.

2. There should be sufficient clearance between the power conductors and the tower structure.

3. There should be an adequate clearance between the line conductors and the ground wires, particularly at the mid-span, so as to avoid flashover to the power conductor upto the protective voltage level used for the line design.

4. The tower footing resistance should be as low as permissible.

The most effective method of providing protection to transmission lines against direct lightning strokes is by the use of overhead ground wires. For simplicity, one ground wire and one line conductor are shown. The ground wires are placed above the line conductors at such positions that practically all lightning strokes are intercepted by them (i.e. ground wires). The ground wires are grounded at each tower or pole through as low resistance as possible. Due to their proper location, the *ground wires will take up all the lightning strokes instead of allowing them to line conductors.

When the direct lightning stroke occurs on the transmission line, it will be taken up by the ground wires. The heavy lightning current (10 kA to 50 kA) from the ground wire flows to the ground, thus protecting the line from the harmful effects of lightning. It may be mentioned here that the degree of protection provided by the ground wires depends upon the footing resistance of the tower. Suppose, for example, tower-footing resistance is R_1 ohms and that the lightning current from tower to ground is I_1 amperes. Then the tower *rises to a potential V_t given by ; $V_t = I_1R_1$ Since V_t ($= I_1R_1$) is the approximate voltage between tower and line conductor, this is also the voltage that will appear across the string of insulators. If the value of V_t is less than that required to cause insulator flashover, no trouble results. On the other hand, if V_t is excessive, the insulator flashover may occur. Since the value of V_t depends upon tower-footing resistance R_1, the value of this resistance must be kept as low as possible to avoid insulator flashover.

10. (a) Explain the term insulation coordination. (b) Describe the construction of volt-time curve and the terminology associated with impulse –testing

Insulation coordination is the process of selecting the most cost-effective equipment dielectric strength and its application to avoid equipment insulation damage or affect continuity of service. The economic design of a reliable substation requires a study of the various overvoltages to which the insulation will be subjected such as switching transients, fault conditions, power frequency resonance conditions, or lightning impulses. At the planning stage, this analysis is a very effective way to identify cost-saving opportunities when specifying equipment ratings. Identifying the location and levels of maximum overvoltages stresses helps the design of the facilities to take into account minimum clearances and space requirements for placement of overvoltage protection equipment, and to achieve a safe operation of the facilities under normal or contingency scenarios.

11. Explain the operation of various types of surge absorbers.

Different Types of Surge Absorber are:

Condenser or Capacitor Surge Absorber

A condenser connected between the line and earth can act as a surge absorber. A capacitor acts as surge absorber to protect the transformer winding. Since the reactance of a condenser is inversely proportional to frequency, it Will be low at high fre-quency and high at low frequency. Since the surges are of high frequency, the capacitor acts as a short circuit and passes them directly to earth. However, for power frequency, the reactance of the capacitor is very high and practically no current flows to the ground.

Inductor and Resistance Surge Absorber

Another Types of Surge Absorber consists of a parallel combination of choke and resistance connected in series with the line. The choke offers high reactance to surge frequencies ($X_L=2\pi fL$). The surges are, therefore, forced to flow through the resistance R where they are dissipated.

Ferranti Surge Absorber

It consists of an air cored inductor connected in series with the line. The inductor is surrounded by but insulated from an earthed metallic sheet called dissipator. This arrangement is equivalent to a transformer with short-circuited secondary. The inductor forms the primary whereas the dissipator forms the short-circuited secondary. The energy of the surge is used up in the form of heat generated in the dissipator due to transformer action. This type of surge absorber is mainly used for the protection of transformers.

12. Narrate the operating principles of electromagnetic relay and mention its types and characteristics.

Electromagnetic relays are those relays which are operated by electromagnetic action. Modern electrical protection relays are mainly micro processor based, but still electromagnetic relay holds its place. It will take much longer time to replace all electromagnetic relays by micro processor based static relays. So before going through detail of protection relay system we should review the various types of electromagnetic relays.

Electromagnetic Relay Working

Practically all the relaying device is based on either one or more of the following types of electromagnetic relays.

Magnitude measurement,

Comparison,

Ratio measurement.

Principle of electromagnetic relay working is on some basic principles. Depending upon working principle these can be divided into following types of electromagnetic relays.

Attracted Armature type relay,

Induction Disc type relay,

Induction Cup type relay,

Balanced Beam type relay,

Moving coil type relay,

Polarized Moving Iron type relay.

13. List the advantages and disadvantages of electromagnetic relay along with applications.

Advantages or merits:

- Electromagnetic relays have fast operation and fast reset
- They can be used for both ac and dc systems for protection of ac and dc equipments
- Electromagnetic relays operating speeds which has the ability to operate in milliseconds are also can be possible
- They have the properties such as simple, robust, compact and most reliable
- These relays are almost instantaneous. Though instantaneous the operating time of the relay varies with the current. With extra arrangements like dashpot, copper rings etc. slow operating times and reset can be possible.

Disadvantages or demerits:

- High burden level instrument transformers are required (CTs and PTs of high burden is required for operating the electromagnetic relays compared to static relays)
- The directional feature is absent in electromagnetic relays
- Requires periodic maintenance and testing unlike static relays
- Relay operation can be affected due to ageing of the components and dust, pollution resulting in spurious trips
- Operation speed for an electromagnetic relays is limited by the mechanical inertia of the component

Applications:

- Electromagnetic relays are employed for the protection of various ac and dc equipments
- The over/under current and voltage protection of various ac and dc equipments
- For differential protection
- Used as auxiliary relays in the contact systems of protective relay schemes

14. What are the kinds of directional relays? Explain each in detail with its construction.

CURRENT-DIRECTIONAL RELAYS : It is used for protection in d-c power circuits, its armature coil being connected either directly in series with the circuit or across a shunt in series with the circuit, so that the relay will respond to a certain direction of current flow. Such relays may be polarized either by a permanent magnet or by a field coil connected to be energized by the voltage of the circuit. A field coil would be used if the relay were calibrated to operate in terms of the magnitude of power (watts) in the circuit. With adjustable calibration, the relay would also have overcurrent (or overpower) or undercurrent (or underpower) characteristics, or both, in addition to being directional.

VOLTAGE-DIRECTIONAL RELAYS Voltage-directional relays are the same as current-directional relays except for the number of turns and the resistance of the armature coil, and possibly except for the polarizing source. Such relays are used in d-c power circuits to respond to a certain polarity of the voltage across the circuit or across some part of the circuit. If the relay is intended to respond to reversal of the circuit-voltage polarity, it is polarized by a permanent magnet, there being no other suitable polarizing source unless a storage battery is available for the purpose. Otherwise, either permanent-magnet polarization or a field coil energized from the circuit voltage would be used. When such a relay is connected across a circuit breaker to permit closing the breaker only when the voltage across the open breaker has a certain polarity, the relay may be called a “differential” relay because it operates only in response to a predetermined difference between the magnitudes of the circuit voltages on either side of the breaker.

VOLTAGE-AND-CURRENT-DIRECTIONAL RELAYS The voltage-and-current-directional relay has two armature coils. Such a relay, for example, controls the closing and opening of a circuit breaker in the circuit between a d-c generator and a bus to which another source of voltage may be connected, so as to avoid motoring of the generator. The voltage armature coil is connected across the breaker and picks 43 the relay to permit closing the breaker only if the generator voltage is a certain amount greater than the bus voltage. The current armature coil is connected in series with the circuit, or across a shunt, and resets the relay to trip the breaker whenever a predetermined amount of current starts to flow from the bus into the generator.

VOLTAGE-BALANCE-DIRECTIONAL RELAYS A relay with two voltage coils encircling the armature may be used to protect a three-wire d-c circuit against unbalanced voltages. The two coils are connected in such a way that their magnetomotive forces are in opposition. Such a relay has double-throw contacts and two restraining springs to provide calibration for movement of the armature in either direction. When one voltage exceeds the other by a predetermined amount, the armature will move one way to close one set of contacts; if the other voltage is the higher, the armature will close the other set of contacts. Such a relay may also be used to respond to a difference in circuit-voltage magnitudes on either side of a circuit breaker, instead of the single-coil type previously described.

CURRENT-BALANCE-DIRECTIONAL RELAYS A relay like a voltage-balance type except with two current coils encircling the armature may be used for current-balance protection of a three-wire d-c circuit, or to compare the loads of two different circuits.

5. How directional relay works? Mention its uses.

The relay operates when the fault current exceeds the pickup current. For Directional Over current relay, the fault current can flow in both the directions through the relay either forward or reverse, depending upon fault location. Therefore, it is necessary to make the relay respond for a particular defined direction, so that proper discrimination is possible. This can be achieved by introduction of directional control elements. During the opposite flow of current the CT polarity reverses, the power measuring device in which the system voltage is used as a reference for establishing the relative phase of the fault current.

Directional relay is used in transmission lines where the power flow is associated in a specific direction.For example, due to any reason at a relay location if power flows in the reverse direction(can be from load side to generating side), a POSITIVE torque is produced(angle between the actuating quantities in less than 90 degrees)

16. Explain briefly about directional static over current relay and inverse –time over current relay.

The overcurrent relays, even though simplest of all types of electromechanical relays, are the most difficult static relays. This is because the induction disc characteristics of the overcurrent relays (inverse characteristics) are not amenable to simple mathematical analysis. The first static relays developed were the high speed differential relays and the distance relays.

Fault current level detectors are termed overcurrent relays. They are more complicated in static form as compared to their electromagnetic counterparts.

inverse –time over current relay the operating time is inversely changed with current. So, high current will operate overcurrent relay faster than lower ones. There are standard inverse, very inverse and extremely inverse types.

17. What are the relays used for over current protection?

Over current relay is nothing but a relay element which operates when the current exceeds the pre-set value. The relay trips the associated circuit breaker. Overcurrent relay protection protects the power systems and its equipments such as transmission lines, transformers, generators, or motors against short circuits, ground faults, over loads etc. The types of over current relay used in power system Protection.

- Instantaneous over current relay
- Definite time over current relay
- Inverse time over current relay
- Inverse mean time over current relay
- Very Inverse time over current relay
- Extreme Inverse over current relay

18. Explain about microprocessor based protective relays.

A microprocessor-based relay system is used in combination with relay contactors and a control circuit therefor to protect an electric motor from overload currents in addition to phase faults, ground faults, load losses, and load jams. The microprocessor is provided with a data base comprising thermal characteristics of the motor during heating and cooling. The heating data comprise current versus time curves stored as a look-up table for which each data point represents a thermal limit, i.e., the maximum time the motor is permitted to operate at a particular current level. The cooling data comprise motor cooling rates. Phase currents are sampled at preselected fixed time intervals during a predetermined period thereof, and an average motor current value is calculated therefrom.

19. Explain about the i) Negative sequence ii) Distance relay iii) Static relay iv) Differential relay v) Over current relay

i) Negative sequence

- Negative sequence is **a balanced 3-phase system with the opposite phase sequence as the original sequence** which means the set of the three pharos are equal in magnitude, spaced 120° apart from each other & having the phase sequence opposite to that of the original pharos

ii) Distance relay

- A distance relay is a type of protection relay most often used for transmission line protection. Distance relays **measure the impedance from the installation side to the fault location** and operates in response to changes in the ratio of measured current and voltage.

iii) Static relay

The relay which does not contain any moving parts is known as the static relay. In such type of relays, the output is obtained by the static components like magnetic and electronic circuit etc. The relay which consists static and electromagnetic relay is also called static relay because the static units obtain the response and the electromagnetic relay is only used for switching operation

iv) Differential relay

The differential relay is one that operates when there is a difference between two or more similar electrical quantities exceeds a predetermined value. In the differential relay scheme circuit, there are two currents come from two parts of an electrical power circuit. These two currents meet at a junction point where a relay coil is connected.

v) Over current relay

The overcurrent relay is defined as the relay, which operates only when the value of the current is greater than the relay setting time. It protects the equipment of the power system from the fault current.

20. What is the need for apparatus protection? Explain its basic function.

The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation. Thus, protection schemes must apply a very pragmatic and pessimistic approach to clearing system faults.

To **ensure the maximum return on the large investment in the equipment**, which goes to make up the power system and to keep the users satisfied with reliable service, the whole system must be kept in operation continuously without major breakdowns.

Primary function of the protective system is **to detect and isolate all failed or faulted components as quickly as possible**, thereby minimizing the disruption to the remainder of the electric system.

21. Briefly explain the protection schemes over stator fault of generator protection.

A **generator** is subjected to electrical stresses imposed on the insulation of the machine, mechanical forces acting on the various parts of the machine, and temperature rise. These are the main factors which make protection necessary for the generator or alternator. Even when properly used, a machine in its perfect running condition does not only maintain its specified rated performance for many years, but it does also repeatedly withstand certain excess of overload.

Preventive measures must be taken against overloads and abnormal conditions of the machine so that it can serve safely. Even ensuring an efficient design, construction, operation, and preventive means of protection – the risk of a fault cannot be completely eliminated from any machine. The devices used in **generator protection**, ensure that when a fault arises, it is eliminated as quickly as possible.

The various forms of protection applied to the generator can be categorized into two manners,

1. Protective relays to detect faults occurring outside the generator.
2. Protective relays to detect faults occurring inside the generator.

Protection against Insulation Failure
The main protection provided in the stator winding against phase to phase or phase to earth fault, is longitudinal differential protection of generator. Second most important protection scheme for stator winding is inter turn fault protection.

Stator Earth Fault Protection
When the stator neutral is earthed through a resistor, a current transformer is mounted in the neutral to earth connection. Inverse time relay is used across the CT secondary when the generator is connected directly to the bus bar. In case of generator feeds power via a delta star transformer, an instantaneous relay is used for the same purpose.

Draw and explain about unbalanced stator protection and overloadprotection of stator

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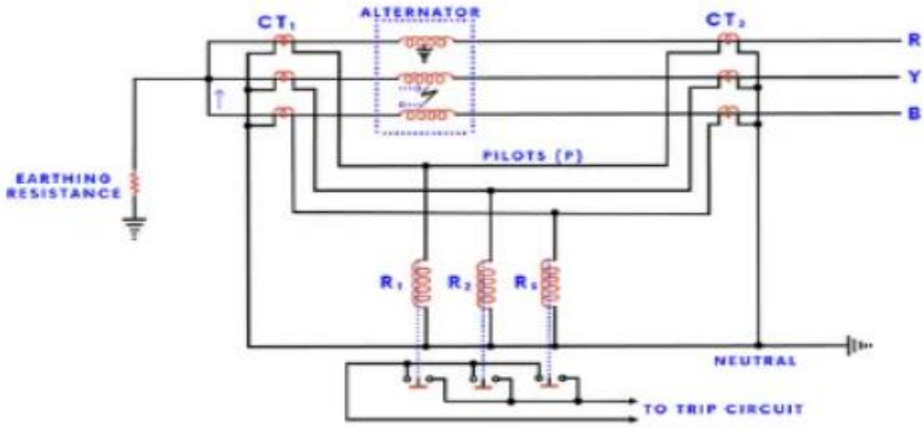

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23. What are effects of loss of excitation? How it is protected?

Loss of excitation protection is used to protect the synchronous machine (alternator or generator) acts as induction motor when the excitation fails. Loss excitation protection operates under many circumstances such as diode failure, rotor winding short circuit, AVR failure, etc.

Under normal condition the generator is connected to the grid, it generates reactive power along with active power to the grid and the rotor speed is same as that of grid frequency. Loss of field or loss of excitation results in loss of synchronism between rotor flux & stator flux (the generator still in online with the grid). The generator works as an induction motor at higher speed and draws reactive power from the grid. This will result in the flow of slip frequency currents in the rotor body as well as severe torque oscillations in the rotor shaft. As the rotor is not designed to sustain such currents or to withstand the high alternating torques which results in rotor overheating, coupling slippage and even rotor failure. A loss of excitation normally indicates a problem with the excitation system. Sometimes it may be due to inadvertent tripping of filed breaker, open or short circuit of field winding or loss of source to the exciter. If the generator is not disconnected immediately when it loses excitation wide spread instability may very quickly develop and major system shutdown may occur.

When loss of excitation alarm annunciates at annunciation panel, the machine may probably be running with less excitation at leading MVAR power. Increase the excitation on the machine until it reaches on lagging MVAR power. The machine trips on the same protection along with alarm resynchronize the machine and try to stabilize at required MVAR power. If not possible, trip the machine immediately and inform to the maintenance staff for thorough checking of the Automatic Voltage Regulator (AVR) and its associated parts.

24. Explain the operation of negative phase sequence protective relay.

Negative Sequence Relay:

Negative sequence relay is used to protect the alternator or generator from the unbalance loading & negative sequence component. The negative sequence current flows through the generator winding due to phase-to-phase short circuit. The negative sequence currents cause the overheating of the generator, alternator, motor, transformer's winding. Negative sequence relays are normally utilized to give protection to the generators & motors against the unbalanced currents.

Negative Sequence Relay Operation:

What is negative sequence. Negative sequence is a balanced 3-phase system with the opposite phase sequence as the original sequence which means the set of the three phases are equal in magnitude, spaced 120° apart from each other & having the phase sequence opposite to that of the original pharos.

25. Explain about A.C motor protection.

AC MOTOR PROTECTION There is a wide range of AC motors since they can be used in numerous applications. AC motors need to be protected but protection selection usually does not depend on the motor and load type. This selection is based on the fundamental AC motor operation processes. There are crucial differences between the protection of induction motors and synchronous motors. Motor operation characteristics have to be particularly considered when applying selected protection. This approach is more important for the motors than for any other power system element. For example, the starting and stalling currents/times have to be known and taken into account when using overload protection. Also the thermal withstand of the AC motor has to be precisely defined under balanced and unbalanced loading conditions. The conditions for which AC motor protection is needed can be separated into two main groups: imposed external conditions and internal short circuits.

INDUCTION AND SYNCHRONOUS MOTORS - extended start relay protection - loss-of-load relay protection - number of starts limitation - stalling relay protection - short circuit relay protection - thermal relay protection - earth fault relay protection - negative sequence current detection - winding RTD measurement/trip - under-voltage relay protection - auxiliary supply supervision SYNCHRONOUS MOTORS IN PARTICULAR - loss of supply relay protection - out-of-step relay protection.

THERMAL (OVERLOAD) RELAY PROTECTION The majority of winding faults are either indirectly or directly triggered by overloading (prolonged or cyclic). Also winding faults can be caused by operation on unbalanced supply voltage, or single phasing. These effects cause excessive heating which deteriorates winding insulation and effectively creates electrical faults. Universally adopted rule is that insulation life is halved for each 10°C rise in temperature above the rated value. This rule is affected by the length of time spent at the higher temperature. As electric motors have a great heat storage capacity, it means that occasional short duration overloads may not adversely impact the motor. Nevertheless, prolonged overloads of only several percent may end in premature ageing and insulation fault. Next, the motor thermal withstand capacity is impacted by winding heating prior to a fault. Hence, it is crucial that the protection relay features consider extremes of zero and full-load pre-fault. These are known as the 'Cold' and 'Hot' conditions, respectively. Different motor designs, various usages, variety of different abnormal working conditions and resulting fault modes result in a complex thermal formula. Therefore, it is not possible to create universal mathematical model that is precise. Nevertheless, it is possible to make an approximate mathematical model. This model assumes that the motor is a homogeneous machine, producing and dissipating heat at a rate proportional to temperature rise. This rule known as the motor 'thermal replica' is used for overload relay protection. The temperature T at any instant can be presented with:

Where Tmax - Maximum/final steady state temperature

τ - heating time constant

26. Explain about bus bar protection with different techniques?

Busbars and lines are important elements of electric power system and require the immediate attention of protection engineers for safeguards against the possible faults occurring on them. The methods used for the protection of generators and transformers can also be employed, with slight modifications, for the busbars and lines. The modifications are necessary to cope with the protection problems wising out of greater length of lines and a large number of circuits connected to a Busbar Protection. Although differential protection can be used it becomes too expensive for longer lines due to the greater length of pilot wires required. Fortunately, less expensive methods are available which are reasonably effective in providing protection for the busbars and lines. In this chapter, we shall focus our attention on the various methods of protection of busbars and lines.

Busbar Protection in the generating stations and sub-stations form important link between the incoming and outgoing circuits. If a fault occurs on a busbar, considerable damage and disruption of supply will occur unless some form of quick-acting automatic protection is provided to isolate the faulty busbar. The busbar zone, for the purpose of protection, includes not only the busbars themselves but also the isolating switches, circuit breakers and the associated connections. In the event of fault on any section of the busbar, all the circuit equipment connected to that section must be tripped out to give complete isolation.

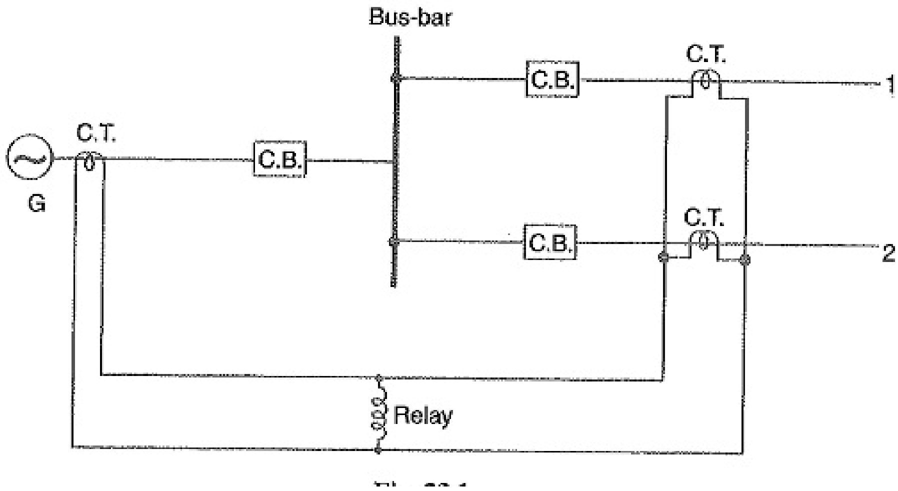
The standard of construction for Busbar Protection has been very high, with the result that bus faults are extremely rare. However, the possibility of damage and service interruption from even a rare bus fault is so great that more attention is now given to this form of protection. Improved relaying methods have been developed, reducing the possibility of incorrect operation.

The two most com-monly used schemes for busbar protection are :

Differential Protection

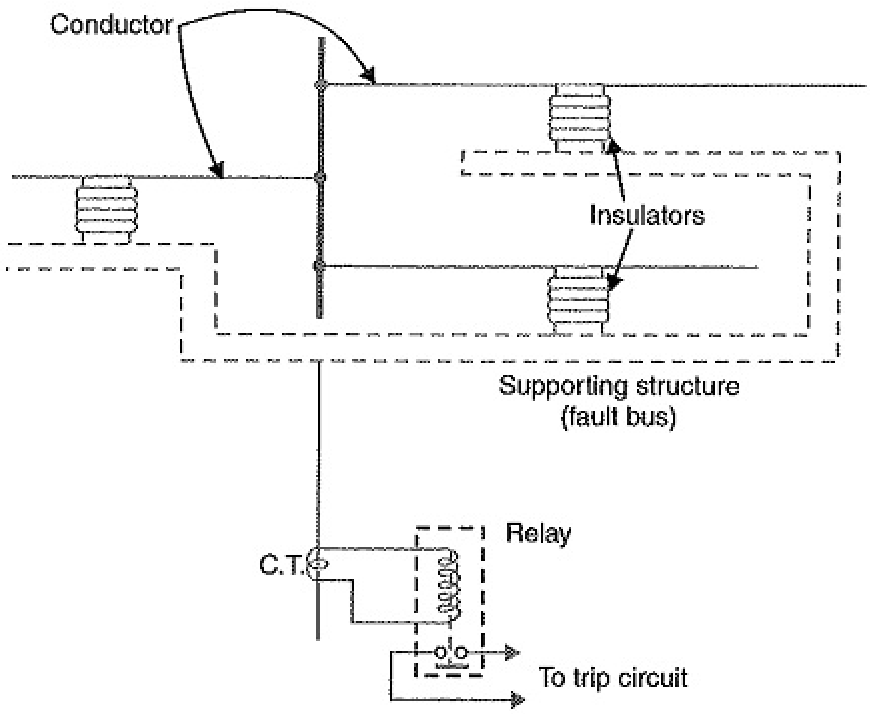
Fault Bus Protection

1. Differential Protection: The basic method for busbar protection is the differential scheme in which currents entering and leaving the bus are totalized. During normal load condition, the sum of these currents is equal to zero. When a fault occurs, the fault current upsets the balance and produces a differential current to operate a relay.



Above figure shows the single line diagram of current differential scheme for a station busbar. The Busbar Protection is fed by a generator and supplies load to two lines. The secondaries of current transformers in the generator lead, in line 1 and in line 2 are all connected in parallel. The protective relay is connected across this parallel connection. All CTs must be of the same ratio in the scheme regardless of the capacities of the various circuits. Under normal load conditions or external fault conditions, the sum of the currents entering the bus is equal to those leaving it and no current flows through the relay. If a fault occurs within the protected zone, the currents entering the bus will no longer be equal to those leaving it. The difference of these currents will flow through the relay and cause the opening of the generator, circuit breaker and each of the line circuit breakers.

2. Fault Bus Protection: It is possible to design a station so that the faults that develop are mostly earth-faults. This can be achieved by providing earthed metal barrier (known as **fault bus**) surrounding each conductor throughout its entire length in the bus structure. With this arrangement, every fault that might occur must involve a connection between a conductor and an earthed metal By directing the flow of earth-fault current, it is possible to detect the faults and determine their location. This type of protection is known as fault bus protection.



show the schematic arrangement of fault bus protection. The metal supporting structure or fault bus is earthed through a current transformer. A relay is connected across the secondary of this CT. Under normal operating conditions, there is no current flow from fault bus to ground and the relay remains inoperative. A fault involving a connection between a conductor and earthed supporting structure will result in current flow to ground through the fault bus, causing the relay to operate. The operation of relay will trip all breakers connecting equipment to the bus.

27. What are the needs of instrument transformers? Explain in detail about the operation of measuring CT and protection CT with distinctive sketch.

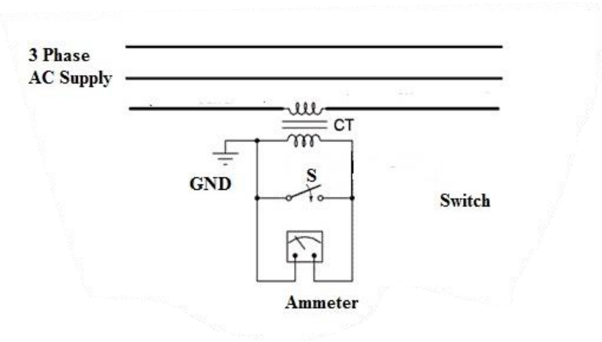
A transformer that is used to measure electrical quantities like current, voltage, power, frequency and power factor is known as an instrument transformer. These transformers are mainly used with relays to protect the power system.

The **Purpose of the instrument transformer** is to step down the voltage & current of the AC system because the level of voltage & current in a power system is extremely high. So designing the measuring instruments with high voltage & current is difficult as well as expensive. In general, these instruments are mainly designed for 5 A & 110 V.

The measurement of high-level electrical quantities can be done using a device namely instrument transformer. These transformers play an essential role in current power systems

Current Transformer

This type of transformer can be used in power systems to step down the voltage from a high level to a low level with the help of a 5A ammeter. This transformer includes two windings like primary and secondary. The current in the secondary winding is proportional to the current in the primary winding as it generates current in the secondary winding. The circuit diagram of a typical current transformer is demonstrated in the following figure.



In this transformer, the primary winding consists of few turns and it is connected with the power circuit in series. So it is called a series transformer. Likewise, the secondary winding includes a number of turns and it is connected to an ammeter directly because the ammeter includes small resistance.

Thus, the secondary winding of this transformer works almost in the condition of a short circuit. This winding includes two terminals where one of its terminals is connected to ground to evade the huge current. So insulation breakdown chances will be reduced to guard the operator from huge voltage.

The secondary winding of this transformer in the above circuit is short-circuited before disconnecting the ammeter with the help of a switch to avoid the high voltage across the winding.

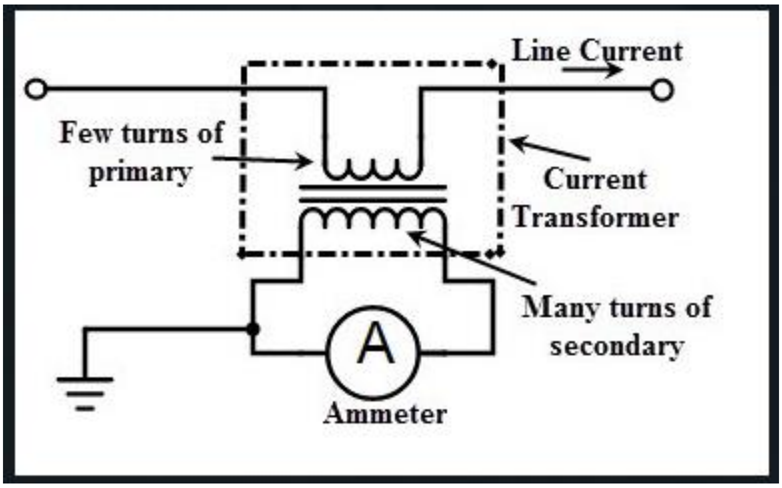
Metering and Protection Current transformers are different types of current transformers with varying properties.

- Current transformers are used for both metering and protection purposes.
- By reduce the power system primary current to lower value CT is used for measuring or metering purpose.
- By permit the use of standard current rating for secondary equipment CT is used for Protection purpose.
- Metering and Protection Current transformers the CTs used for metering and protection purposes have different properties.

Following are the basic differences between two.

Metering Current Transformers:

3. These are noticed by their yellow color in the circuit.
4. The limits are well defined.
5. These require good accuracy up to approximately 120% rated current.
6. Require low saturation level to protect instruments, thus use nickel iron alloy core with low exciting current and **knee point** at low flux density.
7. Metering C.Ts are classified into various classes based on the highest permissible percentage ratio error at rated current.
8. The classes are defined as class 0.1, class 0.2,class 0.5,class 1, class 3, class 5.



Protection Current Transformers:

There are two types of Protection current transformers available. One is the Normal protection CTs and the other is Special Purpose Protection CTs.

Normal Protection C.Ts: These are used for giving input to the relays like Over current and Earth fault to provide protection for feeders and motors etc.

9. These are noticed by their brown color in the circuit.
10. Operation over wide range of currents.
11. Accuracy not as important as measuring CTs.
12. Require accuracy up to many times rated current, thus use grain oriented silicon steel with high saturation flux density.
13. Protection C.Ts are classified into various classes
14. The classes are defined as 5P20, 10P20…

Here 5P20 means

5->%Error

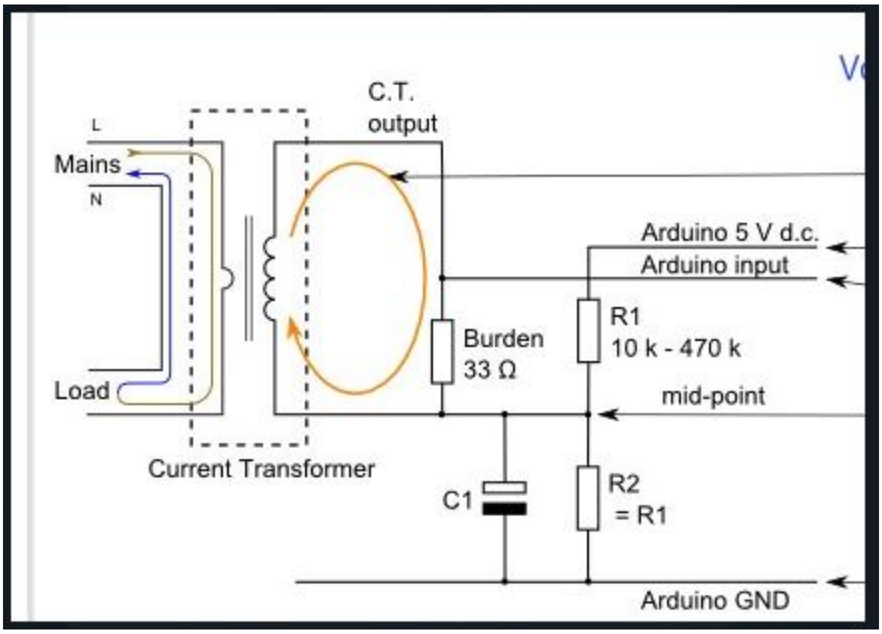
P-> Protection Class

20-> 20 times of rated current

Means when 20 times of rated current is flowing through CT the error in secondary current may be ± 5%.

PS-Class [Special Purpose] Current Transformers:
Class PS transformers are the special purpose protective current transformers. These are used where the required characteristics of the current transformers cannot be conveniently expressed in terms of the ordinary protection current transformers like Class 5P, 10P and 15P current transformers.

The typical applications involve differential and restricted earth fault protection schemes.



The **knee point voltage** is very important factor for designing this type of transformers.

Let us see what the Knee Point Voltage is.

Knee Point Voltage is the sinusoidal voltage of rated frequency applied to the secondary terminals of the current transformer, all other windings being open circuited, which when increased by 10 percent, causes the exciting current to increase by 50 percent.

The performance of the current transformer depends on the specified minimum knee point voltage.