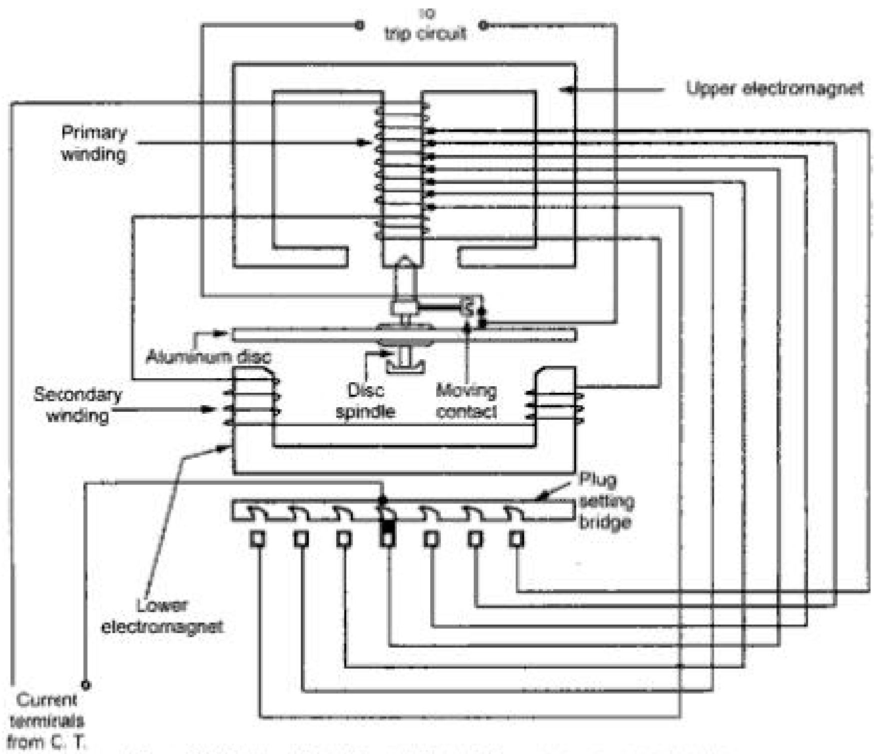
MODULE II

INDUCTION TYPE RELAY

- **Induction type relay:** Non-directional and directional over current relays
- IDMT and Directional characteristics.
- Differential relay – Principle of operation, percentage differential relay
- Bias characteristics, and distance relay – Three stepped distance protection
- Impedance relay, Reactance relay, Mho relay, Buchholz relay
- Negative Sequence relay
- Microprocessor based over current relay – block diagram approach

Non-directional

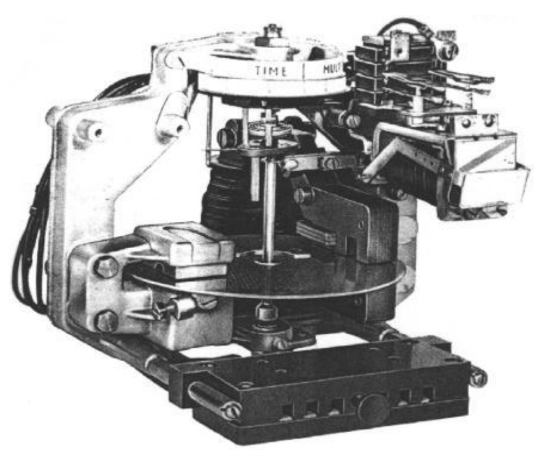
This relay is also called earth leakage induction type relay .The overcurrent relay operates when the current in the circuit exceeds a certain preset value. The induction type non directional overcurrent relay has a construction similar to a watt-hour meter, with slight modification .The fig shows the constructional details of non directional induction type over current relay.

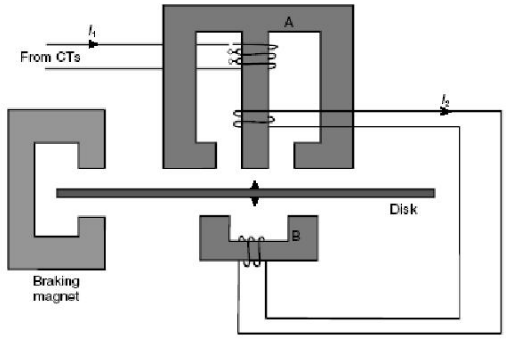


It consists of two electromagnets. The upper is E shaped while the lower is shaped the aluminium disc is free to rotate between the two magnets. The spindle of the disc carries moving contacts and when the disc rotates the moving contacts come in contact with fixed contacts which are the terminals of a trip circuit. The upper magnet has two windings. Primary and secondary. The primary connected to the secondary of C. I. on the be protected. This winding is tapped at intervals. The tapping's are connected to plug setting. With the help of this bridge, number of turns of primary winching can be adjusted. Thus the desired current setting for the relay can be obtained. There are usually seven sections of tapping's to have he overcurrent range from 50% to 20%, in steps of 25%. These values are percentages of the current rating of the relay. Thus a relay current may be MA i.e it car be connected to C.T. with secondary current rating of WA but with 50% setting the relay will start operating at SA. So adjustment of the current setting is made by inserting a pin between spring loaded jaw of the bridge socket. at he proper tap value required. When the pin is withdrawn for the purpose of changing the setting while relay is in service then relay automatically adopts a higher current setting thus secondary of C.T. is not open circuited. So relay remains operative for the fault occurring during the pant-of changing the setting. The secondary winding on the central limb of upper magnet is connected in series with winching on the lower magnet. This winding is energi7ed by the induction from primary By this arrangement: of secondary winding, the leakage duxes of upper and lower magnets are sufficiently displaced in space and time to produce a rotational torque on the aluminium disc. The control torque is provided by the spiral spring. When current exceeds its preset value, disc rotates and moving contacts on spindle make connection with trip circuit terminals. Angle through which the disc rotates is between 0' to 360". The travel of the moving contacts can be adjusted by adjusting angle of rotation of disc. This gives the relay any desired setting which o indicated by a pointer on a time setting dial. The dial is calibrated from 0 to I. This does not give direct operating time but it gives multiplier which can be used along with the time-plug setting multiplier curve to obtain actual operating time of the relay. The time-plug setting multiplier curve is provided by the manufacturer.

Principle of the construction and operation of the electromechanical IDMTL relay

As the name implies, it is a relay monitoring the current, and has inverse characteristics with respect to the currents being monitored. This (electromechanical) relay is without doubt one of the most popular relays used on medium- and low-voltage systems for many years, and modern digital relays' characteristics are still mainly based on the torque characteristic of this type of relay. Hence, it is worthwhile studying the operation of this relay in detail to understand the characteristics adopted in the digital relays.





The above relay can be schematically represented as shown in Figure

In the secondary winding which in turn sets up a flux in B. Fluxes A and B are out of phase thus producing a torque in the disk causing it to rotate. Now, speed is proportional to braking torque, and is proportional to driving torque. Therefore, speed is proportional to I^2.

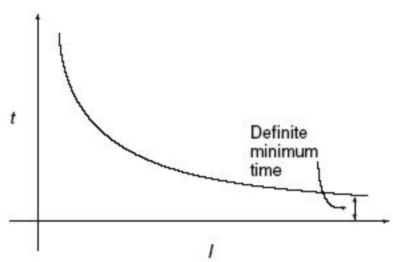
But,

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Hence,

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{1}{I^2}$$

This therefore gives an inverse characteristic (see Figure 9.3).



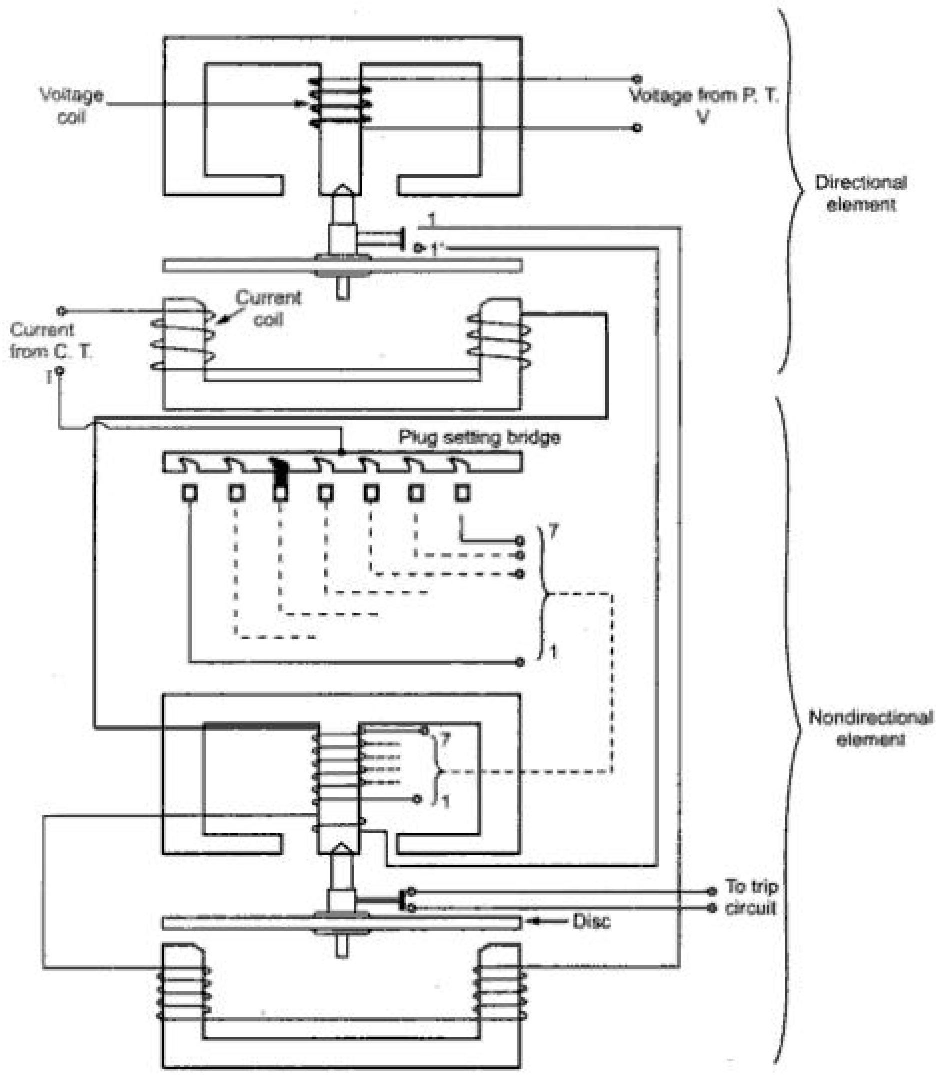
It can be seen that the operating time of an IDMTL relay is inversely proportional to a function of current, i.e. it has a long operating time at low multiples of setting current and a relatively short operating time at high multiples of setting current. The characteristic curve is defined by BS 142 and is shown in below figure. Two adjustments are possible on the relay, namely:

1. **The current pick-up or plug setting:** This adjusts the setting current by means of a plug bridge, which varies the effective turns on the upper electromagnet.

2. **The time multiplier setting:** This adjusts the operating time at a given multiple of setting current, by altering by means of the torsion head, the distance that the disk has to travel before contact is made.

Directional over current relays

Directional Induction Type Overcurrent Relay The directional power relay is not suitable to use as a protective relay under short circuit conditions. This is because under short circuit conditions the voltage frills drastically and such a reduced voltage may not be sufficient to produce the driving torque required for the relay operation. Hence in practice, directional induction type orer current relay is used. This relay operates almost independent of system voltage and power factor. low, directional induction type overcurrent relay uses two relay elements mounted. They elements are I Directional element which is directional power relay 2. Non directional element which is non directional over current relay The schematic arrangement of such a directional relay is shown in the fig:



Directional element: The directional element is nothing but a directional power relay which operates when power in the circuit flows in all particular direction the voltage coil of this element is energized by a system voltage through a potential transformer. The current coil on the lower magnet is energized by the system current through a current transformer .The trip contacts of this relay (1 - V) are connected in series. With the second's y winding of non directional element Non directional element: The current coil of the directional element is connected in series with the primary winding of non directional element. The plug setting bridge is provided in this element to adjust current setting as per the requirement. The trip contacts (I - I') are in series with winding on lower magnet of non directional element. So unless and until trip contacts (1 - V) are closed two the movement of the dice of directional element, the non directional element tannin (the movement of the non directional element is neutralized by the directional element.

Operation Under normal conditions, power flows in the proper direction and hence directional element of the relay is inoperative. Thus the secondary winding on lower magnet of non directional element is open and hence non directional element is also inoperative. When the fault takes place, the current or power in the circuit has a tendency to flow in reverse direction. The current flows through current aid of directional element which produces the flux. The current in the voltage coil produces another flux. The two fluxes interact to produce the torque due to which the disc rotates. As disc rotates, the trip contacts (1 - V) get closed. Note that the design of directional element is such that it is very sensitive and though voltage falls under short circuit, the current coil is responsible to produce sufficient torque to have disc rotation It is so sensitive that it can operate even at 2 % of power flow in reverse direction The current also flows through the primary winding on the upper magnet of non directional element. Thus energizes the winding to produce the flux. This flux induces the e.m.f. in the secondary winding of the non directional element according to induction principle. As the contacts (I - V) are closed, the secondary winding has a closed path. Hence the induced e.m.f. drives the current though it, producing the flux. The two fluxes interact to product. The driving torque which rotates the disc. Thus the contacts of trip circuit get closed and it opens the circuit breaker to isolate the faulty section. So directional element must operate first to have the operation of the non directional element.

Differential relay – Principle of operation, percentage differential relay

In the overcurrent relays, a current is sensed but such relays are not very sensitive as these relays cannot distinguish between heavy loads and minor fault conditions. In such cases, differential relays can be used A differential relay is defined as the relay that operates when the phasor difference of two or more similar electrical quantities exceeds a predetermined value. Thus a current differential relay operates on the result of comparison between the phase angle and magnitudes of the currents entering and leaving the system to be protected. Under normal conditions, the two currents are equal in phase and magnitude hence relay is inoperative. But under fault conditions, this condition no longer exists. The relay is connected in such a manner that the difference between current entering and curial leaving flows through the operating coil. If this difference current exceeds a preset vane then the relay operates and opens the circuit breaker. Almost any type of relay connected in a certain way can be made to operate as a differential relay

Types of Differential Relays: Types of differential relays are.

I. Current differential relay
II. Biased beam relay o: percentage differential relay
III. Voltage balance differential relay

Current Differential Relay of the differential relays is of current differential type. Consider an over current relay connected in the circuit seas to operate as the current differential relay. This is shown in the Fig 3.1. Two current transformers are used having same ratio are connected on the either side of the section to be protected. The secondaries of current transformers are connected in series, so they carry induced currents in the same direction.

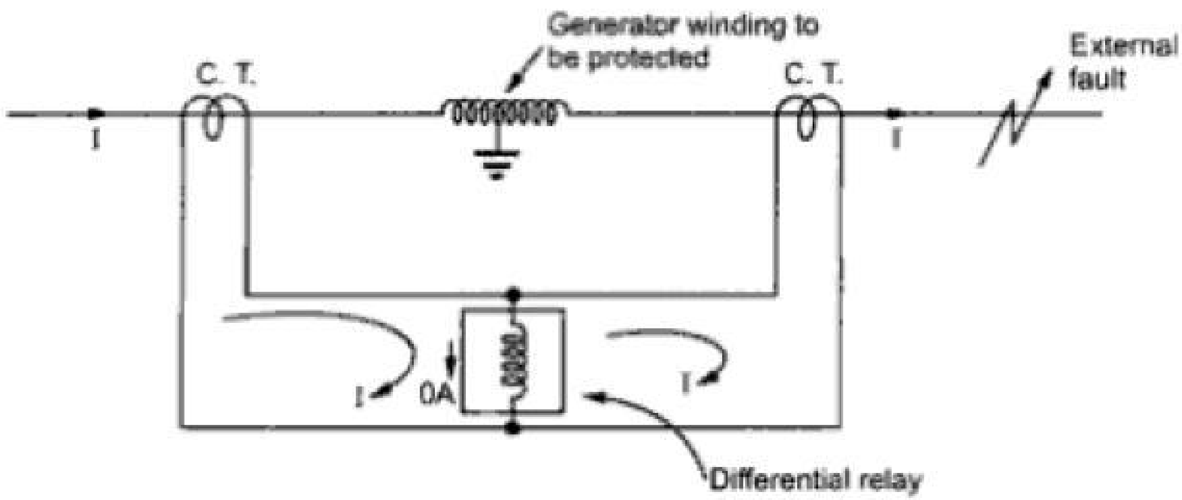


Fig. Current differential relay

This relay suffers front the following disadvantages, I. The current transformers are connected through tables called pilot cables. The impedance of such pilot cables generally CAM'S slight difference between the currents at the ends of the section to be protected A sensitive relay can operate to a very small difference IT the two currents, though there is no fault existing.

Percentage differential relay: As the name suggests, this relay is designed to operate to the differential current In terms of its fractional relation with the actual current flowing through the protected circuit. The Fig. shows the arrangement of a biased beam relay.

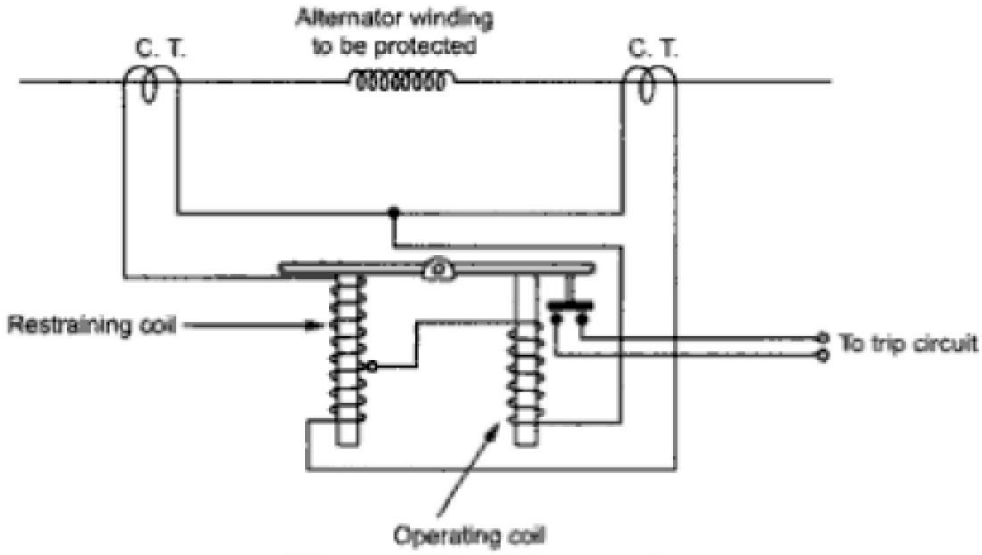


Fig. Biased beam relay

The simple circuit connection of this type of relay is shown in the Fig.

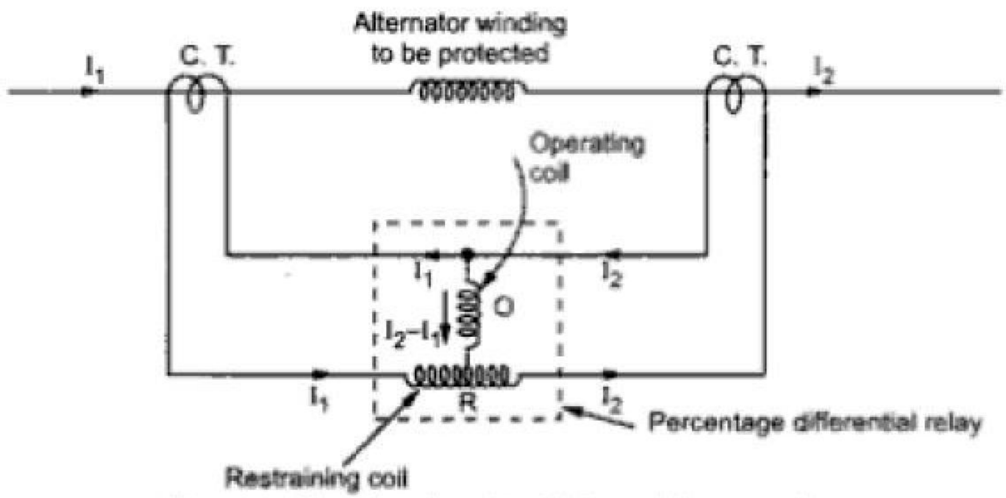


Fig. Simple circuit of biased beam relay

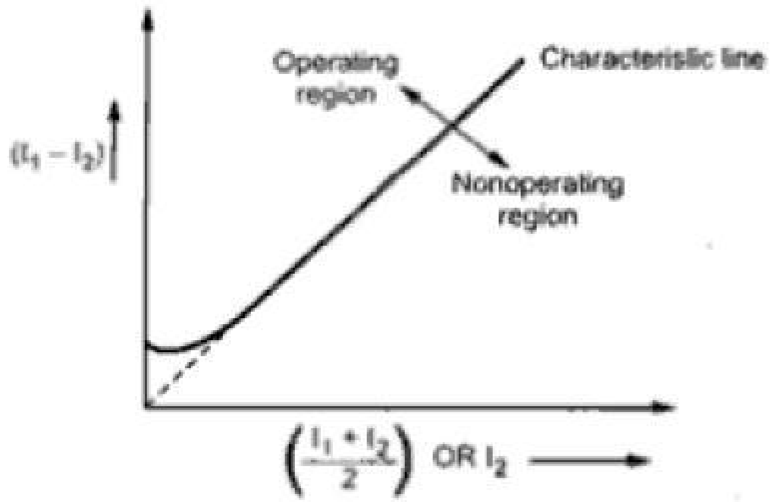


Fig. Operating characteristics

Under normal and through load conditions, the bias force produced due to the restraining coil is greater than the operating force produced by operating coil hence relay is inoperative. When internal fault occurs, the operating force becomes more than the bias force beam moves and the trip contacts are closed to oven then circuit breaker. The operating characteristics of this type of relay are shown in the Fig. It can be seen that except at low currents, the characteristics is. a straight line. Thus the ratio of the differential operating current to the average restraining current is a fixed percentage relay, Hence the relay name is percentage current differential relay relays are called constant slope percentage differential relays: In some relays, the slope of the characteristics increases as the short circuit current increases. Such characteristics are shown in the above graph.

Distance relay

Distance Relays in the relays discussed up till now; the operation of the relays is dependent on the magnitude of the current or voltage of the circuit to be protected. In distance relays the operation k dependent on the ratio of the voltage and current, which is expressed in terms of impedance. Hence basically distance relays are called impedance relays. The impedance is nothing but an electrical measure of distance along a transmission line. The relay operates when the ratio V/I i.e impedance is less than a predetermined value. As the ratio WI affects the performance of these relays, the relays are also called ratio relays. Dependent on the ratio of V and I there are three types of distance relays which are,

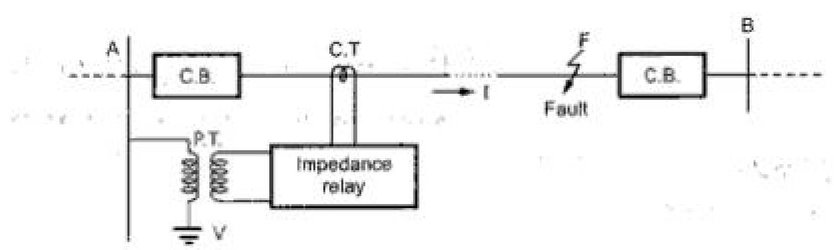
I. Impedance relay which is based on measurement of impedance

2. Reactance relay which is based on measurement of reactance X.

3. Admittance or Mho relay which is based on measurement of component of admittance Y. In short, a distance relay is one whose performance is based on the measurement of impedance, reactance or admittance of lire between the location of relay and the point where fault occurs.

Impedance Relay

The impedance relay works corresponding to the ratio of voltage V and current I of the circuit to be protected. There are two elements in this relay; the one produces a torque proportional to current while the other produces a torque proportional to voltage. The torque produced by the current element is balanced against torque produced by the voltage element. Thus the current element produces operating torque, pickup torque which can be said to the positive torque. The voltage element produces restraining torque, reset torque which can be said to be negative torque. So this relay is voltage restrained overcurrent relay.

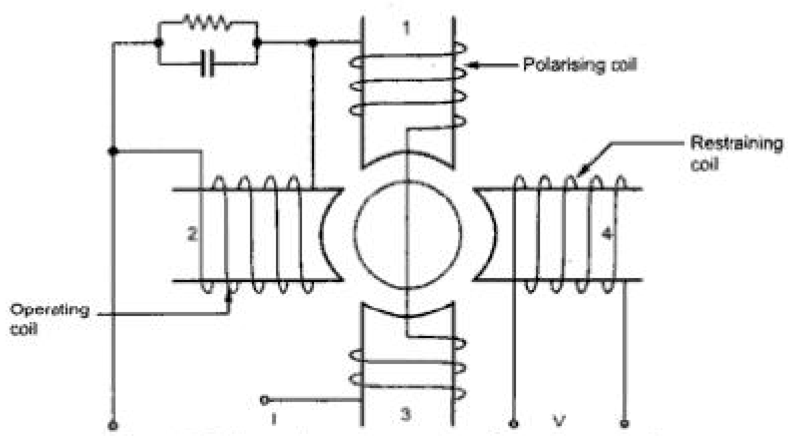


The current element is energized by current though CT while voltage element is energized by voltage through PT* The section Ali of the line n protected under normal conditions, the ratio of voltage V and current I is denoted as which is impedance of line. The relay is inoperative under this condition. When the fault occurs at point F in the protected when then the voltage drops while current increases. Thus the ratio Vin i.e. the impedance reduces drastically. This is the impedance of line between the points at which relay is connected and the point F at which tend so when the impedance reduces than it predetermined value A. it trips and makes the circuit breaker open.

Reactance relay

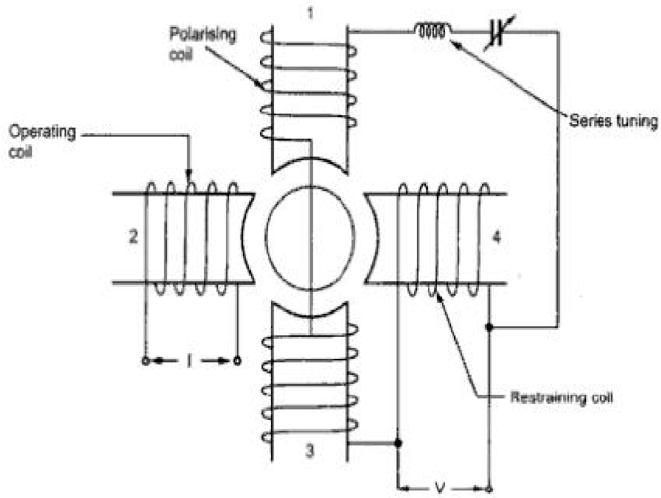
Relay the operating torque b obtained by current while the restraining torque due to a current-voltage directional relay. The overcurrent element develops the positive torque and directional unit produces negative torque. Thus the reactance relay is an overcurrent relay with the directional restraint. The directional element is so designed that the maximum torque angle

Construction



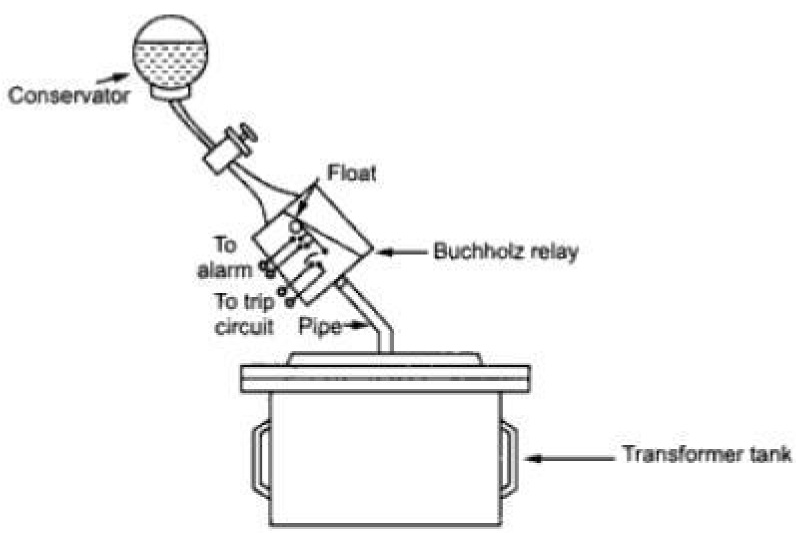
The structure used tor the reactance relay can be of induction cup type. It is a four pole structure. It has operating coil, polarizing coil and a restraining coil. The schematic arrangement of coils for the reactance relay is shown in the Fig. The current I flows from pole 1, through iron core stacking to lower pole 3. The winding on pole 4 is fed from voltage V. 1ow operating torque is produced by interaction of fluxes due to the windings drawing current coils of (produced by poles I. 2 and 3. While the restraining torque is developed due to interaction of fluxes due to the poles 1, 3 and 4). Hence the operating torque is proportional to the square of the current while the restraining torque is proportional to the product of V and I (VI) The desired maximum torque angle is obtained with the help of RC circuit.

Mho relay: In the impedance relay a separate unit is required to make it directional while the same unit can not be used to make a reactance relay with directional feature. The mho relay is made inherently directional by adding a voltage winding called polarizing winding. This relay works on the measurement of admittance Y z 0. This relay is also called angle impedance relay.

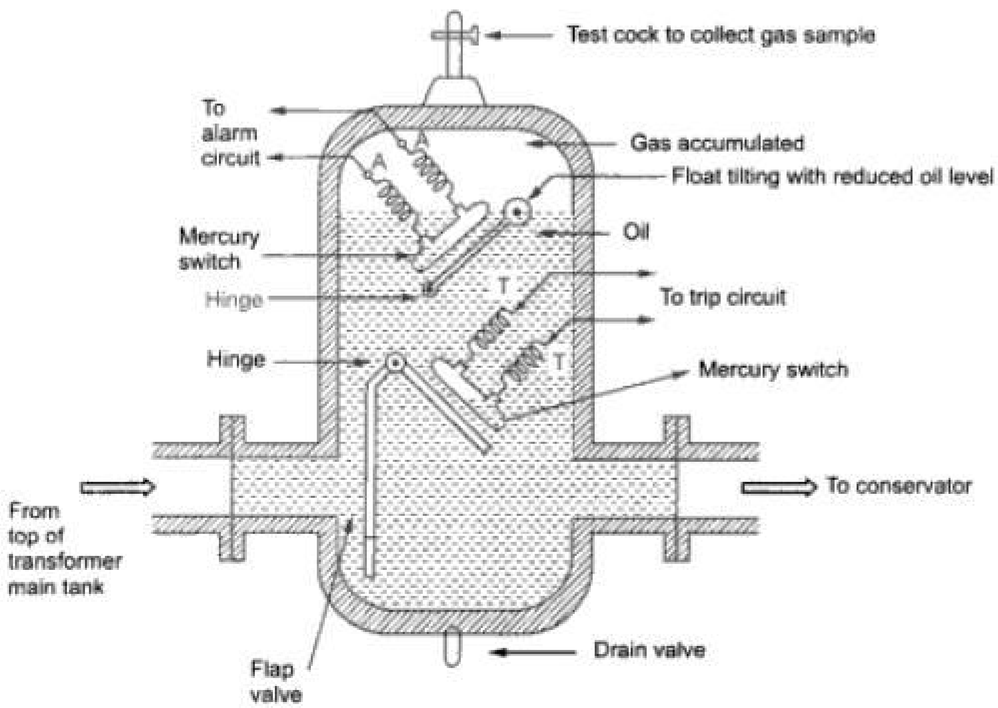


In this relay the operating torque is obtained by V and I element while the restraining torque is obtained by a voltage element. Thus an admittance relay is a voltage restrained directional relay. Thy operating torque is produced by the interaction of the fluxes duo to the windings carried by the poles I, 2 and 3. While the restraining torque is produced by the interaction of the fluxes due to the windings carried by the poles I. 3 and 4. Thus the restraining torque is proportional to the square of the voltage (V2) while the operating torque is proportional to the product of voltage and current (VI). The torque angle is adjusted using series tuning circuit.

Buchholz relay



Operation: There are many types of internal faults such as insulation fault, core heating, bad switch contacts, faulty joints etc. which can occur. When the fault occurs the decomposition of oil in the main tank starts due to which the gases are generated. As mentioned earlier, major component of such gases is hydrogen. The hydrogen tries to rise up towards conservator hut in its path it gets accumulated in the upper part of the Buchholz relay. Through passage of the gas is prevented by the flap valve. When gas gets accumulated in the upper part of housing, the oil level inside the housing falls. Due to which the hollow float tilts and close the contacts of the mercury switch attached to it, this completes the alarm circuit to sound an alarm. Due to this operator knows that there is some incipient fault in the transformer. The transformer is disconnected and the gas sample is tested. The testing results give the indication, what type of fault is started developing in the transformer. Hence transformer can he disconnected before fault grows into a serious one. The alarm circuit does not immediately disconnect the transformer but gives only indication to the operator. This is because some times bubbles in the oil circulating system may operate the alarm



Construction of Buchholz relay

UNIT - 7 & 8

PROTECTION SCHEMES: GENERATOR PROTECTION

- ❖ **Protection Schemes: Generator Protection** - Merz price protection, prime mover faults
- ❖ Stator and rotor faults,
- ❖ Protection against abnormal conditions – unbalanced loading
- ❖ Loss of excitation, over speeding.
- ❖ **Transformer Protection** - Differential protection
- ❖ Differential relay with harmonic restraint, Inter turn faults
- ❖ **Induction motor protection** - protection against electrical faults such as phase fault
- ❖ ground fault, and abnormal operating conditions such as single phasing
- ❖ Phase reversal, over load.

Introduction

The generators used in the power system are the alternators which produce very high a.c voltages the protection of generators is very much complex due to the following reasons:

The generators are very large machines producing, very high voltages and are connected to buabars. Various other equipment's are always associated with the generators. Such equipment's are prime movers, excitation systems, voltage regulators, cooling systems etc. Thus protection of generators must consider the presence of these higher equipment's also.

The generators are very costly, expensive and important factor in a power system. The protection scheme must be such that it should not shut oft the generators as far as possible. The shut oil generators result in a power shortage. All these factors make the design of protection scheme for the generator very much complex.

Generator Faults

The various faults which can occur associated with a generator can be classified as,

1. Stator faults: The faults associated with the stator of the generator

2. Rotor faults: The faults associated with the rotor of the generator.

3. Abnormal running conditions: This includes number of abnormal conditions which may occur in practice, from which the generator must be protected.

Stator Faults

The stator faults mean faults associated with the three phase armature windings of the generator. These faults are mainly due to the insulation failure of the armature windings. The main types of stator faults are.

1. Phase to earth faults

2. Phase to phase faults

3. Inter-turn (involving turns of same phase winding). The most important and common fault is phase to earth fault. The other two are not very common while inter-turn fault is very difficult to detect.

Phase to Earth Faults:

The faults mainly occur in the armature slots. The faults are dangerous and can severe damage to the expensive machine. The fault currents less than 20 A cause negligible burning of core if machine is tripped quickly. But if the fault currents are high, severe burning of stator core can take place. This may lead to the requirement of replacing the laminations which Is very costly and time consuming. So to avoid the damage due to phase to earth faults, a separate, and sensitive earth fault protection is necessary for the generators along with the earthing resistance.

Phase to Phase Faults: The phase to phase faults means short circuit between two phase windings. Such faults are uncommon because the insulation used between the coils of different phases in a slot is large. But once phase to earth fault occurs, due to the over heating phase to phase fault also may occur. This hull is likely to occur at the end connections of the armature windings which are overheating parts outside the slots. Such a fault causes severe arcing with very high temperatures. This may lead to melting of copper and lire if the insulation is not fire resistant.

Stator Inter-Turn Faults: The cols used in the alternators are generally multi tum coils. So short circuit between the turns of One Coil may occur which Is called an inter-turn fault. This fault occurs due to current surges with high value of (L di/do voltage across the turns. But if the coils used are single turn then this fault can not occur. Hence for the large machines of the order of 50 kVA and more, it is a normal practice to use single turn coils. But in some countries, multi tum coils are very commonly used where protection against inter-turn faults is must.

Rotor Faults: The construction of an alternator is generally a field winding as most of the alternators arc of rotating field type. The field winding is made up of number of turns. So the conductor to earth faults and short circuit between the turns of the field winding, are the commonly occurring faults with respect to a rotor. These severe mechanical and thermal stresses, acting on the field winding insulation. The field winding is generally not grounded and hence single line to ground fault does not give any fault current. A second fault to earth will bring circuit the part of the field winding and may there by produce an unsymmetrical field system. Such an unsymmetrical system gives rise to the unbalanced forces on the rotor and results in pressure on the hearings and the shaft distortion, if stub a fault is not cleared vet, early. So it is very much necessary to know the existence of the lust occurrence of the earth fault so that corrective measures can be taken before second pull occurs. The unbalanced loading on the generator is responsible to produce the negative sequence currents. Thee currents produce a rotating magnetic field which rotates in opposite direction to that of rotor magnetic field to this field, there is induced e. m f. in the rotor winding. This causes overheating of the rotor .Rotor earth fault protection and rotor temperature indicators are the essential and arc provided to large rating generators.

Abnormal Running Conditions In practice there are number of situations in which generator is subjected to some abnormal running conditions. The protection must be provided against the abnormal conditions. These abnormal conditions include, I. Overloading 2. Over speeding 3.

Unbalanced loading 4. Over voltage 5. Failure of prime mover (Arc of excitation (Field failure) 7. Cooling system failure

Overloading: Due to the continuous overloading, the overheating of the stator results. This may increase the winding temperature. If this temperature rise exceeds certain limit, the insulation of the winding may get damaged .The degree of overloading decides the effects and temperature the. The protection is generally very high value hence continuous overloads of less value than the setting cannot be sensed by overcurrent protection

Over speeding: In caw of hydraulic generators a sudden loss of load results in over speeding of the generator. This is because the water flow to the turbine cannot be stopped or reduced instantly. Generally a governor is provided to present the over speeding. But it there is any fault in the turbine governor then the dangerous over speeding may take place. Hence it is necessary to supervise the working of turbine governor and rake some corrective measures if there is some fault in the governor.

Unbalanced Loading: The unbalanced loading of the generator results in the circulation of negative sequence currents. These currents produce the rotating magnetic field. This rotating magnetic field rotates at the synchronous speed with respect to rotor. The direction of rotation of this magnetic field is opposite to that of rotor. Hence effectively the relative speed between the two is double the synchronous speed. Thus the e.m.f. gets induced, having double the normal frequency; in the rotor winding .The circulating currents due to the induced e.m.f. are response to overheat the rotor winding as. Rotor stampings. Continuous unbalanced load mote than 10% of the rated load causes tremendous heating which is dominant incase of cylindrical rotor of turbo alternators. The reasons for the unbalanced load conditions arc,

Occurrence of unsymmetrical faults near the generating station. The failure of circuit breaker near the generating station in clearing all the three phony, Negative sequence protection is important to prevent dangerous situations due to negative sequence currents which are because of unbalanced load conditions.

Over voltage: The over voltages ore basically due to the over speeding of generators. Another reason for this the faulty operation of voltage regulators. Not only the internal over voltages are dangerous but atmospheric surge voltages can also reach to the generators. Such atmospheric surge voltages are generated by direct lighting strokes to the aerial lines of high voltage system. Inductively and capacitive, these surges can get transferred to the generator. To protect the generators from surge voltages, the surge arresters and surge capacitors are often used. At the time of re striking across the contacts of circuit breakers, the transient over voltages get generated such surges are called switching surges and can be limited by the uses of modem circuit breakers RC surge suppressors also help in reducing switching surges. Another situation, when the transient over voltages are generated, is when the arcs are pounded. During arcing grounds, the transient voltages having amplitudes five times more than the normal line to neutral peak amplitude are generated Such transient voltages are dangerous and can be reduced by using resistance earthing.

Failure of Prime Mover: The failure of prime mover results in motoring operation of synchronous generator. The generator draws active power from the network and continues to run at synchronous speed as a synchronous motor. This may lead to dangerous mechanical conditions if allowed to persist for more than thirty seconds. The serious overheating of the steam turbine blades may result to prevent this reverse power protection achieved by directional power relays is used.

Loss of Excitation: The loss of excitation or reduced excitation is possible due to the field failure i.e. opening of field winding or due to short circuit in field or due to some fault in exciter system. Such loss of excitation results in loss of synchronism within a second and the. Causes the increase in speed of the generator. Since power input to the machine remains same, the generator starts working as an induction generator, drawing the reactive power from the bus. The machine starts drawing an exciting current from the system. Which is equal to the full load rated value? This leads to the overheating of the stator winding and the rotor body due to induced current' The loss of excitation may also lead to the pole slipping condition which results in the voltage reduction for the output above hail the rated load Loss of excitation should not persist for long and corrective measures disconnection of alternator should be taken immediately. For this a tripping scheme can be used which can trip the generator circuit breaker immediately when there is a field failure.

Cooling System Failure: failure of cooling system also causes severe overheating to rise the temperature above safe limit. This may lead to insulation failure, causing some other faults to occur. The thermocouples or resistance thermometers are used in large machines to sensor the temperature. The corrective measures are taken whenever the temperature exceeds the limit Apart from the above dominant abnormal conditions, some conditions may exist which are fare m practice.

Merz price protection

This is most commonly used protection scheme for the alternator stator windings. The scheme is also called biased differential protection and percentage differential protection. In this method, the currents at the two ends of the protected section are sensed using current transformers. The wires connecting relay coils to the current transformer secondary's arc called pilot wires. Under normal conditions, when there is no fault in the windings, the currents in the pilot wires fed (mm

C.T. secondary's are equal. The differential current is - through the operating cods of the relay as zero. Hence the relay is inoperative and system is said to be balanced. When fault occurs inside the protected section ot the stator windings, the differential current i, - 12 flows through the operating coils of the relay. Due to this current, the relay operates.. This trips the generator circuit breaker to isolate the faulty section. The field is also disconnected and is discharged through suitable impedance.

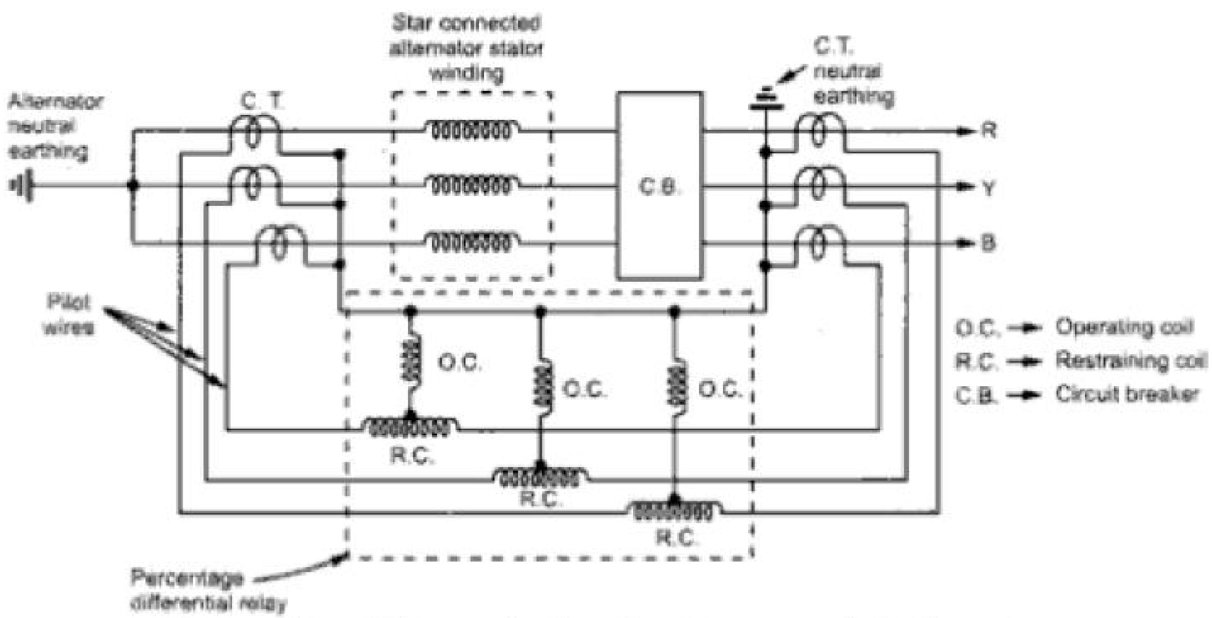


Fig. Merz-Price protection for star connected alternator

Transformer Protection

Percentage Differential Protection for Transformers: percentage differential protection or Wu-Price protection based on the circulating current principle can also be used for the transformers. This system gives protection against phase to phase faults and phase to ground faults to the power transformers. The principle of such a protection scheme is the comparison of the currents entering and leaving the ends of a transformer. The vector difference of currents will passes through the operating coil while the average current will passes through the restraining coil. In normal conditions, the two currents at the two ends of the transformer are equal and balance is maintained. So no current flows through the operating coil of the relay and relay is inoperative. But when there is phase to phase fault or phase to ground fault, this balance gets disturbed. The difference current flows through the operating coil due to which relay operates, tripping the circuit breaker. Compared to the differential protection used in generators, there are certain important points which must be taken care of while using such protection for the power transformers. These points are,

I. In a power transformer, the voltage rating of the two windings is different. 11w high voltage winding is low current winding while low voltage winding is high current winding. Thus there always exists difference in current on the primary and secondary sides of the power transformer. Hence if C.T.s of same ratio are used on two sides, then relay may get operated through there is no Fault existing. To compensate for this difficulty, the current ratios of C.T.s on each side are different. These ratios depend on the line currents of the power transformer and the connection of

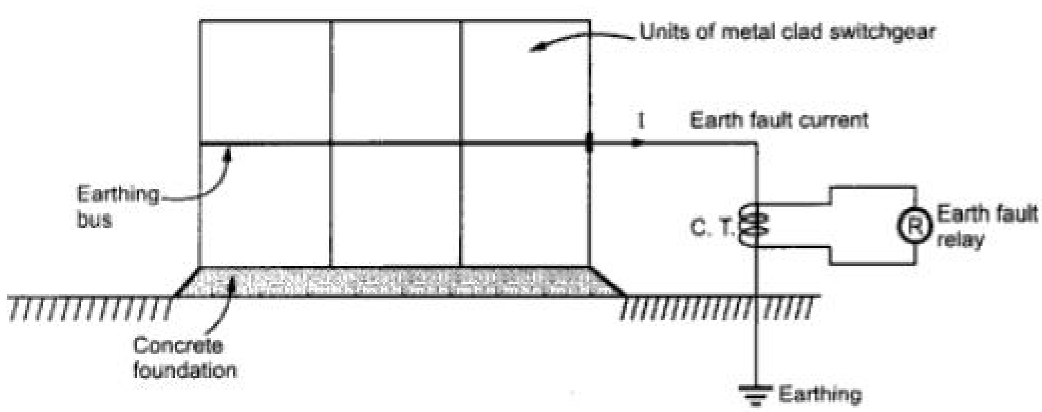
Due to the different turn's ratio; the currents led into the pilot wires from each end are same under normal conditions so that the relay remains inoperative. For example if K is the turns ratio of a power transformer then the ratio of C.T.s on low voltage side is made K times greater thin that of C.T.s on high voltage side.

2. In case of power transformers, there is an inherent phase difference between the Voltages induced in high voltage winding and low voltage winding. Due to this, there exists a phase difference between the line currents on primary and secondary sides of a power transformer. This introduces the phase difference between the CT. secondary currents, on the two sides of a power transformer. Though the turns ratio of C.T.s are selected to compensate for turns ratio of transformer, a differential current may result due to the phase difference between the currents on

two sides. Such a differential current may operate the relay though there is no fault; hence it is necessary to correct the phase difference. To compensate for this, the CT. connections should be such that the resultant currents fed into the pilot wires from either side are displaced in phase by an angle equal to the phase shift between the primary and secondary currents. To achieve this, secondary's of C.T.s on star connected side of a power transformer are connected in delta while the secondary's of C.T.s on delta connected side of a power transformer are connected in star.

Differential relay with harmonic restraint, Inter turn faults

This protection is nothing but the method of providing earth fault protection to the transformer. This protection can be provided to the metal clad switchgear. The arrangement is shown in the Fig. The metal clad switchgear is lightly insulated from the earth. The frame of the switchgear i.e. enclosure is grounded. This is done through a primary of current transformer in between. The concrete foundation of switchgear and the other equipment's are lightly insulated from the ground. The resistance of these equipment's with earth is about 12 ohms. When there is an earth fault, then fault current leaks from the frame and passes through the earth connection provided. Thus the primary of C.T. senses the current due to which current passes through the sensitive earth fault relay. This operates the relay. Such a protection is provided only for small transformers. For the large transformers, the differential protection is enough to sense and operate for the earth faults.



Induction motor protection

Introduction

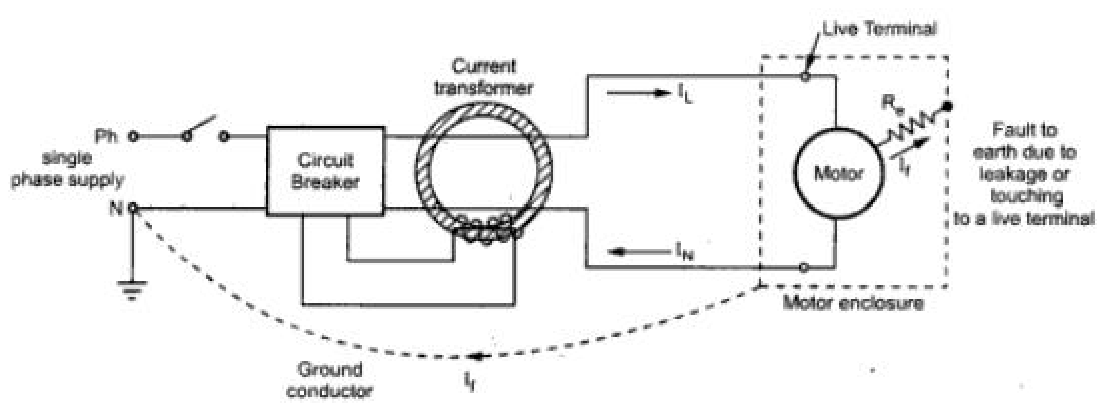
Based on the control action i.e. starting, stopping or reversal, controlling elements known in electrical terms as switchgear are employed for the protection of induction motor. Generally two basic protections viz short circuit protection and overload protection are provided for each motor. The switchgear used for protection includes contactors with H.R.0 fuse and thermal overload relays along with circuit breakers. If the rating of the motor is up to 150 kW then contactors and fuses can be used while for motors having rating beyond 150 kW, circuit breakers are used. The contactor is a kind of switch through which supply can be given to the motor when its coil is energized. If the current to be interrupted is six times the rated current of the motor then contactors can be used.

Abnormal Conditions and Failure in Case of Induction Motor: The three phase induction motors are used in numerous industrial applications. Hence before studying the protection circuit we have to consider the abnormal conditions and failure that may occur in case of induction motor. If the motor is heavily loaded beyond its capacity then it will be overload condition of motor in which case motor draws heavy current from the supply and there will be simultaneous rise in temperature of winding and deterioration of the insulation resulting in damage of winding. Hence the motor must be protected against tins mechanical overloading with overload protection circuits. Normally thermal overload relays, over current relays or miniature circuit breaker with built in trip coils may be used. It might be possible that the rotor is locked or starting lasts for longer duration or rotor does not move because of excessive load (stalling) at start. In all these cases motor draws heavy current from the supply and results in damage to the winding due to overheating as stated above. In this case thermal relays or instantaneous overcurrent relays are used.

If the supply conditions are abnormal such as loss of supply voltage, unbalanced supply voltage, phase sequence reversal of supply voltage, over voltage, under voltage or under frequency then also the performance of the motor is affected. With unbalanced supply voltage there will be excessive heating while with under voltage the motor draws more current for the same load. For under voltage protection, under voltage relays are used. With correct phase sequence, the motor runs in one direction. With change in phase sequence of supply it runs in other direction which is dangerous in some of the applications such as cranes, hoists or elevators. In such cases phase reversal relay may be provided which will disconnect the supply to the motor through the circuit breaker. Due to excessive temperature rise, the insulation may get damaged which may lead to stator earth fault or stator phase to phase fault which are rare in nature. For low rating motors, HRC fuses provide sufficient protection against these faults while for large motors, differential protection may be used. Due to blowing of fuse in any phase or open circuit in one of the three phases results in single phasing. In such case motor continues to run and if it is loaded to its rated value then it will draw excessive current which will damage the rotor and eventually the motor will be damaged due to excessive overheating. Normally thermal overload relays are used against single phasing. Sometimes special single phase preventer may be provided.

Ground fault protection

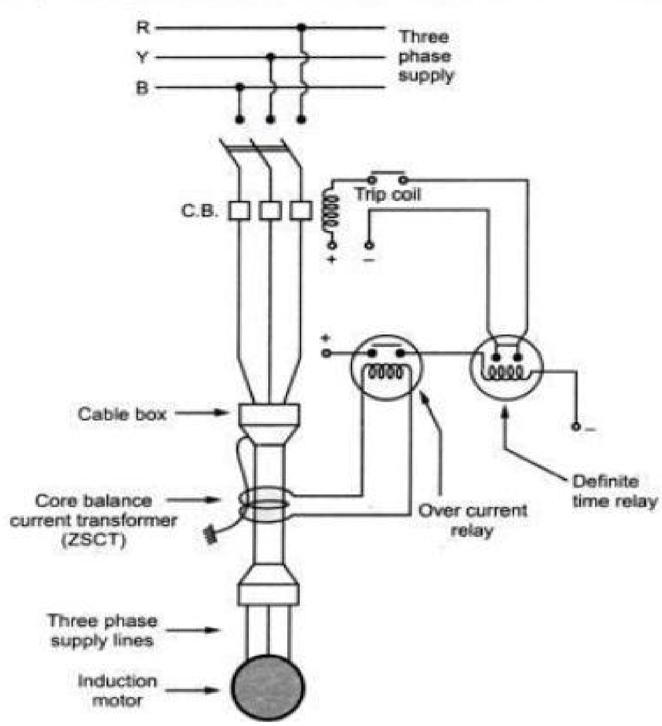
The ground fault protection is achieved using earth leakage circuit breaker (ELCB). When the fault current or leakage current flows through earth return path then it forms the earth fault. These faults are relatively frequent and hence protection is required against these which is provided with the help of Earth leakage circuit breaker. Consider an example of a person whose finger sticks into the socket. Even though the metal enclosure is securely earthed, the person will receive a severe shock. Under such case there must be certain device that will cut the supply. This can he done with the help of ELCB which will typically trip in around 25 cms if current exceeds its preset value. The schematic of ELCB is shown in Fig.



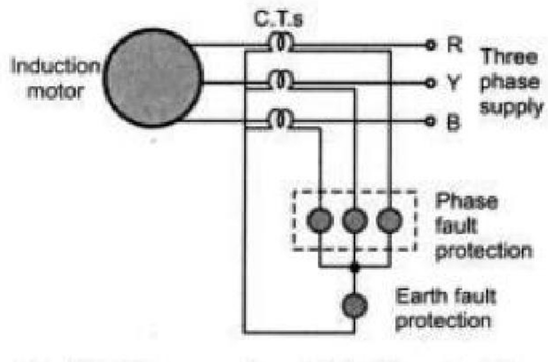
As shown in the Fig ELCB consists of a small current transformer surrounding live and neutral wire. The secondary winding of current transformer is connected to relay circuit which can trip the circuit breaker which is connected in the circuit. Under normal conditions, the current in line and neutral conductor is same so the net current (IL -IN) flowing through the core is zero. Eventually there will not be any production of flux in the core and no induced emf. So the breaker does not trip. If there is a fault due to leakage from live wire to earth or a person by mistake touching to the live terminal then the net current through the core will no longer remain as zero but equal to IL -IN or I, which will set up flux and emf in CT. As per the preset value the unbalance in current is detected by C.T. and relay coil is energized which will give tripping signal for the circuit breaker. As C.T. operates with low value of current, the core must be very permeable at low flux densities.

Phase Fault Protection

This protection is also called short circuit protection. At the time of such a fault, the current increases by 8 to 10 times the full load current of the motor. Attracted armature type relay unit is connected in each phase with a current setting of 4-5 times the full load current. This is because starting current can he 4-5 times full load current.



Earth fault protection by ZSCT



Phase and earth fault protection

The phase faults can cause burn out of coils and stampings and hence motor should be disconnected as quickly as possible when fault occurs. Fast over current relays also are used to provide phase fault protection. As mentioned above to avoid relay functioning during starting, the short circuit protection current setting must be just above the maximum starting current of the motor.

Phase Reversal Protection: The direction of induction motor depends on the direction of rotating magnetic field produced by the stator windings. For a particular phase sequence RYB the motor rotates in a particular direction due to corresponding direction of rotating magnetic field. But if any two lines are interchanged after repairs the phase sequence reverses such as YRB. Then the direction of rotating magnetic field also reverses and induction motor starts rotating in opposite direction. Such a change of direction is dangerous if the induction motor is used for cranes, hoists, lifts or in threading mills etc.

Thus to disconnect induction motor from supply if there is phase reversal, phase reversal protection is provided. This protection is provided using motor driven disc working on electromagnetic principle. The secondaries of two current transformers connected in two lines drive the motor to operate the disc. The arrangement is such that for a normal direction of motor, disc rotates in a particular direction which keeps the auxiliary contacts closed. But if there is phase reversal then the torque produced reverses to rotate the disc in opposite direction. Due to this auxiliary contacts get opened. This in turn either operates the circuit breaker or de-energizes starter coil to disconnect the motor from the supply. Thus phase reversal protection for the induction motor is achieved. Now a day's solid state phase reversal relay sensing the phase reversal is used