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 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 ressure 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. The 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 irection 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 he 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.

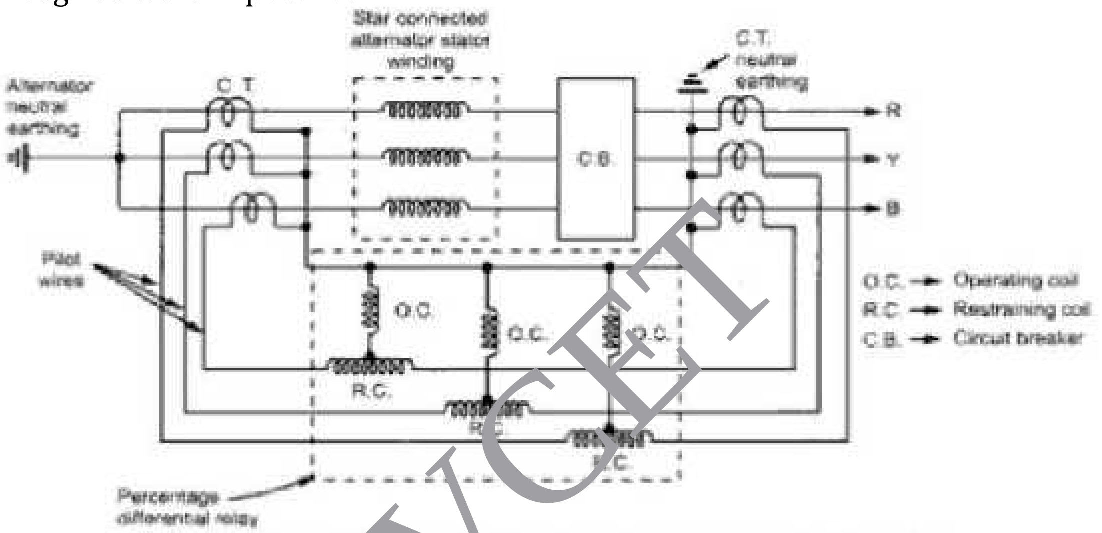


Fig. Merz-Price protection for star connected alternator

Transformer Protection

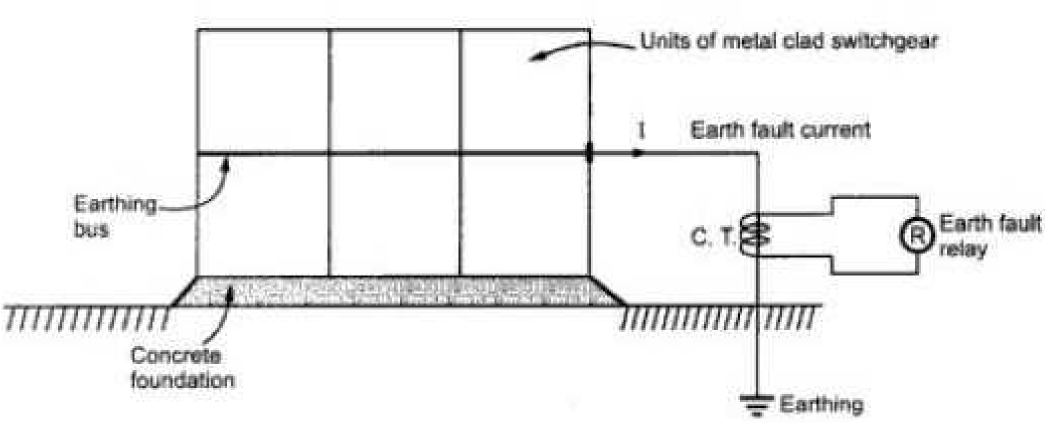
Percentage Differential Protection for Transformers: percentage differential protection or Wu- Price protection based on the circulating current principle can also be used for the transformers. This system gives protection against phase to phase faults and phase to ground faults to the power transformers. 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 aintained. 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 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

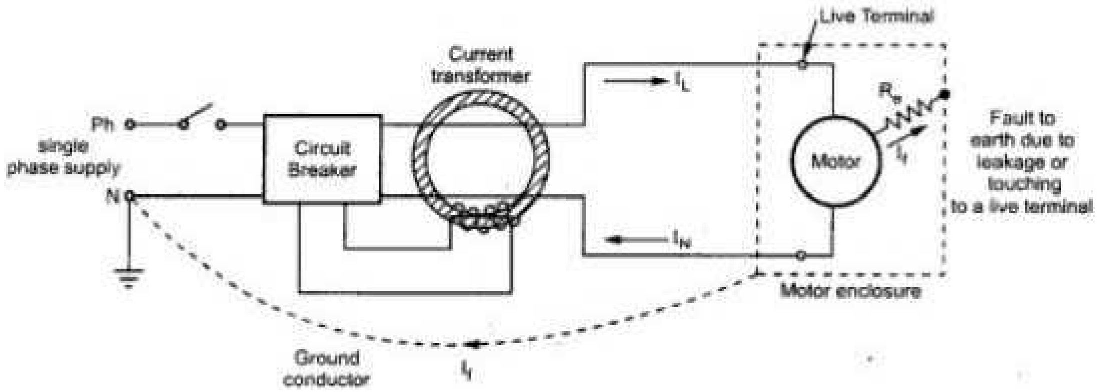
Introduction : Based on the control action i.e. starting, stopping or reversal, controlling elements known in electrical terms as switchgear are employed for the protection of induction motor. Generally two basic protections viz short circuit protection and overload protection are provided for each motor. 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 fill 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 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

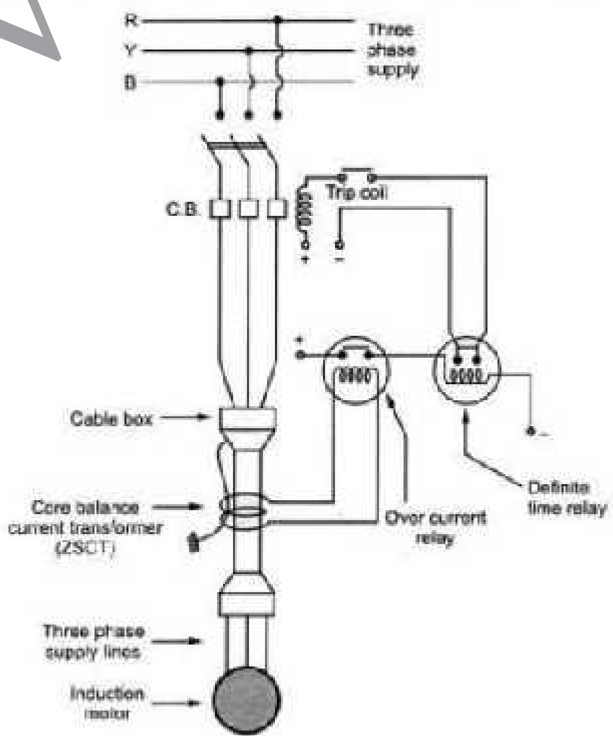
shown in Fig.

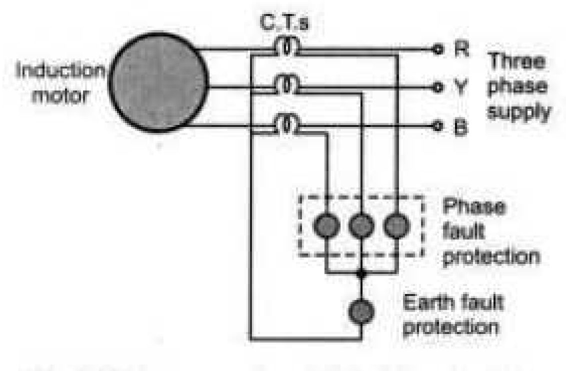


As shown in the Fig ELCB consists of a small current transformer surrounding live and neutral wire. The secondary winding of current transformer is connected to relay circuit which can trip the circuit breaker which is connected in the circuit. Under normal conditions, the current in line and neutral 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.





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