

**Generator Stator Protection, under/over voltage, under /over frequency
and unbalanced loading**

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1. INTRODUCTION OF THE STATOR WINDINGS FAULTS:

Stator winding faults: These types of faults occur due to the insulation breakdown of the stator coils. Different types of stator windings faults are:

- a) phase to earth fault
- b) phase to phase fault
- c) inter turn fault

Phase to earth fault are limited by resistance of the neutral grounding resistor. There are fewer chances for the occurrence of the phase to phase and interturn faults. The insulation between the two phases is at least twice as thick as the insulation between one coil and the iron core, so phase to phase fault is less likely to occur. Inter turn fault occurs due the incoming current surges with steep wave front.

2. STATOR PROTECTION:

2.1 Differential protection for generators: Differential protection is used for protection of the generator against *phase to earth* and *phase to phase* fault. Differential protection is based on the circulating current principle.

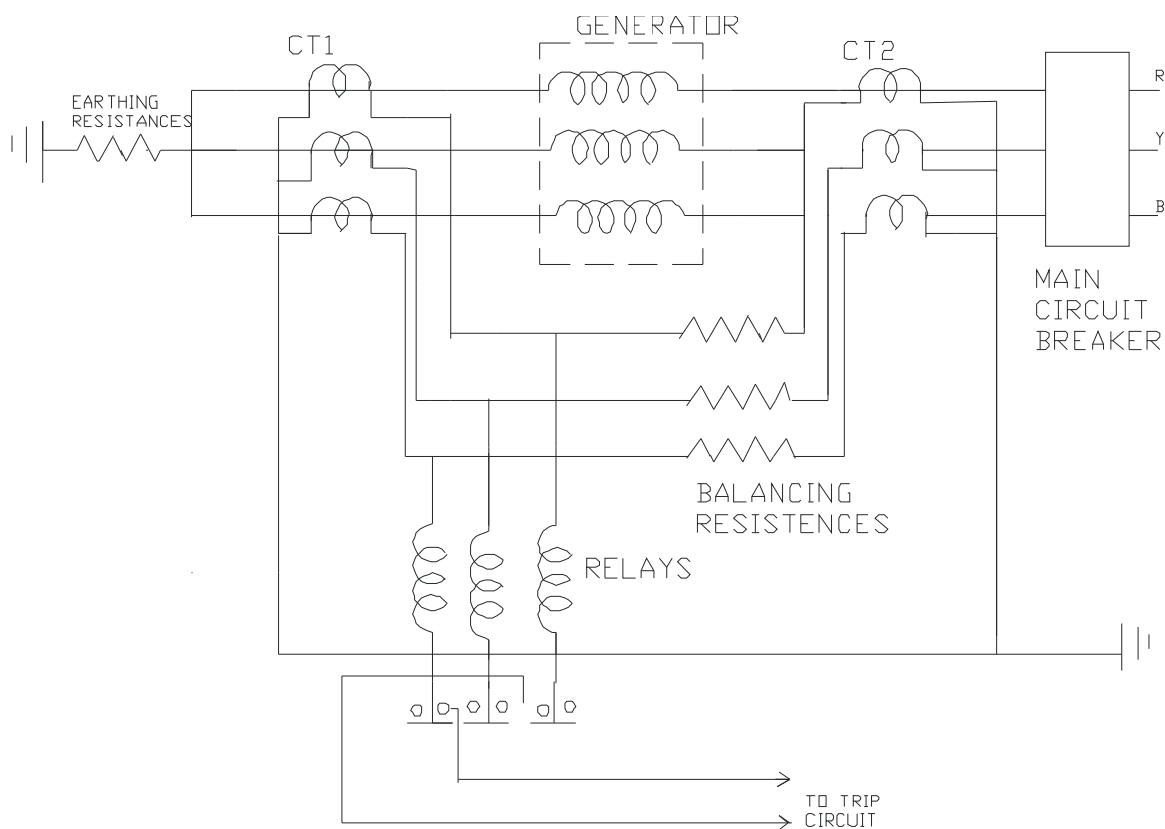


Fig1: Differential protection for generators

In this type of protection scheme currents at two ends of the protection system are compared. Under normal conditions, currents at two ends will be same. But when the fault occurs, current at one end will be different from the current at the end and this difference of current is made to flow through relay operating coils. The relays then closes its contacts and makes the circuit breaker to trip, thus isolate the faulty section. This type of protection is called the *merz price circulating current* system.

Limitations of this method: The earth fault is limited by the resistance of the neural earthing. When the fault occurs near the neutral point, this causes a small current to flow through the operating coil and it is further reduced by the neutral resistance. Thus this current is not sufficient to trip the circuit breaker. By this protection scheme , one can protect only 80 to 85 percent of the stator winding. If the relays with low settings are used the it will not provide desire stability. This difficulty is overcome by using the *modified differential protection*.

2.2 Modified differential protection: In modified differential protection setting of the earth faults can be reduced without any effect on the stability.

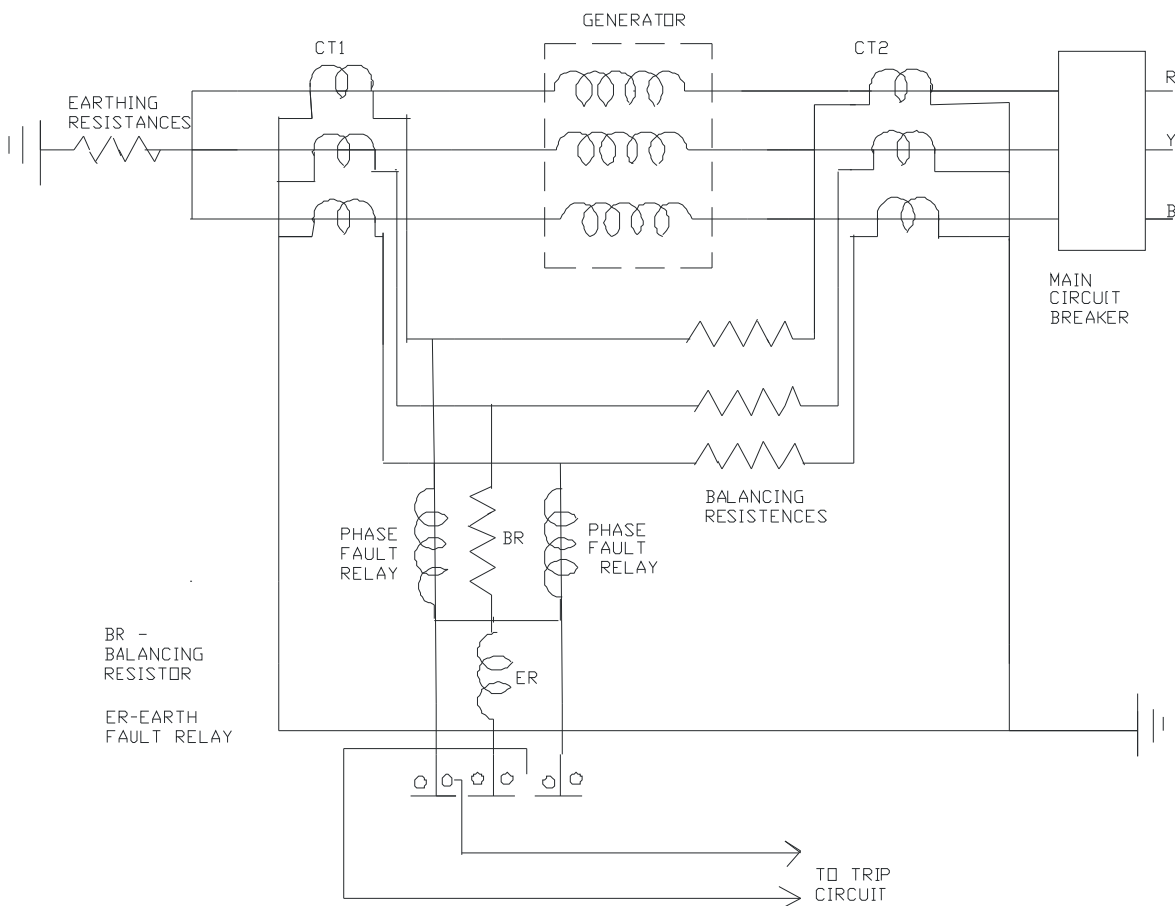


Fig 2: modified differential protection for the generators

In this method two relays are used for the phase to phase fault and one relay is used for the protection of earth fault. In this method the two relays and the balancing resistance are connected in star and the phase fault relay is connected between the star point and the neutral pilot wire. The star connected circuit is symmetrical in terms of impedance. So when the fault current occurs due to the phase to phase fault, it cancels at the star point due to the equal impedance. Thus it is possible with this scheme to operate with the sensitive earth fault relays. Thus this scheme provides protection to the greater percentage of the stator winding.

2.3 Biased circulating current protection (percentage differential relay protection): With the differential protection relaying, the CTs at both end of the stator windings must be same. If there is any difference in the accuracy of the CTs the mal-operation of the relay will occur. To overcome this difficulty, biased circulating current protection is used. In this protection system we can automatically increase the relay setting in proportion to the fault current. By suitable proportioning of the ratio of the relay restraining coil to the relay operating coil any biased can be achieved.

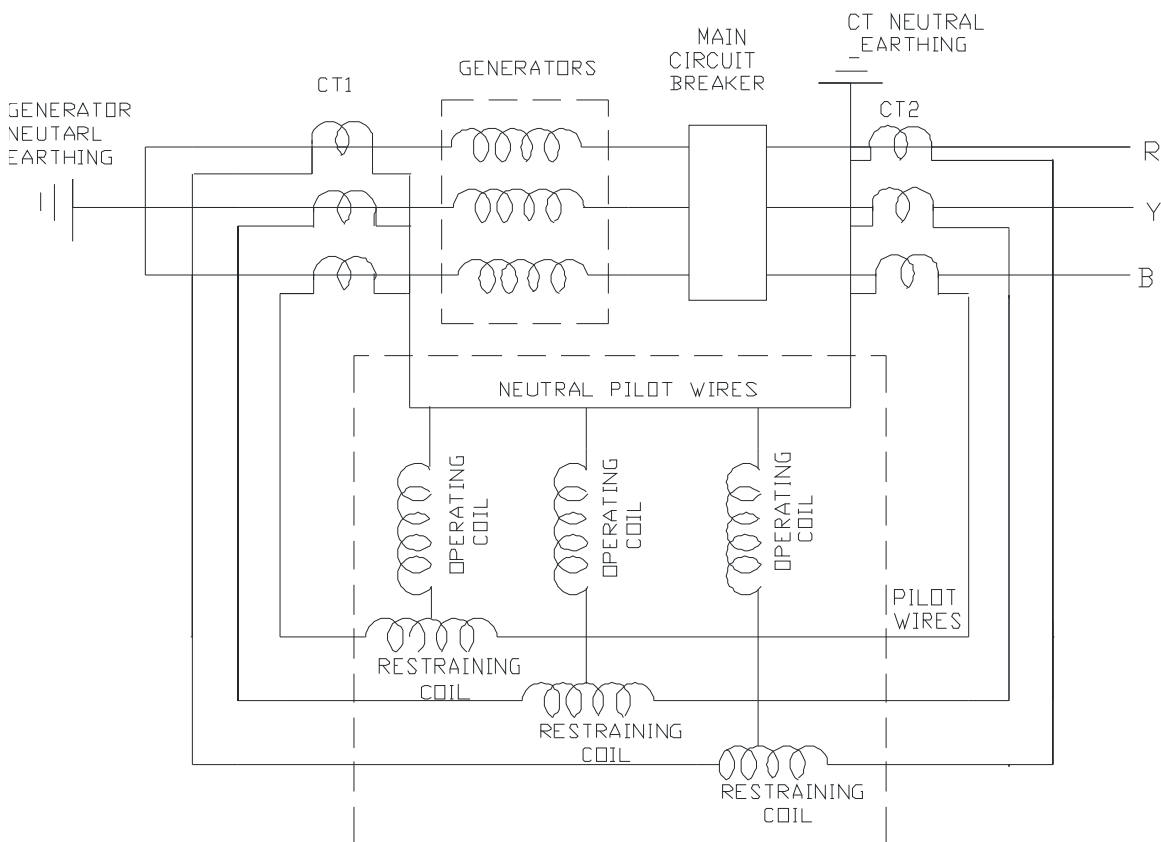


Fig 3 : biased protection of the stator winding

Under normal operating condition current in secondary of the line CTs will be same as the current in the secondary of the CTs at the neutral end. Hence there are balanced current flows in the restraining coils and no current flows in the operating coil. If there is any phase to phase or phase to earth fault occurs then it causes the differences in the secondary current of the two CTs. Thus the current flows through the operating coil and make the circuit breaker to trip.

Advantages of this method: a) It does not require the CTs with balancing features.
b) It also permit the low fault setting of the relay, thus protects the greater percentage of the stator winding.

2.4 Self balance protection system: This type of protection is employed for *earth fault* and also for the *phase to phase fault*.

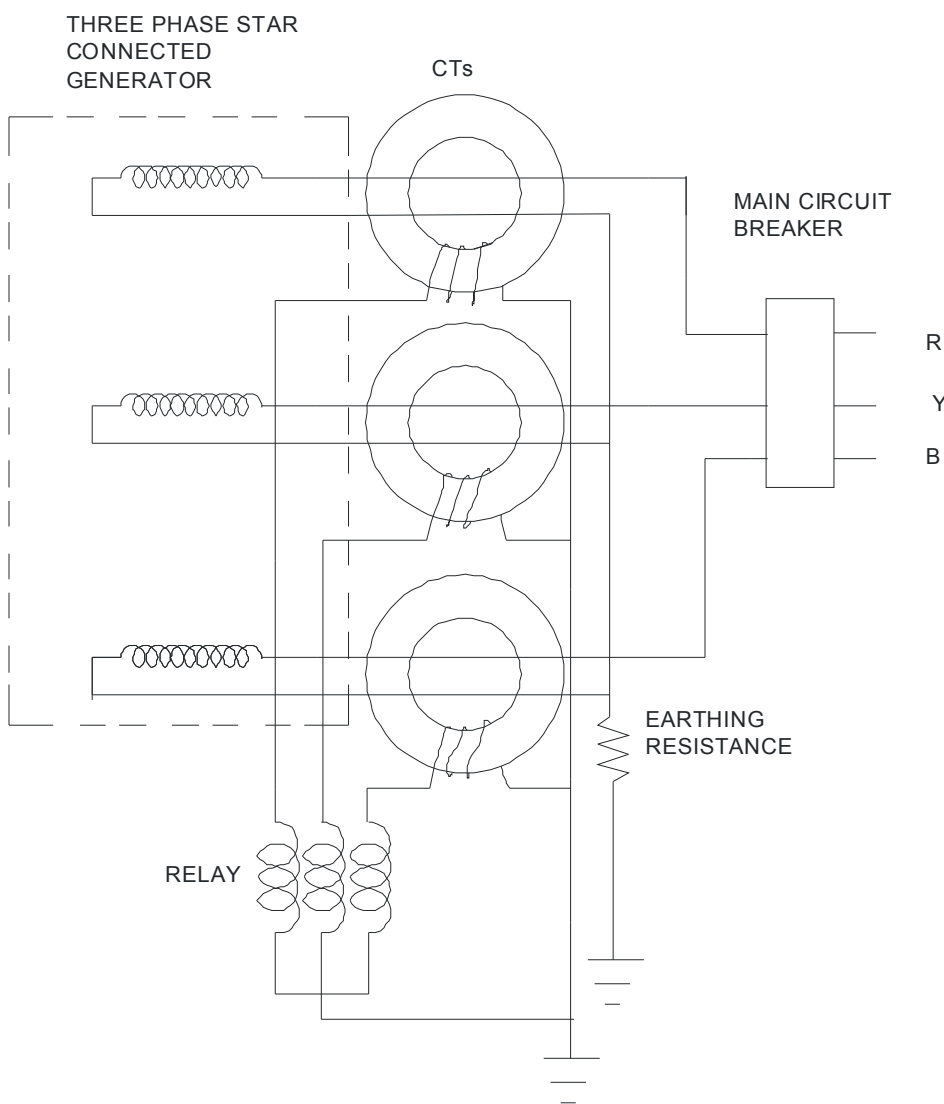


Fig 4 self biasing protection of the stator windings

In this type of protection two cables are required which is connected to the two ends of the each phase. These two cables are passed through the circular aperture of the ring type CTs. Under normal conditions the current flowing in the two leads of the cable will be in the same direction and no magnetisation occurs in the ring type CTs. When the earth fault occurs in any phase the fault current occurs only once through the CTs and thus magnetic flux induced, this induces the emf in the relay circuit causes the circuit breaker to trip.

This is very sensitive type earth fault protection but it also have some limitations:

- a) a different design of the cable lead is required in this scheme.
- b) large electromagnetic forces are develop in the CT ring under the condition of heavy short circuit.

2.5 Stator ground fault protection: The method of grounding effect the degree of protection which is employed by the differential protection. High impedance reduces the fault current and thus it is very difficult to detect the high impedance faults. So the differential protection does not work for the high impedance grounding. The separate relay to the ground neutral provides the sensitive protection. But ground relay can also detect the fault beyond the generator, it the time co-ordination is necessary to over come this difficulty.

If we use the star- delta transformer bank, then it will block the flow of ground currents, thus preventing the occurrence of the fault on other side of the bank from operating ground relays. In unit protection scheme the transformer bank limits the operation of the fault relay to the generator.

Unit connected schemes: In this scheme high resistance grounding is used and system is grounded through the transformer bank and through the resistors.

95% scheme: Relay which uses in the unit connected schemes must be insensitive to the normal third harmonics voltage that may be present between the neutral and the ground, and it must be sensitive to the fundamental harmonics voltage that is the cause of the fault. The magnitude of the neutral shift depends upon its location in the winding of the ground fault. And the general choice of the relay sensitive and distribution transformer voltage provide 95% protection of the winding so this scheme is called 95% scheme.

Neutral third harmonic under voltage: There is the third harmonic present between the neutral and the ground , and other schemes takes advantages of this and respond to the under voltage between the neutral and the ground.

100% scheme: This scheme provides complete protection of the stator winding by injecting the signal between the stator winding and monitors it for change. 95% scheme and third harmonics protection scheme provide protection only at rated speed and rated voltage but it 100% scheme also provide protection at standstill.

2.6 Stator inter turn fault protection: Differential protection for stator does not provide protection against the inter-turn faults on the same phase winding of the stator. The reason is that the current produced by the turn to turn fault flows in the local circuit between the turns involved and thus it does not create any difference between the current entering and leaving the windings at its two ends where the CTs are mounted.

The coils of the modern turbo generator are single- turn , so there is no need to provide inter –turn fault protection for the turbo generator. But the inter turn protection is necessary for the multi turn generator like hydro electric generator. Some times stator windings are duplicated to carry heavy current. In this case stator winding have two different paths.

In this type of protection primaries of the CTs are inserted in the parallel paths and secondaries are inter connected. Under the normal condition current flowing through the two parallel paths of the stator winding will be same and no current flowing through the relay operating coil. Under the inter turn fault, current flowing through the two parallel path will be different and this difference in current flowing through the operating coil and thus causes the circuit breaker to trip and disconnect the faulty section. This type of protection is very sensitive.

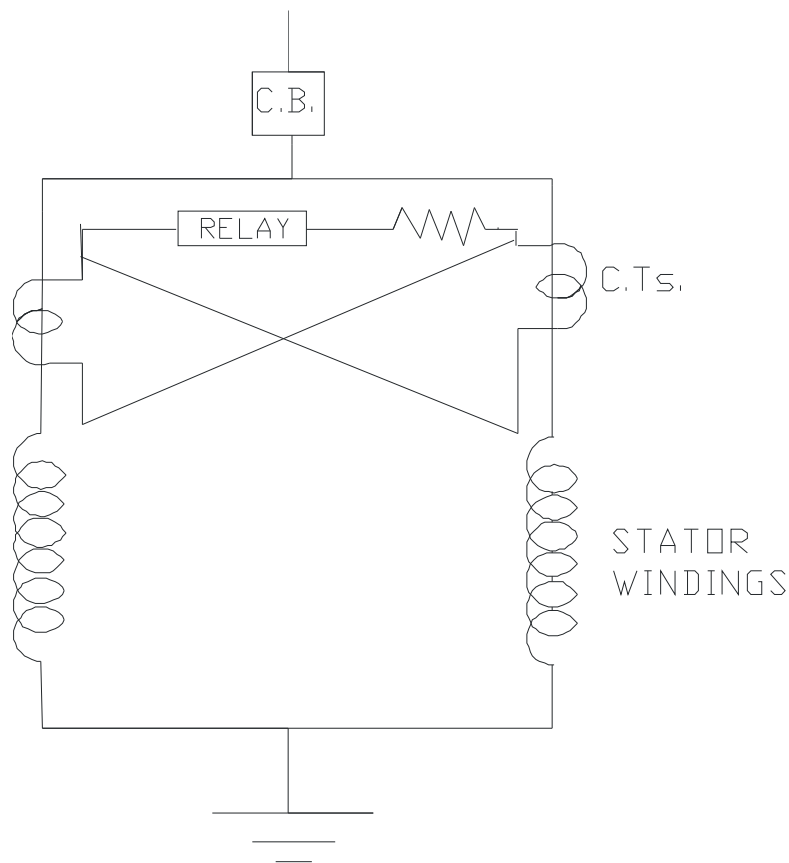


Fig 5 : Inter turn protection of the stator winding

2.7 Stator over heating protection: Stator over heating is caused due to the overloads and failure in cooling system. It is very difficult to detect the over heating due to the short circuiting of the lamination before any serious damage is caused. Temperature rise depend upon I^2Rt and also on the cooling. Over current relays can not detect the winding temperature because electrical protection can not detect the failure of the cooling system.

So to protect the stator against over heating, embed resistance temperature detector or thermocouples are used in the slots below the stator coils. These detectors are located on the different places in the windings so that to detect the temperature throughout the stator. Detectors which provide the indication of temperature change are arranged to operate the temperature relay to sound an alarm.

3. UNDER/OVER FREQUENCY PROTECTION:

3.1 Over frequency operation: Over frequency results from the excess generation and it can easily be corrected by reduction in the power outputs with the help of the governor or manual control.

3.2 Under frequency operation: Under frequency occurs due to the excess. During an overload, generation capability of the generator increases and reduction in frequency occurs. The power system survives only if we drop the load so that the generator output becomes equal or greater than the connected load. If the load increases the generation, then frequency will drop and load need to shed down to create the balance between the generator and the connected load. The rate at which frequency drops depend on the time, amount of overload and also on the load and generator variations as the frequency changes. Frequency decay occurs within the seconds so we can not correct it manually. Therefore automatic load shedding facility needs to be applied.

These schemes drops load in steps as the frequency decays. Generally load shedding drops 20 to 50% of load in four to six frequency steps. Load shedding scheme works by tripping the substation feeders to decrease the system load. Generally automatic load shedding schemes are designed to maintain the balance between the load connected and the generator.

The present practice is to use the under frequency relays at various load points so as to drop the load in steps until the declined frequency return to normal. Non essential load is removed first when decline in frequency occurs. The setting of the under frequency relays based on the most probable condition occurs and also depend upon the worst case possibilities.

During the overload conditions, load shedding must occur before the operation of the under frequency relays. In other words load must be shed before the generators are tripped.

4. UNDER/OVER VOLTAGE PROTECTION:

4.1 Over voltage protection: Over voltage occurs because of the increase in the speed of the prime mover due to sudden loss in the load on the generator. Generator over voltage does not occur in the turbo generator because the control governors of the turbo generators are very sensitive to the speed variation. But the over voltage protection is required for the hydro generator or gas turbine generators. The over voltage protection is provided by two over voltage relays have two units – one is the instantaneous relays which is set to pick up at 130 to 150% of the rated voltage and another unit is IDMT which is set to pick up at 110% of rated voltage. Over voltage may occur due to the defective voltage regulator and also due to manual control errors.

4.2 Under voltage protection: If more than one generators supply the load and due to some reason one generator is suddenly trip, then another generators try to supply the load. Each of these generators will experience a sudden increase in current and thus decreases the terminal voltage. Automatic voltage regulator connected to the system try to restore the voltage. And under voltage relay type-27 is also used for the under voltage protection.

5. PROTECTION OF THE GENERATOR DUE TO UNBALANCE LOADING:

Due to fault there is an imbalance in the three phase stator currents and due to these imbalance currents, double frequency currents are induced in the rotor core. This causes the over heating of the rotor and thus the rotor damage. Unbalanced stator currents also damage the stator.

Negative sequence filter provided with the over current relay is used for the protection against unbalance loading. From the theory of the symmetrical components, we know that an unbalanced three phase currents contain the negative sequence component. This negative phase sequence current causes heating of the stator. The negative heating follows the resistance law so it is proportional to the square of the current. The heating time constant usually depend upon the cooling system used and is equal to $I^2t=k$ where I is the negative sequence current and t is the current duration in seconds and k is the constant usually lies between 3 and 20.

Its general practice to use negative current relays which matches with the above heating characteristics of the generator. In this type of protection three CTs are connected to three phases and the output from the secondaries of the CTs is fed to the coil of over current relay through negative sequence filter. Negative sequence circuit consists of the resistors and capacitors and these are connected in such way that negative sequence currents flows through the relay coil. The relay can be set to operate at any particular value of the unbalance currents or the negative sequence component current.

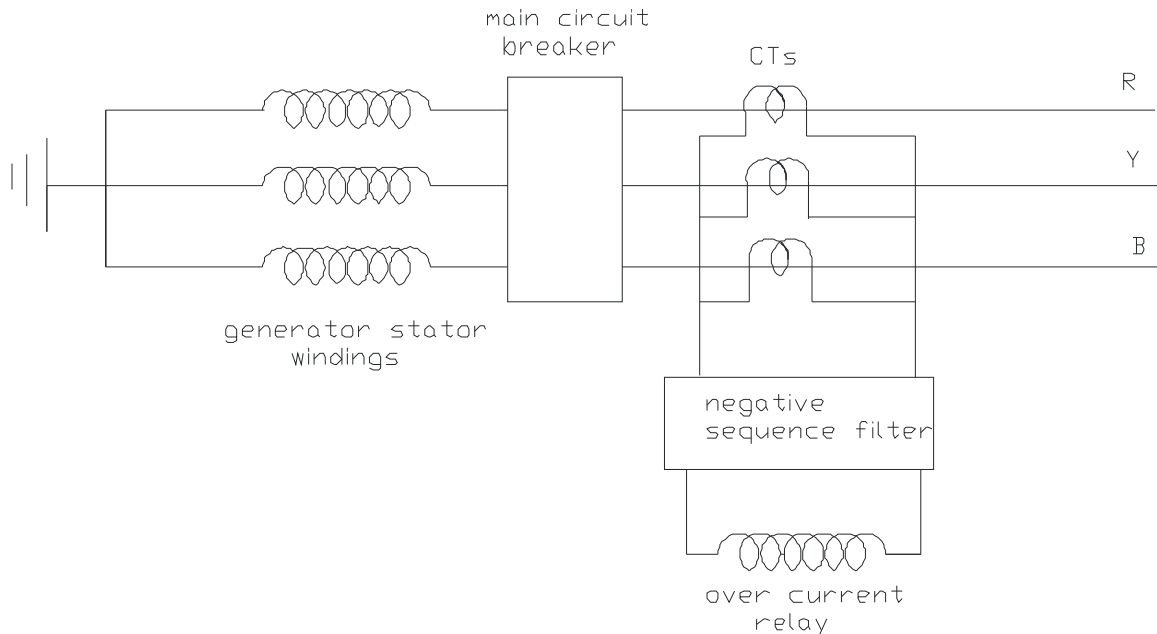


fig 6: protection against unbalance loading

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