Nadar Saraswathi College of Engineering & Technology

NSCET E-LEARNING PRESENTATION

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Electrical and Electronics engineering

IIIYEAR/VIth Semester

EE8602-Protection and Switchgear

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UNIT 03 – Apparatus protection

“**Learning** is not attained by chance, it must be sought for with ardor and attended to with diligence.”

—Abigail Adams

Apparatus protection

Current transformer and potential transformer

Application of CT and PT

Protection of transformer

Protection of generator

Protection of motor

Protection of bus bar

Protection of transmission line

Current Transformer (CT)

- **Definition:** A current transformer is a device that is used for the transformation of current from a higher value into a proportionate current to a lower value.

- It transforms the high voltage current into the low voltage current due to which the heavy current flows through the transmission lines is safely monitored by the ammeter.

The current transformer is used with the AC instrument, meters or control apparatus where the current to be measured is of such magnitude that the meter or instrument coil cannot conveniently be made of sufficient current carrying capacity.

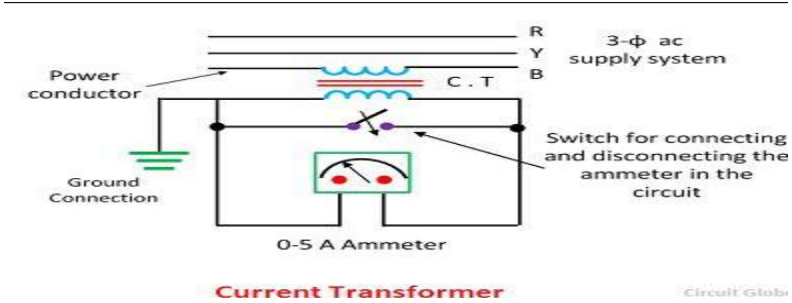
- The primary and secondary current of the current transformers are proportional to each other.

- The current transformer is used for measuring the high voltage current because of the difficulty of inadequate insulation in the meter itself.

- The current transformer is used in meters for measuring the current up to 100 amperes.

Construction of Current Transformers

- The core of the current transformer is built up with lamination of silicon steel.
- The primary windings of the current transformers carry the current which is to be measured, and it is connected to the main circuit.
- The secondary windings of the transformer carry the current proportional to the current to be measured, and it is connected to the current windings of the meters or the instruments.
- The primary and the secondary windings are insulated from the cores and each other.
- The primary winding is a single turn winding (also called a bar primary) and carries the full load current.
- The secondary winding of the transformers has a large number of turns.



- The ratio of the primary current and the secondary current is known as a **current transformer ratio** of the circuit.
- The current ratio of the transformer is usually high. The secondary current ratings are of the order of 5A, 1A and 0.1A.
- The current primary ratings vary from 10A to 3000A or more.
- The symbolic representation of the current transformer is shown in the figure below.

- The working principle of the current transformer is slightly different from the power transformer.
- In a current transformer, the load's impedance or burden on the secondary has slightly differed from the power transformers.
- Thus, the current transformer operates on secondary circuit conditions.
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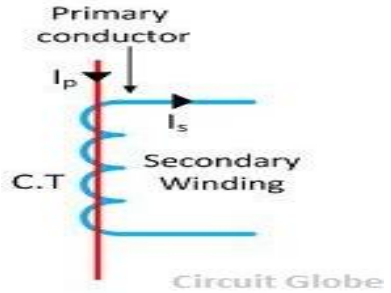


Potential Transformer

- **Potential transformer** or **voltage transformer** gets used in electrical power system for stepping down the system voltage to a safe value which can be fed to low ratings meters and relays

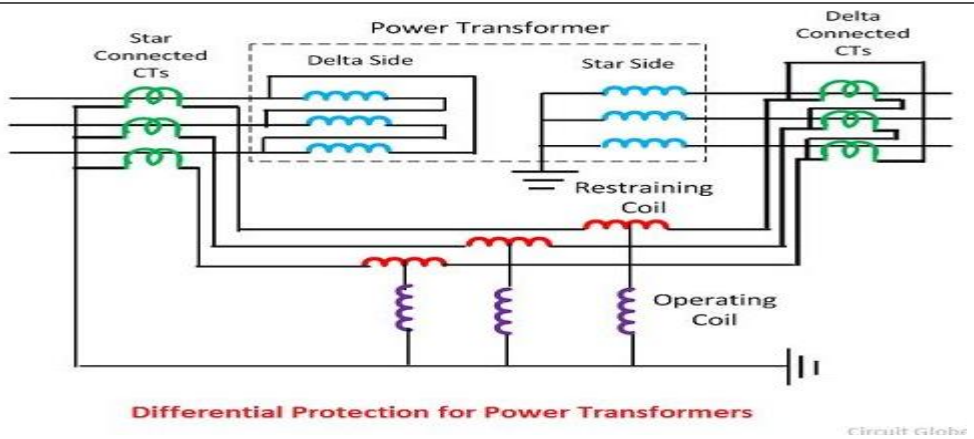
- The secondary voltage of the PT is generally 110 V. In an ideal **potential transformer** or **voltage transformer**, when rated burden gets connected across the secondary; the ratio of primary and secondary voltages of transformer is equal to the turns ratio and furthermore, the two terminal voltages are in precise phase opposite to each other.

- But in actual transformer, there must be an error in the voltage ratio as well as in the phase angle between primary and secondary voltages.

Differential Protection of a Transformer

- The fault occurs on the transformer is mainly divided into two type external faults and internal fault.
- External fault is cleared by the relay system outside the transformer within the shortest possible time in order to avoid any danger to the transformer due to these faults.
- The protection for internal fault in such type of transformer is to be provided by using differential protection system.
- Differential protection schemes are mainly used for protection against phase-to-phase fault and phase to earth faults.
- The differential protection used for power transformers is based on Merz-Prize circulating current principle.

- Such types of protection are generally used for transformers of rating exceeding 2 MVA.



- The power transformer is star connected on one side and delta connected on the other side.
- The CTs on the star connected side are delta-connected and those on delta-connected side are star-connected.
- The neutral of the current transformer star connection and power transformer star connections are grounded.

- The restraining coil is connected between the secondary winding of the current transformers.
- Restraining coils controls the sensitive activity occurs on the system.

- The operating coil is placed between the tapping point of the restraining coil and the star point of the current transformer secondary windings.

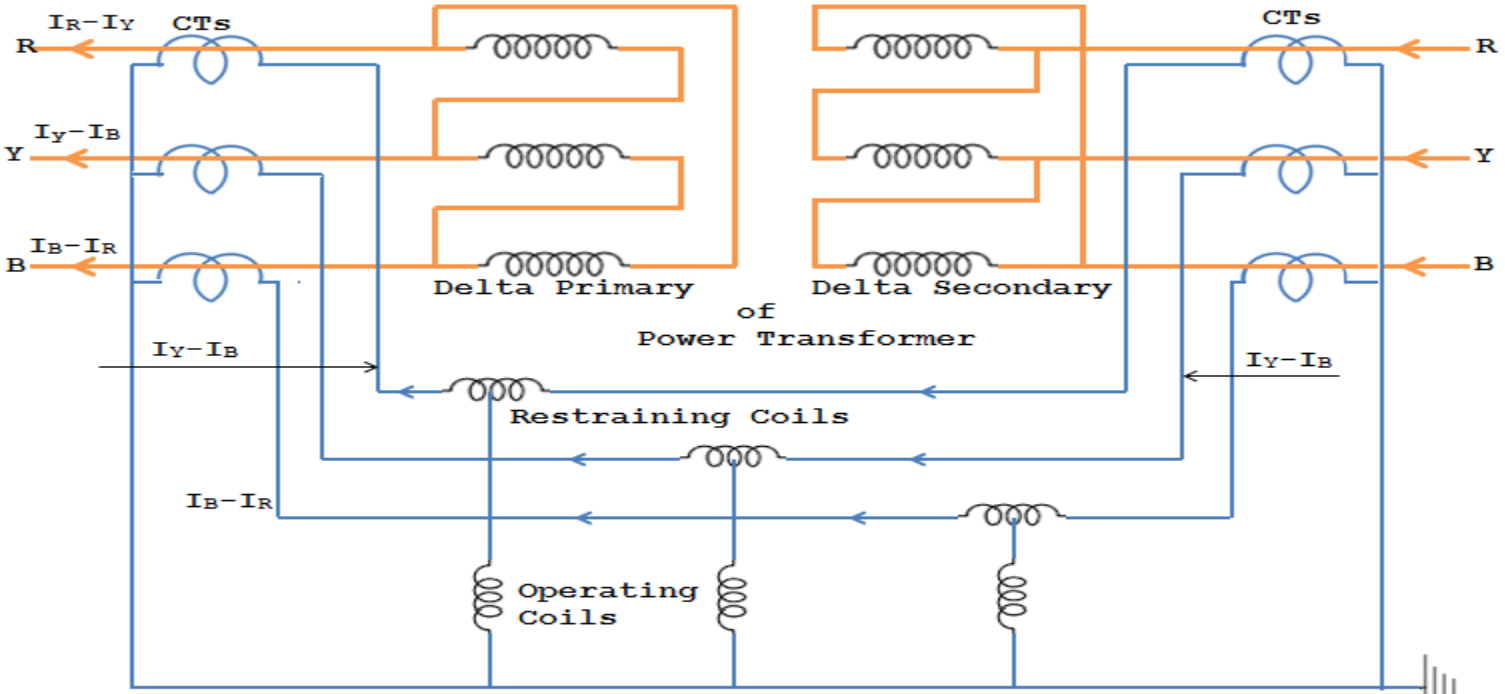
Working of Differential Protection System

- Normally, the operating coil carries no current as the current are balanced on both the side of the power transformers
- When the internal fault occurs in the power transformer windings the balanced is disturbed and the operating coils of the differential relay carry current corresponding to the difference of the current among the two sides of the transformers.

- Thus, the relay trip the main circuit breakers on both sides of the power transformers.

Merz-price Differential Protection for Delta-Delta Power Transformer

- It can be seen that for a **delta/star power transformer**, the CTs on the delta side should be connected in star and those connected in delta are the ones in the star side.
- The CTs on the both sides are connected in star. This is to compensate for the phase difference between the power transformer primary and secondary currents.
- The CTs are connected by **pilot wires** and one relay is used for each pair of CTs.



Merz price differential protection of delta-delta power transformer
(CTs are connected in star)

During normal i.e., no-fault conditions, the secondaries of CTs carry identical currents.

Therefore the currents entering and leaving the pilot wires at both ends are the same and no current flows through (OC) of the relays.

If a **ground or phase to phase faults occurs,** the currents in the CT secondary's will no longer be the same and the **differential current** flowing through the **relay circuit** will make the breaker on both sides of the power transformer to trip.

Differential Protection of a Generator

- Differential protection for a generator is mainly employed for the protection of stator windings of generator against earth faults and phase-to-phase faults.

- The stator winding faults are very dangerous, and it causes considerable damage to the generator.

- For the protection of stator winding of the generator, the differential protection system is used for clearing the fault in the shortest possible time for minimizing the extent of a damage.

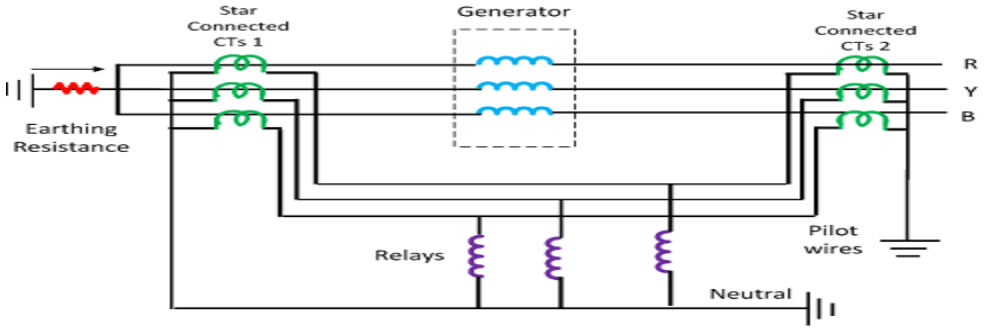
Merz-Prize Circulating Current System

- In this scheme of protection, currents at the ends of the protected sections compare.
- When the system is in normal operating condition, the magnitude of currents is equal on the secondary windings of the current transformers.
- On the occurrence of the faults, the short-circuit current flows through the system and the magnitude of current become differ.
- This difference of current under fault conditions is made to flow through the relay operating coil.
- The relay then closes its contacts and makes the circuit breaker to trip and thus isolated the protection from the system.
- Such a system is called a Merz-Prize circulating current system. It is very effective for earth faults and faults between phases.

- The protection system requires two identical transformers which are mounted on both sides of the protection zone.

- The secondary terminals of the current transformers are connected in stars, and their end terminals are connected through the pilot wire. The relay coils are connected in delta.

- The neutral of the current transformer and the relay are connected to the common terminal.



Merz-Price Protection With Relay Being Connected in the Midpoints of Two Sets of CTs.

The relay is connected across equipotential points of the three pilot wires so that the burden on each current transformer is same.

The equipotential point of the pilot wire is its centre, so the relay is located at the midpoint of pilot wires.

For proper working of the differential protection system, it is essential to locate the relay coils adjacent to the current transformer near the main circuit.

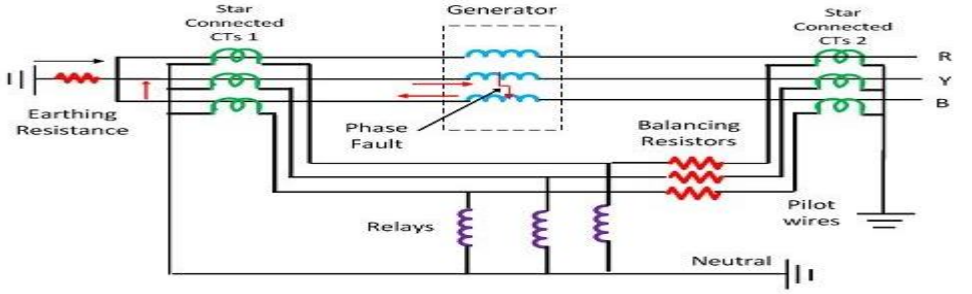
This can be done by inserting the balancing resistance in series with the pilot wires to make equipotential points located near the main circuit breaker.

Consider the fault occurs on the R phase of the network because of the insulation breakdown.

Because of the fault, the current in the secondary of the transformer becomes unequal.

The differential currents flow through the relay coil.

Thus, the relay becomes operative and gives the command to the circuit breaker for operation.



Merz-Price Protection With Relay Being Connected Adjacent To One Set of CTs

If the fault occurs between any two phases, say Y and B then short-circuit current flows through these phases.

The fault unbalanced the current flows through CTs.

The differential current flows through the relay operating coil and thus relay trips their contacts.

A neutral resistance wire is used in the differential protection system for avoiding the adverse effect of earth fault currents.

When an earth fault occurs near the neutral, it will cause a small, short circuit current to flow through the neutral point because of small emf.

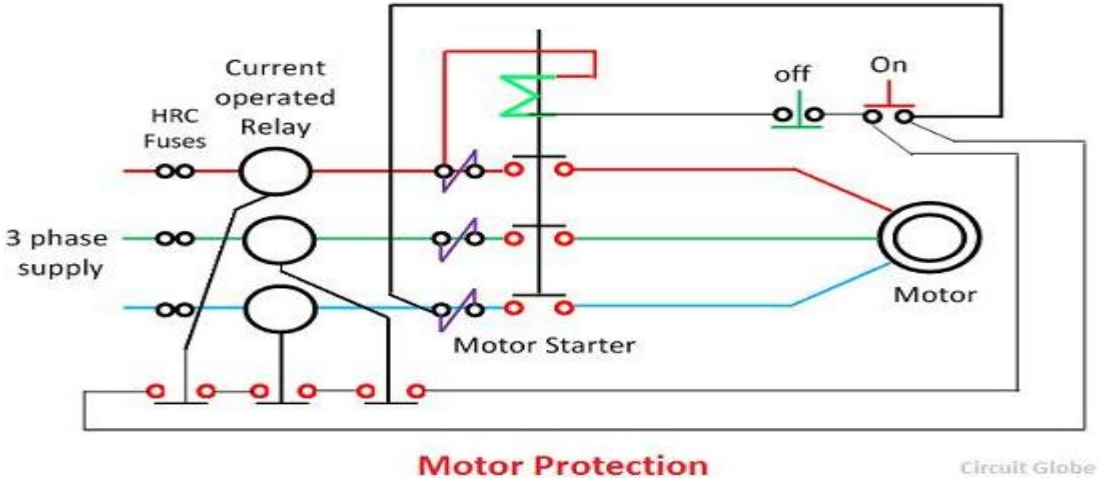
This current is further reduced by the resistance of the neutral grounding. Thus, the small current will flow through the relay. This small current will not operate the relay coil, and hence the generator gets damage.

Motor Protection Scheme

The various types of the protective relays are available for protecting the motor from faults.

These relays sense the abnormal operating condition and make the circuit breaker to trip.

The motors provide protection against faults in windings and associated circuits, excessive overload and short circuits, under voltages, phase unbalances and single phasing, phase reversal and switching overvoltage's.



- The main characteristic of the relay is to reduce the operating time with the increase in the magnitude of the fault current.

1. **Overcurrent Protection** – This is the basic type of protection that is employed for short circuit protection of stator windings.

- The non-essential service motor provides both inverse time and instantaneous phase ground overcurrent relays for automatic tripping.

- The inverse phase relays are adjusted to pick up at about 3.5 to 4 times rated motor current, but to have enough time delay so as not to operate during the motor starting period.

- **2. Stator Overheating of Motor** – The overheating of a motor is mainly due to continuous overloading, stalled rotors or unbalance stator current. For complete protection, the three phase motor should have an overload element in each phase.

- If the rating of the motor is higher than 1000 kW than single relay operating with resistance detector is used instead of inverse time over current relay.

For essential service motors, the automatic tripping is desire. Hence the thermal relay is mainly used for protecting the motor from overheating.

3. Rotor overheating protection – The rotor overheating protection is more likely to occur in wound rotor motor. The increase in rotor current is reflected on stator current and the stator over current protection thereby act.

The settings of the stator over current relay generally of the order of 1.6 times full load current. This is enough to detect the rotor faults.

- **4. Under voltage Protection –** The motor draw excessive current when operated on under voltage and so under voltage protection can be provided by overload devices or temperature sensitive devices.

- **5. Unbalance and Single Phasing Protection –** The unbalanced three phase supply causes the negative sequence current to flow in the motor which may cause overheating of the stator and rotor winding of the motor. The unbalanced condition provided to a motor should be such as to avoid the continuous unbalanced condition.

- **6. Reverse Phase Protection –** The phase reversal is dangerous in some cases, such as in elevators, cranes, hoists, trams, etc. In such cases, the reverse phase protection must be provided. The phase reversal relay is based on the electromagnetic principle consists of a disc motor driven by the magnetic system.

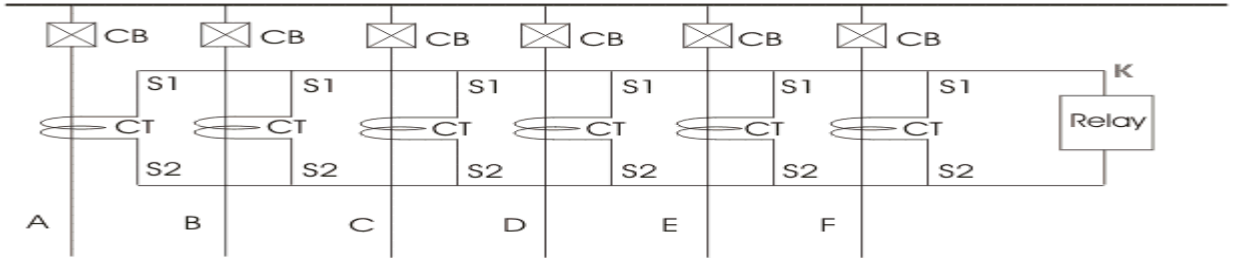
Differential Busbar Protection

- The scheme of **busbar protection**, involves, Kirchoff's current law, which states that, total current entering an electrical node is exactly equal to total current leaving the node.Hence, total current entering into a bus section is equal to total current leaving the bus section.

- The principle of differential busbar protection is very simple. Here, secondary's of CTs are connected parallel.

- That means, S_1 terminals of all CTs connected together and forms a bus wire. Similarly S_2 terminals of all CTs connected together to form another bus wire.

- A tripping relay is connected across these two bus wires.



Here, in the figure above we assume that at normal condition feed, A, B, C, D, E and F carries current I_A, I_B, I_C, I_D, I_E and I_F.
Now, according to Kirchoff's current law,

$$I_A + I_B + I_C + I_D + I_E + I_F = 0$$

Essentially all the CTs used for differential busbar protection are of same current ratio. Hence, the summation of all secondary currents must also be equal to zero.

Protection of Transmission Lines

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Carrier current protection scheme is mainly used for the protection of the long transmission line.

In the carrier, current protection schemes, the phase angle of the current at the two phases of the line are compared instead of the actual current.

the phase angle of the line decides whether the fault is internal and external.

The main elements of the carrier channel are a transmitter, receiver, coupling equipment, and line trap.

The carrier current receiver receives the carrier current from the transmitter at the distant end of the line

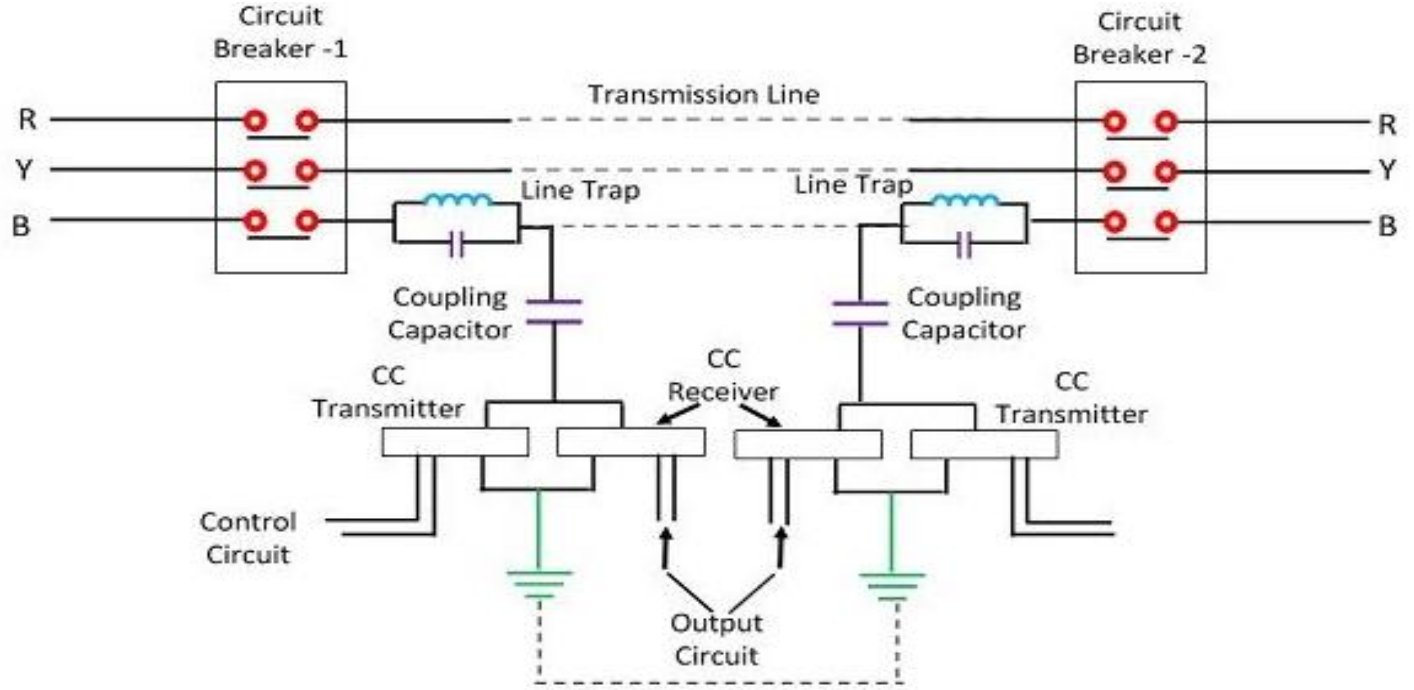
The receiver converts the received carrier current into a DC voltage that can be used in a relay or other circuit that performs any desired function.

The voltage is zero when the carrier current, is not being received.
Line trap is inserted between the bus-bar and connection of coupling capacitor to the line.

It is a parallel LC network tuned to resonance at the high frequency.

The traps restrict the carrier current to the unprotected section so as to avoid interference from the with or the other adjacent carrier current channels.

It also avoids the loss of the carrier current signal to the adjoining power circuit.



Carrier Current Transmission Line Protection Scheme

Circuit Globe

Methods of Carrier Current Protection

The different methods of current carrier protection and the basic form of the carrier current protection are

Directional Comparison protection

Phase Comparison Protection

Directional Comparison Protection

The protection can be done by the comparison of a fault of the power flow direction at the two ends of the line.

The operation takes place only when the power at both the end of the line is on the bus to a line direction.

After the direction comparison, the carrier pilot relay informs the equipment how a directional relay behaves at the other end to a short circuit.

The relay at both the end removes the fault from the bus. If the fault is in protection section the power flows in the protective direction and for the external fault power will flow in the opposite direction.

During the fault, a simple signal through carrier pilot is transmitted from one end to the other. The pilot protection relaying schemes used for the protection of transmission are mainly classified into two types. They are

Carrier Blocking Protection Scheme – The carrier blocking protection scheme restricts the operation of the relay.

It blocks the fault before entering into the protected section of the system. It is one of the most reliable protecting schemes because it protects the system equipment from damage.

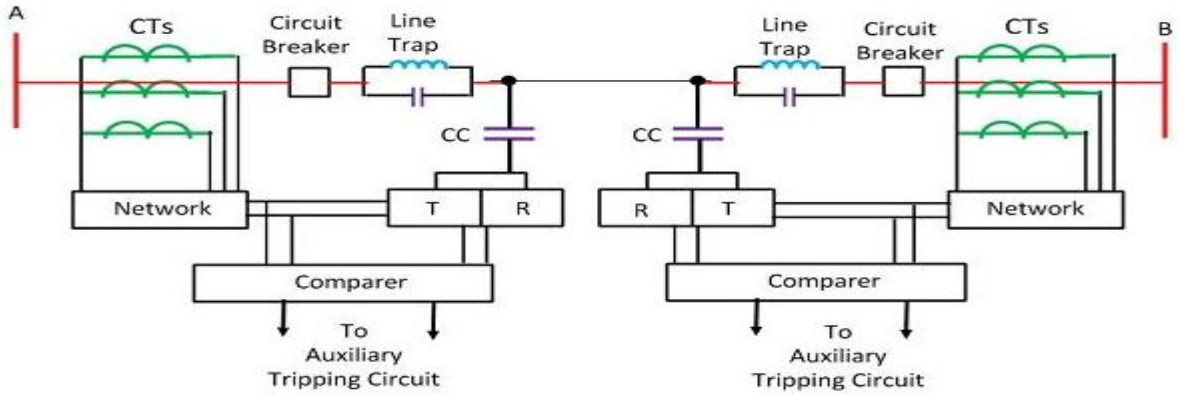
Carrier Permitting Blocking Scheme – The carrier, protective schemes allows the fault current to enter into the protected section of the system.

Phase Comparison Carrier Protection

This system compares the phase relation between the current enter into the pilot zone and the current leaving the protected zone.

The current magnitudes are not compared. It provided only main or primary protection and backup protection must be provided also.

The circuit diagram of the phase comparison carrier protection scheme is shown in the figure below.



The transmission line CTs feeds a network that transforms the CTs output current into a single phase sinusoidal output voltage.

This voltage is applied to the carrier current transmitter and the comparer.

The output of the carrier current receiver is also applied to the comparer.

The comparer regulates the working of an auxiliary relay for tripping the transmission line circuit breaker.

Advantage of Carrier Current Protection

It has a fast and simultaneous operation of circuit breakers at both the ends.

It has a fast, clearing process and prevents shock to the system.

No separate wires are required for signaling because the power line themselves carry the power as well as communication signaling.

It’s simultaneously tripping of circuit breakers at both the end of the line in one to three cycles.

This system is best suited for fast relaying also with modern fast circuit breakers.