UNIT –IV

FEEDER AND BUSBAR PROTECTION

There are many systems of feeder protection and they are classified according to the type of relay used. The fundamental requirement is that a faulty feeder shall isolate from the rest of the system without any interruption of the current. This property is called discrimination. The various protection schemes as applied to feeder protection can be classified as follows:

- Time graded protection
- Differential protection
- Distance protection
- Carrier current protection

Time Graded Over Current Protection:

The conditions required for this protection are • Where time lag is permitted • Where instantaneous operation is not necessary. A few important applications are discussed below

(i) Radial Feeder Protection:

The characteristic features of radial system are that power can flow only in one direction from generator or supply end to load. This arrangement has the drawback that continuity of supply cannot be maintained at the receiving end in the event of occurrence of fault. In a radial system when numbers of feeders are connected in series is shown in fig.7.1. It is desired that the smallest possible part of the system should be off. This can be conveniently achieved by time graded protection. The settings of the relays on a number of series connected feeder circuit are so arranged that a time interval of not less than 0.4sec is obtained between relay panels. Relays located adjacent to the supply source are given a maximum time setting and those at the remote end of the feeder branch operate practically instantaneously. Standard relays have a definite minimum time range adjustable between 0 to 2 sec and with this range it is generally possible to secure selective operative of six relay points in series.

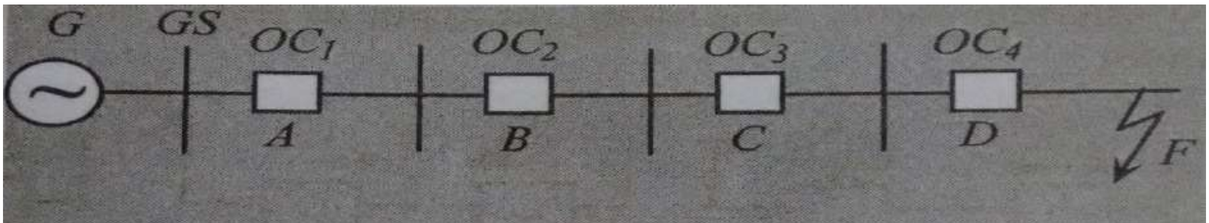


Fig. 7.1: Protection of radial feeder

Consider a scheme in the fig.7.1 in which a generating station (GS) supplies three transformer substations SS,, SS,, SS3 in series . If a fault occurs on the far side of SS3 it is obvious that only the over current relay D should operate and not any of the others and consequently the time taken to operate D should be less than of that of any of the others. Similarly the time taken should increase progressively as the generating station is approached and this is the principle of plain time grading. Here it is assumed that under remote end fault conditions all relays will be operating on the flat portion of their characteristic curve. For example under such conditions the operating time right varies from 0.4 sec for D to 1.6 sec for A.

(ii) Parallel feeder Protection:

The parallel feeder system is usually an extension to the radial system, when owing to increase in power demand, it is found necessary to supplement the supply of the major distributing substations by duplicate feeders or where at any particular point on the system it is considered necessary to provide an alternate supply source to maintain continuity of supply. When a fault occurs on any one feeder, say feeder-2, the current will be fed to the fault as shown in fig. 7.2 by the arrows.

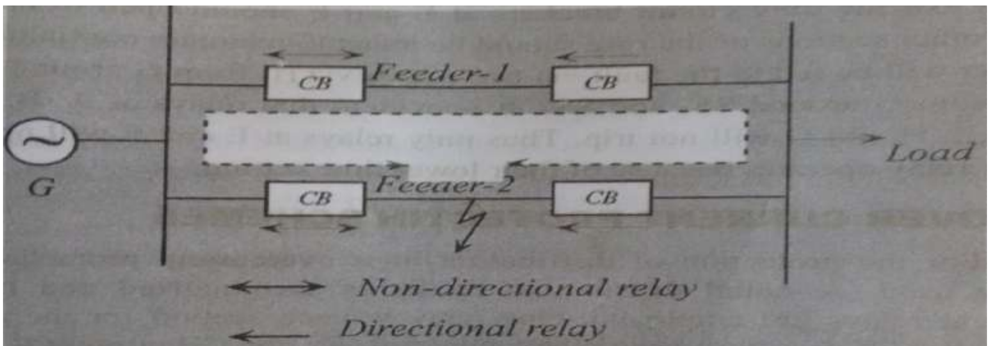


Fig. 7.2 Parallel feeder Protection

It is to be seen that as far as the relays near the source are concerned, the direction, where as the direction of the relay near the load end of the fault feeder is reversed. Therefore, for proper coordination the relays near the source end are non-directional relays whereas relays near the load end are directional relays. The direction of the current for which the directional relay will operate is indicated by the corresponding arrow heads. In this case as soon as fault takes place in feeder-2, the directional relay in feeder -1 corresponds to load current and after some time the non directional relay in feeder-2 will operate, thereby isolating feeder-2 from the source.

(iii) Protection of Ring mains:

The ring main system, which is extensively used in the modern distribution systems comprises simply of connecting a number of substations in series with the first and last having a feeder connected to the same power source. The advantage of this method is that fact alternative power supplies are available at each substation which gives a large measure of security in maintaining continuity of supply.

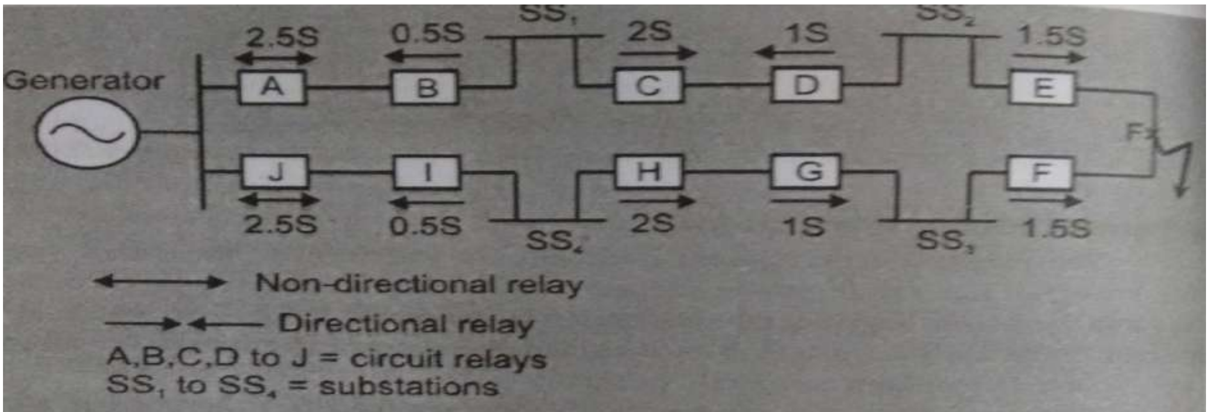


Fig. 7.3 : Protection of Ring mains

A typical ring main system consisting of one generator (G) and four substations (SS1, SS2, SS3 and SS4) is shown in fig. 7.3. Since the power can flow in both directions in this arrangement, therefore, it is necessary to grade in both directions around the ring and also to use directional relays. In order to isolate only faulty section of the ring under faulty conditions, the types of relays and their time settings should be as under.

(i) The two lines leaving the generating station should be equipped with a non directional over current relays (relays at A to J)

(ii) At each sub-station, reverse power or directional relays should be placed in both incoming and outgoing lines (relays at B, C, D, E, F, G, H)

(iii)There should be relative proper time setting of the relays.

Suppose fault occurs at F as shown in fig.7.3 for ensuring the selectivity it is desired that the only circuit breakers at E and F should open to clear the fault where as other sections of the ring should be intact to maintain continuity of supply. The power will be fed to the fault via two routes viz (i) from G around SS, and SS, and (ii) from G around SS4 and SS3. It is evident that relays at A, B, C and D as well as J, I, H and G will not trip. Thus only relays at E and F will operate before any other relay operates because of their lower time setting.

OVER CURRENT PROTECTION SCHEMES:

For the protection of distribution lines over current protection scheme is generally used. A radial distribution feeder is sectionalized and two or more over current relays are employed. One relay in each section for the protection as shown in fig.7.4. if a fault occurs beyond point `R', the CB at point R should strip. The CB at points P and Q should not trip for normal operation is concerned. If the relay at point R fails to operate, the CB at point Q should trip as a back-up protection. Similarly, if a fault occurs in between Q and R the CB at point Q should trip, the CB at point 'P' should not trip. But in the case of failure of relay at point Q, the CB at point P should trip. For proper selectivity of the relays, depending on the system conditions, any one of the following schemes may be used. (i)Time-graded system (ii)Current-graded system (iii)A combination of time and current graded system

Time-Graded System:

Definite time over current relay is employed in this scheme. For a fault current definite time over current relay operates. Starts a timing unit which trips the CB after a preset time, which is independent of the fault current. The relays operating time is adjusted in increasing order from the tail end of the feeder, as shown in fig. 7.4.

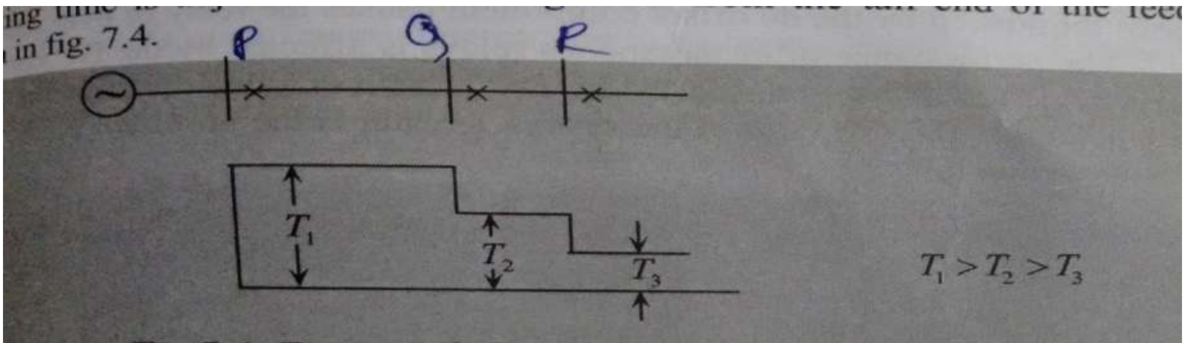


Fig.7.4: Time-graded over current protection of feeder

The protection is provided at the sending end of each substation P,Q,R which are indicated by the vertical lines and the crosses represents the location of relays. When a fault occurs beyond 'R.' the CB at `R' operates first, since relay at R comes into action as fault current flows through it and the protection at point Q and P acts as a back up protection i.e., if the relay or CB at R fails then the relay, at Q will operate and CB at Q will trip. Therefore, it can be observed that if a fault occurs then the relay nearer to that fault with operate first then any other relay.

The time of operation of the relays various locations is so adjusted that the relay farthest from the source will have minimum time of operation and as it approaches towards the source the operating time increases. This is the main drawback of grading the relays in this way because it is required that the more severe a fault is, lesser should be the operating time of the relays where as in this scheme the operating time increases. This system of protection is suitable for a system whose impedance between the substations is low. It means that the fault current is generally the same if a fault occurs on any section of the feeder.

Current-Graded System:

This type of grading is done on a system where the fault current varies appreciably with the location of fault. This means as we go towards the source the fault current increases. With this lf the relays are set to pick at a progressively higher current towards the source. then the draw back of the long time delay that occurs in case of time graded systems can be partially overcome. This is known as current grading. For the protecting of different sections of the feeder, the operating time of the relays is kept same as shown in fig.7.5

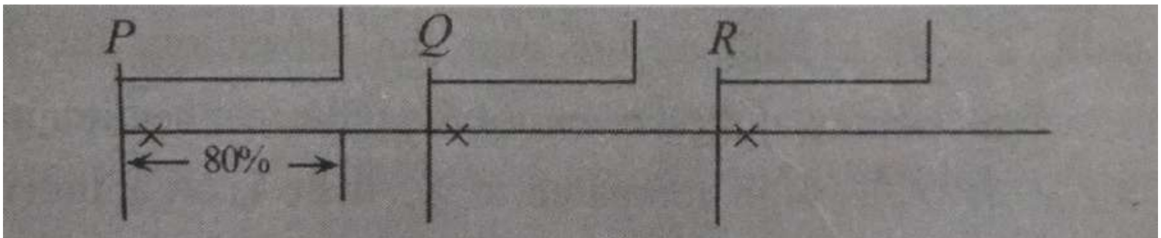


Fig.7.5: Instantaneous overcurrent protection of feeder

If fault in between Q and R, the relay at Q should trip. But it shout not operate for faults beyond point R. Similarly, the relays at point P should trip for fault between points P and Q. The relay at R should trip for faults beyond R. This operation is not achieved due to the following reasons.

- The fault current magnitude cannot be accurately calculated as the parameters of the circuit may, not be known.

- During a fault, there is a transient condition and the performance of the relays is not accurate.

This scheme cannot protect the entire feeder, this system is not used alone. It may be used in conjunction with IDMT relays, as shown in fig. The performance of instantaneous relays is affected by the DC component of transients. The error introduced by the DC offset component causes the relay of over reach. The performance of instantaneous relays is affected by the DC component of transients. The error introduced by the DC off set component causes the relay to overreach. Higher the X/R ratio of the system, greater is the problem, A DC filter is used to overcome this problem.

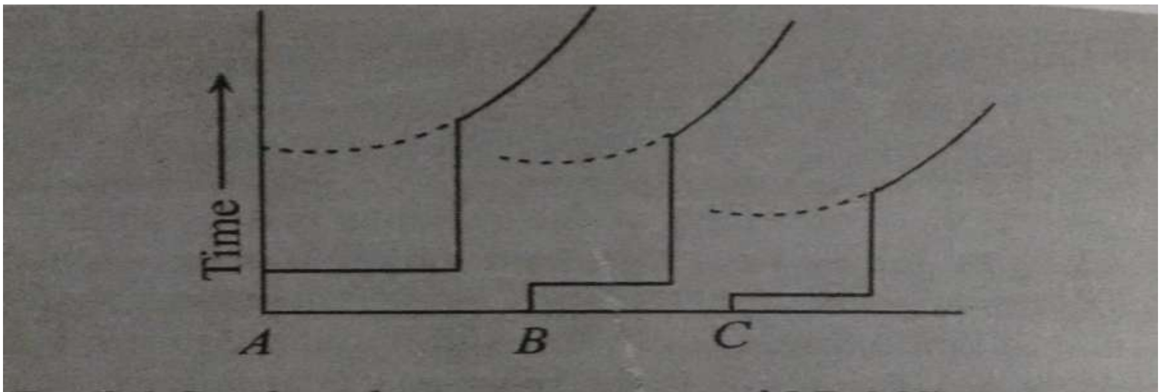


Fig 7.6 Combined instantaneous and I.D.M.T. protection

In the USA an instantaneous relay, employing induction Cup type construction is used for this purpose as it is less sensitive to the D.0 offset component. This arrangement also provides a high reset to pick-up ratio, more than 90%. The current-graded scheme is used where the impedance between substations is sufficient to create a margin of difference in fault currents. For such a system Zs is smaller compared to Zi. The advantage of this system as compared to the graded scheme is that the operating time is less near the power source.

CARRIER CURRENT PROTECTION OF TRANSMISSION LINE:

On long lines carrier pilot relaying is cheaper and more reliable than pilot wire relaying even though the terminal equipment is more expensive and more complicated than that required for use with pilot relays. The essential difference between this scheme and voltage balance pilot wire systems is that in the former, only the phase angles of thecurrent at the two ends of the feeder are compared instead of actual currents used in the latter case. This phase angle decides whether the fault is internal or external.

Principle of operation:

Fig. 7.10 shows the various equipments required for the carrier protection. Line traps are parallel resonant circuits having negligible impedance to power frequency currents, but very high impedance to carrier frequency currents. These traps are used to confine the carrier currents to the protected section so as to avoid interference with or from other adjacent carrier current channels. Coupling capacitor is used for injection into and receipt of carrier signals from the line. These capacitors are tuned to the signal frequency by means of series connected inductors. The other major items of equipments are the high frequency generator and receiver unity's and the fault detecting and direction comparison relays. It is also necessary to protect the equipment form high voltage surges on the line. This includes drainage resistors which offer a low resistance path to earth for high voltage surges. The carrier frequency range is from 30kHz to 500kHz at power of about 100W. There are different methods of carrier current protection and basic forms of carrier protection are (i) phase comparison protection and (ii) Directional comparison protection

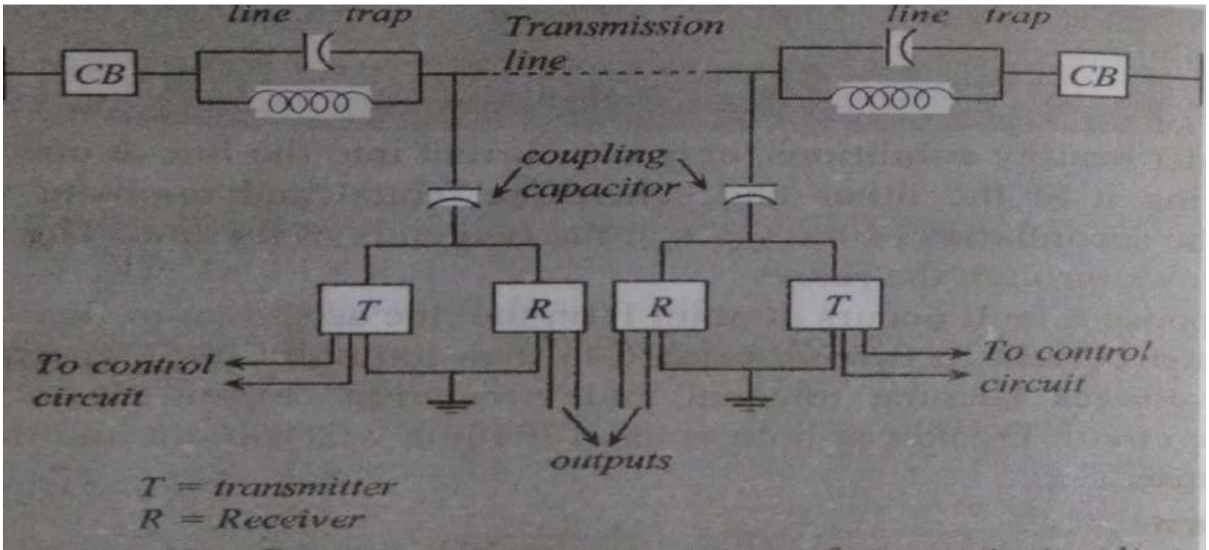


Fig. 7.10 : Carrier current protection of transmission line

Carrier phase comparing Relaying:

Fig.7.11 shows the principle elements of equipment at both ends of a transmission line using carrier pilot. The transmission line CT's feed a network that transforms the CT output currents into a signal phase sinusoidal output voltage, the voltage is applied to a carrier current transmitter and to a comparer. The comparer control the operation of an auxiliary relay for the tripping of the transmission line circuit breaker. These elements provide means for transmitting and receiving carrier current signals for comparing at each end the relative phase relations of the transmission line control at both ends of the line. The line CT's are so connected that their secondary currents are 180degrees out of phase \N hen normal current is flowing in the feeder. For an external fault at D in fig.7.12, the directions of current flow are

180 degrees out of phase as for normal operation.

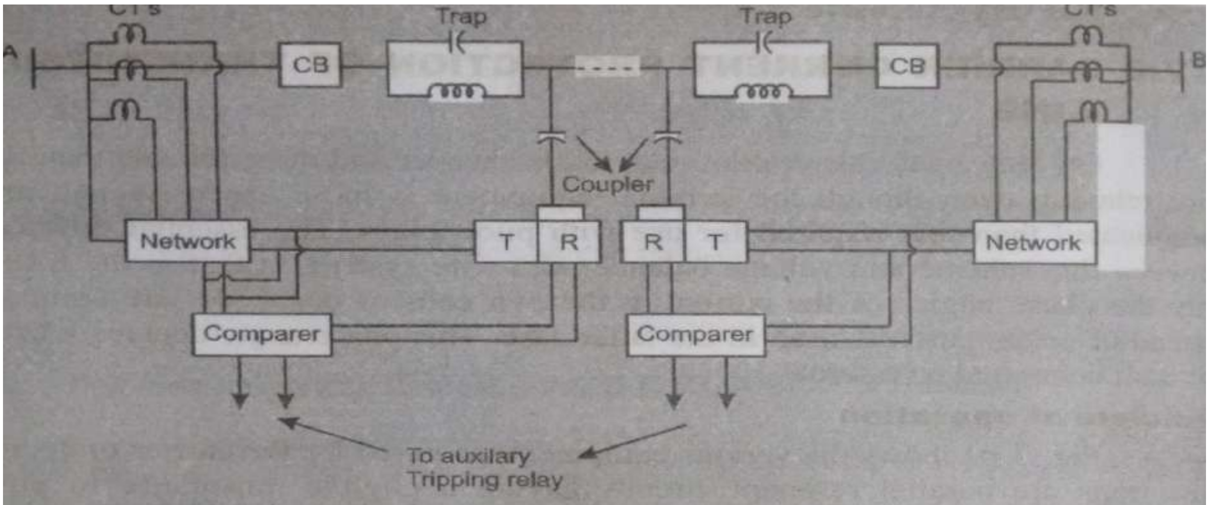


Fig. 7.11 Schematic diagram of phase comparison carrier protection

Since an AC voltage is used to control the transmitter, carrier current is transmitted only during the half cycles of the voltage when the polarity is positive. The carrier current signals transmitted from A and B are displaced in time so that there is always a carrier current signal from one end or the other. There is no operation of the relay.

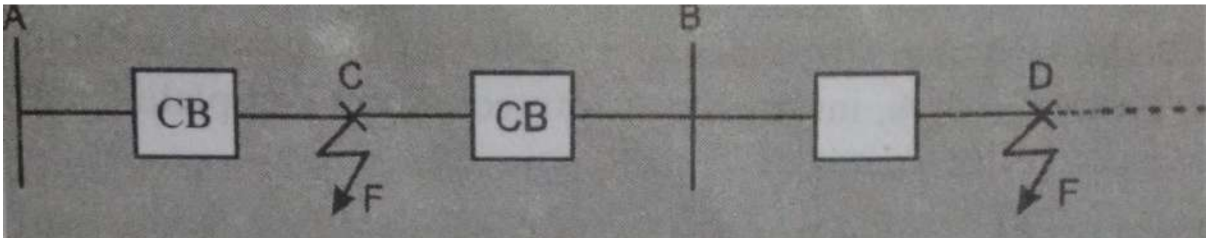


Fig. 7.12

For internal fault at C, currents are fed from both ends, the phase between the secondary currents is zero and a tripping signal is transmitted. Phase comparison relay acts to block tripping at both terminals wherever the carrier current signals are displaced in time to that there is little or no time interval when a signal is riot being transmitted from one end or the other. When the carrier current signals are in phase, tripping will occur whenever there is sufficient short circuit current flowing. Fig. 7.13 explains the operation of carrier phase protection.

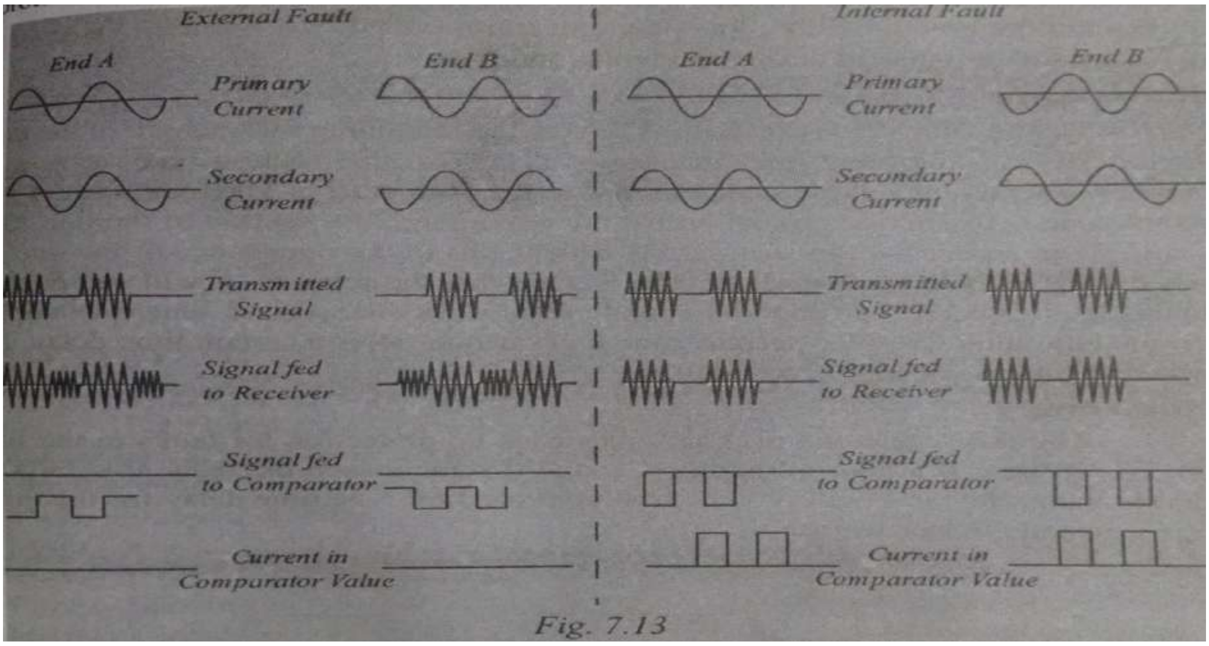


Fig. 7.13

Advantages:

- Fast, simultaneous operation of circuit breakers at both ends
- Fast clearing prevents shocks to systems
- For simultaneous faults, carrier-current protection provides easy discrimination

Three zone distance relay protection:

Basically, a large range of distance protection schemes is possible, which differ in speed of operation, characteristic of measuring unit and the type of fault covered.

Both the time, graded and pilot wire, systems are not suitable for the protection of very long high voltage transmission lines. Because of disadvantages of giving an unduly long time delay in fault clearance at the generating station end when there are more than four or five sections and high cost of pilot wire system, the relays using distance protection were developed, in which the action of the relay depends upon the distance (or impedance) between the points without using pilot wires. In this type of relays, instantaneous protection for complete length of the line is obtained.

Operation:

Consider fig.7.14 which consists of two line sections i.e., AB and CD, it is desired to provide distance protection scheme. The protection scheme is divided into three zones. Let us assume thethree-zones are Z_{1a}, Z_{2a} and Z_{3a} for relay at bus A.

First Zone:

First zone Z_{1a} corresponds to approximately 80% 1ength of the line AB. It is a high speed is used for the primary protection of the protected line. It is to be noted here that the first zone is extended only up to 80% and not 100% length of the line-as the relay impedance measurement will not be very accurate towards the end of the lineespecially "when the current is offset. If the relay operates for a faultbeyond the-protected line, this phenomenon is called "over reach". Overreach may occur due to transient during the fault condition.

Second Zone:

Second zone Z_{2a} for relay at A covers the remaining 20% length of the line AB and 20% of adjoining line. In case of a fault in this section relay at A will operate when the time elapsed corresponds to the ordinate Z_{2a}. The main idea of thesecond zone is to provide protectionfor the remaining 20% section of the line AB. in case of an arcing fault in section AB which adds to the impedance of the line as seen by the relay at A, the adjustment is such that the relay at A will see & that impedance is second zone and will operate. This is why the second zone is extended into the adjoining line. The second zone unit operates after a certain time delay. Its operating time is usually0.2secto 0.5sec.

Third zone:

The third zone unit at A provides back up protection for faults in the line CD, i.e., if there is a fault in the line CD and if some reason the relay at C fails to operate then relay at A will provide backup protection. The time delay for the third zone is usually 0.4sec to 1sec.

In case the feeder is being fed from both the ends and let the fault takes place in the 2^{nd}zone of line AB(20% of the line AB), the relay at B will operate instantaneously where as the fault lies in the second zone of the relay at A. This is undesirable from stability point of view and it is desirable to avoid this delay. This is made possible when the relayat B gives an interruption signal at A in order to tripthe breaker quickly rather than waiting for zone 2 tripping.

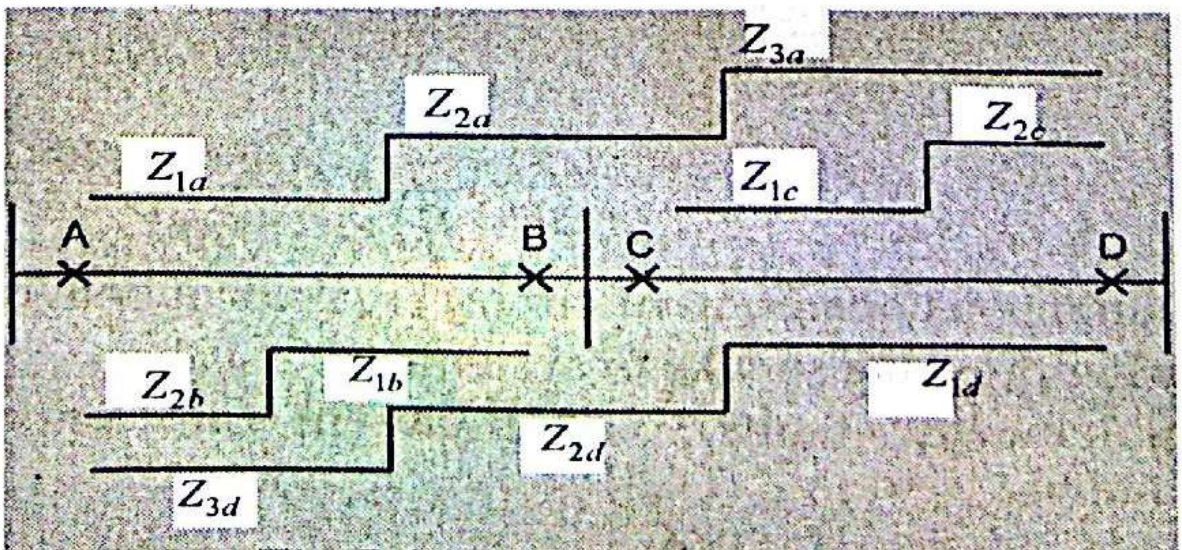


Fig.7.14 : 3 Zone protection

Distance relay using impedance relays:

An impedance relay measures the impedance of the line at the relay location. When a fault occurs on the protected line section, the measured impedance is the impedance of the line section between the relay location and the point of fault. It isproportional to the length of the line. As such an impedance relay has no directional feature and will operate irrespective of the direction of the current. Fig. 7.15 shows the characteristics for a 3-zone impedance relay with directional unit D. It is usual to make maximum torque angle φ smaller than line impedance angle θ. Thisis done in order to reduce the effect of arc resistance on the reach of the relay.

The zone 3 element Z3 controls the operation of the timer and thus is the starting unit, the contact circuit is shown in fig.7.16. The zone1 element operates without any intentional time delay, but still it has some finite time of operates t1, where as Z2 and Z3 operate with a time delay of t2, and t3 respectively.

Let fault is in zone-1, all the three units will start but since the operating time of unit 1 is smallest, this will operate and the faulty section will be isolated from the source. In case the fault is in second zone, the units Z2 and Z3 will start but unit Z2 will operate in time r2 and isolate the faulty section from the source.

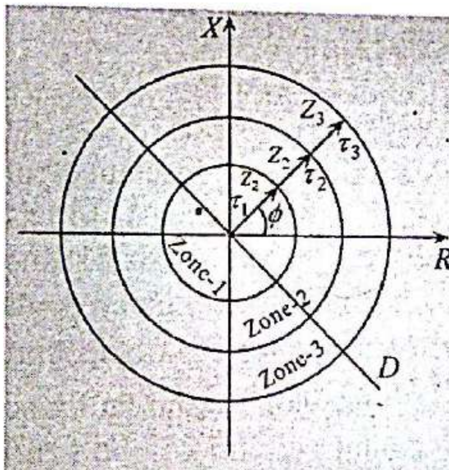


Fig.7.15

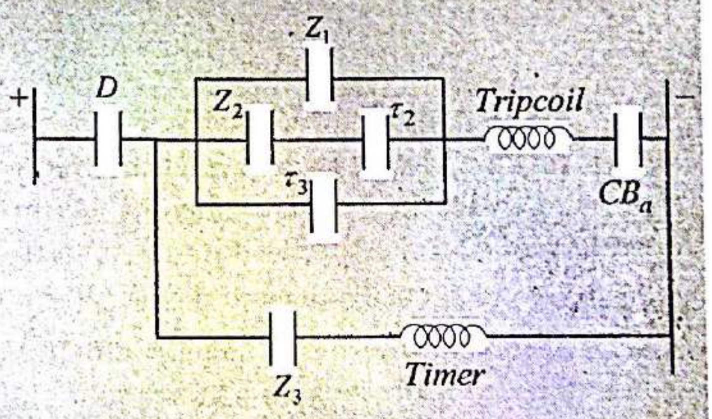
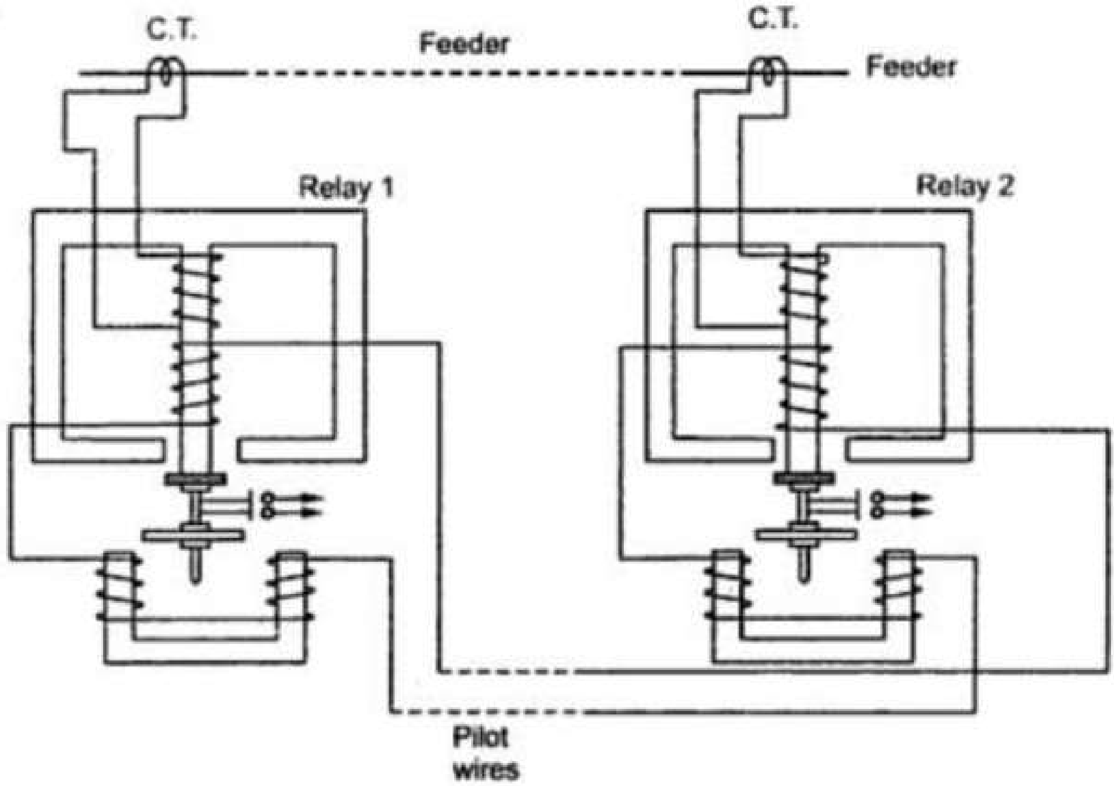


Fig. 7.16

Translay Scheme :

The translay relay is another type of differential relay. The arrangement is similar to overcurrent relay but the secondary winding is not closed on itself. Additionally copper ring or copper shading bands are provided on the central limb as shown in the figure below.

In this scheme, two such relays are employed at the two ends of feeder as shown in the figure below.



The secondaries of the two relays are connected to each other using pilot wires. The connection is such that the voltages induced in the two secondaries oppose each other. The copper coils are used to compensate the effect of pilot wire capacitance currents and unbalance between two currents transformers.

Under normal operating conditions, the current at the two ends of the feeder is same. The primaries of the two relays carry the same currents inducing the same voltage in the secondaries. As these two voltages are in opposition, no current flows through the two secondaries circuits and no torque is exerted on the discs of both the relays. When the fault occurs, the currents at the two ends of the feeder are different. Hence unequal voltages are induced in the secondaries. Hence the circulating current flows in the secondary circuit causing torque to be exerted on the disc of each relay. But as the secondaries are in opposition, hence torque in one relay operates so as to close the trip circuit while in other relay the torque restricts the operation. Care must be taken so that, at least one relay operates under the fault condition. Role of copper ring: Mainly relays may operate because of unbalance in the current transformers. The copper rings are so adjusted that the torque due to current induced in the copper ring due to primary winding of relay is restraining and do not allow the disc to rotate. It is adjusted just to neutralize the effect of unbalance existing between the current transformers. The copper rings also neutralize the effect of pilot capacitive currents. Though the feeder current is same at two ends, a capacitive current may flow in the pilots. This current leads the secondary voltage by 90o. The copper rings are adjusted such that no torque is exerted on the disc, due to such capacitive pilot currents. Therefore in this scheme the demerits of pilot relaying scheme is somewhat taken care of.

The advantages of this scheme are,

1. Only two pilot wires are required.
2. The cost is very low.
3. The current transformers with normal design can be employed.
4. The capacitive effects of pilot wire currents do not affect the operation of the relays.

Protection of Bus Bars:

The majority of the faults are single-phase in nature and are, in part, temporary in character. So, the bus bars are mostly designed to be protected against these faults. In the event of fault on any section of the bus bar all the circuit equipments connected to that section must be tripped out to give complete isolation in shortest possible time so that damage is avoided to the installation due to heating of conductors. Internal bus faults are less frequent than line faults. A bus fault tends to be appreciably more severe, both with respect to the safety to personal system stability and the damage. A major system shutdown may he caused in the absence of bus protection.

The standard of construction for bus bars has been very high, with the result that bus fault are extremely rare. However, the possibility of damage and service interruption from even a rear bus fault is so greater that more attention is now given to this form of protection. Improved relaying methods have been developed, reducing the possibility of incorrect operation. The most commonly used schemes for bus bar protection are

• Differential protection
• Differential Over-Current Protection
• Frame leakage protection or Fault bus protection
• Circulating current protection

Differential protection:

Differential protection of bus bar is extensively employed in modem power station or substations. In differential protection system the currents entering and leaving the bus bar are totalized. During normal operating or external fault conditions, the sum of these currents is zero. When the fault occurs, the fault currents upset the balance and develops a differential current which operates the relay. The schematic arrangement of this protection to station bus bar is shown in fig. The secondaries of CTs in the generator load in line -1 and line-2 are connected in parallel. The protective relay is connected across this parallel connection. Regardless of the capacities of the various circuits, all CT's must be of the same ratio in the scheme. When fault occurs within the protected zone, the currents entering the bus will no longer be equal to those leaving it. The difference of these currents will flow through the relay and cause opening of generator circuit breaker and each of the line circuit breaker.

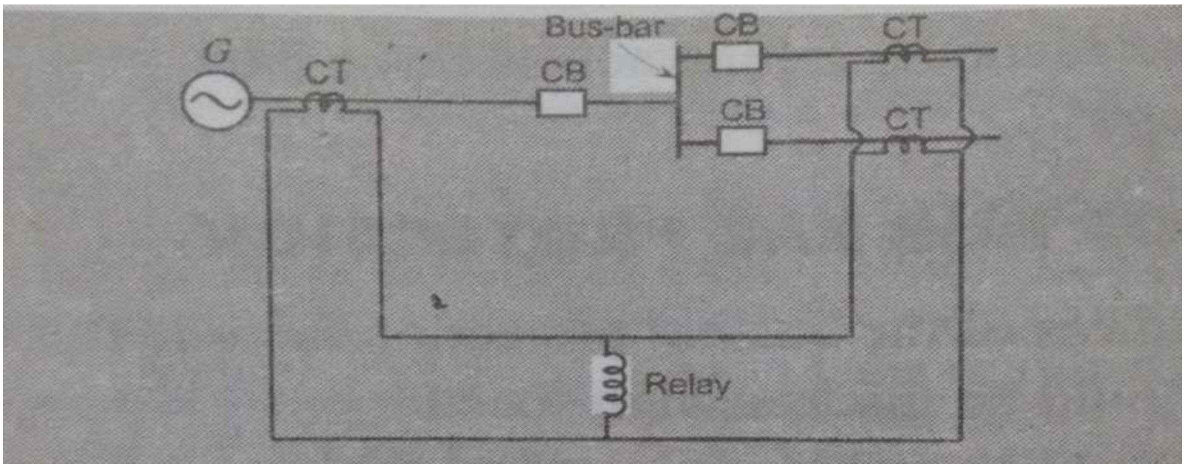


Fig.7.23: Differential Protection Scheme

Limitations:

(i) The circuit is complicated due to sectionalizing

(ii) Due to large load variation setting of relays require a change

(iii) Under external fault condition there might he a mal-operation, this is due to the saturation of one of the CT due to DC components in fault current (iv)Under external fault conditions differential (spill) current is caused due to the left over magnetism is cores of the CT's and also the difference in the primary current of the CT's will cause a differential current.

To overcome the problem of C.T saturation and to improve the stability without intentional time delay, the following protection schemes have been developed.

(i) Biased differential bus zone protection

(ii) High impedance bus zone protection

(iii) High impedance voltage differential bus zone protection.