29

Distance Protection

Introduction — Principle of R-X Diagram — Theory — Impedance Relay — Time — Direction Impedance Relay — Mho type Admittance Type Distance Relays — Distance Protection schemes — Applications — 3 step Characteristics Coordination — Method of Analysis — Load Impedance — Power Swings — Various Characteristic Shapes.

29.1. INTRODUCTION TO DISTANCE PROTECTION

Distance relays are double actuating quantity relays with one coil energized by voltage and the other coil energized by current (Ref. Fig 29.1). The torque produced is such that when V/I reduces below a set value, the relay operates. During a fault on a transmission line the fault current increases and the voltage at fault point reduces. The ratio V/I is measured at the location of CT's and VT's. The voltage at VT location depends on the distance between the VT and the fault. If fault is nearer, measured voltage is lesser. If fault is further, measured voltage is more. Hence assuming constant fault resistance each value of V/I measured from relay location corresponds to distance between the relying point and the fault along the line. Hence such protection is called *Impedance Protection or Distance Protection.*

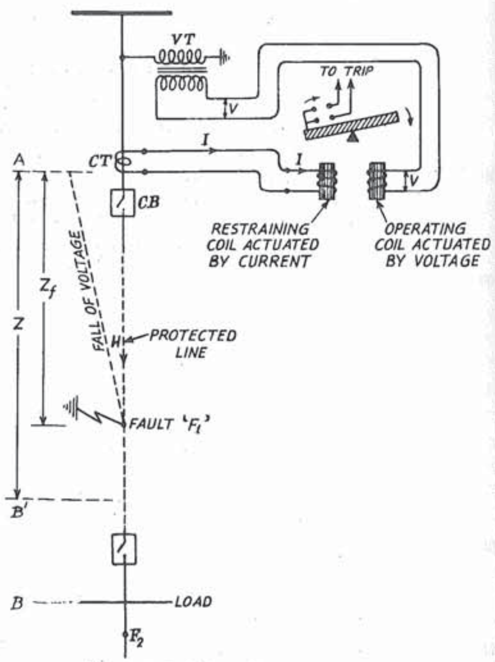


Fig. 29.1. Explaining Distance Protection.

Distance protection is *non-unit* type protection, the protection zone is not exact. The distance protection is high speed protection and is simple to apply. It can be used as a primary and back-up protection. It can be used in Carrier Aided Distance Schemes and in Autoreclosing Schemes. Distance protection is very widely used in protection of transmission lines.

29.2. PRINCIPLE OF R-X DIAGRAM

R-X diagrams are useful in plotting characteristics of Distance Relays.

The three variables V, I and ϕ are converted into two variables R and X. Impedance Z_1 is defined as ratio of r.m.s values of V and I, *i.e.*

$$|Z_1| = \frac{|V_1|}{|I_1|}$$

Z can be plotted on R-X diagram. (Ref. Fig. 29.2).

$$R_1 = Z_1 \cos\phi\ ;\ X_1 = Z_1 \sin\phi$$

ϕ is positive if I_2 lags V_1, ϕ is negative if I_1 leads V_1.

Thus V_1, I_1 and ϕ can be converted on R-X diagram as shown in Fig. 29.2.

The family of impedance relays (Distance Relays) can offer wide range of characteristics.

The basic principle should be understood and needs clear explanation.

Relays which measure plain impedance (Z) are called impedance relays. Their characteristic on R-X plane is a circle with centre as origin and radius as Z, Fig. 29.2.

Relays which measure impedance but respond to faults on one direction only are called directional impedance relay. Their characteristic on R-X plane is a semi-circle on an inclined line. The centre of semi-circle is at centre of R-X diagram.

Relays having voltage restraint in additional to directional and impedance elements have a circular characteristic on R-X diagram but with centre shifted from origin.

Mho-relays have a circular characteristic, the circumference of the circle passes through the origin.

The detail explanation about these characteristics has been given below.

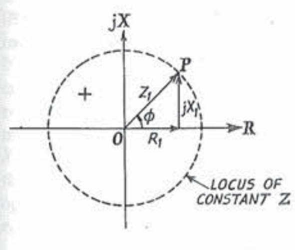
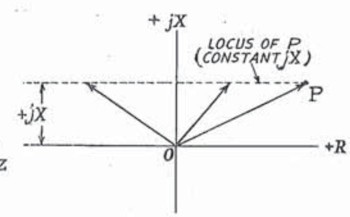
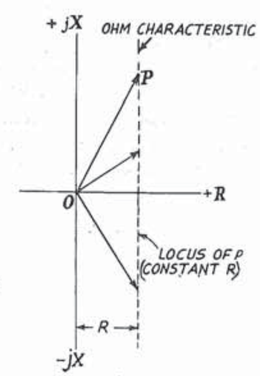


Fig. 29.2. Representation of Z on R-X diagram.



Locus of point P for constant X.
Fig. 29.3 Characteristic of reactance element on R-X diagram.



Locus of constant R.
Fig. 29.4. Characteristic of ohm relay on R-X diagram.

29.3. THEORY OF IMPEDANCE MEASUREMENT

The term impedance applied to resistance plus reactance. We know that the ratio of voltage across a branch to current in the branch gives impedance of the branch, *i.e.*

$$\frac{V}{I} = Z = R + jX$$

The impedance relay operates for certain conditions of the ratio V to I which may expressed as impedance.

In any impedance relay, there are two actuating quantities namely V and I. The current gives operating torque. The voltage gives restraining torque.

The characteristic in terms of V and I is shown in Fig. 29.5.

The impedance relay can be made to sense the ratio between voltage and current at a point on the line. In such a case we can say the relay is sensing the impedance. The impedance between the location of CT, VT and the fault is proportional to the distance between the above location and the fault. Hence impedance relay is called distance relay. Such a relay operates if the impedance is below that of the relay setting, hence if the fault is within a certain length of the transmission line.

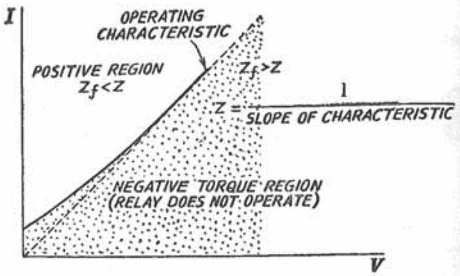


Fig. 29.5. Operating characteristic of an impedance relay.

Distance relay is a versatile family of relays that includes

1. **Impedance relay** ; measures...Z.
2. **Reactance relay** ; measures...X.
3. **Mho type relay** ; measures a component of admittance Y.

A distance relay is one whose operation is based on measurement of impedance, reactance or admittance of line between the location of relay and the fault point.

29.3.1. R-X Diagrams of Plain Impedance Relay

In Fig 29.5, the operating characteristic of an impedance relay on V-I plane. It is in the form of a straight line. By adjustment, the slope of the operating characteristic can be changed.

The more convenient way of describing the operating characteristic of a distance relay is by means of 'Impedance Diagram' or R-X diagram. Since the relay operates for certain value, less than the set value of, the Z operating characteristic is a circle of radius Z.

Any value of Z_f less than the radius of the circle produces positive torque. Any value of Z_f more than the radius, of circle produces a negative torque and relay does not operate. This is a rule regardless of phase angle between V and I.

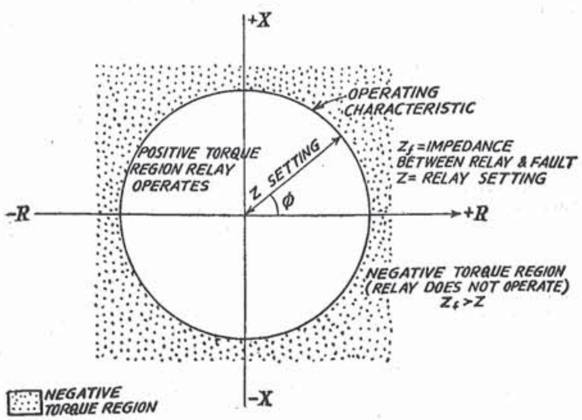


Fig. 29.6 R-X diagram of impedance relay for characteristic shown in Fig. 29.5.

29.3.2. Plain Impedance Characteristics.

The plain impedance characteristic shown in Fig. 29.7(b) is the simplest in use and consists of a circle with centre at the origin.

Operation occurs in the shaded area inside the circle. The significance of this is that the relay operates below certain impedance level, which is independent of the phase angle between voltage and current. A straight line on VI plane (Fig. 29.5) having a constant slope gets converted into a circle of radius V/I on R-X plane.

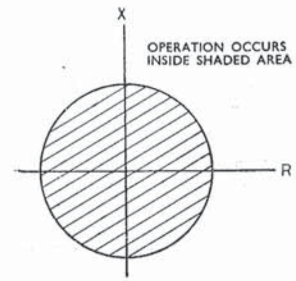
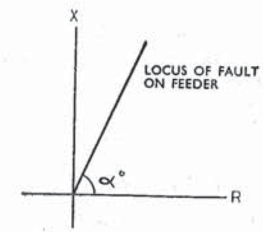


Fig. 29.7 (b). Plain Impedance Characteristics of relay.



α-Phase angle of feeder Impedance.
Fig. 29.7 (a). Impedance Diagram of System Fault.

The resistance and reactance between the relay location and fault can also be plotted on R-X diagram as shown in Fig 29.7(a). The angle α will depend upon ratio R/X of line per unit length. For a given fault condition, the measured impedance can be marked on this line [Fig. 29.7(a)]. The line can also be superimposed on the relay characteristic (Fig. 29.8). If the measured impedance of line is within the circle, the relay operates, the circle gives the relay characteristics. The *distance* along transmission line can be represented by a line on R-X diagram. By superimposing the line characteristic, on the relay characteristic, the operation of the relay can be predicted. (Referring to Fig. 29.8)

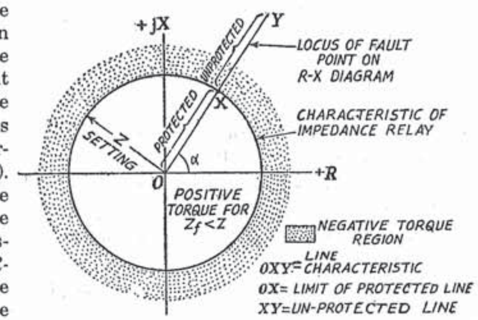


Fig. 29.8. Superimposition of line characteristic OXY on relay characteristics.

OX represents the feeder on RX diagram.

If fault occurs within distance OX, the relay operates. For fault beyond X region XY, relay does not operate.*

29.3.3. Disadvantages of Plain Impedance Relay.

Plain impedance relay has the following disadvantages.

— It is non-directional. It responds to the faults on both sides of CT,VT location. Hence it cannot discriminate between internal and external faults.

— It is affected by arc resistance of line fault and results in under-reach.

— It is sensitive to power swings as a large area is covered by the circle on each side on R-X plane.

* Ref. Sec. 42.13 and 42.14 for Examples on setting distance relays with the help of R-X diagram.

29.3.4. Time Characteristic of High Speed Impedance Relay

Fig. 29.9 shows a typical operating time *vs.* impedance characteristic of a high speed impedance relay for one value current. For other currents similar characteristics are obtained. It is observed that for impedance values above 100% pickup impedance, the relay does not operate. The curve I represents actual characteristics. Curve II is simplified representation of the same (right angle instead of curve).

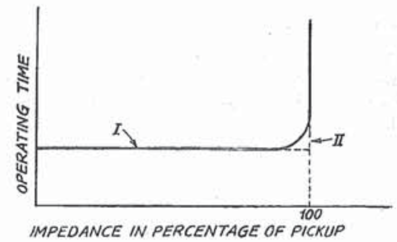


Fig. 29.9. Time characteristics of high speed impedance relay.

The relay unit used for distance protection are double actuating quantity instantaneous relays. The electromagnetic relays of balanced beam type or induction cup type are preferred.

Static impedance relays are preferred in modern installations.

29.4. METHODS OF ANALYSIS

Characteristics of various types of distance relays of R-X plane are in form of circles or sectors of circles.

There are mainly three categories of these characteristics on R-X plain

— Circle with centre at origin.
— Circle with circumstances passing through origin.
— Semi-circle above a directional line passing through origin.
— Circle enclosing the origin.
— Circle cut-off from top by a line parallel to X-axis.

These varieties of characteristics are obtaining by changing the operating coil/restraining coil design, providing the additional polarised coils supplied by voltage or current, providing two or more elements within a single relay case.

The type of relay can be identified on the basis of the form of characteristic on R-X plane.

The characteristic of transmission line is, as a rule, a straight line on R-X plane. The length of the line is proportional to the length of transmission line.

The length of transmission line covered by positive torque region of relay characteristics indicates the reach of distances relay, *i.e.* the length of line protected by the relay. (Ref Sec. 42.13).

29.5. DIRECTIONAL IMPEDANCE RELAY

Directional features senses the direction in which the fault power flows with respect to the location of CT and VT. Directional impedance relay operates for following conditions :

— Impedance between fault point and relay location is less than the relay setting Z.
— The fault power flows in a particular direction from relay location. The direction power flow is sensed by measuring phase angle between voltage and current.

Directional Characteristics

The characteristic presented on R-X diagram is a straight line passing through the origin as shown in Fig. 29.10. Operation takes place on one side of the line as indicated by shading.

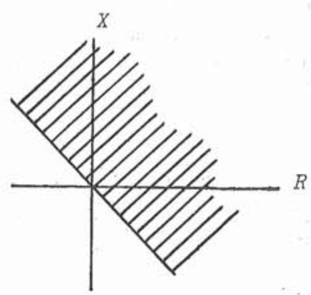


Fig. 29.10. Purely directional characteristics (operation in shaded area).

Suppose the location of fault. Point (with corresponding R and X) is plotted on R-X diagram.

In case of Directional Relay, the positive torque is provided when the fault point lie on right hand side of the inclined line (Hatched area in Fig. 29.10). This line when superimposed on the characteristic of plain impedance relay, we get final characteristic of Directional Impedance Relay (Fig. 29.11)

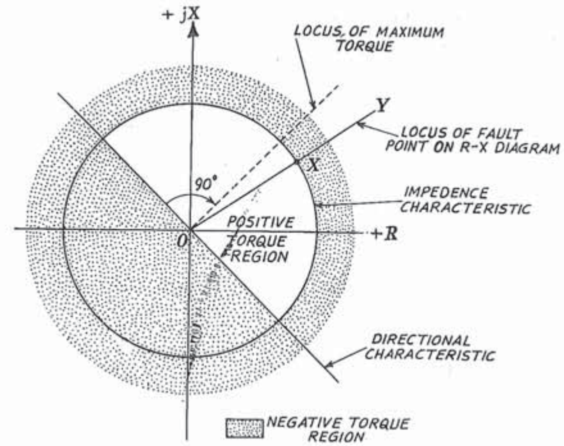


Fig. 29.11. R-X Diagram of Directional Impedance Relay.

With Directional Characteristic added to the plain impedance characteristic, the results in a characteristic with a sector of a circle (Fig. 29.11). Consider a locus of fault point on transmission line (locus OY). Angle $ROY = \alpha$ depends upon the phase angle between V and I with given setting of directional element, the operating torque is positive within the semi-circle with radius Z and on right hand side of the inclined line of directional characteristic DD'.

For faults on one side of the relay location, angle α lies between angle DOD'. Hence relay operates for two conditions :

— Locus OXY should have angle α with angle DOD' given by Directional Feature.
— Impedance measured by relay should be less than the Setting Z.

29.6. TORQUE EQUATION OF DIRECTIONAL IMPEDANCE RELAY

The directional relay responds to the phase angle between V and I at relay location.

Suppose torque of directional unit is given by,

$$T = K_1 VI \cos(\phi - \theta) \quad \text{...(1)}$$

where T = Torque
K_1 = Constant
V = Voltage supplied to relay coil
I = Current supplied to relay coil
ϕ = Phase angle between V and I
θ = Angle of maximum torque

when the relay is on verge of operation.

$$T = 0$$

Hence $\cos(\phi - \theta) = 0$

i.e. $(\phi - \theta) = \pm 90°$ ...(2)

Hence for positive torque, ϕ should be within $\theta \pm 90°$.

This directional characteristic when presented on R-X diagram is a straight line (DOD) for which ϕ is within $\theta \pm 90°$.

However, impedance characteristic puts another conditions, *i.e.* $V/I < Z$ represented by a circle on R-X diagram (Ref. Fig. 29.11). Hence the net characteristic of directional impedance relay is a semi-circle above a straight line passing through zero. (Fig. 29.11). The radius of circle corresponds to measured impedance.

29.7. MODIFIED (SHIFTED) CHARACTERISTIC

The impedance unit may be given a current bias, *i.e.* the voltage coils is supplied by additional voltage proportional to line current (say DI), Basic Torque equation gets modified to

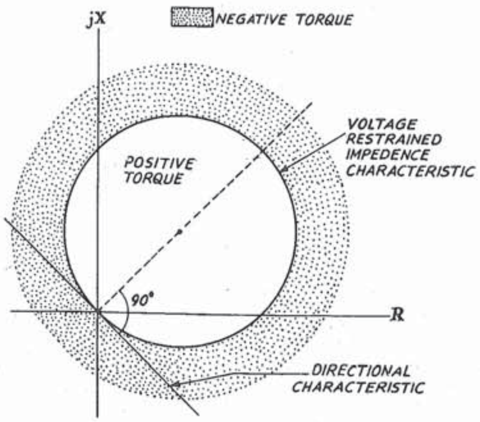


Fig. 29.12. Directional offset impedance characteristic on R-X plane.

$T = K_1 I^2 - K_2 (V + DI)^2$ $(V + DI)$ is the voltage supplied to voltage coil of impedance relay.

The characteristic when plotted on R-X diagram is a circle with radius V/I and with centre shifted from origin.

The circle may be completely 'offset' from the origin so much so that origin is left out of the circle.

Directional feature combined with offset impedance characteristic is shown in Ref. Table 29.1.

29.8. REACTANCE TYPE DISTANCE RELAY

The reactance relay has a characteristic such that all the impedance radius vectors whose outer ends lie on a straight line having constant X component. X is the reactance of protected line between the relay location and the fault point.

The reactance type distance relay has reactance measuring unit. The reactance measuring unit has an overcurrent element developing positive torque and a directional element ($VI \cos \phi$) which either gives a positive or negative torque.

Hence reactance relay is an over-current relay with directional restraint.

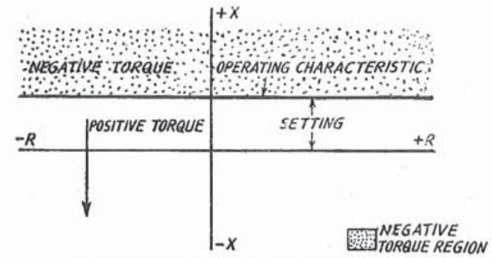
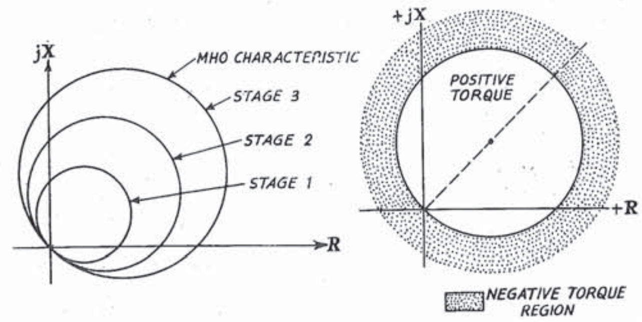


Fig. 29.13. Ideal characteristic of plain reactance type distance relays (simplified).

The directional element is arranged to develop maximum negative torque when current lags behind voltage by 90°, (*i.e.* $\phi = -90°$).

The complete characteristic of voltage restrained reactance relay is illustrated in Fig. 29.14.



(*a*) (*b*)

Fig. 29.14. Voltage Restrained Directional Characteristic (Ohm Characteristic).

29.9. MHO TYPE DISTANCE RELAY

Mho relay is also known as *Admittance Relay* and measures a component of admittance $Y < \theta$. It is also called as angle impedance relay.

The characteristic of mho relay on admittance diagram is a straight line.

The mho characteristic on R-X diagram is a circle passing through origin. This characteristic is obtained by polarizing the impedance relay and directional relay (refer : reactance type distance relay). From Fig. 29.14 the following points can be noted :

1. Characteristic is directional and will operate for faults in one direction only.
2. Relative reach of the relay goes on changing for various ratios of R/x.

Summary

The distance protection responds to the ratio V/I. The impedance relay is set for a value Z such that when the value V/I measured by the relay is less than the set value Z, the relay operates. Characteristics of Distance Relays are plotted on a R-X plane. Distance Relays are used for protection of transmission lines, distribution lines etc. These relays are generally high speed relays.

Details about distance protection schemes are given in Chapter 30.

29.10. APPLICATION OF DISTANCE PROTECTION

Distance protection schemes are used universally for protection of high voltage AC transmission lines and distribution lines. They have replaced the over-current protection of transmission line (Refer Part 30.A). The success of distance protection is due to the following :

— faster protection — simpler co-ordination
— less effect of amount of generation and fault levels, fault current magnitude.
— permits high line loading
— simpler application ; permanent setting without need for readjustments
— static distance relays have superior and versatile characteristics (Refer Ch. 42) Sec. 42.1 enlists several addition merits of static distance schemes.

Distance protection schemes are generally used for providing the Primary Protection (Main Protection) and Back-up protection for AC transmission and distribution lines against

— 3 phase faults — phase to phase faults
— phase to earth faults

In some schemes for short lines, the phase to earth faults protection sensing may be by distance relay and measurement by over-current relays because distance protection for shorter lines are susceptible to errors due to arc fault resistance. In general, the choice of type of distance protection depends on length of line, configuration of lines, whether single infeed/double infeed, tripping time required and co-ordination requirements. Refer Table 30.2 regarding alternative distance schemes. **Todays trend is toward the use of static distance protection for all types of line faults, main and back-up for short, medium and long lines.** These have been dealt in Chapter 42. The following paragraphs give an overall review.

Distance relays respond to the ratio of V/I. They measure impedance V/I or a component of impedance from the location of CT, VT. The measured V/I is proportional to the distance between the location of CT/VT and location of fault. Hence the relays are called distance relays.

The operating limits of an impedance relays are usually specified in terms of impedance components resistance and reactance. *It is convenient to describe the operation limits on R-X diagram on rectangular co-ordinates with resistance R on abscissa and reactance j-X on ordinate.* The operating characteristics on R-X diagram in the form of simple geometrical figures such as circles or sectors of a circle or rectangles. Electromagnetic relays can achieve only circular characteristics. **Static Distance Relays** *can achieve rectangular, quadrangular, lense, type, double-mho and a variety of characteristics on R-X diagram* (Sec. 42.5, 42.17).

The choice of R-X characteristic is made such that the relay operates for line faults in the protected portion of line but remains stable during power swings.

29.10.1. R-X Diagram

The geometrical figure on R-X diagram (a circle, quadrangle or a sector of circle) may be in the first or second quadrant of rectangular co-ordinates. ...(Table 29.1)

Relay Characteristics

The operating region is within the characteristic figure *i.e.* when the measured impedance component is less than the set value (boundary of characteristic figure) the relay operates (Figure 29.7 *b*). Refer Fig. 29.15.

29.10.2. Line Characteristics

Refer Fig. 29.7 (*a*) representing line characteristics. The locus of line impedance before occurrence of a fault measured by the relay and plotted on R-X diagram is a straight line passing through

Further References :
Ch. 30. Distance Protection Schemes.
Ch. 42. Static Distance Relays and Distance Protection of EHV lines.
Sec. 42.14. Setting of Distance Relays.

the origin. The angle α of this line characteristic depends on natural ratio of R/X of line per unit length. ($\sin \alpha = X/Z$). Each point on the line represents certain distance from origin in terms of Z.

The setting of the relay decides the radius of the characteristic circle or shape of boundary of the characteristic.

For pre-determining the operation of relay in response to fault on transmission line, the line characteristic. Fig. 29.7 (*a*) is superimposed on relay characteristic Fig. 29.7(*b*) as in Fig. 29.8. Refer Fig. 29.17 also.

29.10.3. Condition for Relay Operation (Refer Fig. 29.17)

The fault point F shifts from line end towards origin O depending the location of the fault with respect to location of CT/VT (substation). For a fault away from the sub-station, the point is farther from origin. If it is outside the boundary of the characteristic figure, (Circle or Quadrangle). The relay does not operate. During a fault on line, (assuming negligible fault impedance) the V/I measured between origin and the fault reduces and the point moves towards the origin. If the point moving along the line characteristic comes within the characteristic of the relay (Fig. 29.8) the relay operation.

29.10.4. Operating Time

The time characteristic of high speed distance relays is a straight line (Fig 29.9). The relay operates within set time. When measured Z falls within its pick-up value. If measured Z is beyond its pick-up value the relay will not operate.

29.10.5. Stages of Relay Time Characteristics

The long transmission lines are with intermediate sub-stations. In each sub-station the distance relays are provided for line protection. The settings of these relays are set with respect of impedance (radius of characteristic circle) and operating time (position of horizontal step Fig. 29.9).

The distance relay in each sub-station has generally 3 step characteristic with respective settings of Z and t for each step. The three-step characteristics of distance relay of each sub-station is achieved by providing three sets of relays in each sub-station for protection of each line. Sec. 30.12 and Fig. 30.12 illustrate a three-step characteristic of distance protection of transmission line. Refer. 29.15 also.

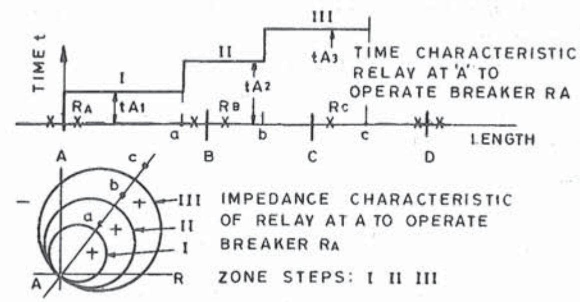


Fig. 29.15. Three-step time-characteristics of Distance Relay at Station A.

3 Step-Characteristics

Ref. Fig. 29.15. This figure explains a time-distance characteristic of a 3-step distance scheme in sub-station A for one direction. There are three sets of relays for protection of each line. Each relay provides characteristic for one zone. The combined effect the distance scheme in substation A provides.

— Primary protection for first zone *AB* with minimum time setting. Normally 85% of first zone is covered to take care of errors such as fault resistance.

— Remote Back-up (Refer Sec. 25.5.3) for the second zone *BC* with time setting....and Remove Back-up for the 3rd Zonal *CD* with time setting...

First Zone. The first zone setting is 85 to 90% of line length and with highest speed of protection so that these relays operate at the earliest and will never operate for the fault in 2nd and 3rd zones. Also the margin of 15 to 10% takes care of fault resistance seen by the relay measurement as additional line impedance.

Underreach. Suppose line impedance is Z_L and arc resistance relay measures $(Z_L + R_f)$ instead of measuring only Z_L. Thereby the relay will see the fault as beyond its characteristic circle and will not operate even though it should have operated. This is called *Underreach* Defn. Sec. 25.8.(34).

Second Zone. The second zone relay at A provides protection for remaining 15 to 10% of line section AB. The relay is set to reach beyond the length AB and twenty to fifty per cent of the next line section BC. For achieving time co-ordination, the second zone relay at sub-station 1 is set with time t_2 with a time delay of 0.2 to 0.5 seconds between the first zone t_1 and second zone t_2. The primary protection for section BC is provided by first zone relay at sub-station B.

Third Zone. The third zone relay at A provides back-up protection for section AB, BC and CD. The primary protection for line section CD is provided by first zone relay at sub-station C.

Third zone protection at sub-station A is delayed by 0.4 to 1 second from first zone and 0.2 to 0.5 seconds from second zone.

29.10.6. Co-ordinated Characteristics of Distance Relays in three stations.

Fig. 29.16 illustrates the time distance characteristic settings of Distance Relays at Station A, B, C for one direction. Similar relays are provided for other direction.

1. **Relays at Sub-station A**

3-step distance characteristic of relay at sub-station A having following features :

— **First Zone.** Primary protection to 85 to 90% on line AB (First Zone) with time $t\,A_1$ to operate breaker RA.

— Second zone covering remaining 15 to 10% of section AB and about 20 to 50% of section BC with time $t\,A_2$.

— Third zone covering remaining 80 to 50% of section BC and further 20% of section CD.

2. **Relays at Sub-station B**

This has three-step characteristic just like that of sub-station A.

1. First zone protects 85 to 100% of section BC as primary protection with time $t\,B_1$ and, second zone covering remaining 15 to 10% of BC with higher time. Third zone covering remaining protection of line BC and further 20% of line CB.

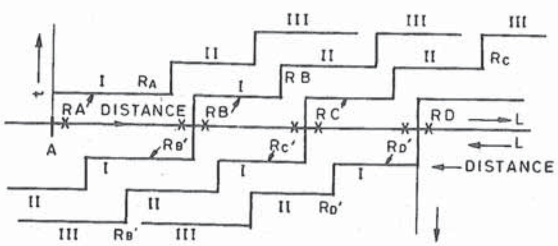


Fig. 29.16. Co-ordination of 3-step time characteristics at Station A, B, C for forward and opposite directions.

2. Relay at station B provides primary protection to section BC and remote back-up to DC, DE.

3. **Relay at Sub-station C**

This provides primary protection to 85 to 90% of section CD as first zone protection with minimum time $t\,C_1$. This is primary protection at sub-station C to operate breaker R_C.

Three steps in R-X Diagram

The impedance characteristics of zone 1, 2, 3 are similar geometrical figures with different impedance settings (Fig. 29.14). In case of static distance relays with quadrangular characteristics, the characteristics of 3 zones are in the form of different straight lines forming the quadrangle.

29.10.7. Significance of R-X Diagram and Method of Analysis

A distance relay should operate below set fault impedance within set-time. It should not fail to operate for faults beyond protected zone. It should operate for faults within protected zone. It should not operate due to power swings. For the purpose of analysis and choice of settings of first zone, second zone and third zone Distance Relays in each sub-station and their co-ordination; the R-X Diagram is very useful. The following characteristics are plotted on the same R-X diagram.

— Relay characteristic (circle or sectors of circles or some geometrical shapes).

— Line characteristic (Straight line passing through origin)

— Load impedance region

— Power swings.

Relay characteristic should cover the line characteristic.

Relay characteristic should be away from load region. Normal power swing should touch relay characteristic. Ref. Fig. 29.17.

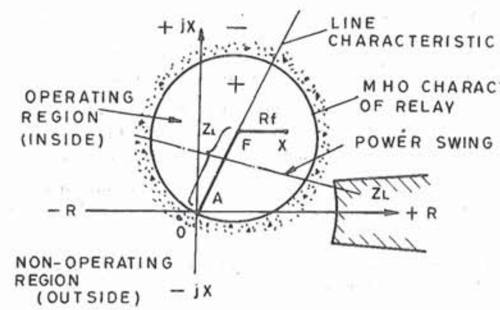


Fig. 29.17. Summary of characteristic of a distance relay.

29.10.8. Load Impedance

The load on transmission line represented by certain load impedance having certain *R* and *X* values. This is covered by region Z_L shown in Fig. 29.17.

Load impedance is much higher than fault impedance and line impedance. Therefore, the distance relay does not operate due to change in load impedance under normal load conditions. During faults on the line the measured line impedance falls. Operating point suddenly comes from region Z_L on line AB.

29.10.9. Line Impedance

This is represented by a straight line passing through the origin. During no-load the point on the line represents the impedance seen by the relay from origin. During the fault, the relay will measure the line impedance upto fault point.

Fault Resistance. The faults on overhead line will be arc faults having pure resistance R_f. This is represented by a horizontal line on R-X diagram.

Total impedance measured by the relay is equal to line impedance upto fault point (Z_L) plus arc resistance (R_f) *i.e.* $Z_L + R_f$.

The relay characteristic should be broad in the middle (Fig. 29.17) and Fig. 42.31) so that X is within relay characteristic.

29.10.10. Power Swings

During switching of lines, large loads or generating units, surges of real power and reactive power flow through transmission lines causing oscillations in the voltage vectors and current vectors (Sec. 42.9).

The power swing is represented by a curve originating in load region and travelling towards relay characteristic.

During power swings the measurement of V/I by distance relays at sending-end and receiving-end sub-stations do not represent true V/I characteristic of the line. The measurement is falsified by power swings and the distance relay may operate wrongly if the measured V/I falls within the operating characteristic of the relay (Sec 42.9.2). The power swing point travels from load region L towards are relay characteristic as shown in Fig. 42.18.

The shape of characteristic is such that the minor low magnitude power swings approaching from load region do not enter the enclosed area of the relay characteristic. For this purpose the characteristic is narrow near the bottom half region. The area of characteristic is restricted at the bottom and enlarged at the top.

The static relays are provided with features to block the relay against permissible power swing but operate for faults.

29.10.11. Choice of Characteristic Mho/Reactance Mho/Static

The various types of characteristics on R-X diagram have been re-viewed in Table 29.1.

Plain impedance characteristic has several limitation mentioned in the Table 29.1 (a).

Solved Example 42.1 (a) in section 42.14 illustrates how the relay fails to detect a fault within 80% of protected line because of fault resistance FX. In past plain impedance relay was used extensively for long lines and short lines. However, now it is no more preferred.

Mho-characteristic (Table 29.1 C) is used for protection of long lines. The characteristic is a circle passing through the origin on R-X diagram and with axis almost coinciding with the line characteristic.

The measurement error due to arc fault resistance remains within the characteristic circle as shown in Figs. 30.13, 30.14 and Example 42.2.

Hence such a characteristic is preferred for short lines. Oval characteristic (Fig. 42.9) for Quadrangular characteristic (Fig. 42.11 and Fig. 42.28). These are achieved by static relays and are such that arc fault resistance is within relay characteristic (board at middle) and minor power swings do not touch relay characteristic (narrow at the bottom).

With modern static relays, a very wide choice of relay characteristic and settings are available. The choice is made on the basis of application requirements.

QUESTIONS

1. Describe the principle of impedance type distance relay and explain its characteristic on V-I and R-X planes.
2. Derive expressions for torque developed by a double activating quantity distance relay. Show that the relay operates when fault is within the protected distance of line.

3. Explain the Directional Impedance relay by means of its characteristic on R-X plane.
4. Write short notes on :
   — Reactance Relay — Mho Relay — Directional Impedance Relay
5. Explain the principle of following distance characteristics with the help of R-X diagram.
   — Plain impedance characteristics. — Directional impedance characteristics
   — Plain Reactance characteristics — Mho characteristics
   — Offset Mho characteristic
6. Define the following terms and explain their significance in distance protection.
   — Reach of a distance relay — Under-reach
7. Explain how the arc resistance introduces an error in distance measurement.

Refer Sec. 42.13 and Sec 42.14 for examples on setting of Distance Relays.

Refer Ch. 42 for static distance relays.

Refer Ch. 30 for Sec. 30.8 to 30.16 for applications of distance relays.