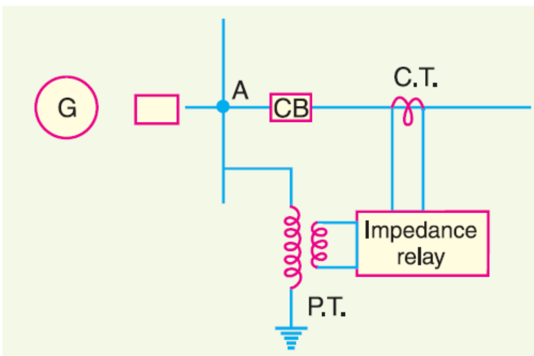
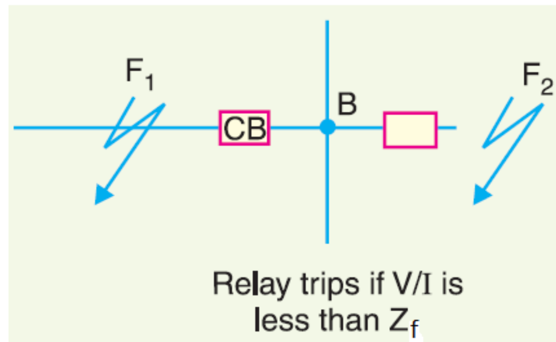
EEE4227: POWER SYSTEM PROTECTION
TERM: FINAL-TERM

Lecture 10
Distance protection

Distance protection

- Distance protection is a general term in which relaying devices measure the impedance or reactance of the line both of which are proportional to distance between measuring point and the fault.





Distance protection

- The ratio of $\frac{V}{I}$ is measured at the relay location, i.e. at the location of CT and PT.
- If the fault is nearer to the relay location, voltage at the relay point is lesser and opposite happens when the fault is further from the relay point.

- Application-
  - Long high voltage transmission line
  - Becoming popular, in a modified form, on lines operating at 66 kV, 33 kV and even 11 kV.

Types of distance relay

- Three types available-
  - Impedance relay
  - Reactance relay
  - Admittance relay

Impedance relay

- Equation of torque-

The ratio of voltage and current across a branch gives impedance of the branch.

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

The current gives the operating torque and the voltage gives the restraining torque.
The general equation torque equation of an impedance relay is-

$$T = K_1 I^2 - K_2 V^2 - K_3$$

At threshold, $T=0$

$$K_2 V^2 = K_1 I^2 - K_3$$

$$\frac{V^2}{I^2} = \frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}$$

Where,
T= net torque
$K_1 I^2$= operating torque
$K_2 V^2$= retraining torque
K_3= effect of control spring

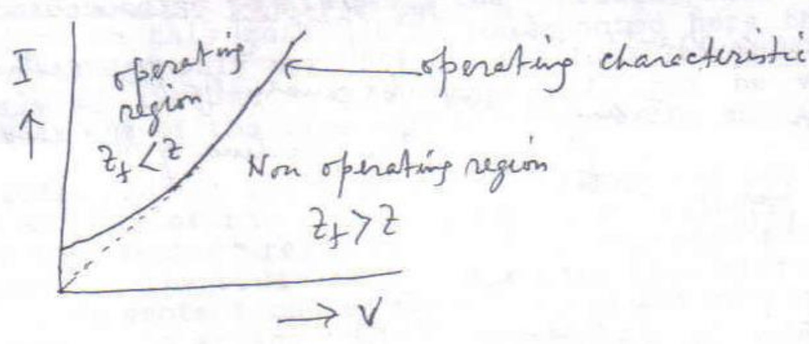
Torque equation

If the effect of control spring is neglected then,

$$\frac{V}{I} = Z = \sqrt{\frac{K_1}{K_2}} = \text{constant}$$

- ❖ Relay will operate if fault impedance Zf ($\frac{\mathrm{Vf}}{\mathrm{If}}$) is less than $Z = \sqrt{\frac{K_1}{K_2}}$ = constant
- ❖ Relay will not operate if fault impedance Zf ($\frac{\mathrm{Vf}}{\mathrm{If}}$) is greater than $Z = \sqrt{\frac{K_1}{K_2}}$ = constant

Characteristic curve



operating characteristic of an impedance relay

R-X diagram

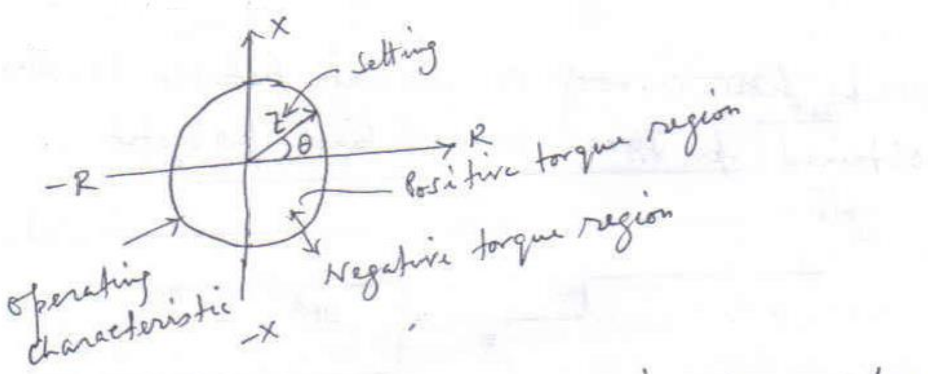


Fig : R-X diagram of an impedance relay

Reach of the relay

- ❖ If the fault path impedance/reactance/admittance is greater than the set value of impedance / reactance /admittance of the relay then the relay would not operate. This setting is known as reach of the relay.
  - ❖ Over reach of the relay
  - ❖ Under reach of the relay

Overreach of the relay

- A distance relay is said to overreach when the impedance presented to it is less than the apparent impedance of the fault.
- Example-
  - Presence of the DC offset in the fault current wave.

Underreach of the relay

- A distance relay is said to overreach when the impedance presented to it is greater than the apparent impedance of the fault.
- Example-
  - Presence of arc resistance in the fault path.

Drawbacks of impedance relay

- It is not directional.
- It is affected by arc resistance.
- It is highly sensitive to power swing.

Above mentioned drawbacks are modified in reactance relay.

Reactance relay

- Measuring unit is reactance.
- Reactance measuring unit has an over current element developing positive torque and a directional element (VIsinϴ) which provides either positive/negative torque.

Torque equation

- Directional unit in the reactance relay is so designed that its maximum torque angle is 90°, i.e. T =90° in the torque equation.

$$T = K_1 I^2 - K_2 VI\cos(\theta - \tau)$$

According to design of the reactance relay

$$\cos(\theta - \tau) = \cos(\theta - 90°) = sin\theta$$

Net torque, $T = K_1 I^2 - K_2 VI\, sin\theta$

On the verge of relay operation T=0

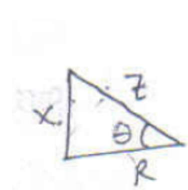
$$K_1 I^2 = K_2 VI\, sin\theta$$

$$\frac{V}{I} sin\theta = \frac{K_1}{K_2}$$

Torque equation

$$Z sin\theta = \frac{K_1}{K_2}$$

Hence, $X = \frac{K_1}{K_2}$

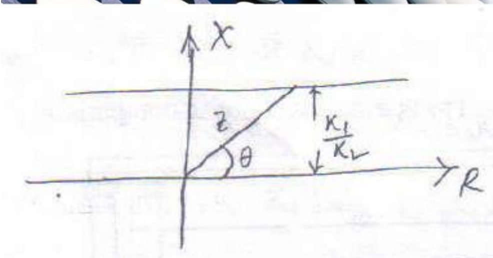


This is the equation of a reactance relay.

For the operation of the relay, $X_f < \frac{K_1}{K_2}$

i.e. relay will operate only if the fault path reactance is less than the set reactance ($X = \frac{K_1}{K_2}$) of the relay.

Characteristics curve of reactance relay

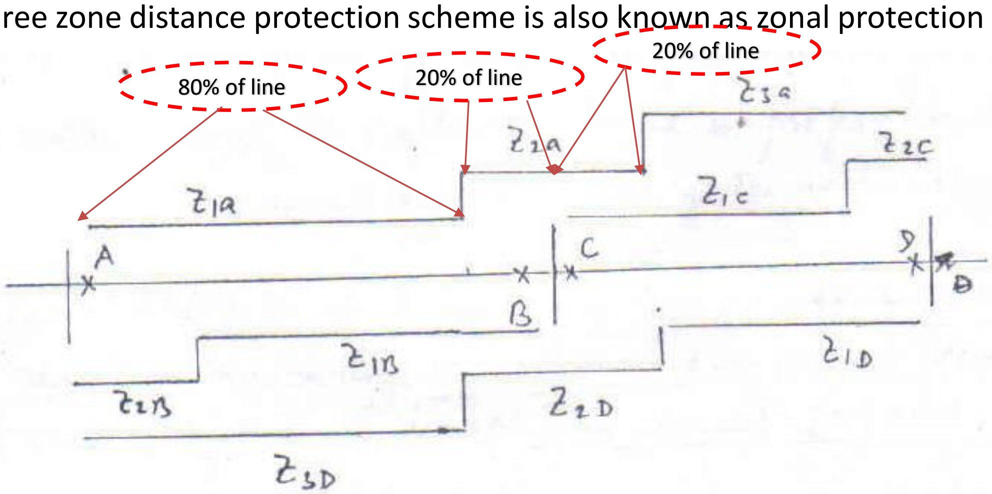


Important points to be noted-

- Resistive component of the impedance on the fault path does not have any affect on the relay operation.
- Relay setting does not vary in the presence of arc resistance

Three zone distance protection scheme by impedance relay

- Three zone distance protection scheme is also known as zonal protection scheme.



Three zone distance protection scheme by impedance relay

Correct co-ordination between distance relays on a power system is obtained by controlling the reach settings and tripping times of the various zones of measurements. A conventional distance protection will comprise an instantaneous directional zone-1 protection and one or more time delayed zones. Typical three zone distance protection scheme is shown in the figure which consists of two line sections AB and CD.

The protection scheme is divided in three zones. Say for relay at A, the three zones are Z1a, Z2a and Z3a. The Z1a represents the reach setting of relay at A for the instantaneous zone-1 protection and corresponds to approximately 80% impedance (length) of the line AB. No intentional time lag is provided for this zone. The ordinate shown corresponding to Z1a gives the operating time when the fault takes place in this zone. It is to be noted here that the first zone is extended only upto 80% and not 100% length of the line AB as the relay impedance measurement will not be very accurate towards the end of the line especially when the current is offset.

Three zone distance protection scheme by impedance relay

Second zone, Z2a for relay at A covers remaining 20% length of the line AB and 20% of the adjoining line i.e. line CD. In case of a fault in this section relay at A will operate when the time elapsed corresponds to the ordinate Z2a. The main idea of the second zone is to provide protection for the remaining 20% section of the line AB. In case of an arcing fault in the 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 in second zone and will operate. This is why the second zone is extended into the adjoining line. The operating time of the second zone is normally about 0.2 to 0.5 seconds.

The 3rd zone unit at relay A provides back up protection for faults in the line CD. That means, if there is a fault in the line CD and if for some reasons the relay at C fails to operate then relay at A will provide back up protection. The delay time for the 3rd zone is usually 0.4 to 1.0 second.

- Reference-
- Topic 30.9,30.9.1,30.9.3,30.13/ Chapter 30/ Switchgear protection and power systems/Sunil S. Rao

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