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5. Case – I

$I_a = 0.7 \angle -172.73°$ kA

$|I_a| = 0.7$ kA > I_{pickup} (= 0.3 kA)

$V_a = 30.65 \angle 88.27°$

wrt I_a, $\angle V_a = -99° < Y$

⇒ Block region

$I_b = 0.71 \angle 65.14°$ kA

$|I_b| = 0.71$ kA > I_{pickup}.

⇒ Block region

$I_c = 0.68 \angle -54.38°$ kA

$|I_c| = 0.68$ kA > I_{pickup}

$V_c = 31.21 \angle -149.93°$ kV

wrt I_c, $\angle V_c = \angle -95.55° < Y$

⇒ Block region

Directional Relay will not operate in this region.

5.

Case-2:

$I_a = 0.07 \angle -94.57°$ kA

$|I_A| = 0.07$ kA $< I_{pickup}$

$\Rightarrow$ Block Region

$I_b = 0.65 \angle -102.82°$ kA

$|I_b| = 0.65$ kA $> I_{pickup}$.

$V_b = 59.23° \angle -92.40$ kV

wrt I_b $\angle V_b = 10.42° < \beta (145°)$

$\Rightarrow$ Trip region

Relay trips.

$I_c = 0.72 \angle 78.04°$ kA

$|I_c| = 0.72$ kA $> I_{pickup}$

$V_c = 60.46 \angle -123.73°$ kV.

wrt I_c, $\angle V_c = 153.23° < \beta (145°)$

$\rightarrow$ Trip Region

Relay trips

$\therefore$ for bcg fault, relay trips.

Expt: 3b

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Case-1

1. Fault Type: Phase-A-ground fault
2. Voltage of Phase A during fault
   $V_a = 235.8\ V\ (rms)$
   Current during fault = $I_a = 18.85\ A$
3. $Z_{app} = \frac{V_a}{I_a + k_0 I_0} = \frac{V_a}{I_a}\ (k_0 = 0) = \frac{235.8}{18.85}\ \Omega = 12.51\ \Omega$
4. Line Impedance $(Z) = (1.7 + j\,28.59)\ \Omega = 28.64 \angle 86.6^\circ\ \Omega$
   Zone 1 setting = 80% $Z_L = 22.91 \angle 86.6^\circ\ \Omega$
   $Z_{app} = 12.51\ \Omega$
   $Z_{app} <$ Zone 1 setting $\Rightarrow$ fault is in zone 1
5. Here relay has tripped for fault
   Relay decision time = 23 ms
   Circuit breaker operation time = 28 ms.
6. Here the relay trips as the fault in zone-1. Apparent Impedance is close to line impedance in normal condition but here it is not the case as the relay has tripped.
   $\frac{Z_{app}}{Z_{line}} = \frac{12.51}{28.64} = 0.437\ \%$

Hence the fault occurred at 44% of the line in zone-1. Also $k_0 = 0$ here as no mutual inductance was taken as zero between lines which is not generally the case in real.

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Case-2

1) Fault type : Phase-C-ground fault

2) $V_c = 237.8\,V$, $I_c = 14.35\,A$

3) $Z_{app} = \frac{V_c}{I_c + k_0 I_0} = \frac{V_c}{I_c} = \frac{237.8}{14.35}\,\Omega = 16.57\,\Omega$

($k_0 = 0$)

4) $Z_{line} = 28.64 \angle 80.6°\,\Omega$

Zone-1 setting = 80% Z_{line} = $22.91 \angle 87°\,\Omega$

$Z_{app} = 16.57\,\Omega$

$Z_{app} < Z_{one\text{-}1\ setting}$

∴ Fault in Zone-1.

5) Relay has tripped for fault

Relay decision time = 35 ms

Circuit breaker operation time = 31 ms

Total time from fault start to fault clearance = 66 ms

6) Discussion:

In this case, the relay trips since the fault in zone-1.

$\frac{Z_{app}}{Z_L} = \frac{16.57}{28.64} = 0.579 \simeq 58\%$

fault occured at 58% of line i.e, in zone-1. Here $k_0 = 0$ as the lines are not mutually coupled here.

The relay takes 35 ms to decide and circuit breaker breaks in 31 ms, so total time taken in trip = 66 ms.

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8.)

PT ratio = 132kV/110V.

Zapp referred to secondary side = 4.25Ω

Zapp referred to primary =

$$= 4.25 \times \frac{132\times10^3}{110} \times \frac{1}{500}\,\Omega = 51\,\Omega$$

Total line impedance is Z_L.

$$= (0.03 + 0.3j) \times 250$$

$$= 75.37\angle 84.3^\circ\ \Omega$$

Zone-1 setting = $80\% \text{ of } Z_L = 60.3\angle 84.3^\circ\ \Omega$

$Z_{app} < \text{Zone-1-setting}$

$\therefore$ fault is in zone-1.