EE-465 (Term 162)

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Solution of HW4

10.1 Using Eq. (10.2.1):

$$V' = \frac{1}{n}V = \frac{345\times 10^3}{3000} = \underline{\underline{115\ \text{V}}}\ \text{(line-to-line)}$$

$$I = \frac{S_{3\phi}}{\sqrt{3}\,V_{LL}} = \frac{600.\times 10^6}{(\sqrt{3})(345\times 10^3)} = 1004\ \text{A}$$

From Eq. (10.2.2), $I_e = 0$ for zero CT error. Then, from Figure 10.7:

$$I' + I_e = I' + 0 = \frac{1}{n}I = \left(\frac{5}{1200}\right)(1004)$$

$$\underline{\underline{I' = 4.184\ \text{A}}}$$

10.3 From Figure 10.8, the secondary resistance $Z' = 0.125\,\Omega$ for the 200:5 CT.

(a) Step (1) – $I' = 10$ A

Step (2) – $E = (Z' + Z_B)I' = (0.125+1)(10) = 11.25$ V

Step (3) – From Figure 10.8, $I_e = 0.18$ A

Step (4) – $I = \left(\frac{200}{5}\right)(10+0.18) = \underline{\underline{407.2\ \text{A}}}$

(b) Step (1) – $I' = 10$ A

Step (2) – $E = (Z' + Z_B)I' = (0.125+4)(10) = 41.25$ V

Step (3) – From Figure 10.8, $I_e = 1.5$ A

Step (4) •– $I = \left(\frac{200}{5}\right)(10+1.5) = \underline{\underline{460\ \text{A}}}$

(c) Step (1) – $I' = 10.$ A

Step (2) – $E = (Z' + Z_B)I' = (0.125+5)(10) = 51.25$ V

Step (3) – From Figure 10.8, $I_e = 30$ A

Step (4) – $I = \left(\frac{200}{5}\right)(10+30) = \underline{\underline{1600\ \text{A}}}$

10.7 **(a)** The current tap setting (pickup current) is $I_p = 1.0$ A.

$\frac{I'}{I_p} = \frac{10}{1} = 10.$ From curve ½ in Figure 10.12

$t_{operating} = \underline{\underline{0.08}}$ s

(b) $\frac{I'}{I_p} = \frac{10}{2} = 5.$ Interpolating between curve 1 and curve 2 in Figure 10.12, $t_{operating} = \underline{\underline{0.55}}$ s

(c) $\frac{I'}{I_p} = \frac{10}{2} = 5.$ From curve 7, $t_{operating} = \underline{\underline{3\text{ s}}}$

(d) $\frac{I'}{I_p} = \frac{10}{3} = 3.33$ From curve 7, $t_{operating} = \underline{\underline{5.2\text{ s}}}$

(e) $\frac{I'}{I_p} = \frac{10}{12} < 1$. The relay does not operate. It remains in the blocking position.

10.11 **(a)** For the 700. A fault current at bus 3, fault-to-pickup current ratios and relay operating times are:

$$\text{B3:}\ \frac{I'_{3fault}}{TS3} = \frac{700/(200/5)}{3} = \frac{17.5}{3} = 5.83$$

From curve ½ of Figure 10.12, $t_{operating3} = 0.10$ seconds. Adding the breaker operating time, primary protection clears this fault in $(0.10 + 0.083) = 0.183$ seconds.

$$\text{B2:}\ \frac{I'_{2fault}}{TS2} = \frac{700/(200/5)}{5} = \frac{17.5}{5} = 3.5$$

From curve 2 in Figure 10.12, $t_{operating2} = 1.3$ seconds. The coordination time interval between B3 and B2 is $(1.3 - 0.183) = 1.12$ seconds.

(b) For the 1500-A fault current at bus 2:

$$\text{B2:}\ \frac{I'_{2fault}}{TS2} = \frac{1500/(200/5)}{5} = \frac{37.5}{5} = 7.5$$

From curve 2 of Figure 10.12, $t_{operating2} = 0.55$ seconds. Adding the breaker operating time, primary protection clears this fault in $(0.55 + 0.083) = 0.633$ seconds.

$$\text{B1:}\ \frac{I'_{1fault}}{TS1} = \frac{1500/(400/5)}{5} = \frac{18.75}{5} = 3.75$$

From curve 3 of Figure 10.12, $t_{operating1} = 1.8$ seconds. The coordination time interval between B2 and B1 is $(1.8 - 0.633) = 1.17$ seconds.

Fault-to-pickup ratios are all > 2.0

Coordination time intervals are all > 0.3 seconds.

10.15 (a) Three-phase permanent fault on the load side of bus 3.

From Table 10.7, the three-phase fault current at bus 3 is 2000 A. From Figure 10.19, the 560 A fast recloser opens 0.04 s after the 2000 A fault occurs, then recloses ½ s later into the permanent fault, opens again after 0.04 s, and recloses into the fault a second time after a 2 s delay. Then the 560 A delayed recloser opens 1.5 s later. During this time interval, the 100 T fuse clears the fault. The delayed recloser then recloses 5 to 10 s later, restoring service to loads 1 and 2.

(b) Single line-to-ground permanent fault at bus 4 on the load side of the recloser. From Table 10.7, the IL-G fault current at bus 4 is 2600 A. From Figure 10.19, the 280 A fast recloser (ground unit) opens after 0.034 s, recloses ½ s later into the permanent fault, opens again after 0.034 s, and recloses a second time after a 2 s delay. Then the 280 A delayed recloser (ground unit) opens 0.7 s later, recloses 5 to 10 s later, then opens again after 0.7 s and permanently locks out.

(c) Three-phase permanent fault at bus 4 on the source side of the recloser. From Table 10.7, the three-phase fault at bus 4 is 3000 A. From Figure 10.19, the phase overcurrent relay trips after 0.95 s, thereby energizing the circuit breaker trip coil, causing the breaker to open.

10.17 (a) For a fault of P_1, only breakers B34 and B43 operate; the other breakers do not operate. B23 should coordinate with B34 so that B34 operates before B23 (and before B12, and before B1). Also, B4 should coordinate with B43 so that B43 operates before B4.

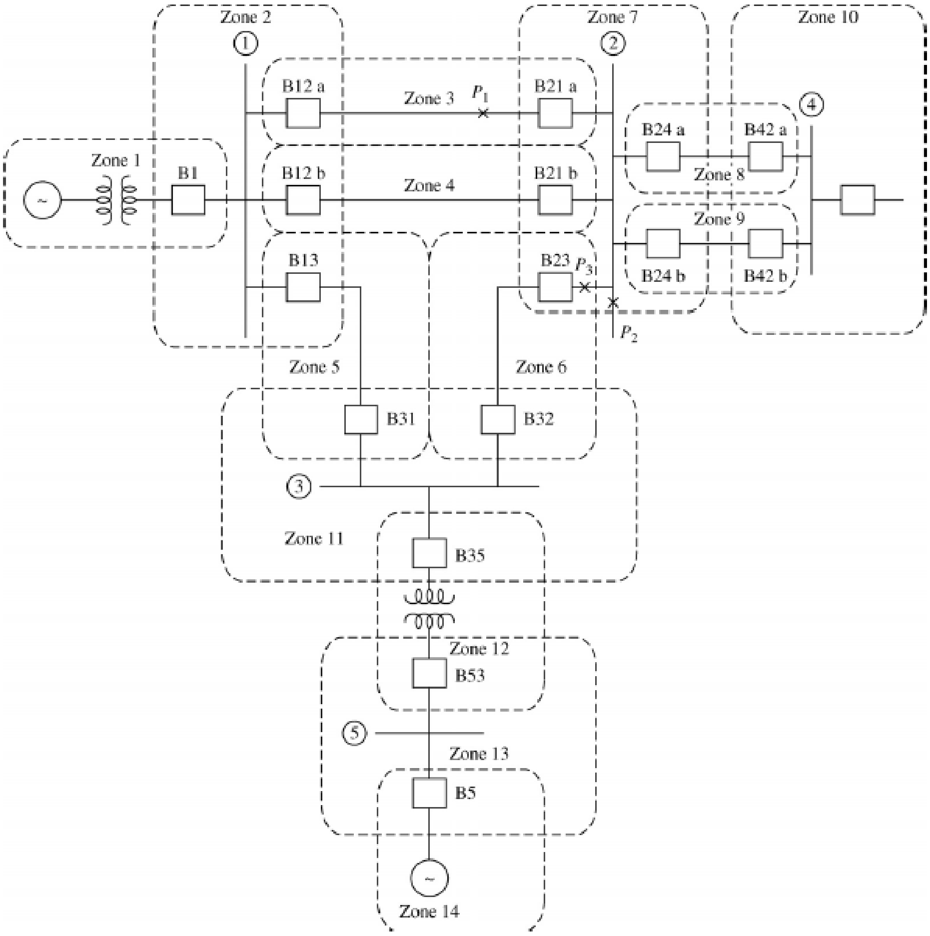
(b) For a fault of P_2, only breakers B23 and B32 operate; the other breakers do not operate. B12 should coordinate with B23 so that B23 operates before B12 (and before B1). Also B43 should coordinate with B32 so that B32 operates before B43 (and before B4).

(c) For a fault of P_3, only breakers B12 and B21 operate; the other breakers do not operate. B32 should coordinate with B21 so that B21 operates before B32 (and before B43, and before B4). Also, B1 should coordinate with B12 so that B12 operates before B1.

(d)

Fault Bus	Operating Breakers
1	B1 and B21
2	B12 and B32
3	B23 and B43
4	B4 and B34

10.18



(**a**) For a fault at P_1, breakers in zone 3 operate (B12a and B21a).

(**b**) For a fault at P_2, breakers in zone 7 operate (B21a, B21b, B23, B24a, B24b).

(**c**) For a fault at P_3, breakers in zone 6 and zone 7 operate (B23, B32, B21a, B21b, B24a, and B24b).

10.20 **(a)** $\bar{Z}' = \frac{V'_{LN}}{I'_L} = \frac{V_{LN}/(4500/1)}{I_L/(1500/5)} = \left(\frac{V_{LN}}{I_L}\right)\frac{1}{15}$

$$\bar{Z}' = \frac{\bar{Z}}{15}$$

Set the B12 zone 1 relay for 80% reach of line 1–2:

$Z_{r1} = 0.8(6 + j60)/15 = \underline{\underline{0.32 + j3.2}}\ \Omega$ secondary

Set the B12 zone 2 relay for 120% reach of line 1–2:

$Z_{r2} = 1.2(6 + j60)/15 = \underline{\underline{0.48 + j4.8}}\ \Omega$ secondary

Set the B12 zone 3 relay for 100% reach of line 1–2 and 120% reach of line 2–3:

$Z_{r3} = 1.0(6 + j60)/15 + 1.2(5 + j50)/15 = \underline{\underline{0.8 + j8.0}}\ \Omega$ secondary

(b) The secondary impedance viewed by B12 during emergency loading is:

$$\bar{Z}' = \left(\frac{\bar{V}_{LN}}{\bar{I}_L}\right)\left(\frac{1}{15}\right) = \left(\frac{\frac{500}{\sqrt{3}}\angle 0^\circ}{1.4\angle -\cos^{-1}0.9}\right)\frac{1}{15} = 13.7\angle 25.8^\circ\ \Omega$$

$\bar{Z}'$ exceeds the zone 3 setting of $(0.8 + j8.0) = 8.04\ \angle 84.3^\circ\ \Omega$ for B12. Hence, the impedance during emergency loading lies outside the trip region of this 3-zone mho relay (see Figure 10.29 (b)).