EE493 Protection of Power Systems I

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slides 5-14 are from Chapter 10, pages 533-541, of "Power System Analysis and Design", Fifth Edition, 2012, J. D. Glover, M. S. Saema, T. J. Overbye

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Introduction

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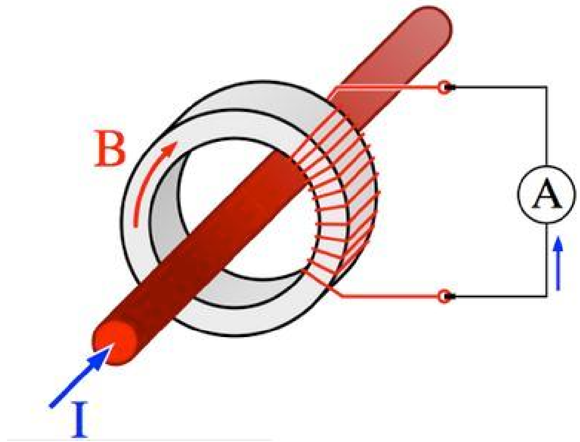
Current Transformer (CT)



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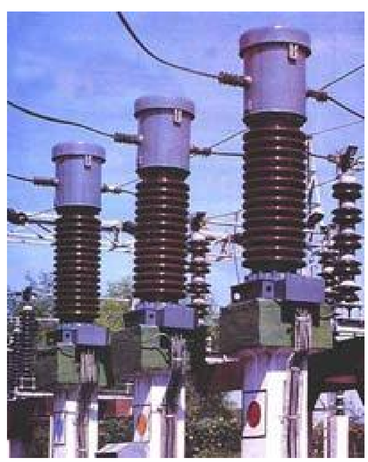

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Standard CT ratios

Current Ratios						
50:5	100:5	150:5	200:5	250:5	300:5	400:5
450:5	500:5	600:5	800:5	900:5	1000:5	1200:5
1500:5	1600:5	2000:5	2400:5	2500:5	3000:5	3200:5
4000:5	5000:5	6000:5				

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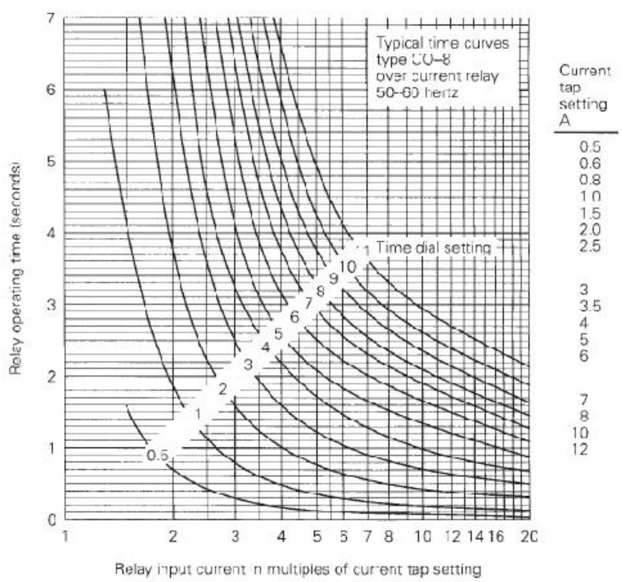
OVERCURRENT RELAYS



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Operating time for a CO-8 time-delay overcurrent relay

The CO-8 relay with a current tap setting of 6 amperes and a time-dial setting of 1 is used. Determine the relay operating time for each case.

$$I = 5\text{ A} \quad I = 8\text{ A} \quad I = 15\text{ A}$$

Solution

First the given current should be presented in per unit which means the given current should be divided by Current Tap Setting (which is considered as the base value). Then, the associated relay operation time for the given current in per-unit is determined according to the curve of the relay (here is curve #1)

a. From

$$I = 5\text{ A} \qquad \frac{I}{I_p} = \frac{5}{6} = 0.83$$

The relay does not operate. It remains in the blocking position.

b.

$$I = 8\text{ A} \qquad \frac{I}{I_p} = \frac{8}{6} = 1.33$$

Using curve 1, $t_{operating} = 6$ seconds.

c.

$$I = 15\text{ A} \qquad \frac{I}{I_p} = \frac{15}{6} = 2.5$$

From curve 1, $t_{operating} = 1.2$ seconds.

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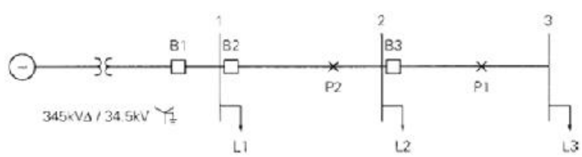
RADIAL SYSTEM PROTECTION

Select current tap settings (TSs) and time-dial settings (TDSs) to protect the system from faults. Assume three CO-8 relays for each breaker, with a 0.3-second coordination time interval.

Assume a 34.5-kV (line-to-line) voltage at all buses during normal operation



Maximum loads:

Bus	S MVA	Lagging p.f.
1	11.0	0.95
2	4.0	0.95
3	6.0	0.95

Bus	Maximum Fault Current (Bolted Three-Phase) A
1	3000
2	2000
3	1000

Notice that bus means substation. Breakers are located inside substations. For example, B3 is located inside bus 2 (i.e. substation 2). Therefore, the maximum short circuit current that B3 sees is equal to maximum fault current at Bus 2

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Breaker, CT, and relay data

Breaker	Breaker Operating Time	CT Ratio	Relay
B1	5 cycles	400:5	CO-8
B2	5 cycles	200:5	CO-8
B3	5 cycles	200:5	CO-8

Maximum loads

Bus	S MVA	Lagging p.f.
1	11.0	0.95
2	4.0	0.95
3	6.0	0.95

fault currents

Bus	Maximum Fault Current (Bolted Three-Phase) A
1	3000
2	2000
3	1000

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SOLUTION First, select TSs such that the relays do not operate for maximum load currents. Starting at B3, the primary and secondary CT currents for maximum load L3 are

$$I_{L3} = \frac{S_{L3}}{V_3\sqrt{3}} = \frac{6 \times 10^6}{(34.5 \times 10^3)\sqrt{3}} = 100.4 \text{ A}$$

$$I'_{L3} = \frac{100.4}{(200/5)} = 2.51 \text{ A}$$

From Figure 10.12, we select for the B3 relay a 3-A TS, which is the lowest TS above 2.51 A.

Note that $|S_{L2} + S_{L3}| = |S_{L2}| + |S_{L3}|$ because the load power factors are identical. Thus, at B2, the primary and secondary CT currents for maximum load are

$$I_{L2} = \frac{S_{L2} + S_{L3}}{V_2\sqrt{3}} = \frac{(4+6) \times 10^6}{(34.5 \times 10^3)\sqrt{3}} = 167.3 \text{ A}$$

$$I'_{L2} = \frac{167.3}{(200/5)} = 4.18 \text{ A}$$

From Figure 10.12, select for the B2 relay a 5-A TS, the lowest TS above 4.18 A. At B1,

$$I_{L1} = \frac{S_{L1} + S_{L2} + S_{L3}}{V_1\sqrt{3}} = \frac{(11+4+6) \times 10^6}{(34.5 \times 10^3)\sqrt{3}} = 351.4 \text{ A}$$

$$I'_{L1} = \frac{351.4}{(400/5)} = 4.39 \text{ A}$$

Select a 5-A TS for the B1 relay.

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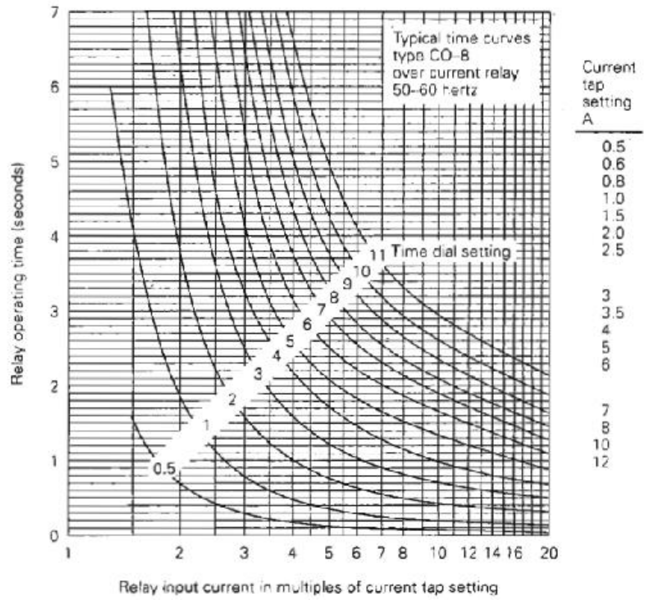

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Starting at B3, the largest fault current through B3 is 2000 A, which occurs for the three-phase fault at bus 2 (just to the right of B3). Neglecting CT saturation, the fault-to-pickup current ratio at B3 for this fault is

$$\frac{I'_{3Fault}}{TS3} = \frac{2000/(200/5)}{3} = 16.7$$

Since we want to clear faults as rapidly as possible, select a 1/2 TDS for the B3 relay. Then, from the 1/2 TDS curve in Figure 10.12, the relay operating time is $T3(16.7) = 0.05$ seconds. Adding the breaker operating time (5 cycles = 0.083 s), primary protection clears this fault in $T3(16.7) + T_{breaker} = 0.05 + 0.083 = 0.133$ seconds.

For this same fault, the fault-to-pickup current ratio at B2 is

$$\frac{I'_{2Fault}}{TS2} = \frac{2000/(200/5)}{5} = 10.0$$

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Adding the B3 relay operating time ($T3(16.7) = 0.05$ s), breaker #3 operating time (0.083 s), and 0.3 s coordination time interval, we want a B2 relay operating time

$$T2(10.0) = T3(16.7) + T_{breaker} + T_{coordination} = 0.05 + 0.083 + 0.3 \approx 0.43 \text{ s}$$

From Figure 10.12, select TDS2 = 2.

Next select the TDS at B1. The largest fault current through B2 is 3000 A, for a three-phase fault at bus 1 (just to the right of B2). The fault-to-pickup current ratio at B2 for this fault is

$$\frac{I'_{2Fault}}{TS2} = \frac{3000/(200/5)}{5} = 15.0$$

From the 2 TDS curve in Figure 10.12, $T2(15.0) = 0.38$ s. For this same fault

$$\frac{I'_{1Fault}}{TS1} = \frac{3000/(400/5)}{5} = 7.5$$

$$T1(7.5) = T2(15.0) + T_{breaker} + T_{coordination} = 0.38 + 0.083 + 0.3 \approx 0.76 \text{ s}$$

From Figure 10.12, select TDS1 = 3. The relay settings are shown

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Breaker	Relay	TS	TDS
B1	CO-8	5	3
B2	CO-8	5	2
B3	CO-8	3	1/2

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