

Relay Coordination: Step-by-Step Numerical Calculations

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1. Fault Parameters from System

- Fault Location: Bus_6
- Fault Type: 3-Phase Symmetrical
- Fault Current from ETAP: $I_f = 2.372$ kA
- Relay Involved: Relay3 (Inverse Time Overcurrent)
- Relay Trip Time: $T_r = 99.4$ ms
- Circuit Breaker Trip Time: $T_{cb} = 83.3$ ms

2. Overcurrent Protection Type

Protection is based on the IEEE Inverse Time Overcurrent Relay Equation (Type: Standard Inverse):

$$T = \frac{K}{\left(\left(\frac{I_f}{I_{\text{pickup}}} \right)^P - 1 \right)}$$

Where:

- T : Operating time (seconds)
- I_f : Fault current seen by relay (in multiples of pickup current)
- I_{pickup} : Pickup current setting of the relay
- K, P : Relay constants (from IEEE standard or manufacturer data)

Assume:

- $K = 0.14, P = 0.02$ (standard inverse settings)

- $I_{\text{pickup}} = 1.2 \text{ kA}$
- $I_f = 2.372 \text{ kA}$

3. Relay Operating Time Calculation

Calculate fault current in multiples of pickup:

$$M = \frac{I_f}{I_{\text{pickup}}} = \frac{2.372}{1.2} = 1.9767$$

Substitute into the inverse time formula:

$$T = \frac{0.14}{(1.9767^{0.02} - 1)} = \frac{0.14}{(1.0138 - 1)} = \frac{0.14}{0.0138} = 10.14 \text{ seconds}$$

Note: Actual relay trip time from ETAP is given as $T_r = 99.4 \text{ ms}$, which corresponds to a lower I_{pickup} , or modified relay time dial setting. ETAP likely uses an adjusted or manufacturer-specific curve.

4. Circuit Breaker Operation

Circuit breaker trip time is given as:

$$T_{\text{cb}} = 83.3 \text{ ms}$$

This indicates:

- CB1 and CB2 are faster than the backup relay trip.
- Relay3 acts as backup and records the trip condition.
- Coordination ensures CB operates first to minimize outage area.

5. Relay Coordination Logic

1. Fault occurs at Bus_6.
2. Fault current $I_f = 2.372 \text{ kA}$ flows.
3. Relay3 detects the current and begins timing.
4. Circuit breakers CB1 and CB2 isolate the fault after 83.3 ms.
5. Relay3 logs or communicates the fault after 99.4 ms if CBs fail.
6. Coordination margin $= 99.4 - 83.3 = 16.1 \text{ ms}$ ensures selectivity.

6. Conclusion

Relay3 and CBs are properly coordinated:

- The CBs operate first to clear the fault quickly.
- Relay trip time is delayed to act as backup.
- The inverse-time overcurrent logic provides time-grading with other protection devices.