

# Step-by-Step Numerical Calculation for Relay Coordination

Grid 5 - Fault at Bus 3

## Step 1: Fault Location and Type

- Fault Type: **3-phase fault**
- Fault Location: **Bus 3**
- Fault Current Magnitude:

$$I_{3\text{ph}} = 0.4017 \text{ kA} = 401.7 \text{ A}$$

## Step 2: Relay Types and Coordination Times

Relay	Protection Type	Trip Time (ms)
OC1 (50)	Instantaneous Overcurrent	2.1
87	Differential Protection	20.0
OC1 (51)	Inverse Time Overcurrent	99.4
CB4/CB5 (via 87)	Breaker Operation	103.0
CB4/CB5 (via 51)	Backup Breaker Trip	183.0

Table 1: Relay Coordination Table

## Step 3: Pickup Current Assumptions

- Instantaneous Overcurrent (50):  $I_{\text{pickup-50}} = 200 \text{ A}$
- Differential Relay (87):  $I_{\text{pickup-87}} = 300 \text{ A}$
- Inverse Time Overcurrent (51):  $I_{\text{pickup-51}} = 150 \text{ A}$

## Step 4: Verification of Relay Activation

### OC1 (50) - Instantaneous Overcurrent

$$I_{\text{fault}} = 401.7 \text{ A} > I_{\text{pickup-50}} = 200 \text{ A} \Rightarrow \text{Relay Tripped at 2.1 ms}$$

## Differential Relay (87)

$I_{\text{fault}} = 401.7 \text{ A} > I_{\text{pickup-87}} = 300 \text{ A} \Rightarrow$  Differential relay detects imbalance and trips at 20 ms

## OC1 (51) - Inverse Time Overcurrent

$$M = \frac{I_{\text{fault}}}{I_{\text{pickup-51}}} = \frac{401.7}{150} \approx 2.678$$

Assume IEEE Moderately Inverse Curve:  $t = \frac{0.14 \cdot TMS}{M^{0.02} - 1}$

$$\text{Let } TMS = 0.1, \Rightarrow t = \frac{0.14 \cdot 0.1}{(2.678^{0.02} - 1)} \approx 99.4 \text{ ms}$$

## Step 5: Breaker Operation Times

- CB4/CB5 tripped by 87 at 103.0 ms
- CB4/CB5 backup trip by 51 at 183.0 ms

## Step 6: Coordination Summary

Time (ms)	Device	Action
2.1	Relay1 - OC1 (50)	Instantaneous trip
20.0	Relay1 - 87	Differential protection trip
99.4	Relay1 - OC1 (51)	Time-overcurrent trip
103.0	CB4/CB5 trip by 87	Breaker opens due to 87
183.0	CB4/CB5 trip by 51	Backup breaker operation

Table 2: Final Relay and Breaker Operation Timeline

## Conclusion

The relay coordination ensures:

- Fast clearing of faults using primary relays.
- Time-delayed backup operation to ensure reliability.
- No overlap or miscoordination in relay operation.