Relay Coordination Calculation for Bus 5

System Information

- Fault Type: 3-Phase Solid Fault
- Location: Bus 5
- Fault Current (RMS): $I_{\text{rms}} = 9.746\,\text{kA}$
- Frequency: $f = 50\,\text{Hz}$
- Relay Operation Times:
  - Relay2: 20.0 ms
  - T1_HS2: 83.3 ms
  - T1_LS2: 83.3 ms
- Breaker Clearing Time: 83.3 ms

Step-by-Step Numerical Calculations

Step 1. Fault Type and Location: A solid 3-phase fault is assumed at Bus 5, meaning all three phases are shorted with negligible fault impedance ($Z_f = 0$).

Step 2. Given Fault Current (RMS): From MATLAB simulation,

$$I_{\text{rms}} = 9.746\,\text{kA}$$

Step 3. Peak Fault Current:

$$I_{\text{peak}} = \sqrt{2} \cdot I_{\text{rms}} = \sqrt{2} \cdot 9.746 \approx 13.78\,\text{kA}$$

Step 4. Fault Current Expression:

$$I(t) = I_{\text{peak}} \cdot \sin(2\pi f t) = 13.78 \cdot \sin(2\pi \cdot 50 \cdot t)$$

Step 5. Relay2 Operation at 20 ms: Relay2 is the primary protection. Although instantaneous current at $t = 20$ ms is:

$$I(0.02) = 13.78 \cdot \sin(2\pi \cdot 50 \cdot 0.02) \approx -0.048\,\text{kA}$$

This value is near zero due to waveform crossing, but relays trip based on RMS value, not instantaneous.

Step 6. Backup Relays T1_HS2 and T1_LS2: These relays provide backup with delay. They operate at:

$$t = 83.3\,\text{ms}$$

Delay margin:

$$\Delta T = 83.3 - 20.0 = 63.3\,\text{ms}$$

Step 7. Breaker Clears Fault: After relay detection, breaker operates at 83.3 ms to isolate the fault.

$$I(t > 83.3\,\text{ms}) = 0$$

Relay Timeline Summary

Event	Time (ms)	Description
Fault Occurrence	0.0	3-phase fault initiated at Bus 5
Relay2 Operation	20.0	Primary protection trips
T1_HS2 Operation	83.3	Backup transformer high-side trips
T1_LS2 Operation	83.3	Backup transformer low-side trips
Breaker Tripping	83.3	Fault is isolated

Relay Coordination Summary Table

Parameter	Value
Bus 5 Fault Current (RMS)	9.746 kA
Peak Fault Current	13.78 kA
Relay2 Operation Time	20.0 ms
T1_HS2 Operation Time	83.3 ms
T1_LS2 Operation Time	83.3 ms
Breaker Clearing Time	83.3 ms

Conclusion

Relay coordination ensures that the primary relay (Relay2) clears the fault at Bus 5 rapidly, while backup relays (T1_HS2 and T1_LS2) are set with appropriate delay. The breaker isolates the fault at 83.3 ms. The maximum 3-phase fault current is 9.746 kA (RMS), with a peak of 13.78 kA. This coordination guarantees system selectivity, protection, and operational reliability.