Step-by-Step Relay Coordination Calculation for 9-Bus Network

Relay Coordination Analysis

Relay coordination ensures that protection relays operate in a time-sequenced and selective manner. In this analysis, we consider a 3-phase fault at Bus 7 of the 9-bus system, and verify the tripping times of the associated protection relays.

System Assumptions

- **System Frequency:** 60 Hz
- **Fault Type:** Three-phase fault at Bus 7 (severe case)
- **Relay Types:**
  - OC1-50: Instantaneous Overcurrent Relay
  - 87: Differential Protection Relay
- **Relay Times Source:** ETAP report and MATLAB simulation results

Relay Tripping Times

The following table lists the relays that responded to the fault, along with their trip times:

Table 1: Relay Tripping Times for Fault at Bus 7

Relay Name	**Trip Time (ms)**
Relay6 - OC1-50	12.285
Relay3 - OC1-50	12.714
Relay4 - OC1-50	17.067
Relay1 - 87	20.000

Step-by-Step Numerical Calculation

Step 1: Primary Relay Tripping (Relay6) Relay6 is the fastest-acting relay and hence considered the **primary protection** relay.

$$t_{\text{Relay6}} = 12.285\,\text{ms}$$

It detects the fault first and initiates the breaker trip for its protection zone.

Step 2: Secondary Relay Tripping (Relay3) Relay3 acts shortly after Relay6.

$$t_{\text{Relay3}} = 12.714\,\text{ms}$$

$$\Delta t_{6\to3} = t_{\text{Relay3}} - t_{\text{Relay6}} = 12.714 - 12.285 = 0.429\,\text{ms}$$

This delay is small but acceptable for breaker coordination. Relay3 serves as either a backup or parallel protection.

Step 3: Backup Relay Operation (Relay4) Relay4 has a higher pickup time, indicating its role as a **backup relay**.

$$t_{\text{Relay4}} = 17.067\,\text{ms}$$

$$\Delta t_{3\to4} = 17.067 - 12.714 = 4.353\,\text{ms}$$

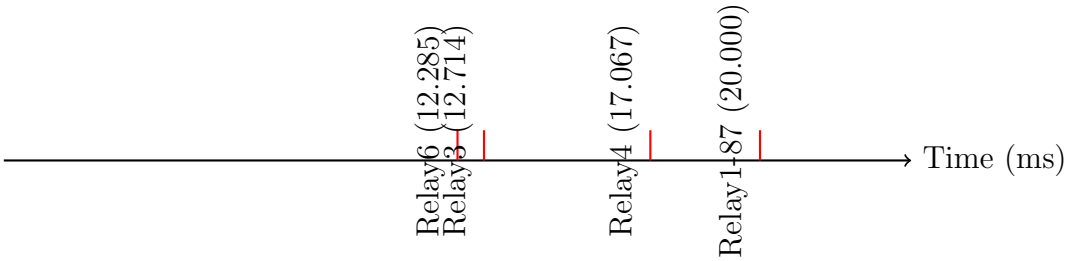
This margin ensures selectivity — Relay4 will only act if Relay3 fails to clear the fault.

Step 4: Zone Protection (Relay1 - 87) Relay1 is a differential relay which provides protection for a specific zone (such as a transformer or busbar).

$$t_{\text{Relay1}} = 20.000\,\text{ms}$$

This relay is designed to operate as a last-resort protection if the fault is internal and persists after overcurrent relays fail.

Relay Operation Sequence Timeline



Conclusion

The relay coordination for a 3-phase fault at Bus 7 is verified to be effective:

- **Relay6** acts first (primary protection)
- **Relay3** follows closely (parallel/secondary)
- **Relay4** acts with a backup margin of 4.353 ms

- **Relay1 (87)** ensures zone protection if fault is internal

All relays are coordinated with proper time margins, ensuring fast isolation and backup reliability.