Bus Protection Considerations for Various Bus Types

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Introduction and Purpose

• Protection complexity and considerations
• Fixed bus types
  ♦ Single bus
  ♦ Breaker and a half
  ♦ Double bus, double breaker
• Configurable bus type – double bus, single breaker
Fundamentals: KCL and Zones

- Kirchhoff’s current law
- Differential zone boundary determined by CTs
Differential Protection

- High-impedance differential relay
- Low-impedance differential relay
- Advanced differential relay
High-Impedance Differential

![High-Impedance Differential Diagram]
High Impedance: CT Saturation

CT saturation creates false differential current

\[ I_R = \frac{R_{\text{LEAD}} + R_{\text{CT}}}{R_{\text{LEAD}} + R_{\text{CT}} + R_R} \cdot I_{\text{SEC}} \]
Low Impedance: Slope Restraint

\[ IOP = \left| \sum_{k=1}^{N} I_k \right| \]

\[ IRT = \sum_{k=1}^{N} |I_k| \]
Advanced Low-Impedance Relay

- Internal fault – IOP ↑ and IRT ↑
- External fault – IOP (no change) and IRT ↑
Single Bus
Overlapping Sectionalizing CTs

Zone 1  Sectionalizing Breaker  Zone 2
Nonoverlapping Sectionalizing CTs
Single Sectionalizing CT

Zone 1

Zone 2
Fault Current After Initial Trips

Zone 1

Zone 2
Breaker Failure Fault Clearing

About 10 Cycles to Clear
Fast Bus Protection

- Radial distribution system applications
- Protection via coordination between main and feeder overcurrent relays
Faulted Radial System

Main

Feeders

F2

F1
Breaker-and-a-Half Configuration
Double-Bus, Double-Breaker Configuration
Double-Bus, Single-Breaker Configuration

- Two buses for load sharing
- One breaker per terminal
- Transfer bus shown
Double Bus, Single Breaker

Bus 1 (Zone 1)
Bus 2 (Zone 2)

F1BB1
F1BB2
I01
I02
I03
I04

Bus Coupler

CBB1
CBB2

TBB1
TBB2

Feeder 1

Double Bus, Single Breaker
Alternate Station Arrangement

Bus 1 (Zone 1)

Bus 2 (Zone 2)

F1BB1
F1BB2

F1LD

Feeder 1
Dynamic Zone Selection

- Zones are formed dynamically based on disconnect switch status
- Microprocessor-based relays can reconfigure zones without changes to physical wiring
Additional Trip Criteria

• Check zone
• Directional element
• Fault voltage signature
Check Zone

Zone 1

Sectionalizing Breaker

Zone 2

Check Zone
Directional Element

- External fault with CT saturation can cause false operating current
- Directional element declares internal fault if all terminal currents are substantially in phase
Directional Element

Zone 1 | Sectionalizing Breaker | Zone 2

Diagram of a system with directional elements and sectionalizing breakers.
Fault Voltage Signature

- V1 ↓ (all faults)
- V0 and V2 ↑ (unbalanced faults)
- No voltage signature indicating whether fault is in zone
Transfer Operation

- Operation allows breaker maintenance without load interruption
- CT position (inboard or outboard) is important during transfer
Inboard
Advanced
Check Zone

Transfer Bus

Bus 1 (Zone 1)

Bus 2 (Zone 2)

89CL04
CTBD

CBB1
TBB1

I02
Bus Coupler

CBB2
TBB2

I03

F1BB1
F1BB2

I01
F1TB

I04
Feeder 1

Feeder 1
Conclusion

• Consider station reliability versus protection complexity
• Determine appropriate relaying based on application
Questions?