

Protecting Distribution Substation Assets – Modern Protection Schemes With Microprocessor-Based Relays

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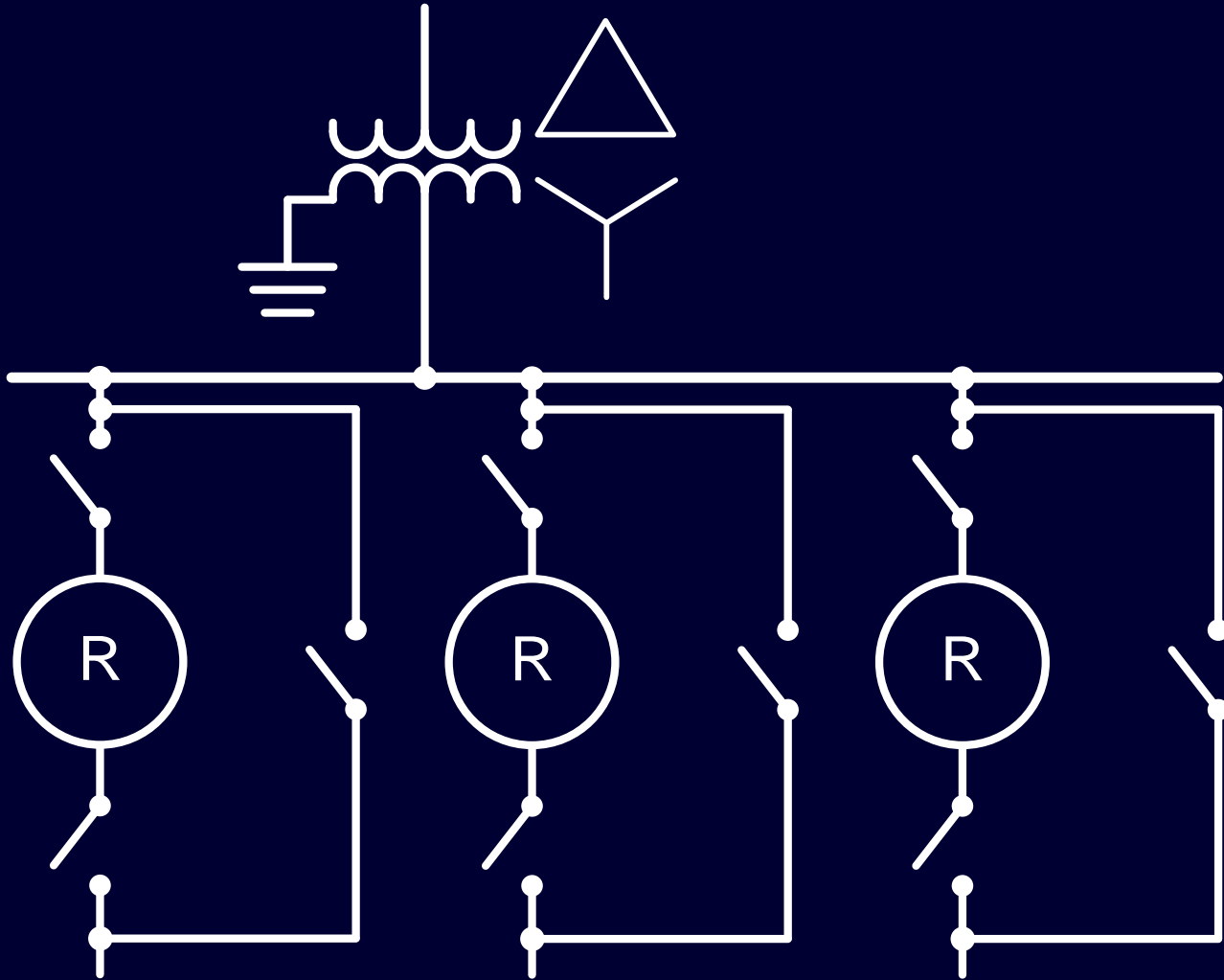
History at Mid-Carolina Electric Cooperative

- Earliest basic scheme
 - ◆ Transformers fused on high side
 - ◆ Hydraulic reclosers on feeders
- First relay scheme
 - ◆ Three electromechanical differential relays – protected transformer only
 - ◆ Four overcurrent relays – limited protection for low-side bus

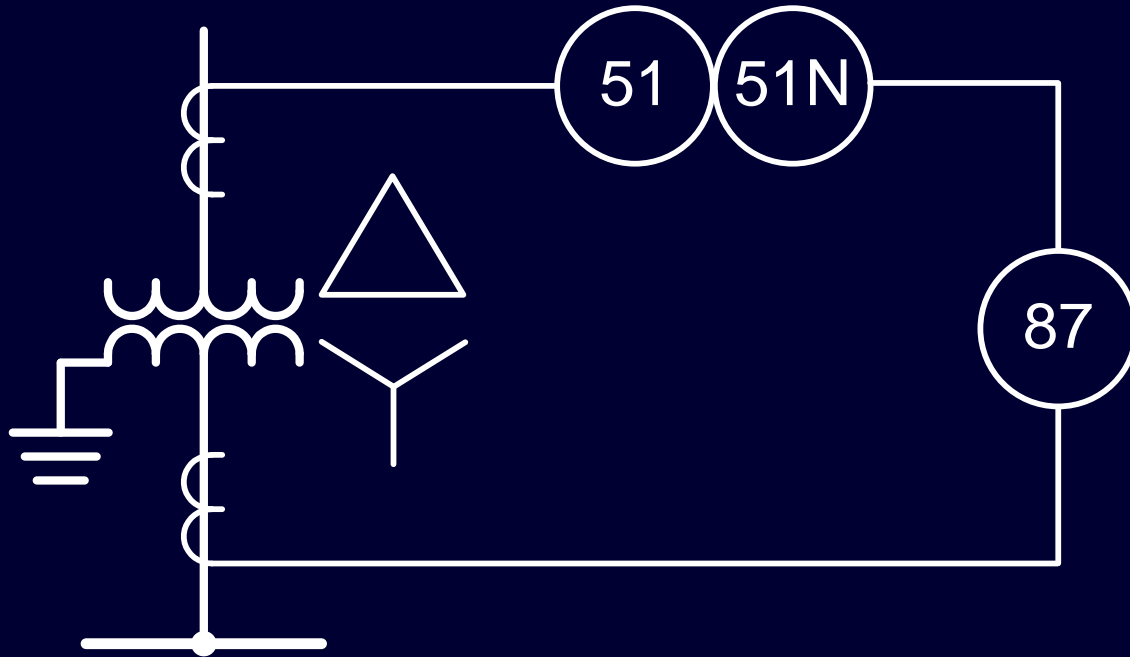
Tandem Switch / Bypass Arrangement

- Hydraulic reclosers replaced with three-phase electronic reclosers
- Bypass switches used fused or solid blade
 - ◆ Fused bypasses were personnel hazard
 - ◆ Solid bypasses did not provide feeder circuit protection for line-to-ground faults

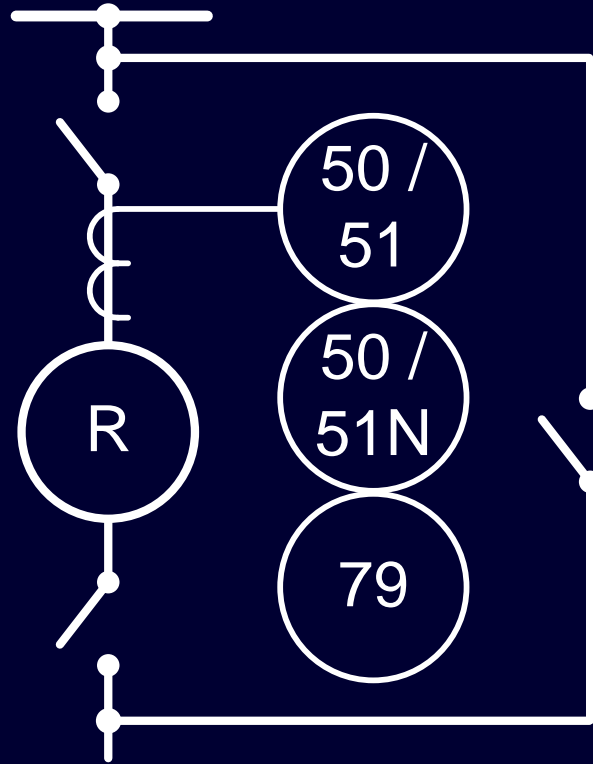
Tandem Switch / Bypass Arrangement



Switch / Bypass Transformer Relays



Switch / Bypass Feeder Relays



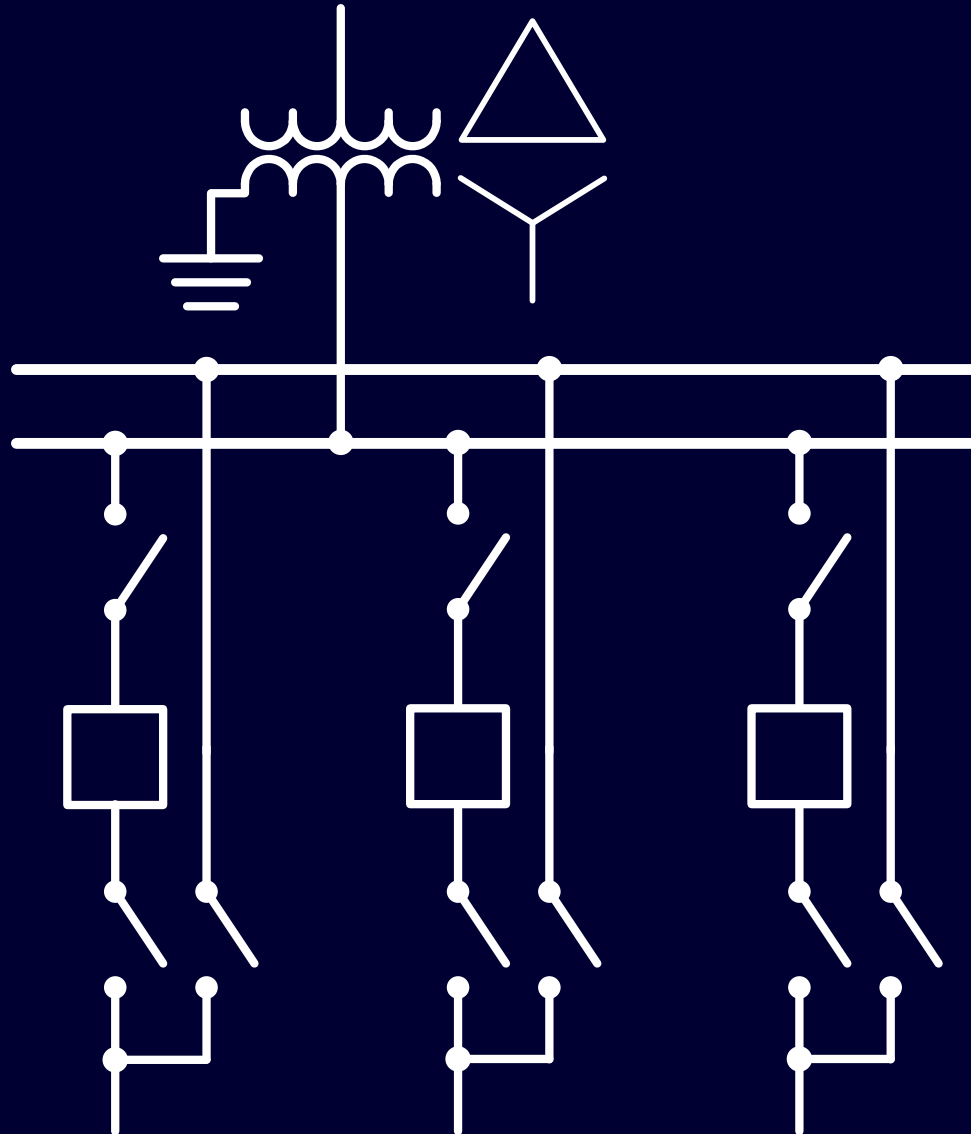
Tandem Switch / Bypass Arrangement



More Recent Applications – Circa 1990

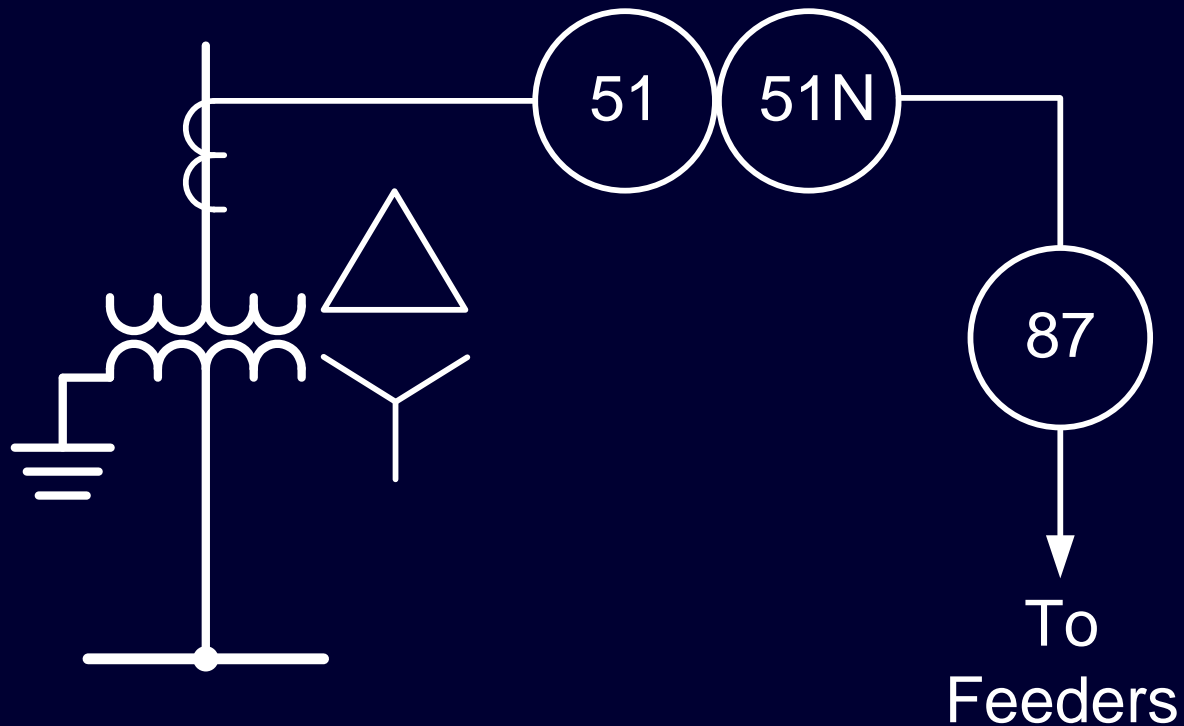
- Electronic reclosers replaced with circuit breakers and reclosing relays
- Main and transfer bus employed to
 - ◆ Enhance personnel safety
 - ◆ Provide protection for line-to-ground faults

Main and Transfer Bus Arrangement



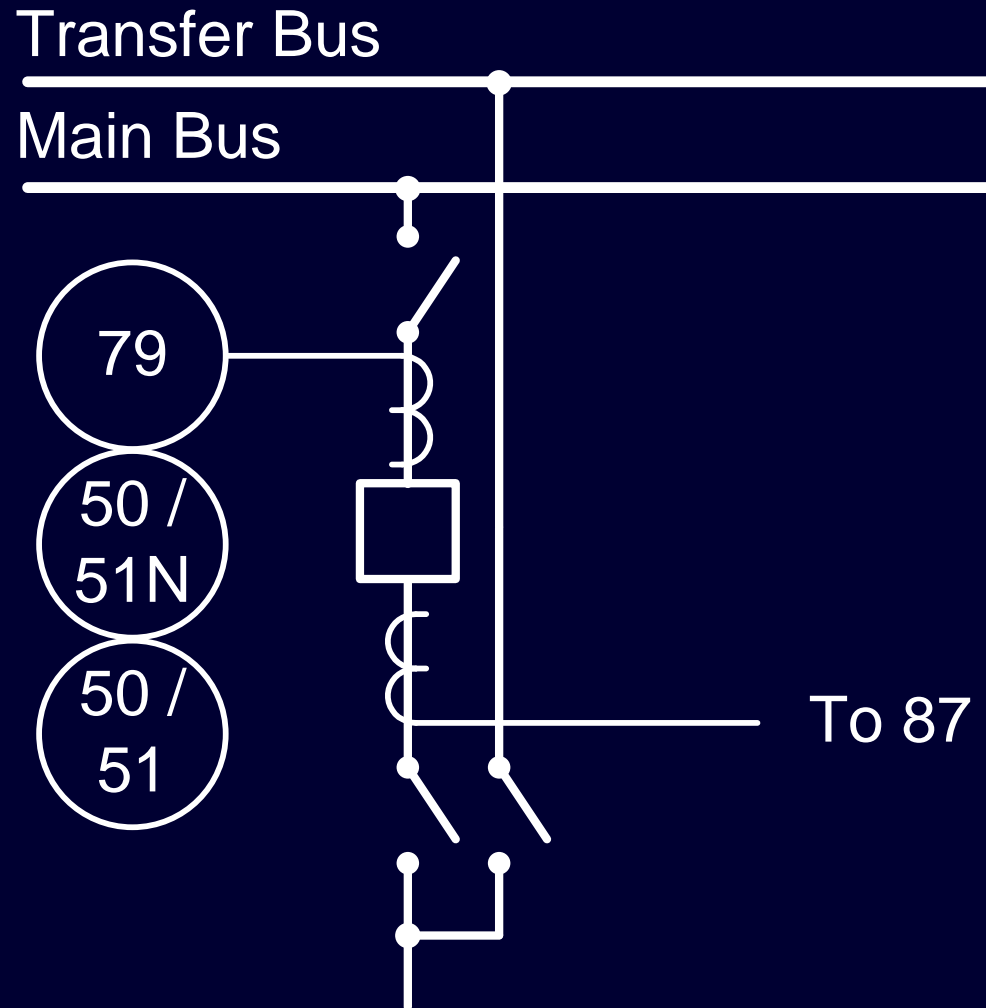
Main and Transfer Bus

Transformer Relays



Main and Transfer Bus

Feeder Relays



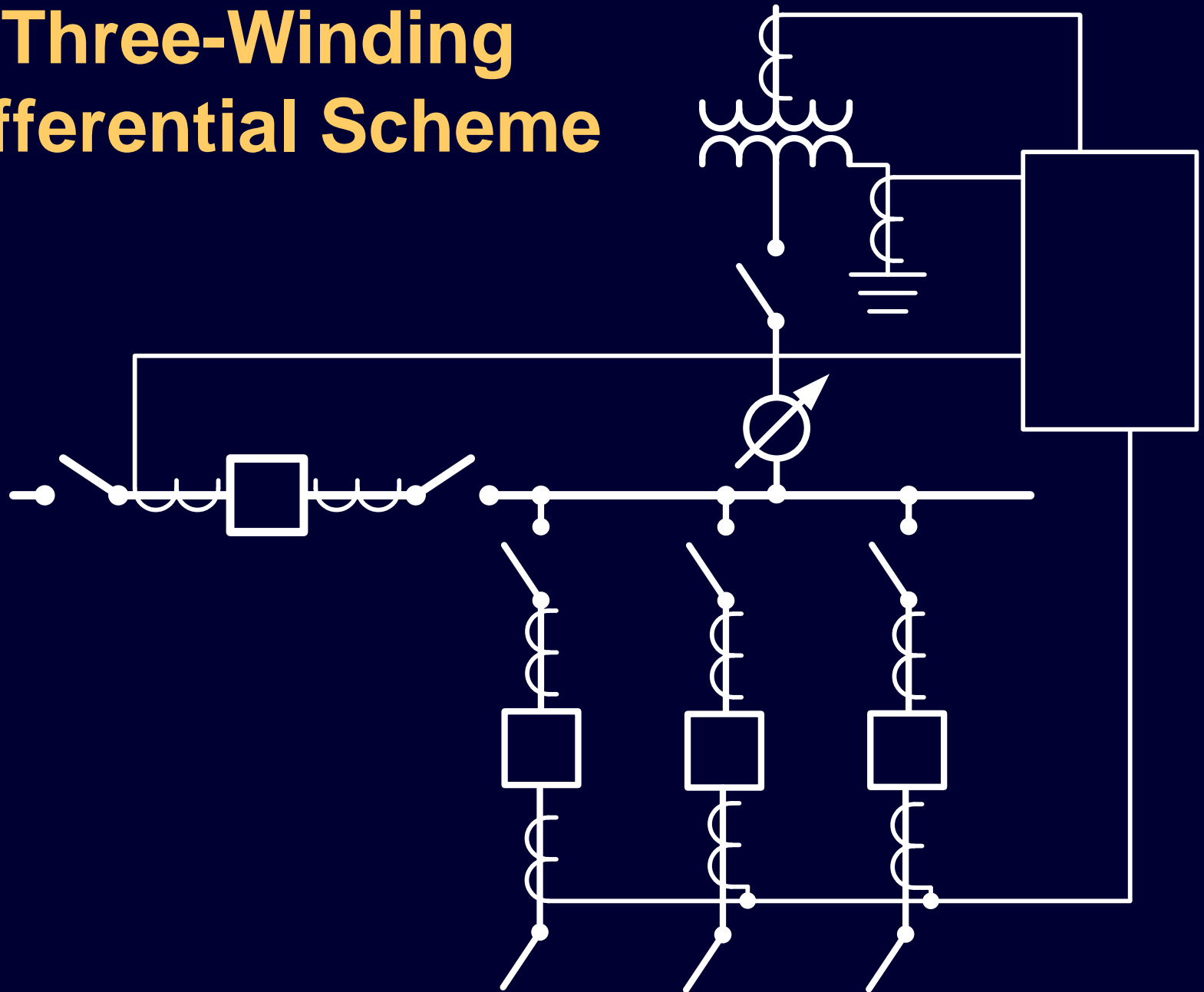
Main and Transfer Bus Arrangement



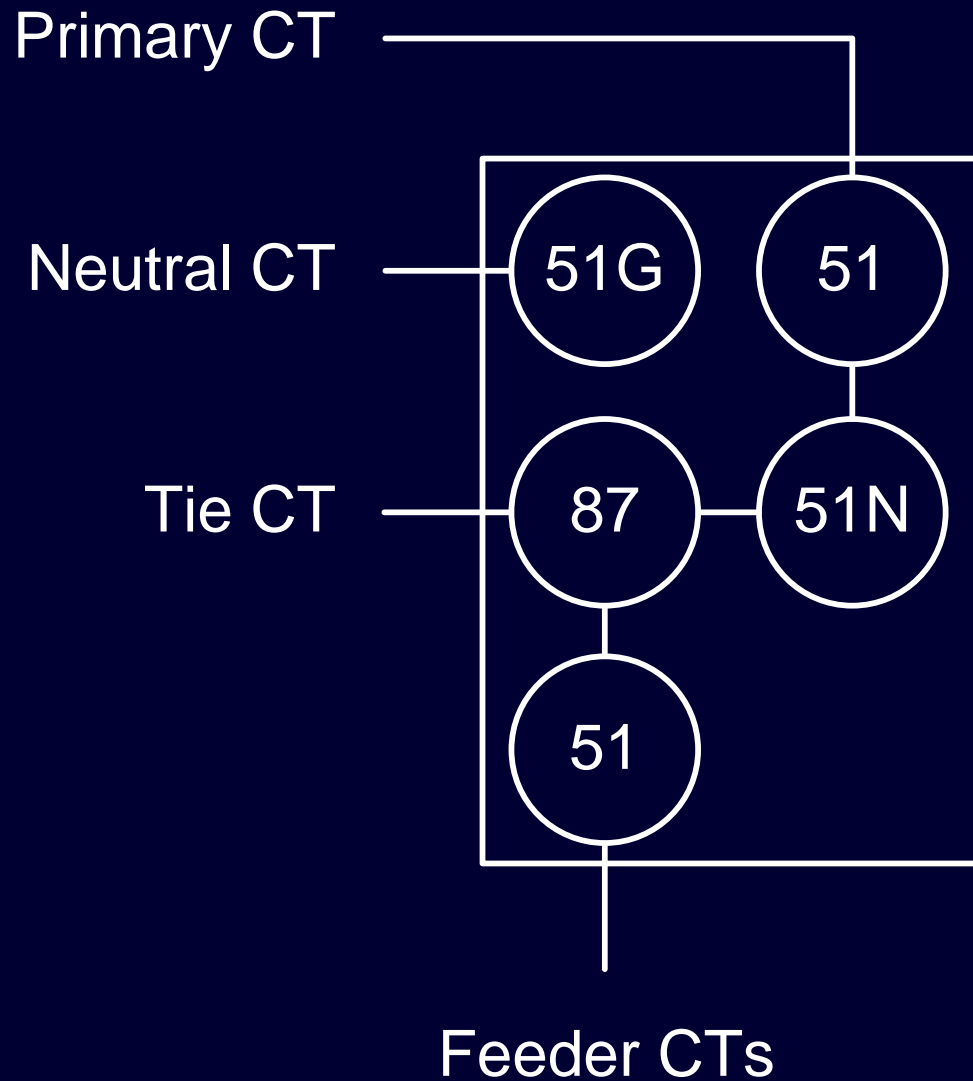
Microprocessor-Based Relays

- Two microprocessor-based relays in place of seven electromechanical relays
- Three-winding differential relay
 - ◆ Provided transformer *and* bus protection
 - ◆ Backed up failed feeder relays
- Three-phase overcurrent for transformer backup protection

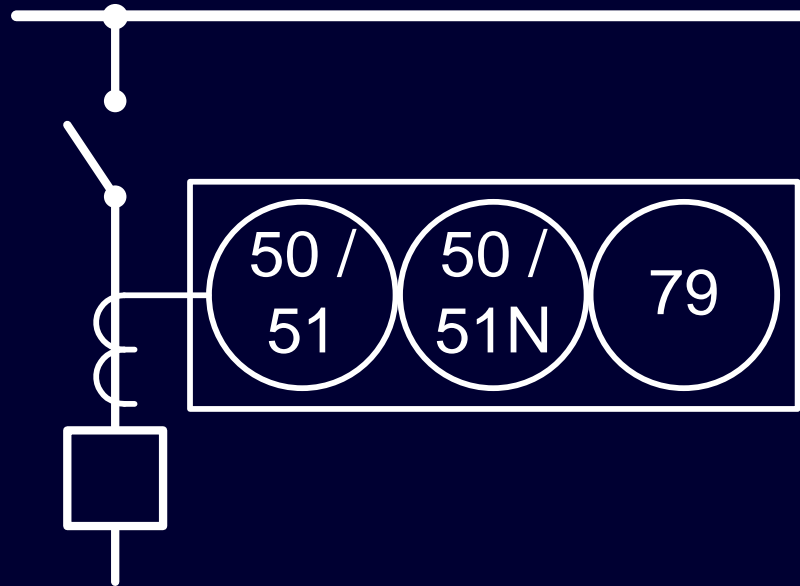
Three-Winding Differential Scheme



Three-Winding Transformer Relay



Feeder Relay



Why Change Now?

Three-Winding Scheme Problems

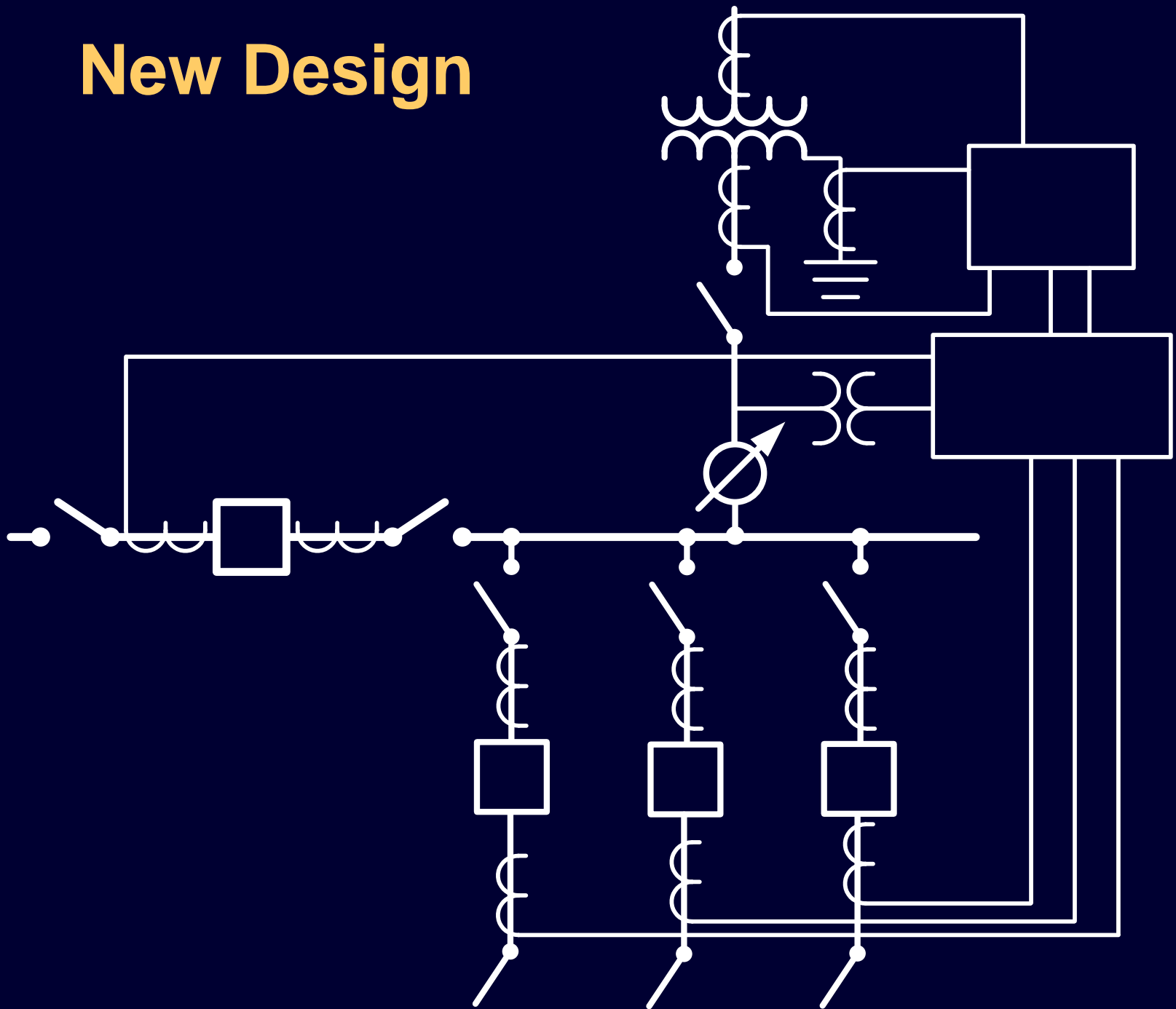
- Event analysis difficult
 - ◆ No time synchronization
 - ◆ No remote access to retrieve event reports
 - ◆ Multiple software packages for local access
- Relay-to-relay communications not available

Why Change Now?

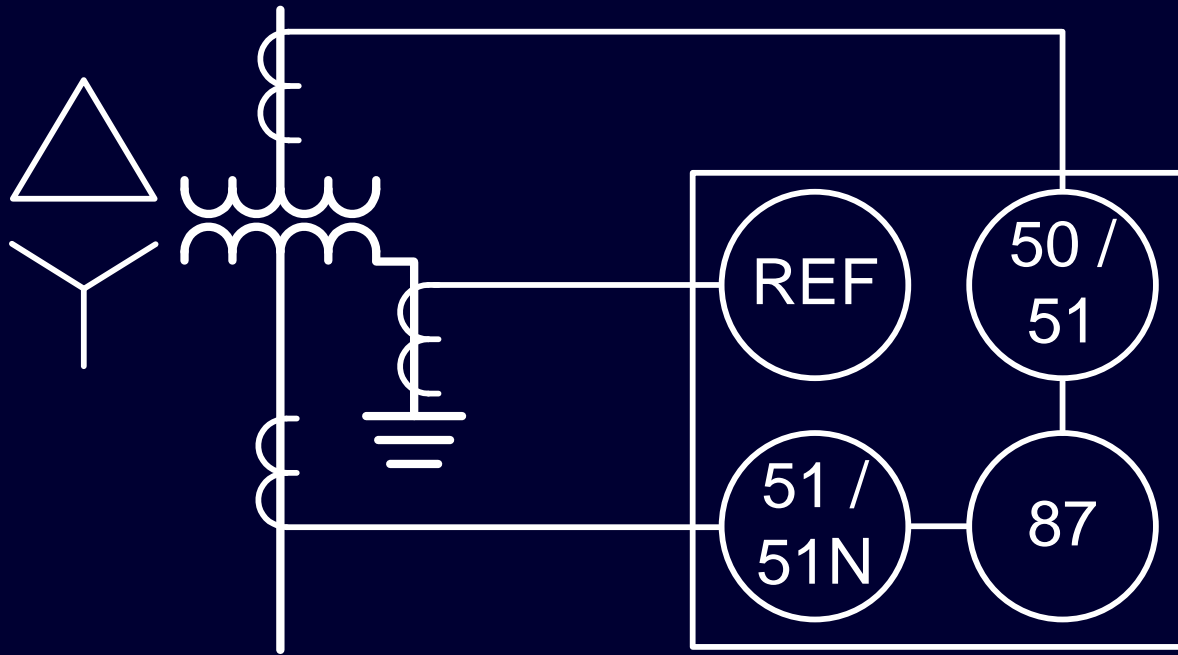
Three-Winding Scheme Problems

- Relay failure backup scheme
 - ◆ Provides backup overcurrent – summation of all feeders
 - ◆ Creates problem for simultaneous feeder faults
- Fault location (if fault not visible)

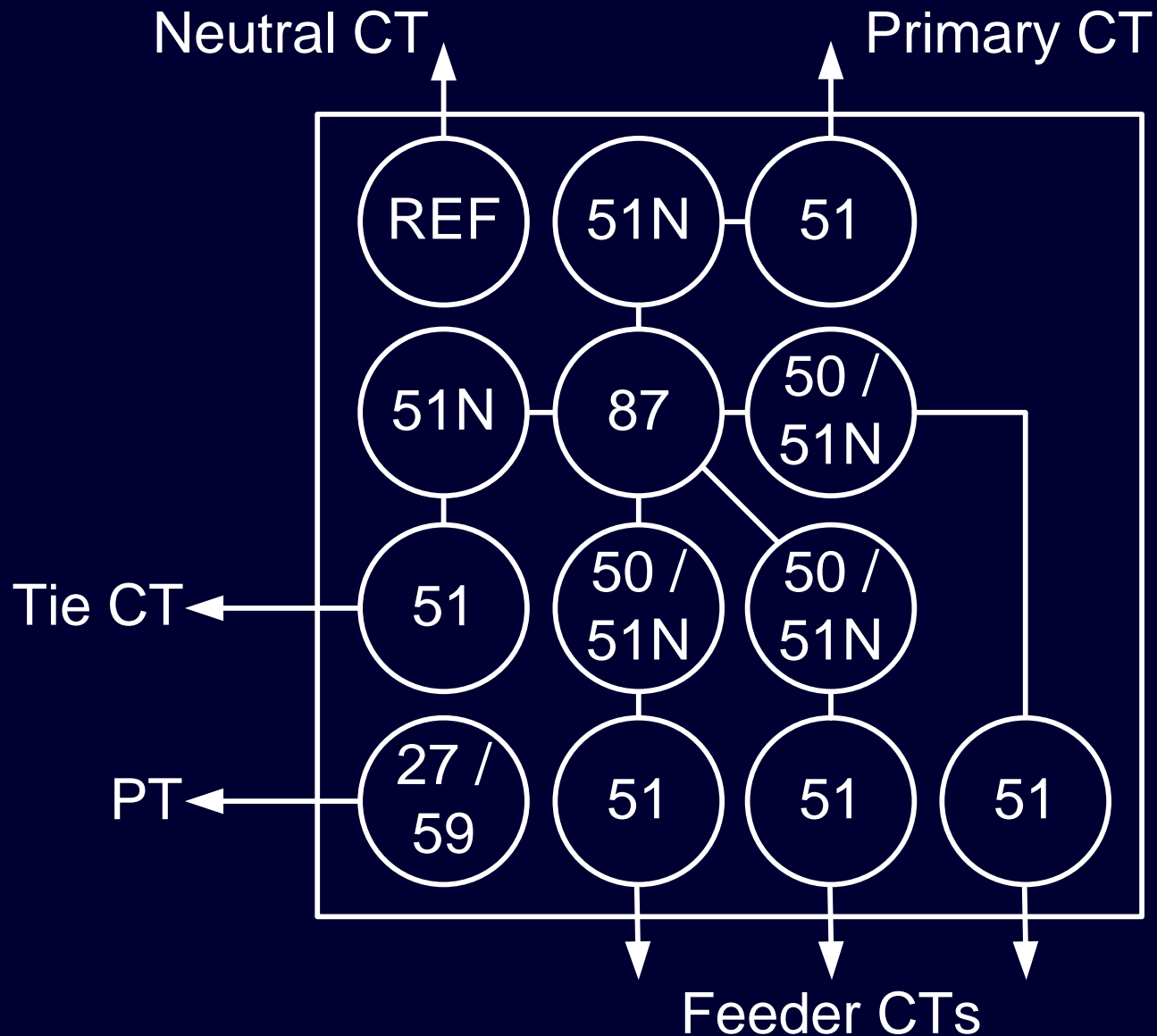
New Design



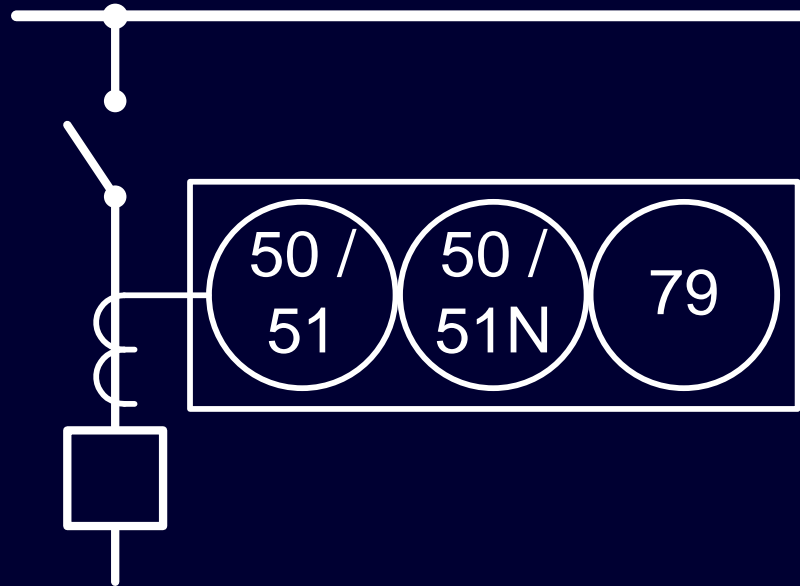
Two-Winding Transformer Relay



Five-Winding Transformer Relay



Feeder Relay



Five-Winding Transformer and Bus Differential Relay

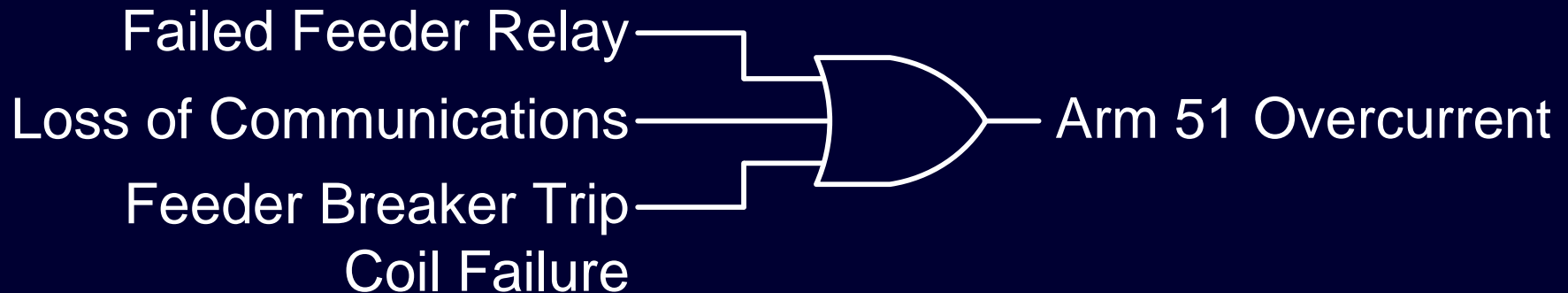
- Apply backup protection for failed feeder relay
 - ◆ Provides SCADA alarm and torque control backup overcurrent
 - ◆ Provides individual winding currents for each feeder
 - ◆ Eliminates simultaneous feeder fault concern
- Detect failed feeder breaker trip coils

Five-Winding Transformer and Bus Differential Relay

- Set backup overcurrent protection identical to feeder relay
- Provide better sensitivity and personnel and equipment protection

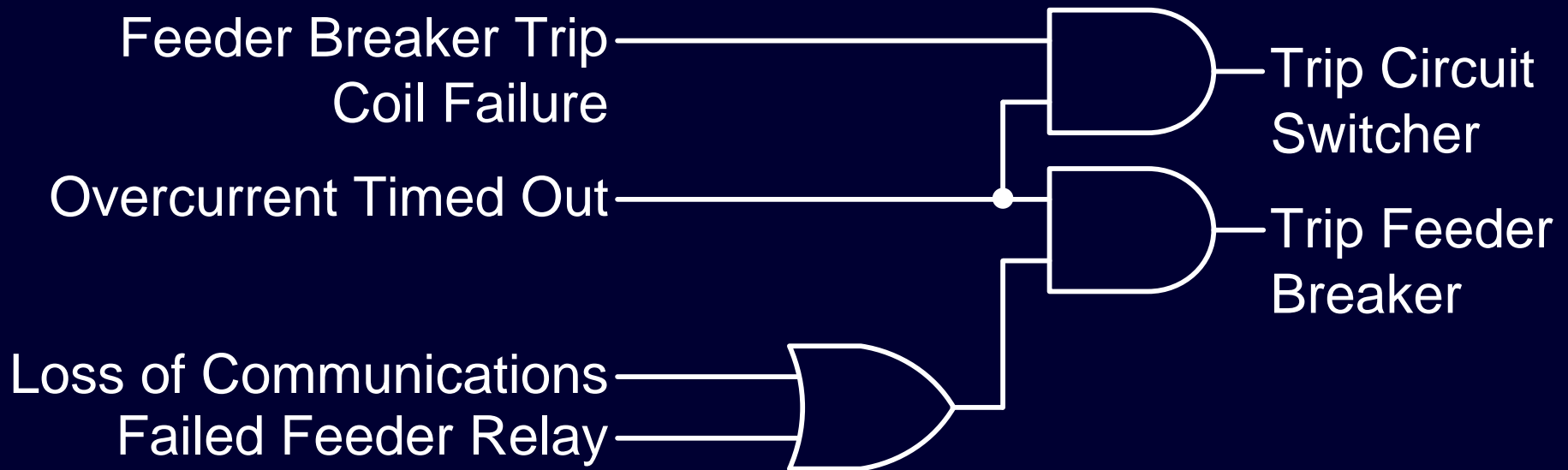
Feeder Backup Logic

51 Torque Control



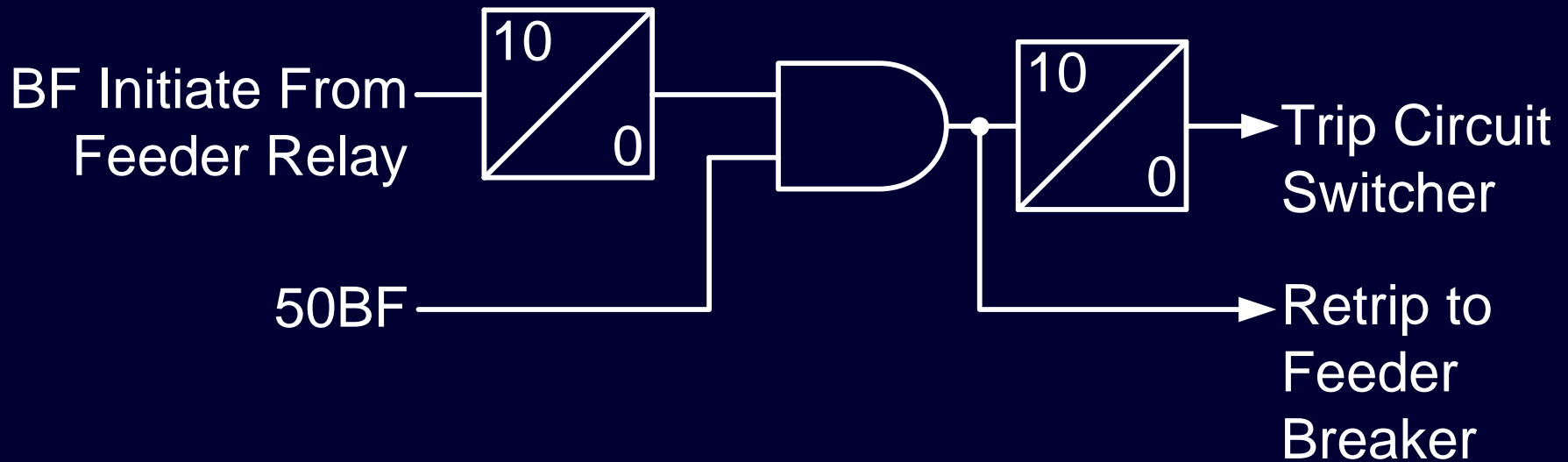
Feeder Backup Logic

51 Trip Logic



Feeder Backup Logic

Breaker Failure Logic



Five-Winding Transformer and Bus Differential Relay

- Includes breaker failure timer and logic for failed feeder breaker
 - ◆ Retrip feeder breaker
 - ◆ Trip transformer high side after 10-cycle delay
- Enhances protection with restricted earth fault (REF) – 67G or 87N
 - ◆ Fast and secure
 - ◆ Low-side bus and bus regulator protection

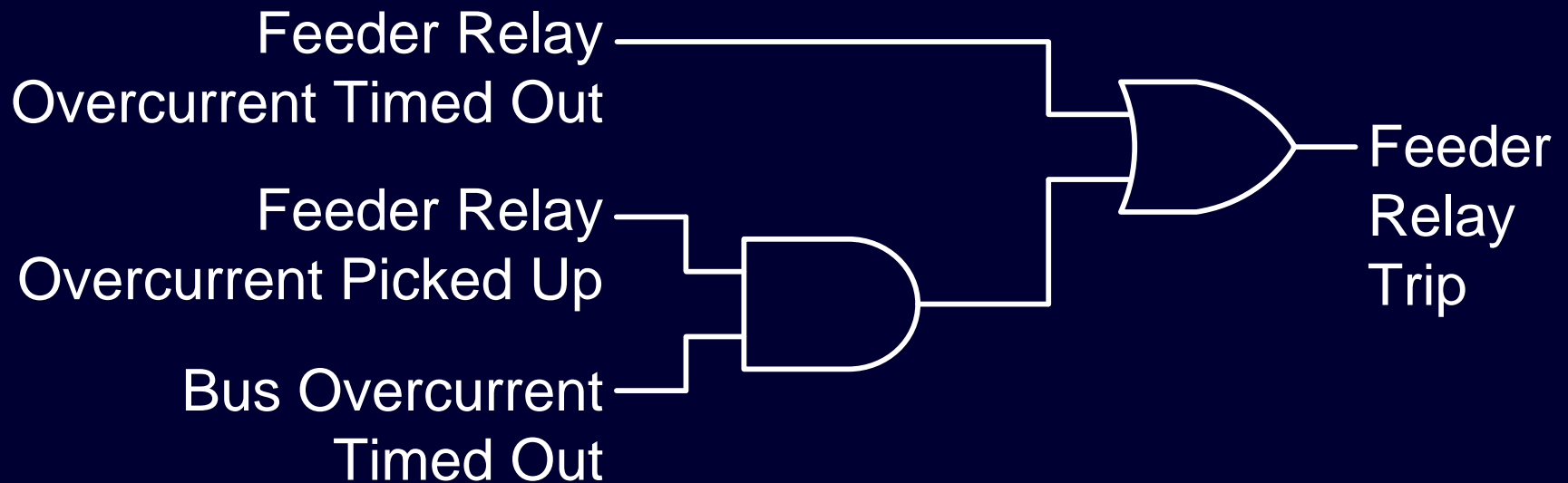
Five-Winding Transformer and Bus Differential Relay

- Detects high-side open conductor
 - ◆ Voltage elements
 - ◆ 60-cycle delay
- Provides subcycle differential tripping
- Uses Ethernet connection
 - ◆ SCADA DNP3
 - ◆ Engineering access and event retrieval

Two-Winding Transformer Differential

- Provides backup for five-winding differential relay
- Supplies definite indication of transformer fault
- Includes REF protection
- Provides backup overcurrent elements
 - ◆ High-side transformer protection
 - ◆ Low-side communication with feeder relays

Feeder Relay Trip Logic



Relay Communications

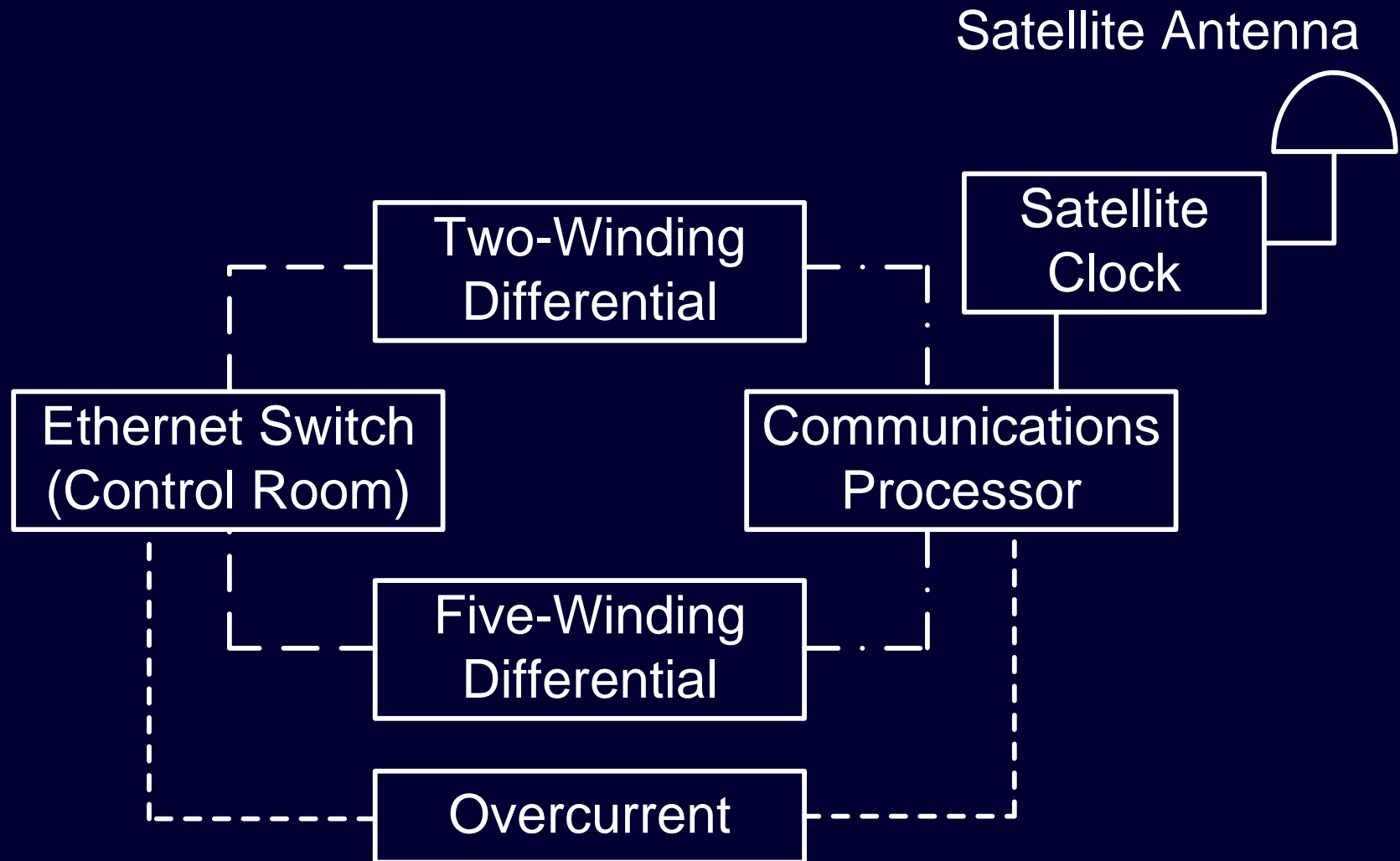
High-Speed Serial Communication

- From feeder relays to transformer and bus differential relay
 - ◆ Failed feeder relay
 - ◆ Trip coil failure in feeder breaker
 - ◆ Breaker failure initiate
- From two-winding transformer differential relay to feeder relays – bus overcurrent trip signal

Time Synchronization

- Satellite clock to serial communications processor – IRIG-B distributed via serial cable to feeders
- Four fibers (two pair) to each feeder breaker
- IEC 61850 (considered)

Relay Communications



Example of Personnel Safety

- Technician performed routine bus voltage regulator exercising
- Technician tapped out of limits
- Internal bridging reactor failed
- Differential tripped high side and feeders
- Catastrophic damage to regulator and serious injury to operator were prevented

Value of Bus Protection

- Protection detects line-to-ground faults for single-phase bus regulators
- Differential trips for wildlife contacts with minimal or no damage to equipment
- Bushing failure clears without catastrophic equipment meltdown

Conclusions

- Feeder relays, failed trip coils in feeder breakers, and breaker failure backed up by transformer and bus differential relay
- Low-voltage substation bus and bus regulators provide primary and backup protection in differential relays

Conclusions

- Phase differential and REF in both differential relays
- High-speed protection for entire substation
 - ◆ Minimizes personnel hazard (arc flash)
 - ◆ Maximizes equipment protection
- Better system metrics
 - ◆ Reduce outage durations – improve SAIDI
 - ◆ Correctly trip only affected equipment – improve SAIFI

Questions?