Bus Protection Application Challenges

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  - Increase Security with Supervising Elements
  - Open CT Detection
  - Monitoring Isolator Positions
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  - Engineering Experience of Complex Bus Protection Schemes
  - End Fault Protection Schemes
- Conclusions

Challenges to Bus Zone Protection

High fault current levels can:

- Damage equipment from mechanical stress on busbars
- Lead to CT saturation
- Cause high levels of arc flash

Mal-operation of bus protection has significant impact

- Loss of customer loads may damage customer assets
- Detrimental impact on industrial processes
- System voltage levels stability may be adversely impacted

Challenges to Bus Zone Protection

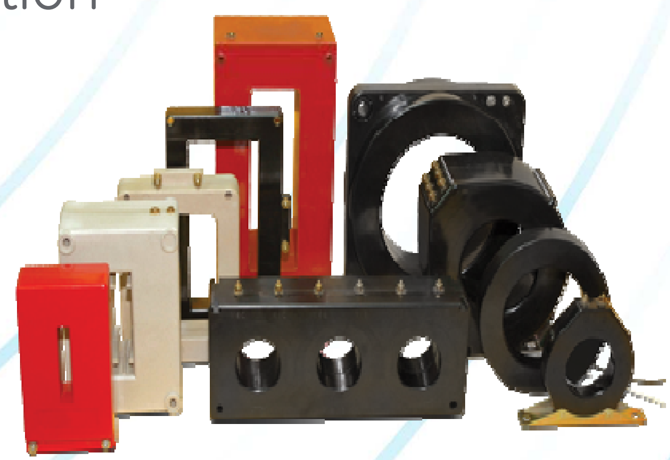
Many different bus topologies

- Many switchyard configurations possible
- Many different CTs possible
- Single bus, double bus, main and transfer bus, breaker-and-a-half, etc.

Buses may reconfigure at any time

- Different components may be connected/disconnected to a bus
- Switching invoking bus reconfiguration occurs from different sources

Bus Protection Must be Dependable and Secure, With Emphasis on Security…

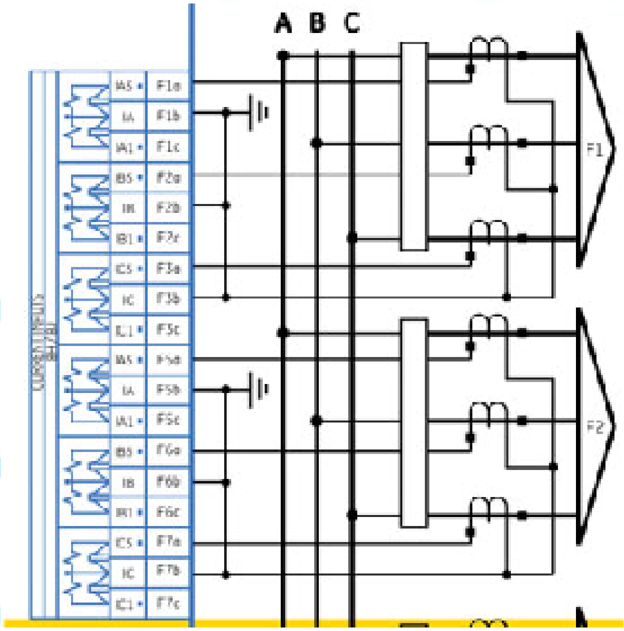


Additional Security for The Bus Differential Zone

- No matter reliability, any relay may fail. For bus applications, any MTBF never high enough
- Consider securing the application against reasonable contingencies
  - CT problems, AC wiring problem
  - Problems with aux. switches for breakers, isolators
  - DC wiring problems involving the Dynamic Bus Replica
  - Failure of relay hardware (single current input channel, single digital input)
- Security above and beyond inherent security mechanisms in IEDs
  - CT Saturation Detector
  - Directional (Phase) Comparison
  - Isolator monitoring

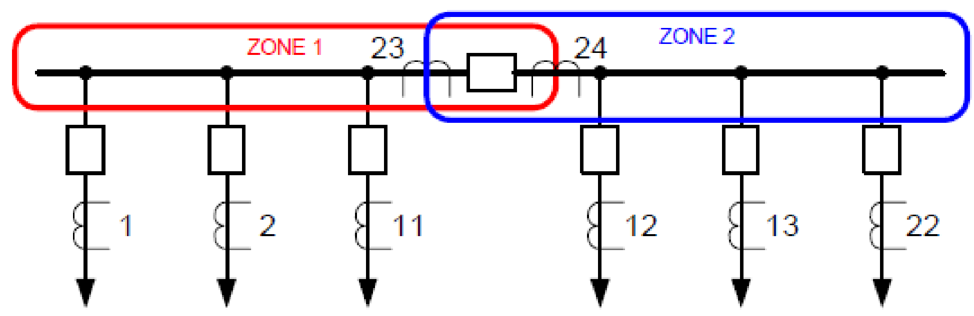
External Check Zone

- Principle:
  - Develop independent copy of differential current for entire bus regardless of dynamic zones for individual bus sections
  - Use the check zone to supervise the tripping zone(-s)
  - Use independent CTs / CT cores if possible to guard against CT and wiring problems
  - Use independent relay current inputs to guard against relay problems
  - Alarm on spurious differential
- Guards against:
  - CT problems and AC wiring problems
  - Malfunctioning of auxiliary 52/89 contacts for breakers and isolators
  - DC wiring problems for dynamic bus replica
  - Failures of current inputs

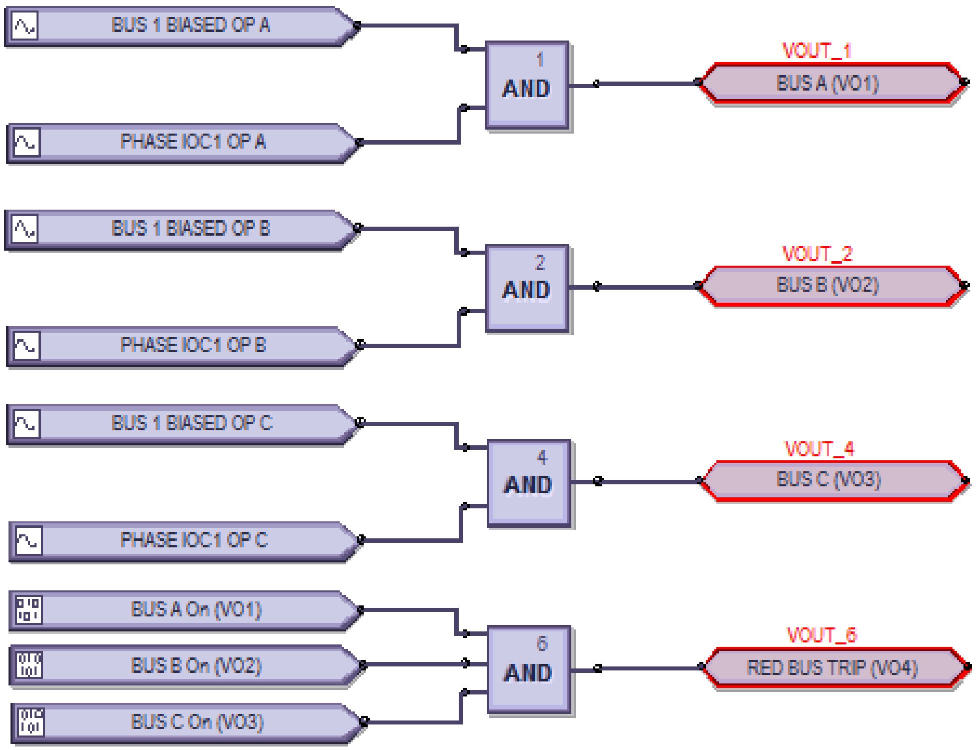


Application of Overcurrent Check Zone

- External check zone can be configured as unrestrained zone that (ideally) uses separate CTs or CT cores
- IOC function can be configured to operate on the externally summated currents (from different IED or Inputs)
- For external zone, CTs summed for this overcurrent must:
  - Have identical CT ratios or matching transformers are required
  - Be of same type
  - Make use of three ground CT inputs (IG) and Ground IOC or unused 3-phase bank & Phase IOC elements as check zone



Application of Overcurrent Check Zone



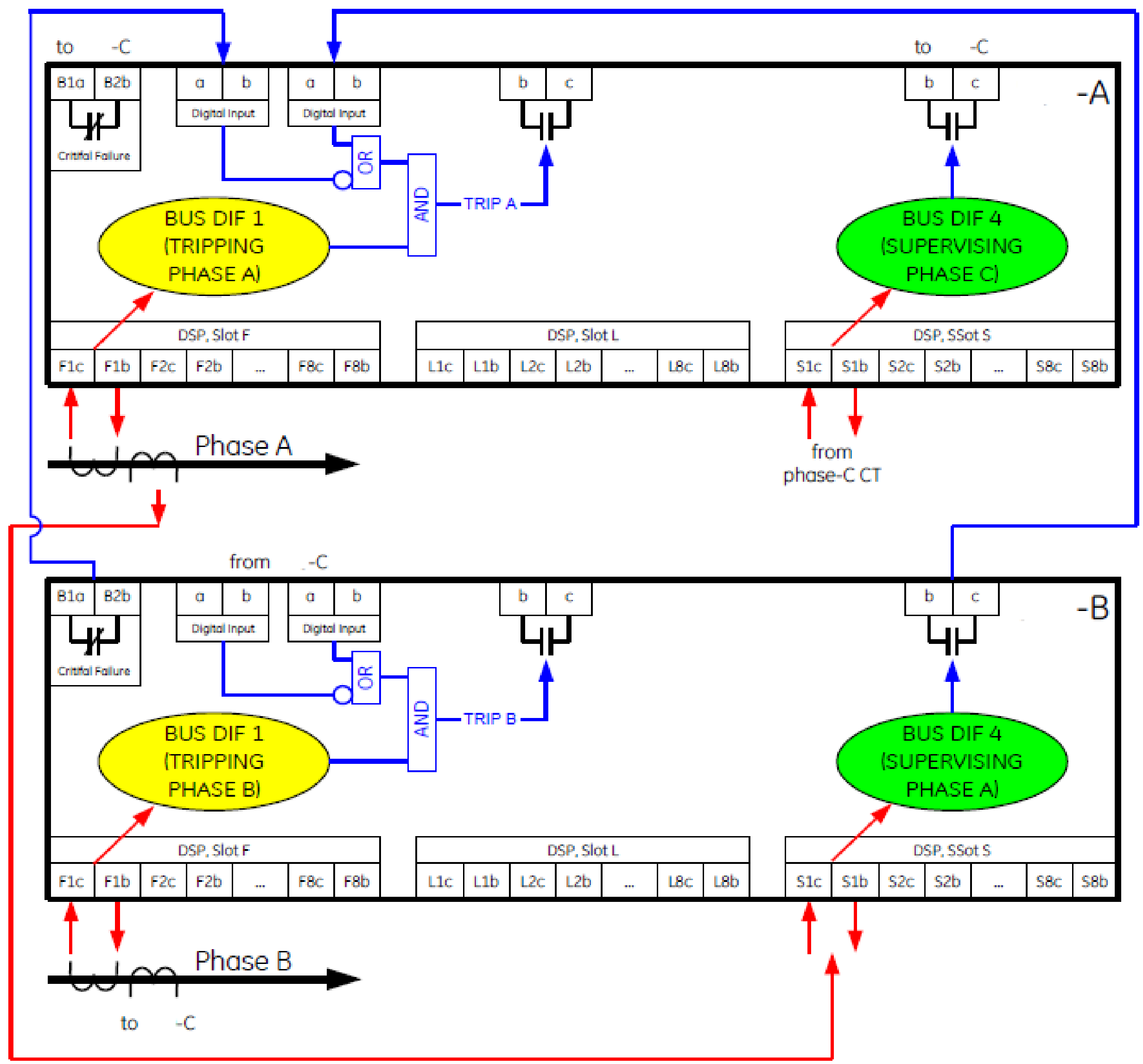
87B phase A supervised by IOC1 phase A; the IOC responds to the externally formed differential current

Three-phase trip command

External IED Check Zone

Equivalent Bus Zone

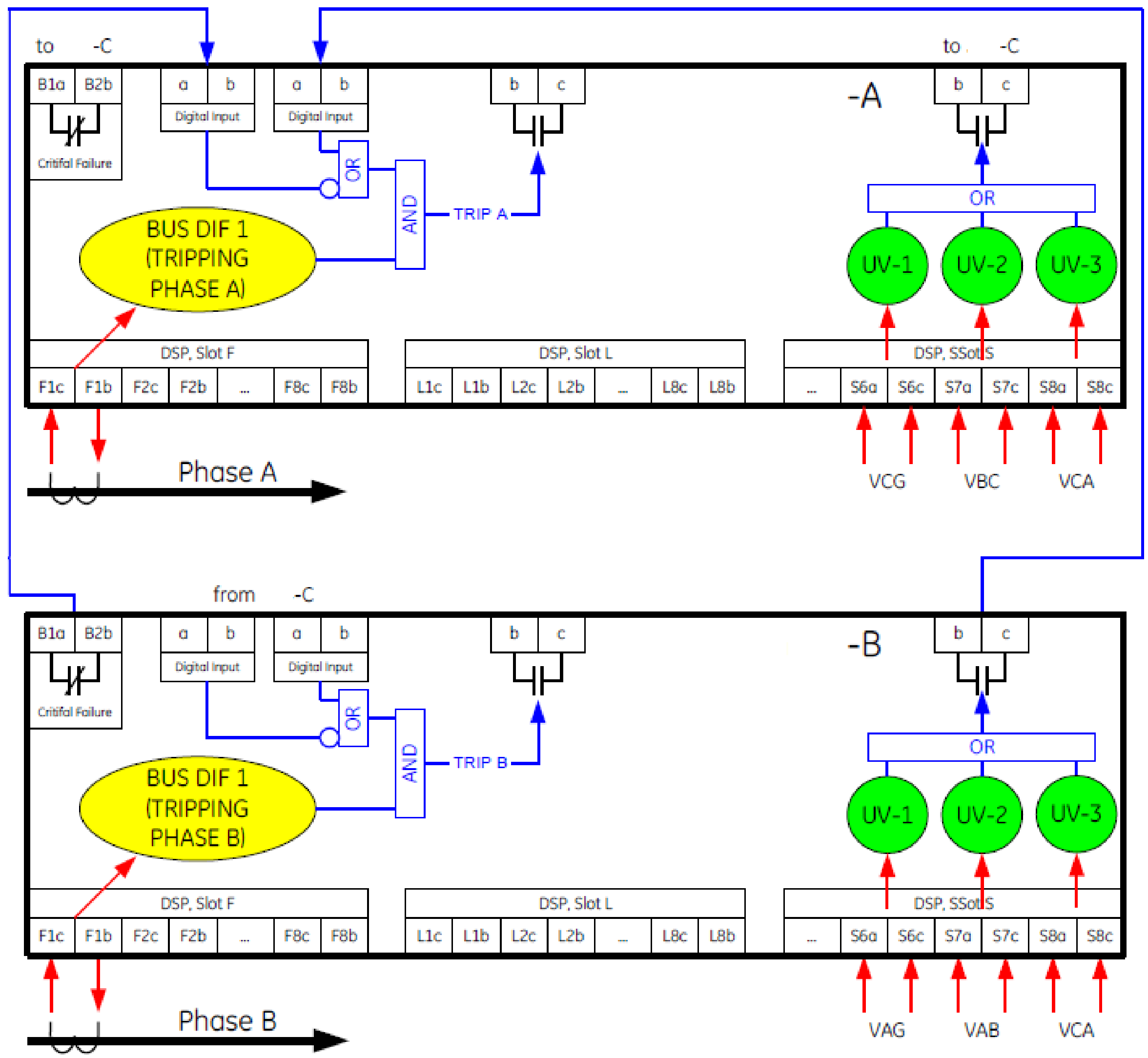
- Use two different CTs / CT cores
- Place the supervising zone in a different chassis
- Strong security bias, practically a 2-out-of-2 independent relay scheme
- Use fail-safe output to substitute for the permission if the supervising relay fails / is taken out of service



External IED Check Zone

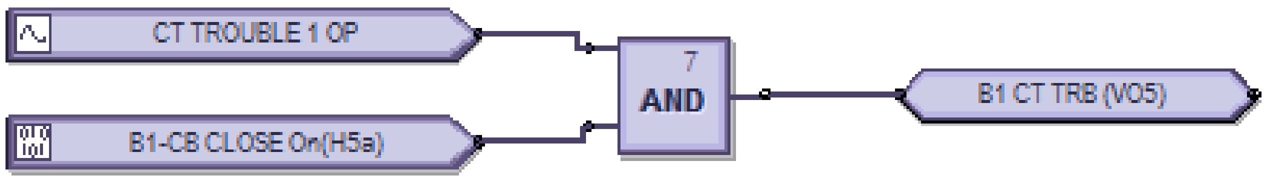
External Voltage Supervision

- Place the supervising voltage inputs in a different IED
- Guards against relay problems and bus replica problems
- Does not need any extra ac current wiring
- Use fail-safe output to substitute for the permission if the supervising relay fails / is taken out of service



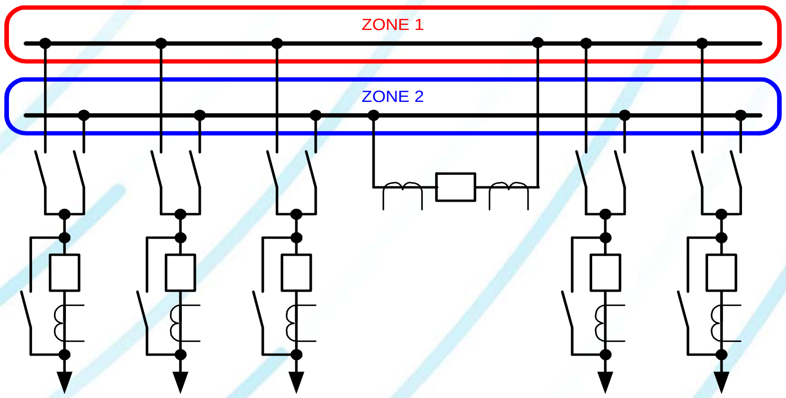
Open CT Detection

- CT problems and AC wiring problems challenge security of Bus Protection
- Secondary open CT must be identified – hazardous overvoltage (Safety)
- Multifunctional IEDs calculating sequence components (I2) capable to detect
- Phase Segregated IEDs can't calculate sequence components (Centralized schemes)
- Alternative: use CT Trouble/Low Diff, Breaker status and Current Supervision.
- Implemented in Centralized 400kV & 220kV schemes

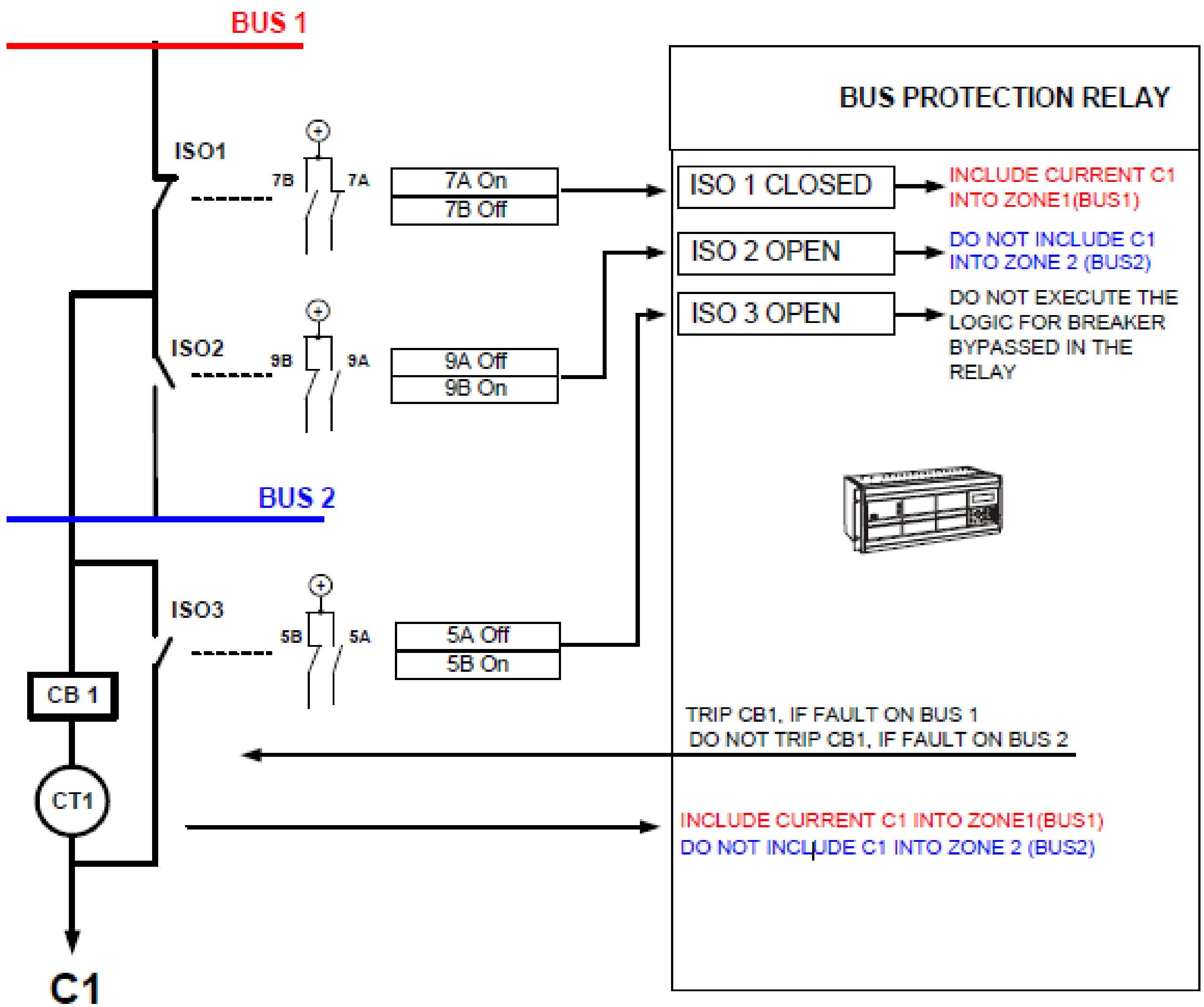


Monitoring Isolator Positions

- Reliable "Isolator Closed" signals needed for Dynamic Bus Replica
- In simple applications, a single normally closed contact sufficient
- For maximum security:
  - Use both N.O. (89a) and N.C. (89b) contacts
  - Alarm for non-valid combinations (open-open, closed-closed)
  - Inhibit switching operations until bus image is recognized
  - Optionally block 87B operation from Isolator Alarm
- Each isolator position signal determines:
  - Circuit currents to be included in the differential calculations
  - Circuit breakers to be tripped

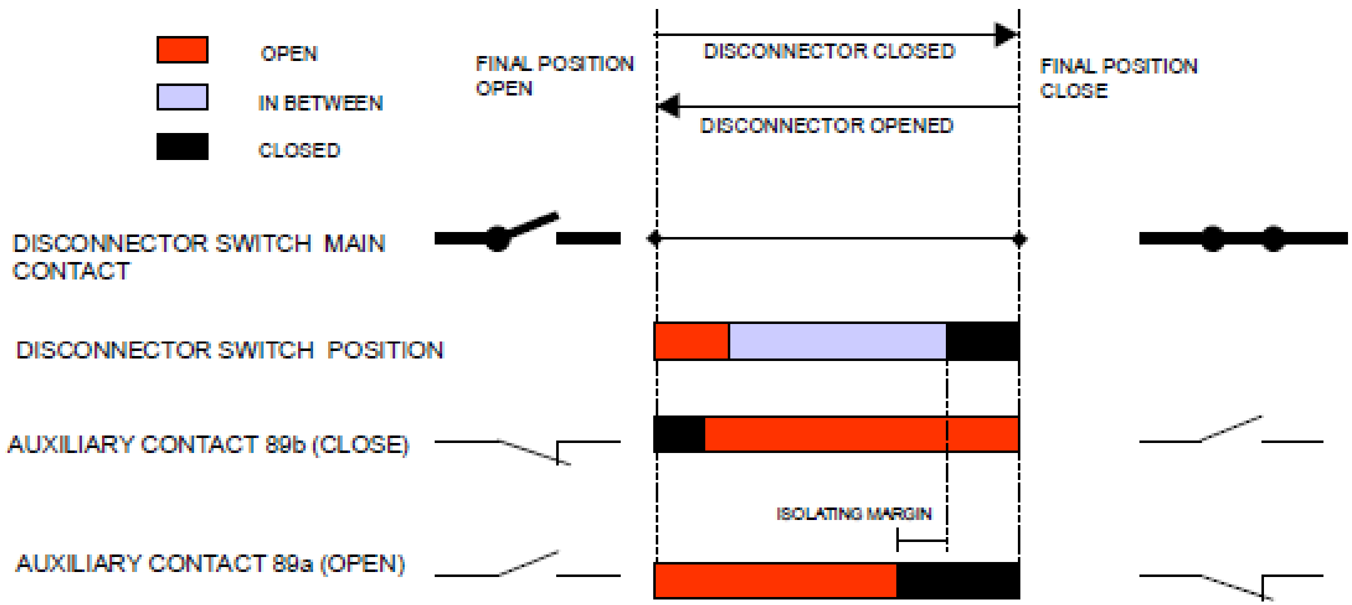


Typical Isolator Connections

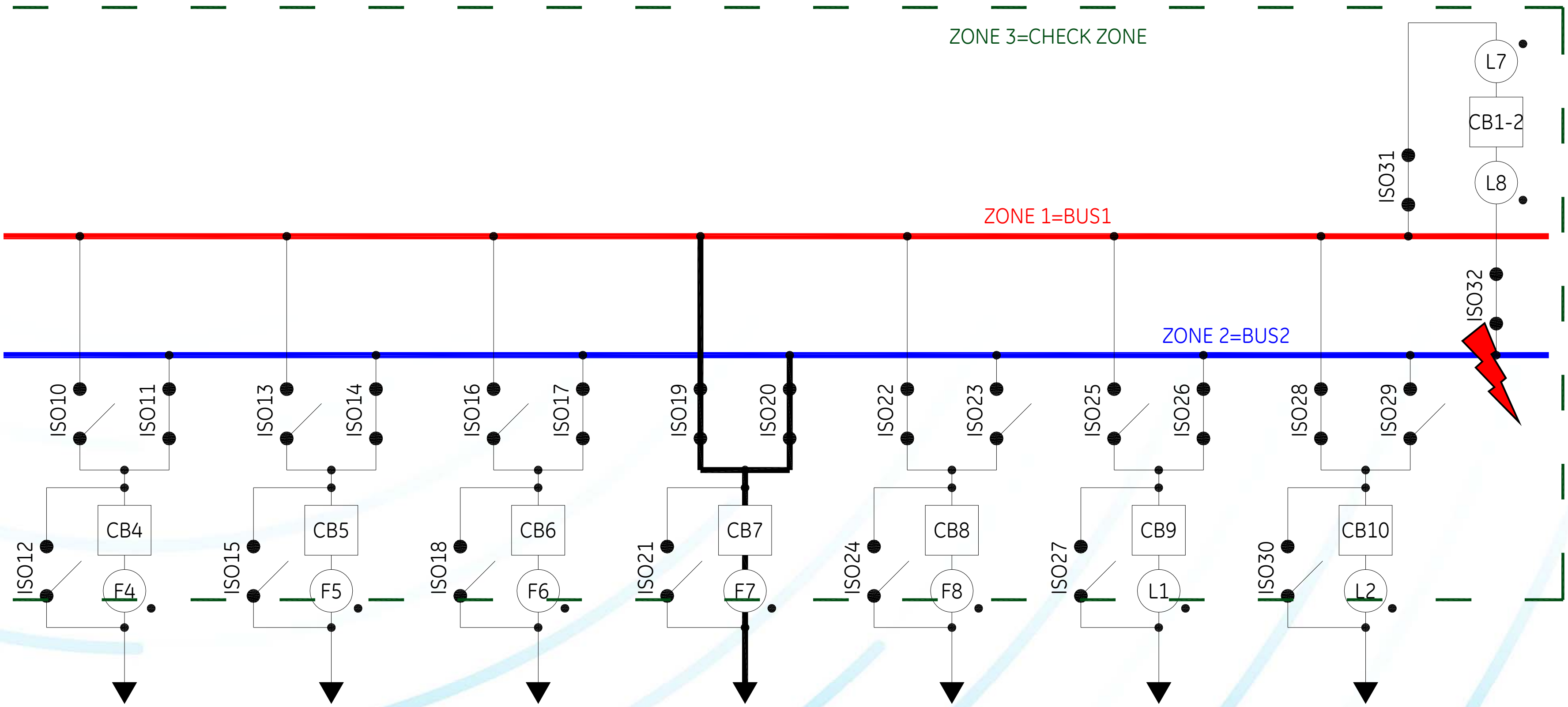


Isolator Switching Sequence

- Time of Open/Close of 89a/89b must be adjusted to ensure current of circuit included when Isolator closes
- 89a/89b close indication must be just before circuit current flowing through Isolator; not after
- 89a/89b open indication must be just after Isolator interrupted current

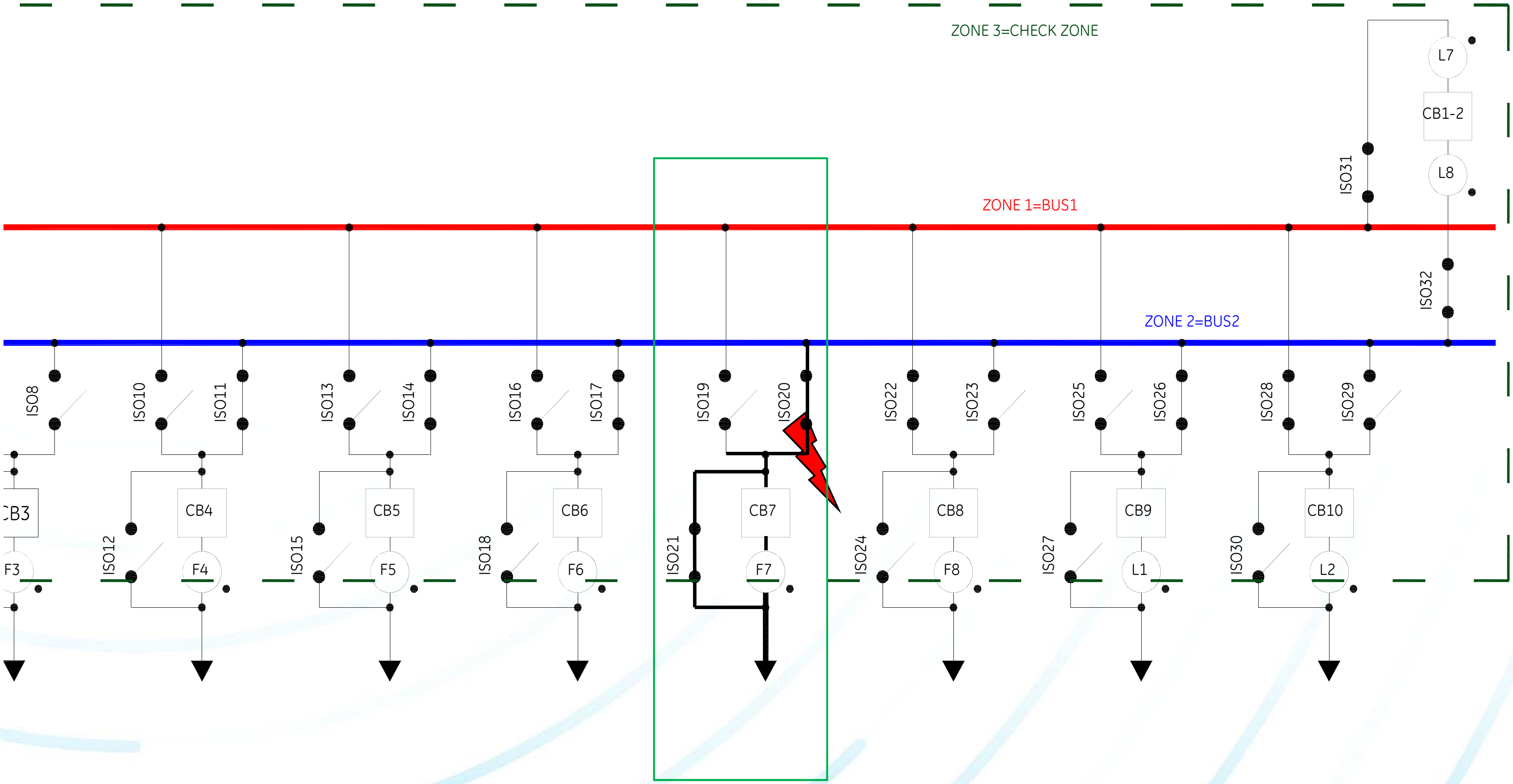


Isolator Switching Sequence Importance Eg. 1



What happens when an AG fault occurs on Bus 2 during transition of F7 from Bus 1 to Bus 2 with both Isolators Iso19 and Iso20 closed?

Isolator Switching Sequence Importance Eg. 2

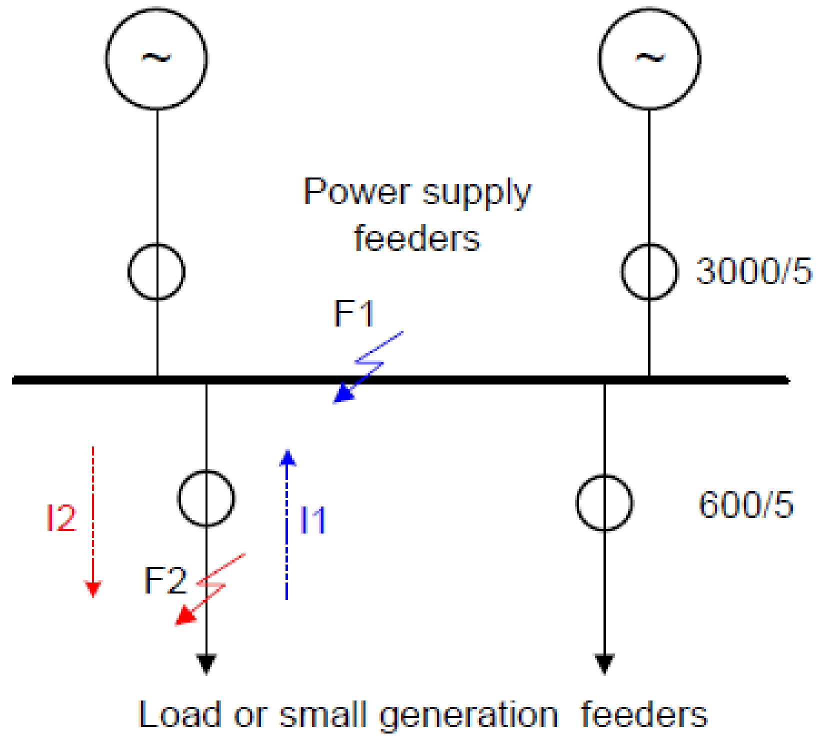


What happens when an Internal AG fault occurs on feeder F7 with bypass Isolator Iso21 closed?

- Zone 2 Disabled
- Only Active Protection
  - Breaker Fail
  - Backup O/C

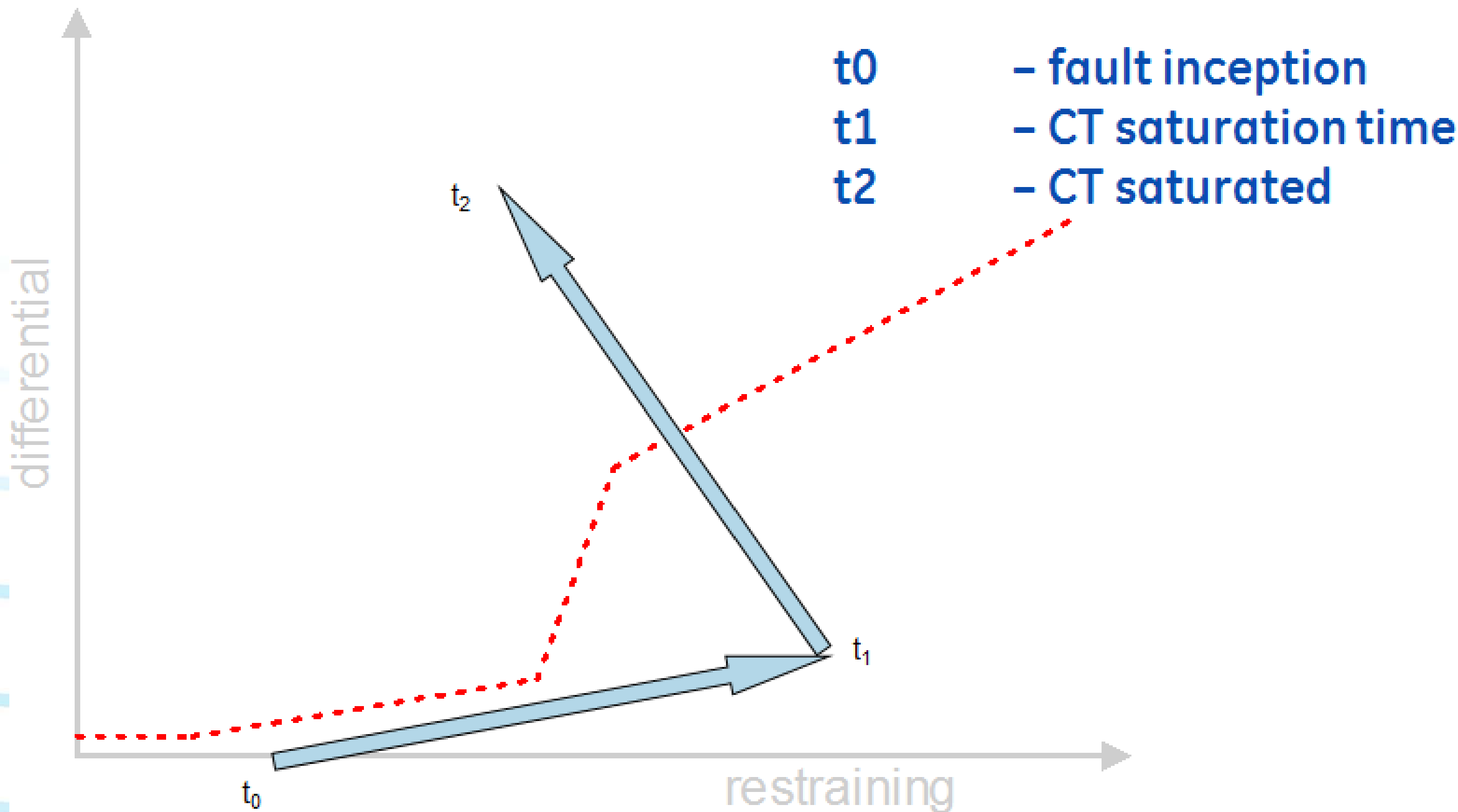
Detection of External Faults

- Bus configuration could require large CT ratio differences:
  - Main power feeders large CT ratio
  - Load/small generation feeders low CT ratio's
- Hence, I2 due to F2 will be significantly larger than I1 due to F1
- General recommendation: increase CT ratio
- Load/small generation feeder CT sized for load and not system fault condition;
- Hence, significant CT saturation can occur due to I2



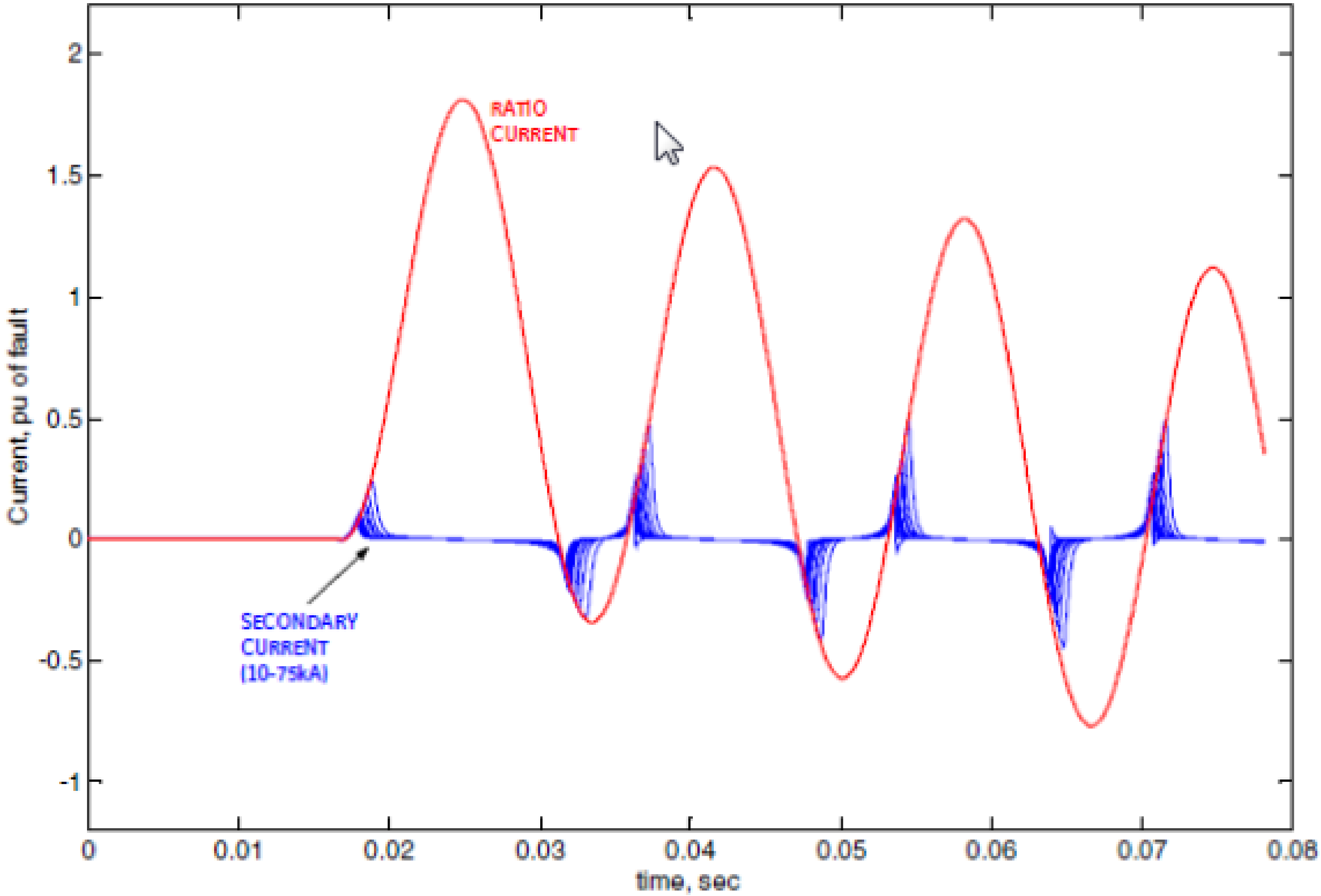
External Faults: CT Saturation Detection

- CT saturation detection in some IEDs counts on Differential vs Restraining current trajectory
- Expect trajectory to move from t0 to t1, then to t2
- This is possible with at least 2ms saturation-free current



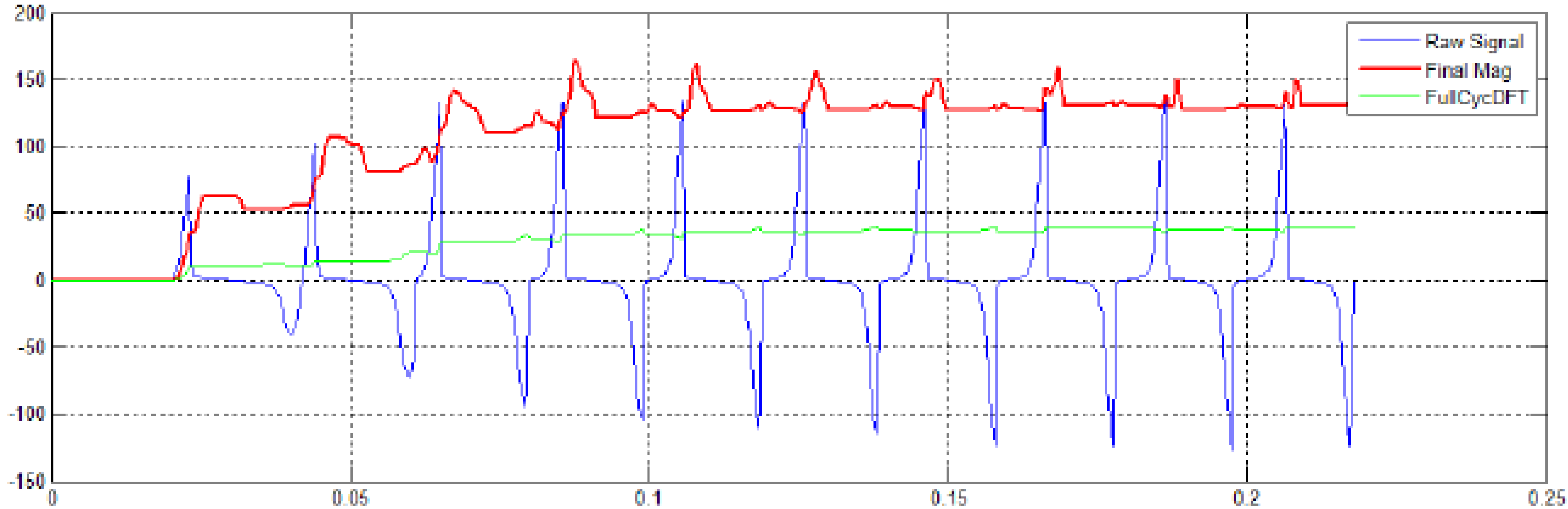
External Faults: Extreme CT Saturation Detection

- CT saturation below in less than 2.5ms at 50Hz
- CT saturation too fast to guarantee secure CT saturation detection



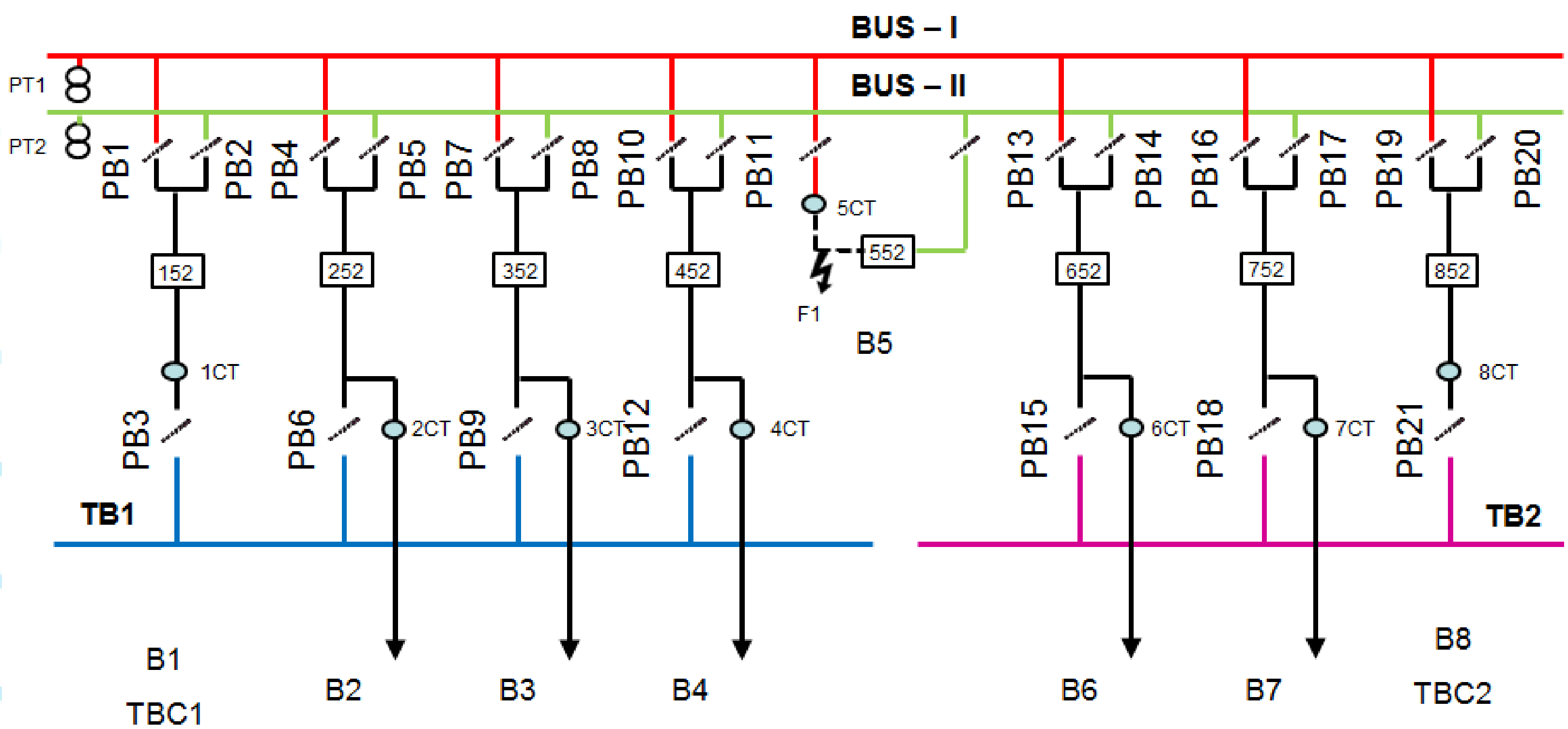
External Faults: CT Saturation Alternative

- General recommendation: Increase CT ratio
  - Not economical feasible
  - Increased CT ratio impacts local feeder protection sensitivity
- Alternative: use very fast current magnitude detection faster than 87B
- Conventional current detection based on DFT too slow – slower than 87B
- Time domain sample-based overcurrent (3 – 5ms reaction) faster than 87B
- Comparison between full cycle Fourier (Green) and Fast OC Mag Det (Red)
- Fast OC Mag Detection used to supervise 87B on external faults



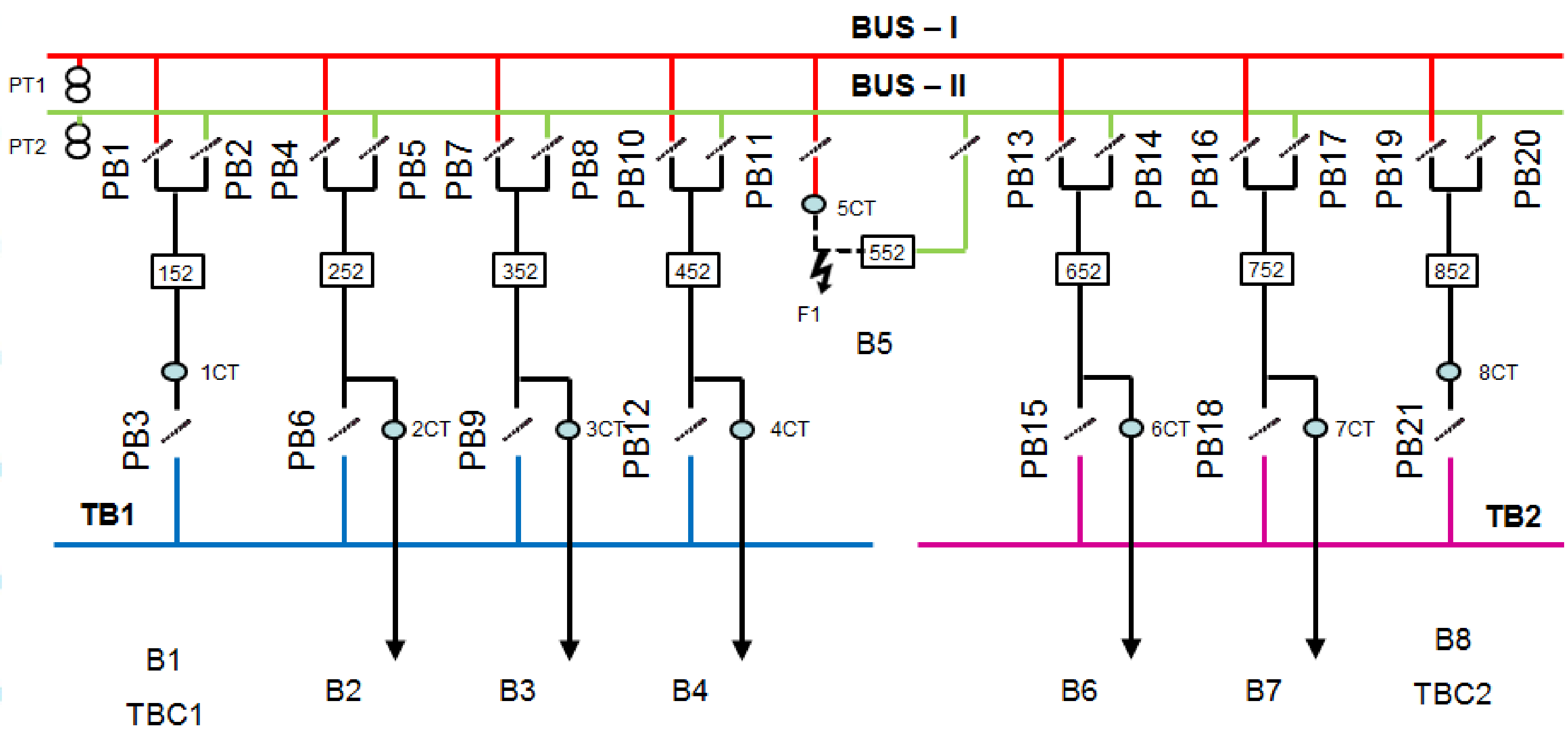
Engineering Experience : Complex Buses (1)

- Complex bus arrangements (Double bus with 2 transfer busses) can have Main Bus operated as Transfer Bus – 4 Zones plus 2 check zones
- Complex operational procedures to facilitate maintenance requirements
- Traditionally very complex operational procedures required on Bus Protection (Main Bus to act as Aux Bus) to maintain protection security
- Very unreliable operations achieved if not followed in detail – misoperations
- With a low impedance IED bus replica bus protection, this is eliminated.

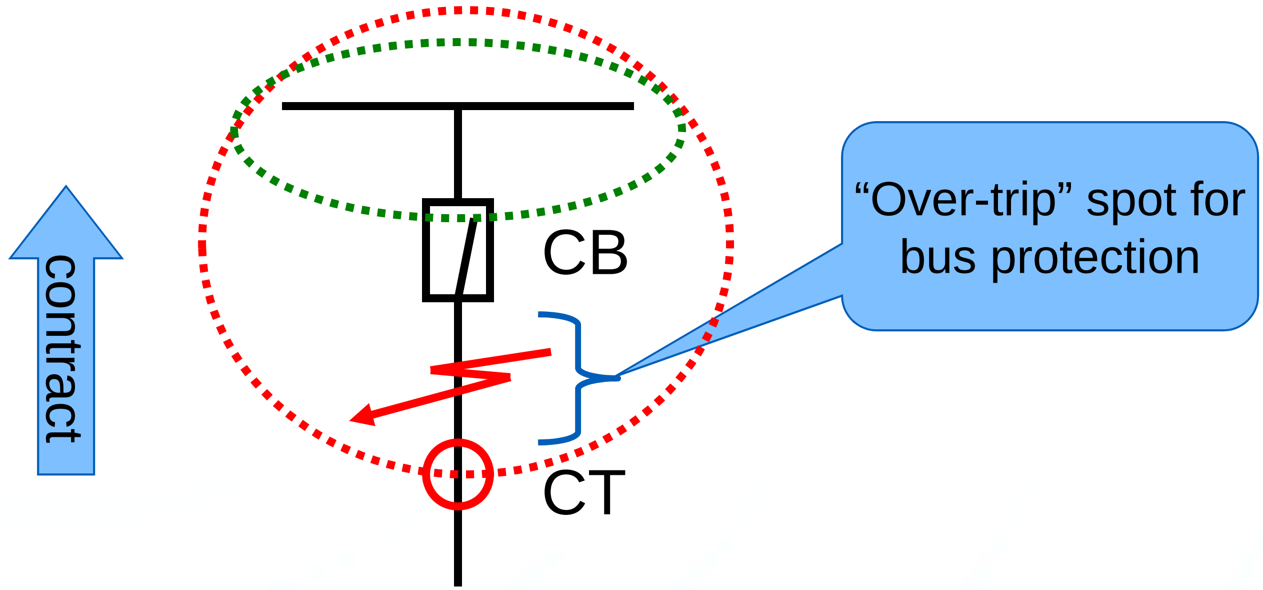


Engineering Experience : Complex Buses (2)

- Fault at F1 detected as Bus 2 fault – trips all Bus 2 Breakers.
- However fault in Bus 1 – hence not cleared since seen as external fault
- Normally cleared by Breaker Failure – unacceptable time delay
- End Fault used for accelerated tripping (40ms) – normal circumstances
- Delayed tripping logic (150ms) added from Bus 1 OR Bus 2 trip in event breaker contacts or wiring failed.

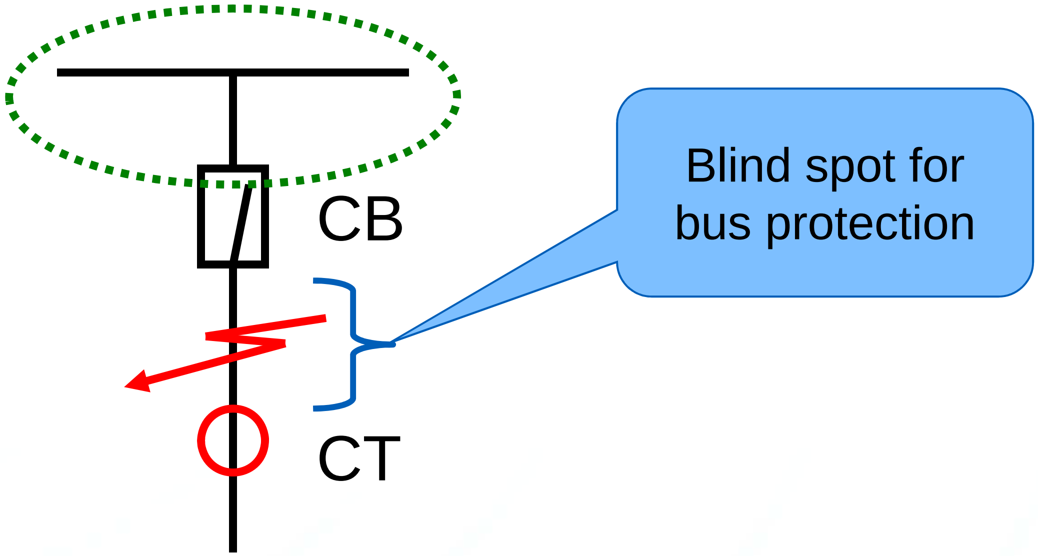


End Fault Protection: Changing the Zone



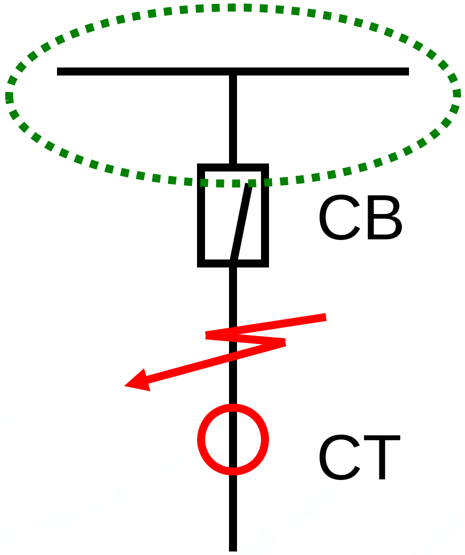
- "Over-trip" between CB and CT when CB is open
- When CB is open, current must be removed from 87B calculation – contracting 87B zone to CB
- This exposes this small part of the power system to uncleared faults until cleared by backup protection, but…

End Fault Protection: Changing the Zone



- But…
- A blind spot is created when the bus zone contracted to the CB
- End Fault Protection is required to trip remote circuit breaker(s) for this fault

End Fault Protection (EFP)



- Instantaneous overcurrent enabled when associated CB is open to cover blind spot between CB and line-side CT
- Pickup delay must be long enough to ride-through ramp down of current interruption (1.3 cycles max)
- EFP sends transfer trip to remote end of circuit/PS component
- End Fault Protection must be inhibited from Manual Close command
- Most Bus Protection IEDs (Centralized and De-centralized) do have EFP

Conclusions

- Power systems are evolving; hence the need that Bus Protection should follow
- Bus Protection must remain very dependable and secure
- Low Impedance most suitable for new application challenges
- Six application challenges, with implemented changes, covered where conventional Bus Protection falls short

Thank You

Questions?