Bus Protection Considerations for Various Bus Types

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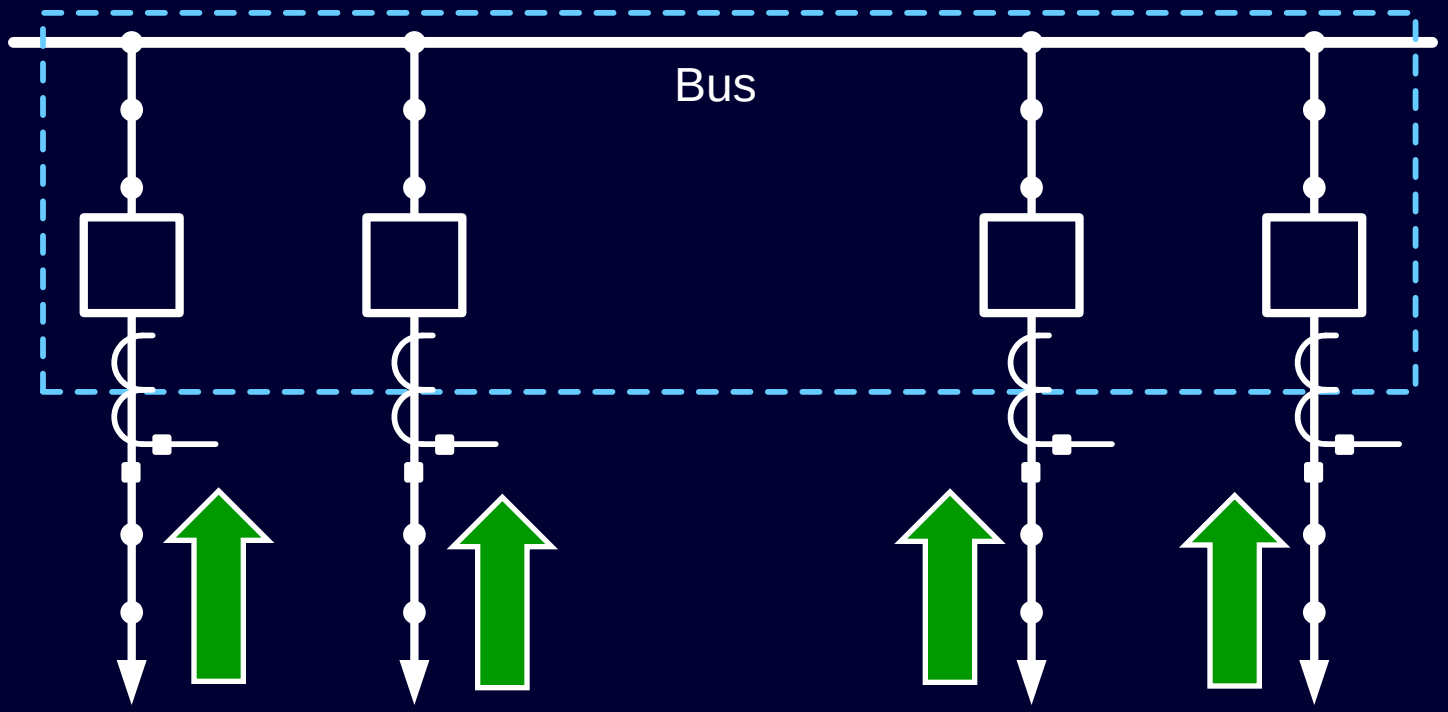
Introduction and Purpose

- 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

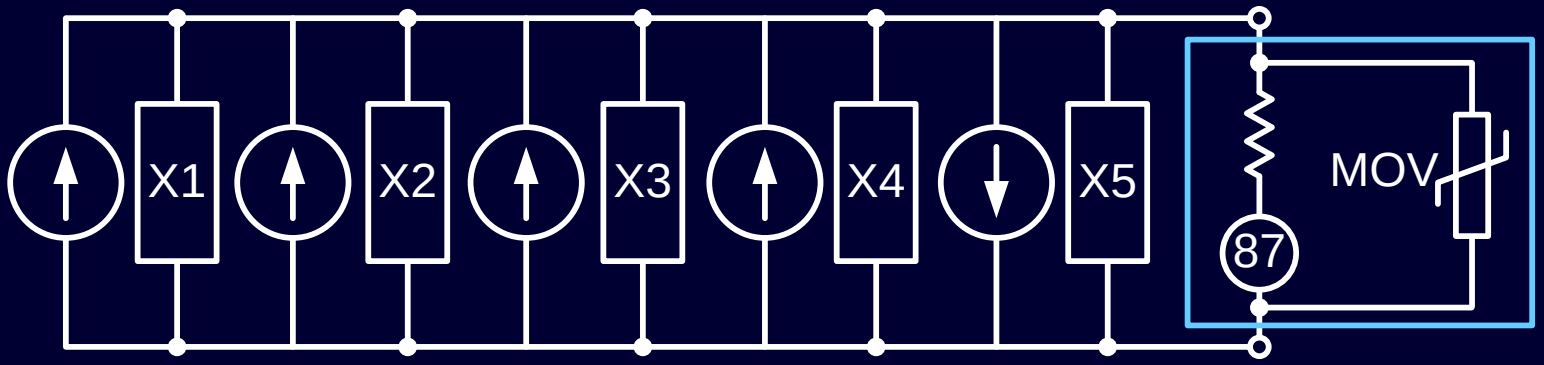
- Kirchhoff's current law
- Differential zone boundary determined by CTs



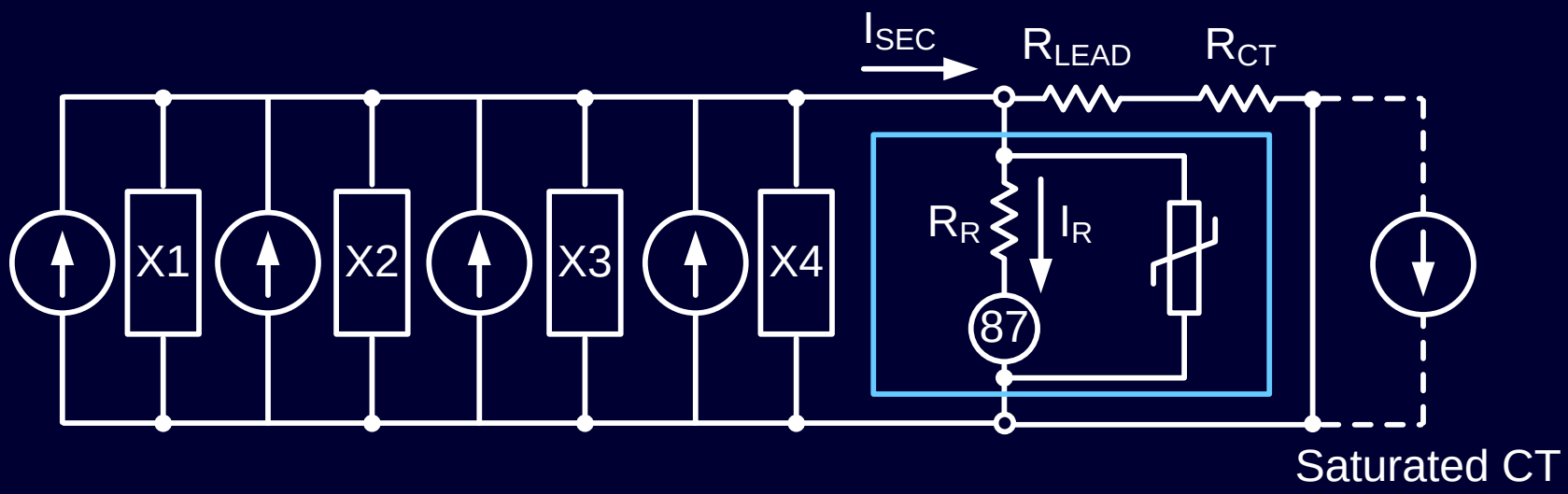
Differential Protection

- High-impedance differential relay
- Low-impedance differential relay
- Advanced differential relay

High-Impedance Differential



High Impedance: CT Saturation



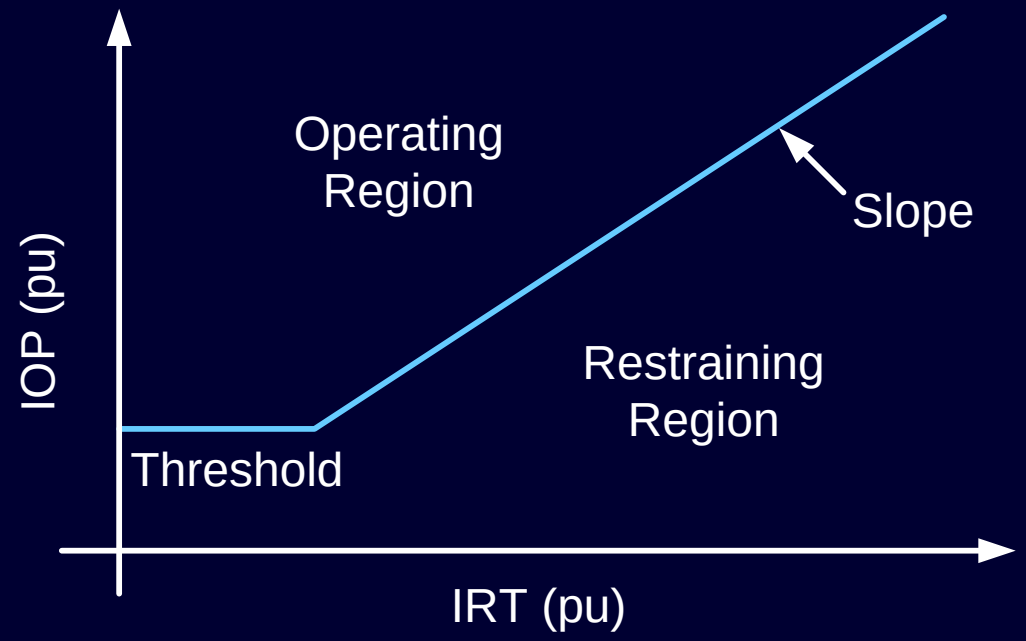
$$I_R = \frac{R_{LEAD} + R_{CT}}{R_{LEAD} + R_{CT} + R_R} \bullet I_{SEC}$$

CT saturation creates false differential current

Low Impedance: Slope Restraint

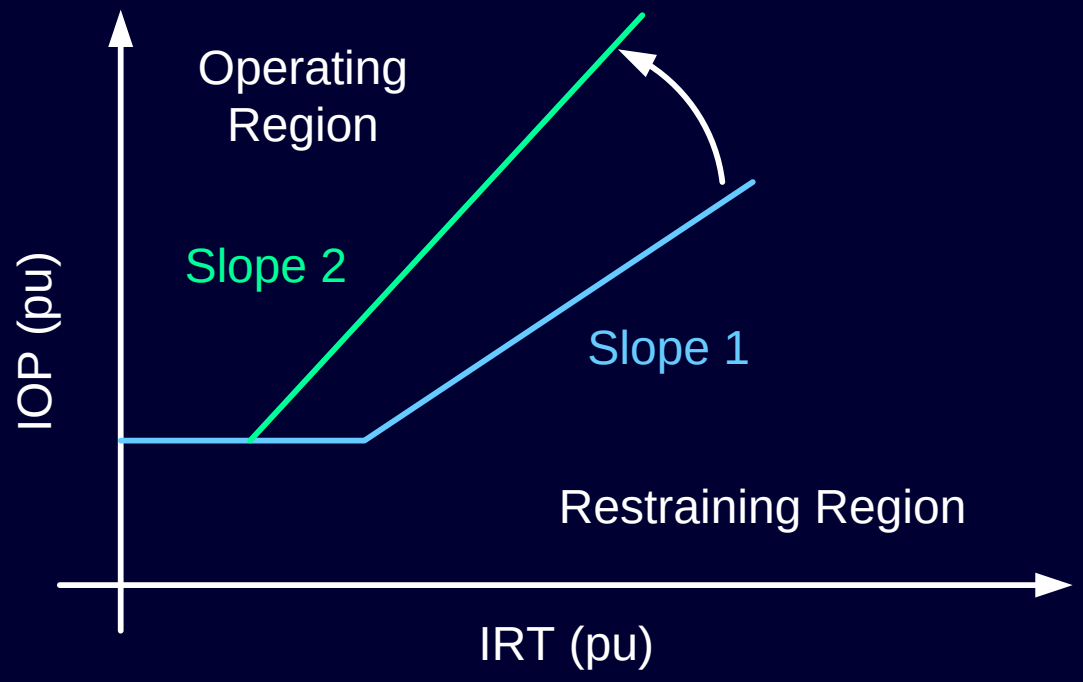
$$IOP = \left| \sum_{k=1}^{N} I_k \right|$$

$$IRT = \sum_{k=1}^{N} \left| I_k \right|$$

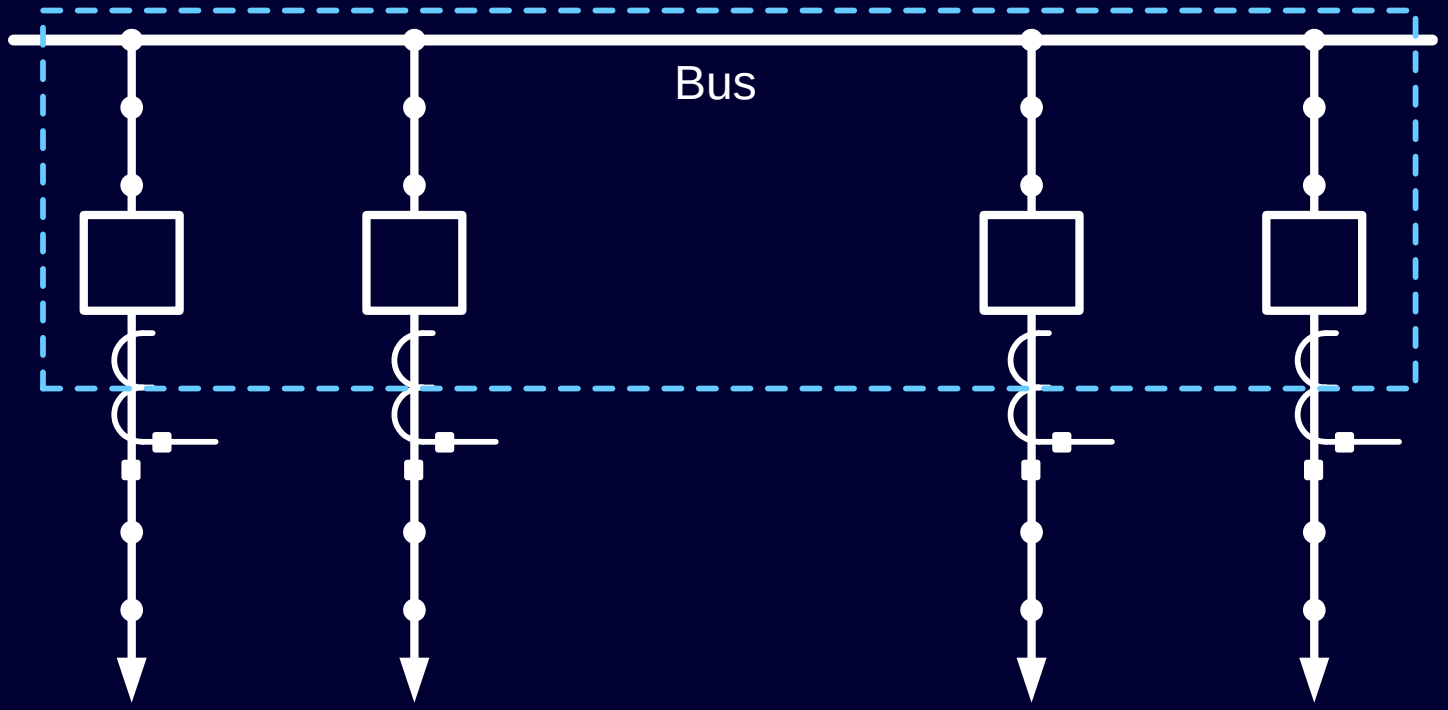


Advanced Low-Impedance Relay

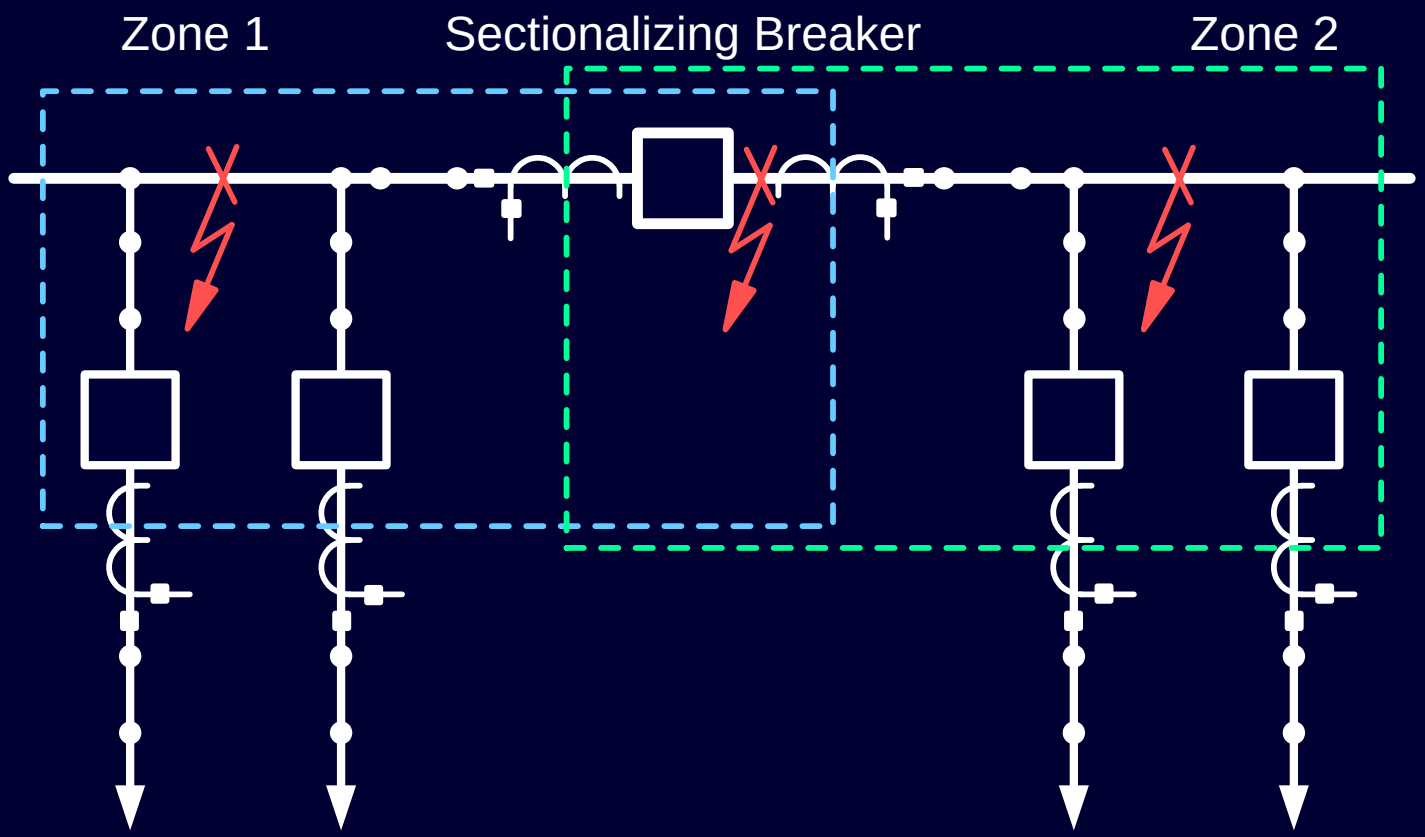
- Internal fault – IOP ↑ and IRT ↑
- External fault – IOP (no change) and IRT ↑



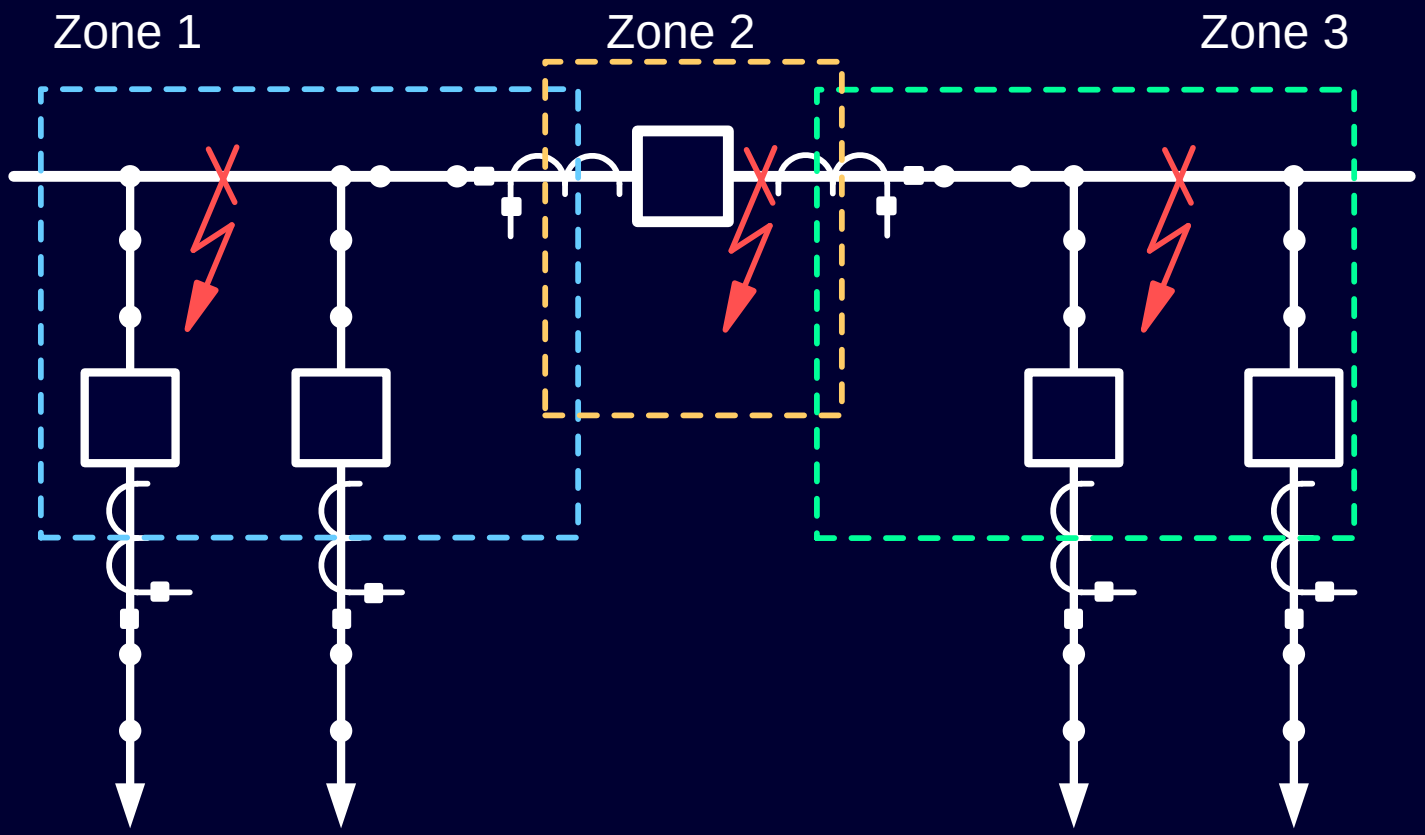
Single Bus



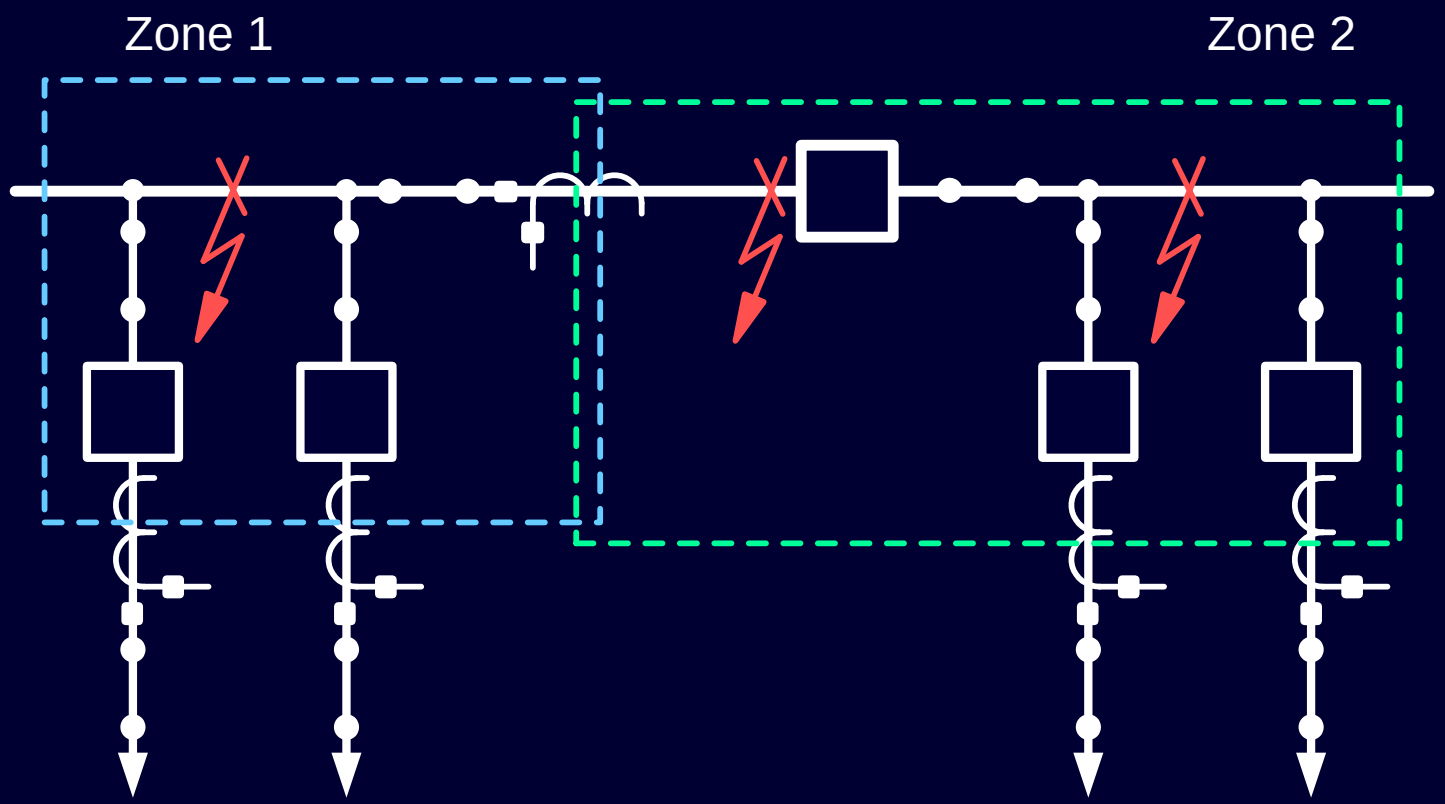
Overlapping Sectionalizing CTs



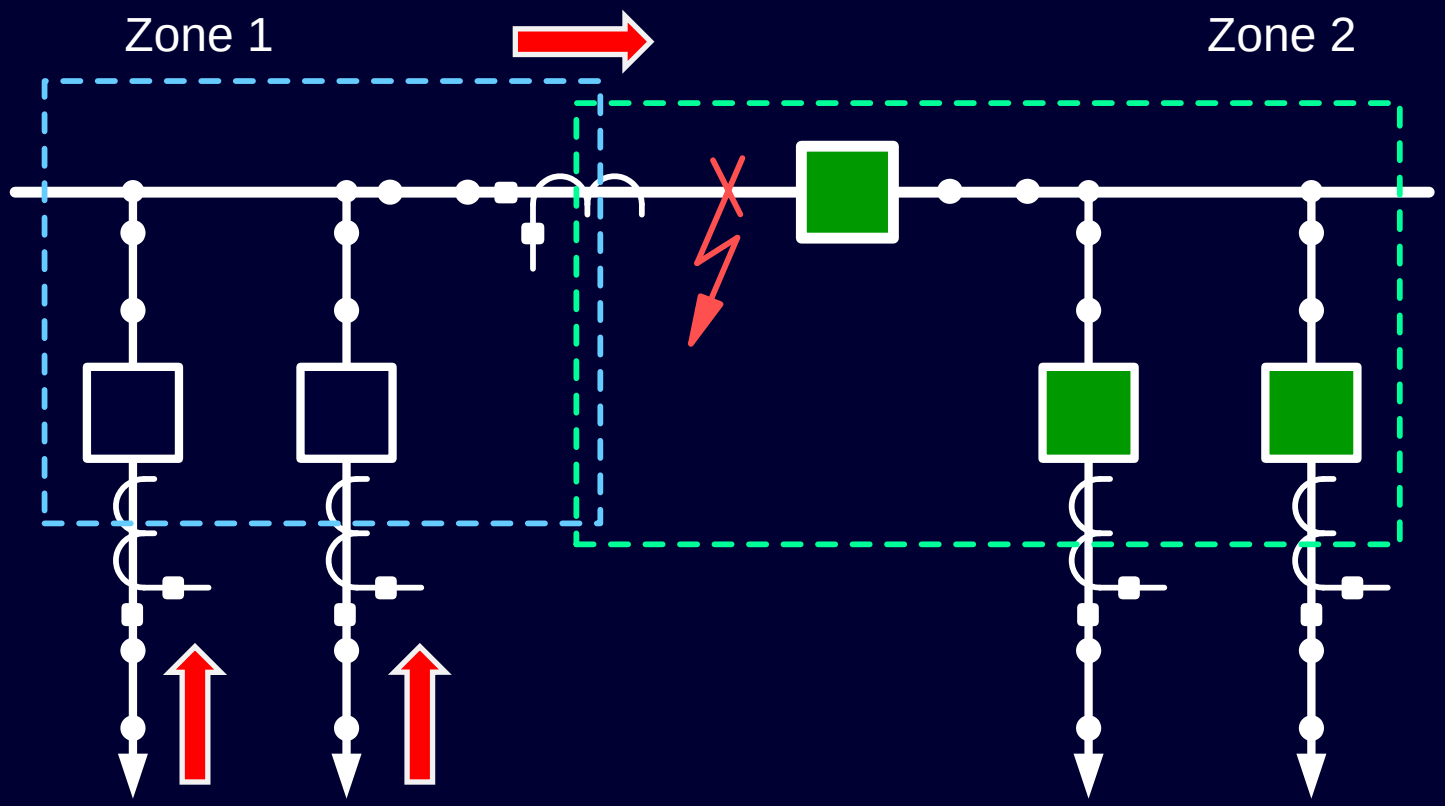
Nonoverlapping Sectionalizing CTs



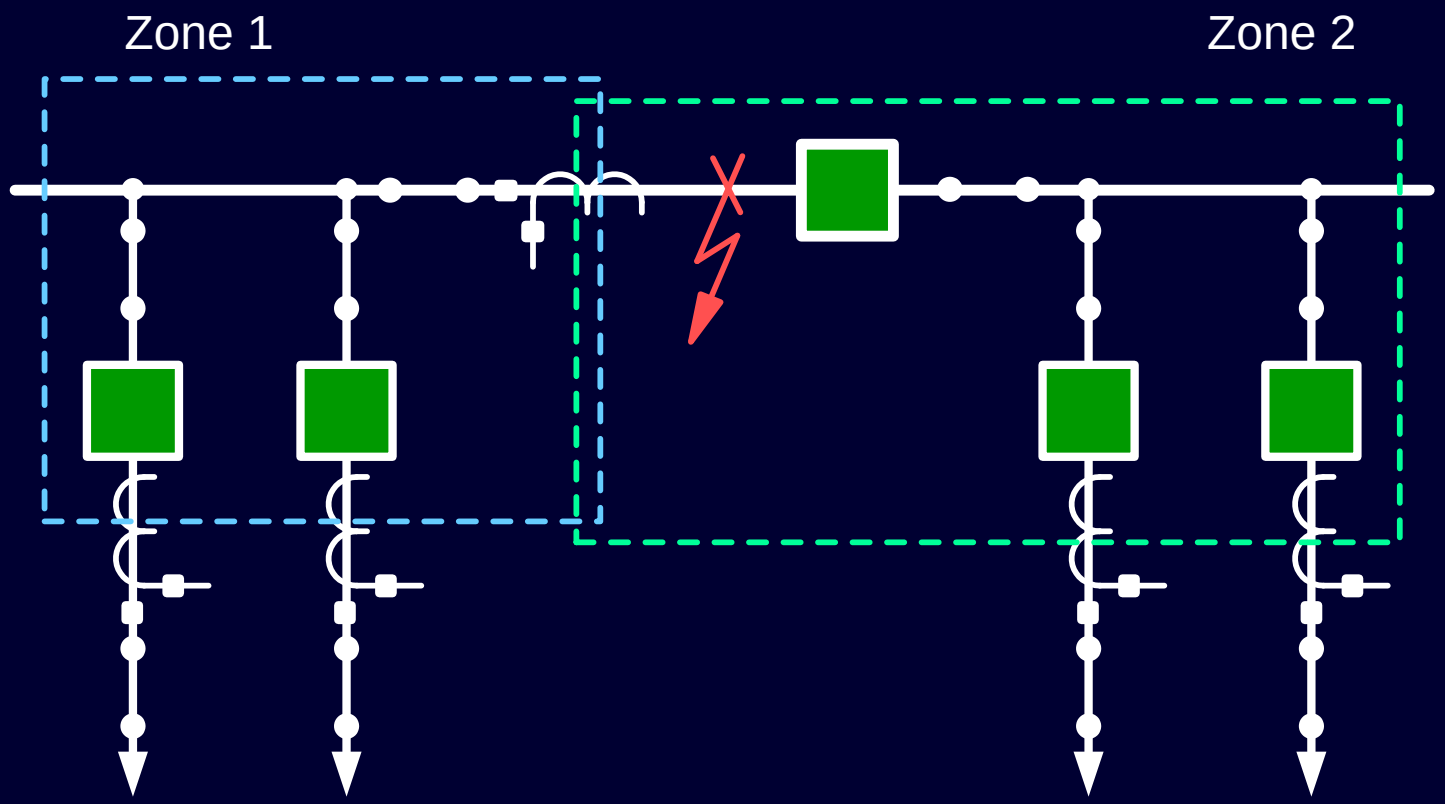
Single Sectionalizing CT



Fault Current After Initial Trips



Breaker Failure Fault Clearing

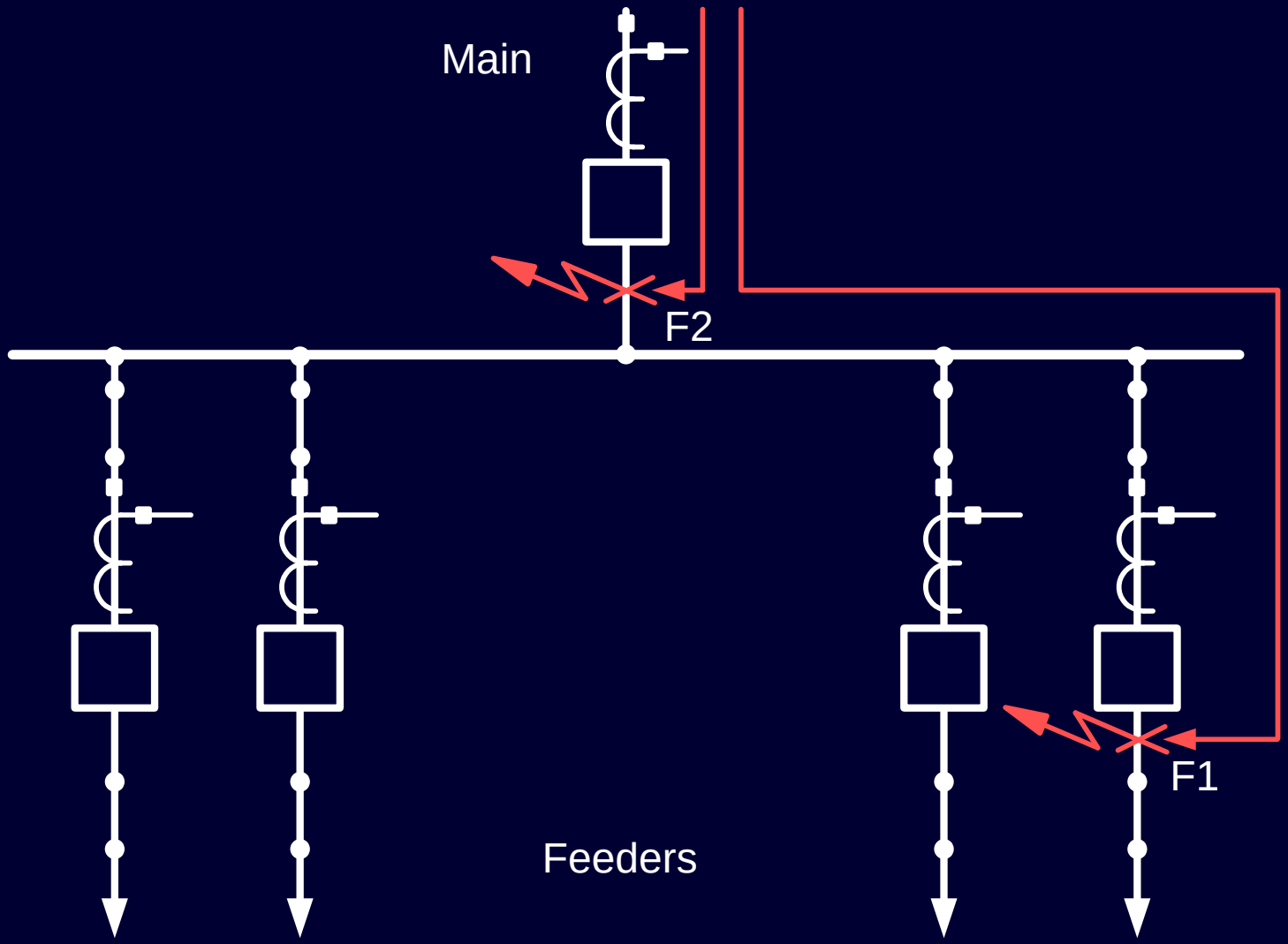


About 10 Cycles to Clear

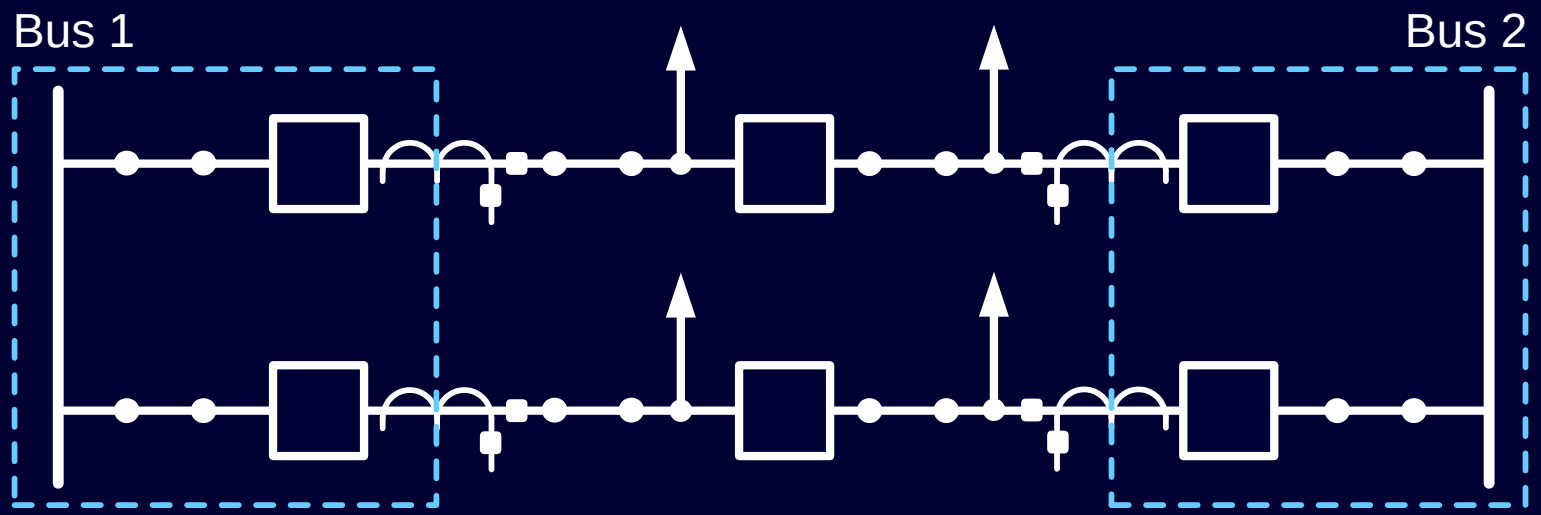
Fast Bus Protection

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

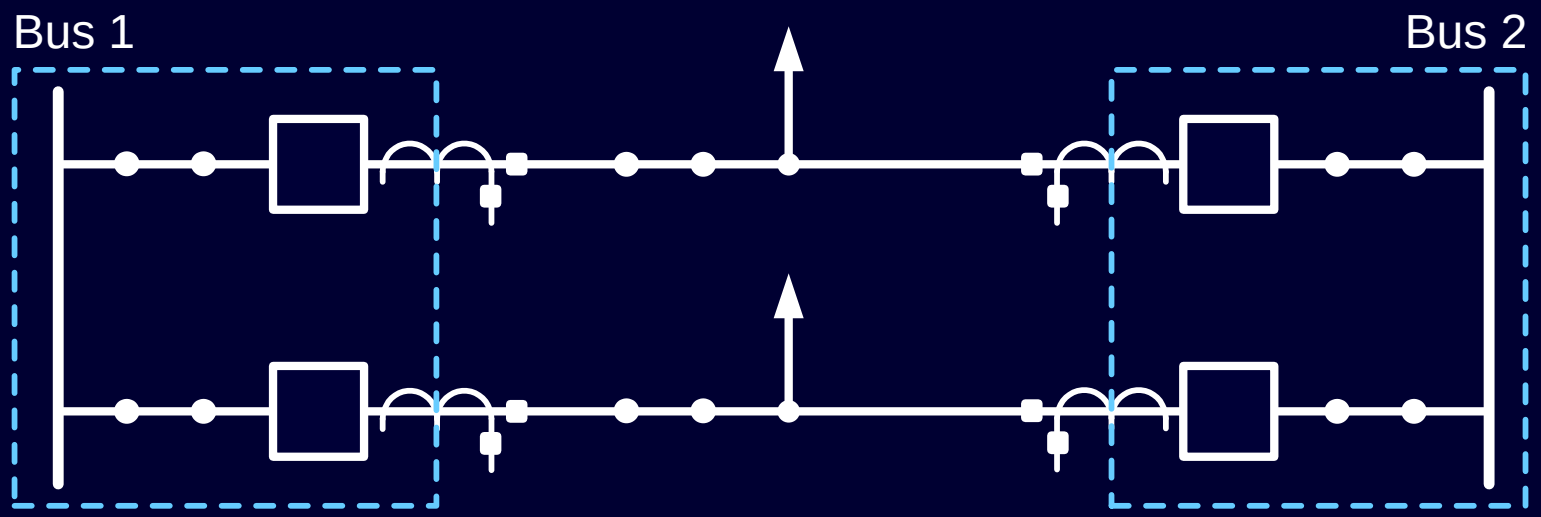
Faulted Radial System



Breaker-and-a-Half Configuration

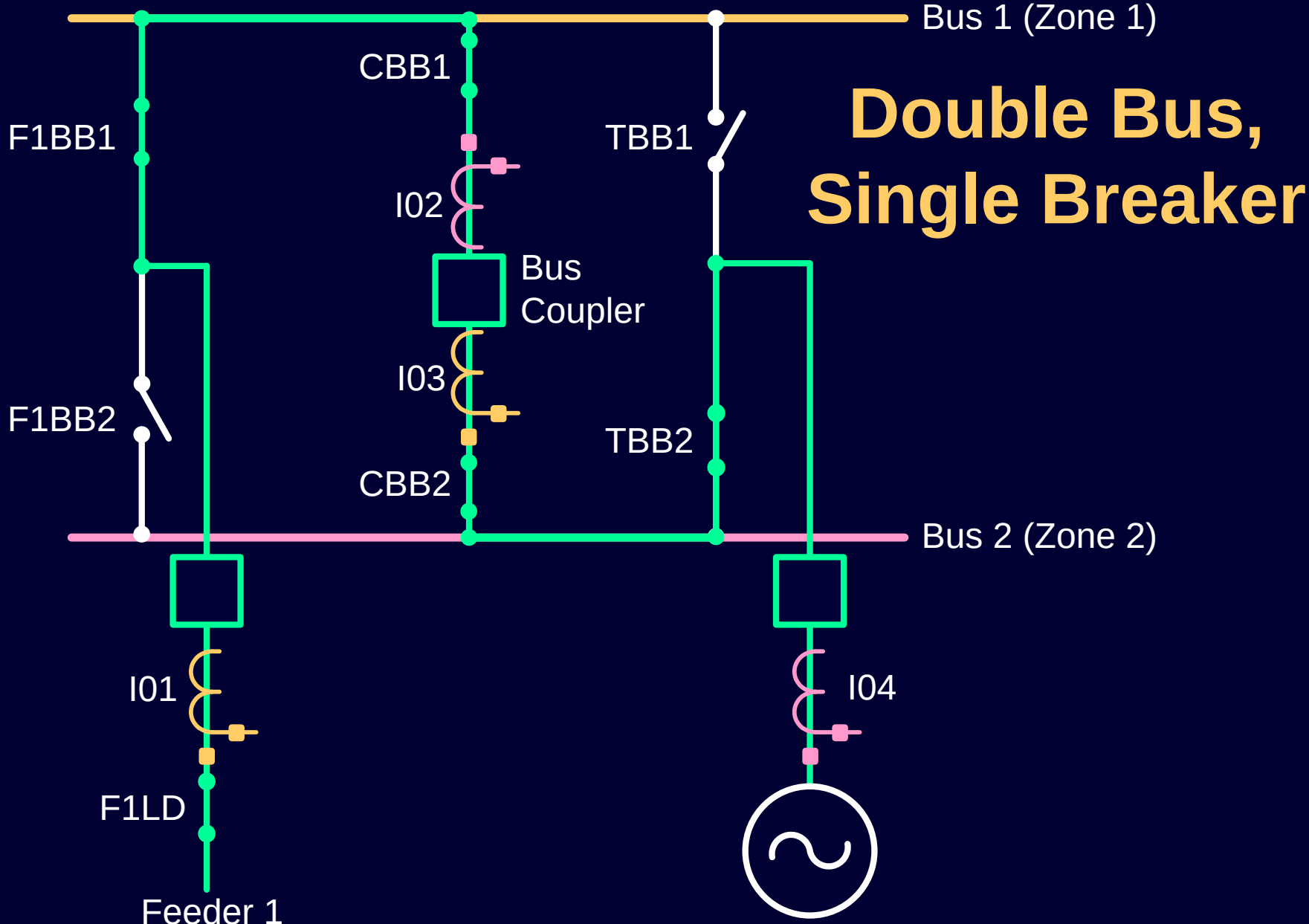


Double-Bus, Double-Breaker Configuration

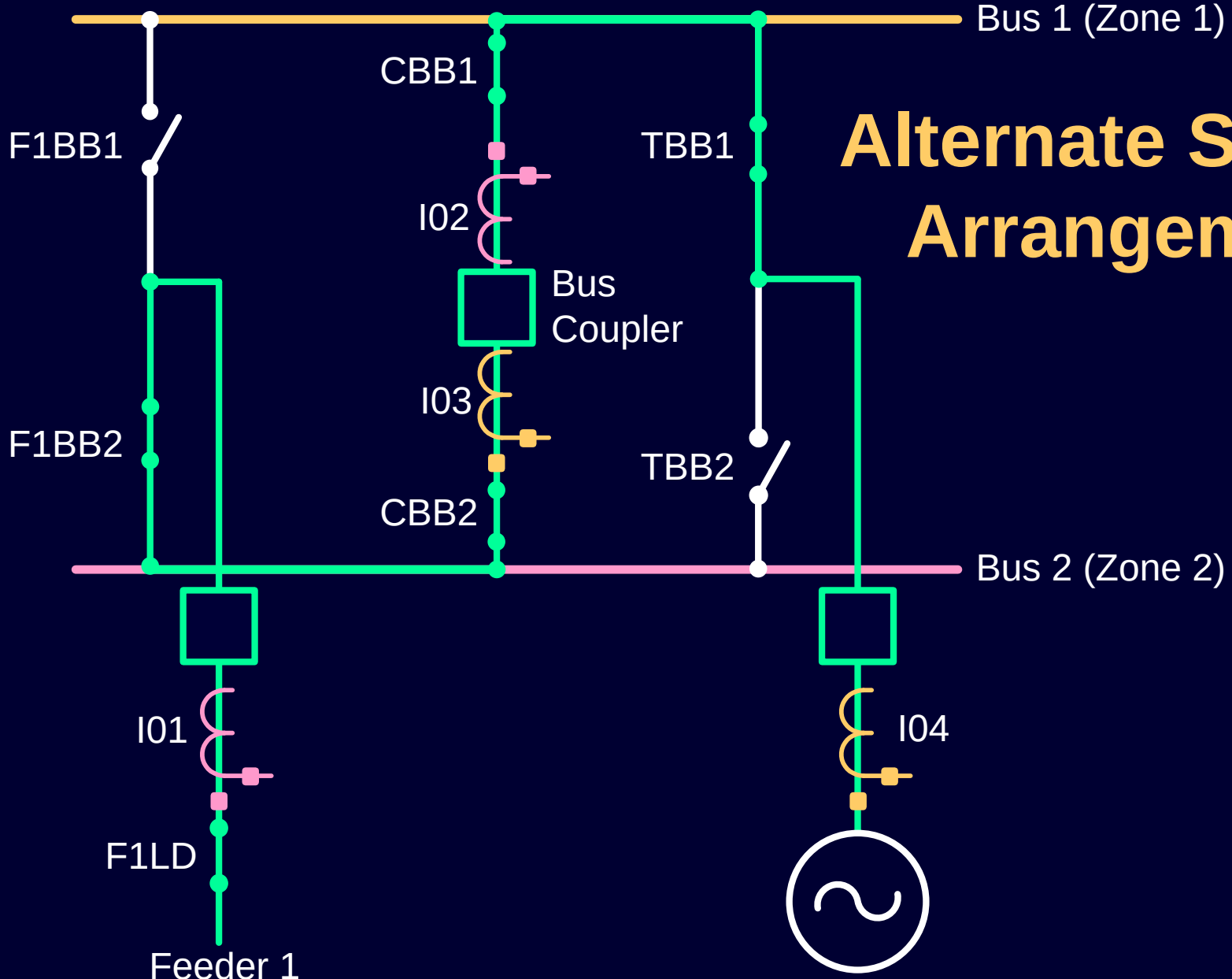


Double-Bus, Single-Breaker Configuration

- Two buses for load sharing
- One breaker per terminal
- Transfer bus shown



Double Bus, Single Breaker



Alternate Station Arrangement

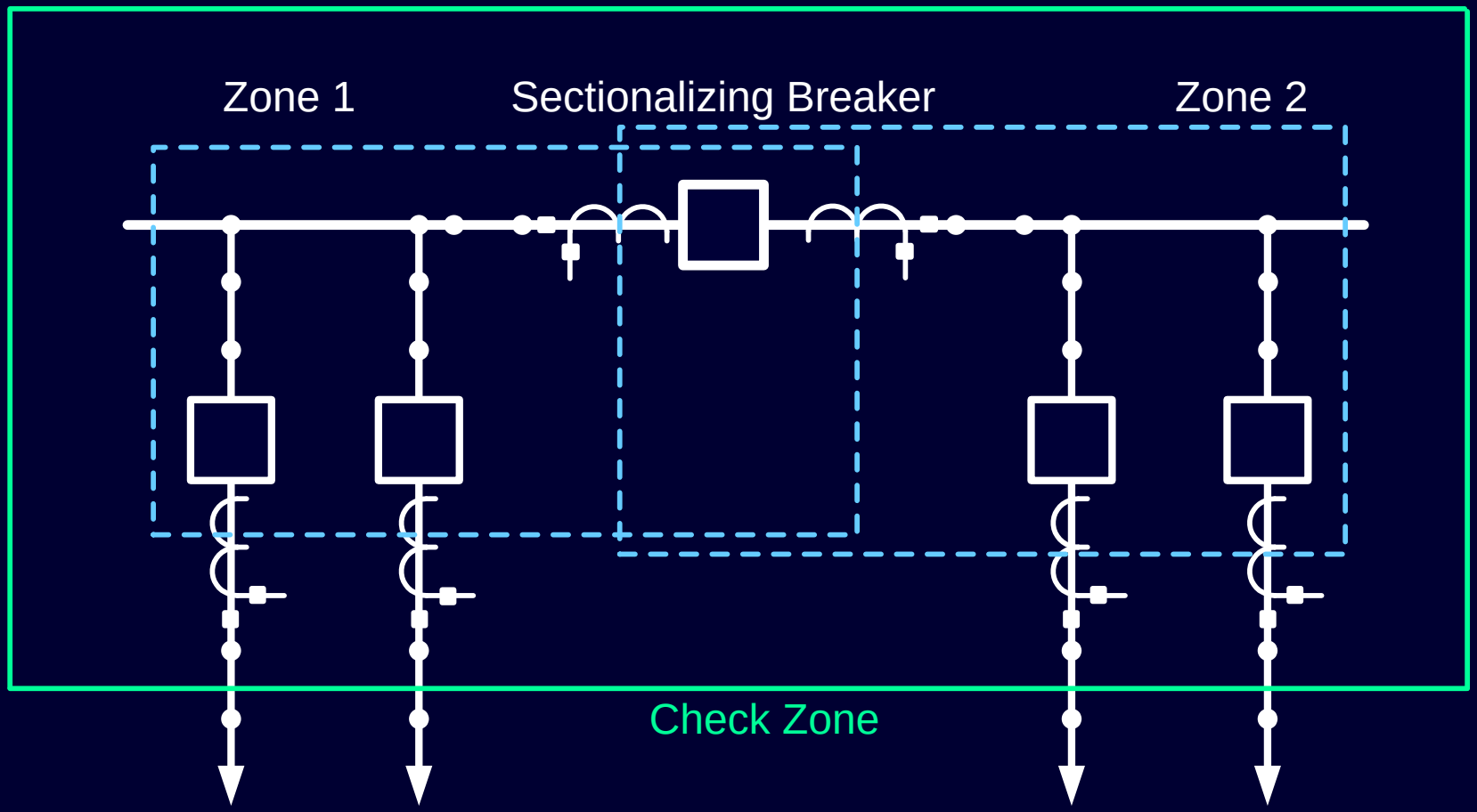
Dynamic Zone Selection

- 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

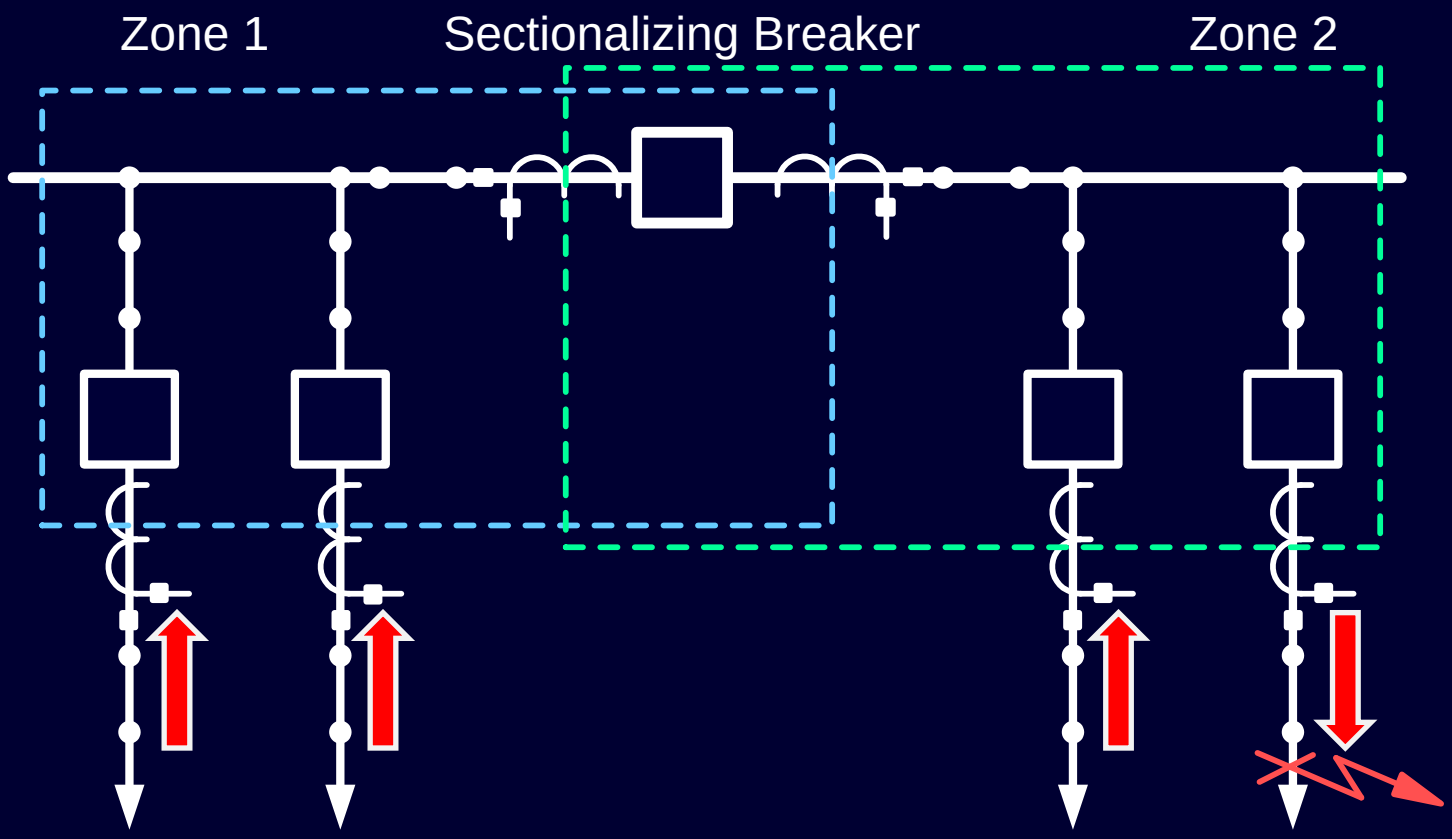
Check Zone



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

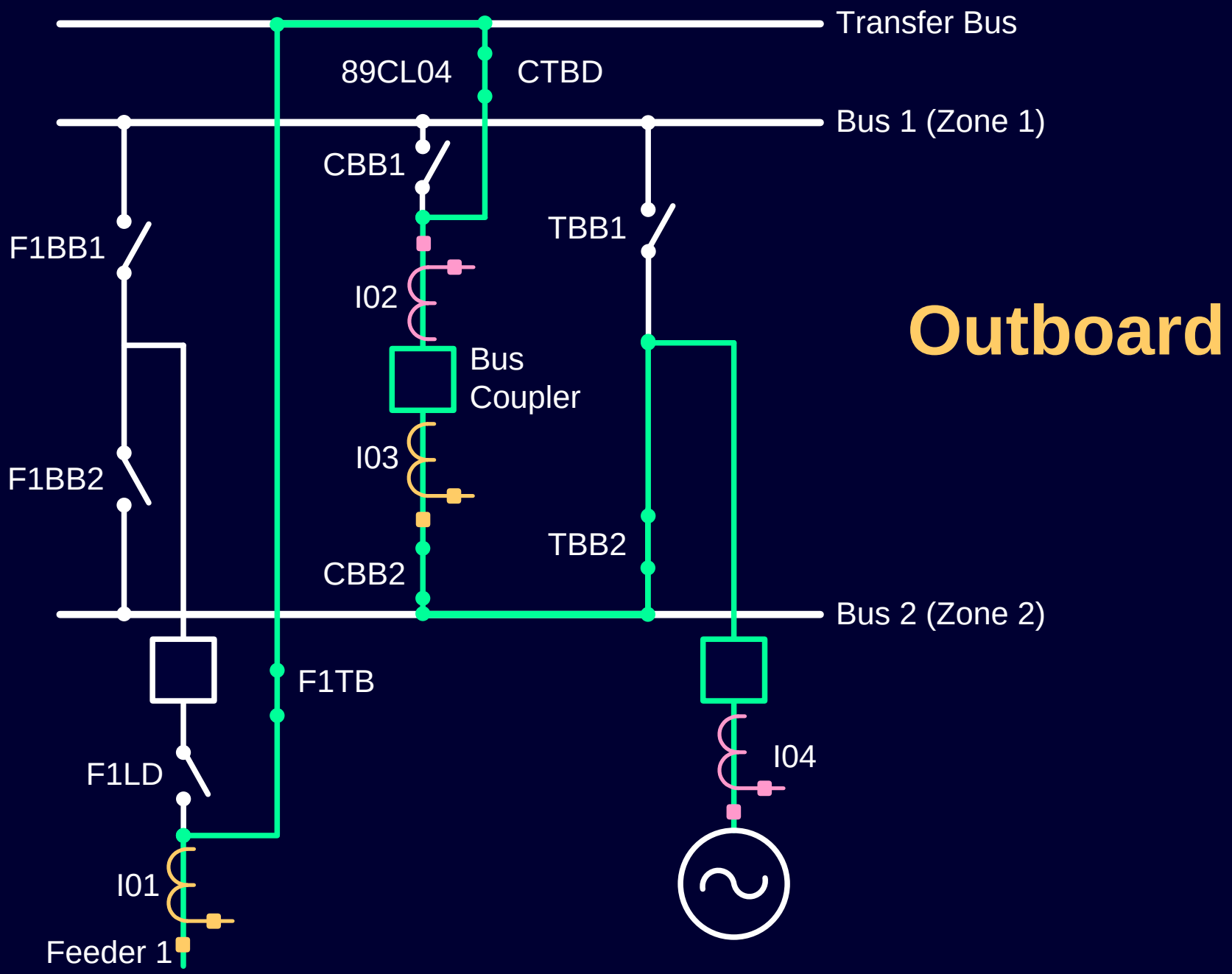


Fault Voltage Signature

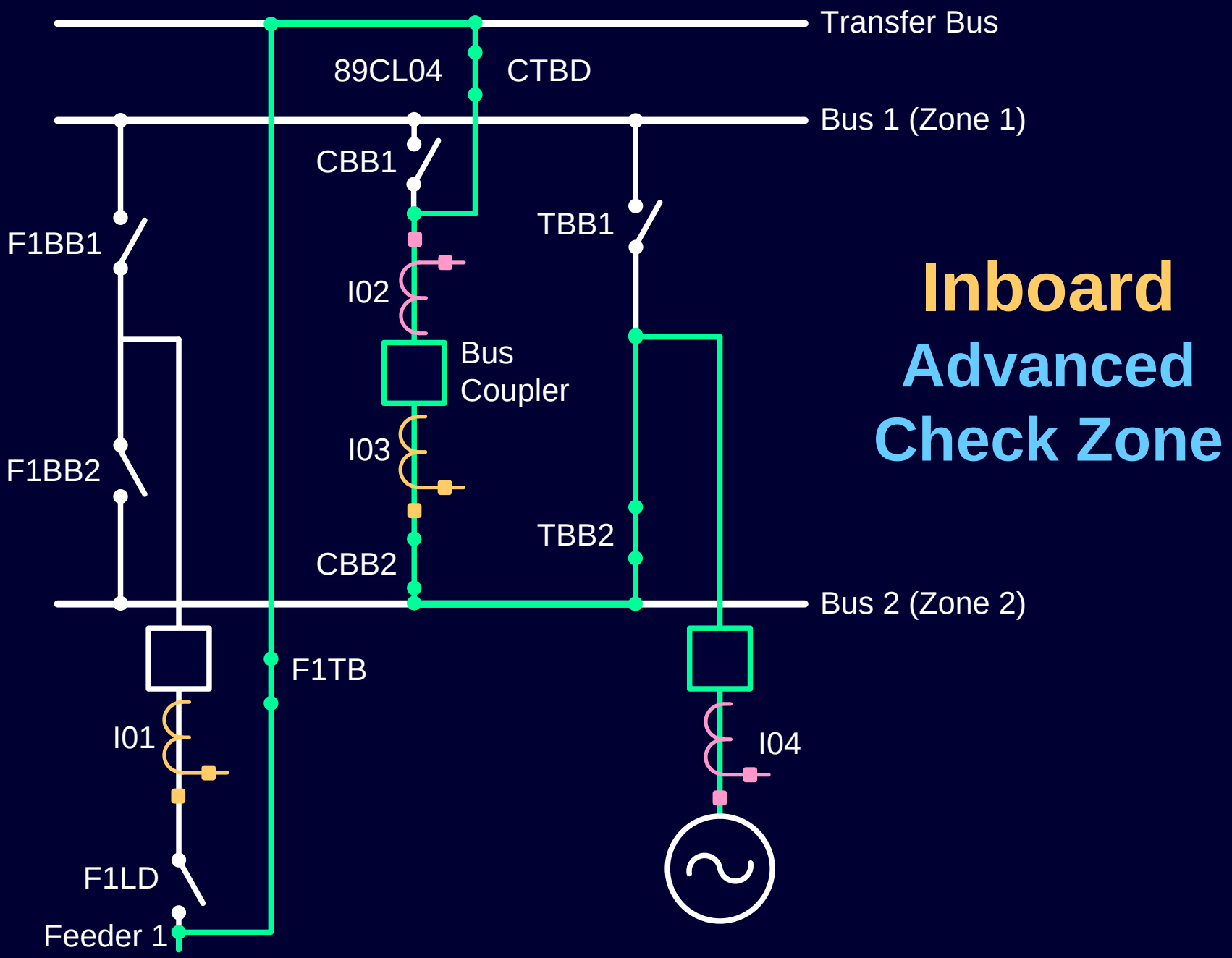
- V1 ↓ (all faults)
- V0 and V2 ↑ (unbalanced faults)
- No voltage signature indicating whether fault is in zone

Transfer Operation

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


Transfer Bus
89CL04
CTBD
Bus 1 (Zone 1)
CBB1
TBB1
F1BB1
I02
Bus
Coupler
I03
F1BB2
TBB2
CBB2
Bus 2 (Zone 2)
F1TB
I04
F1LD
I01
Feeder 1

Outboard



Inboard
Advanced
Check Zone

Conclusion

- Consider station reliability versus protection complexity
- Determine appropriate relaying based on application

Questions?