

Minimizing Capacitor Bank Outage Time Through Fault Location

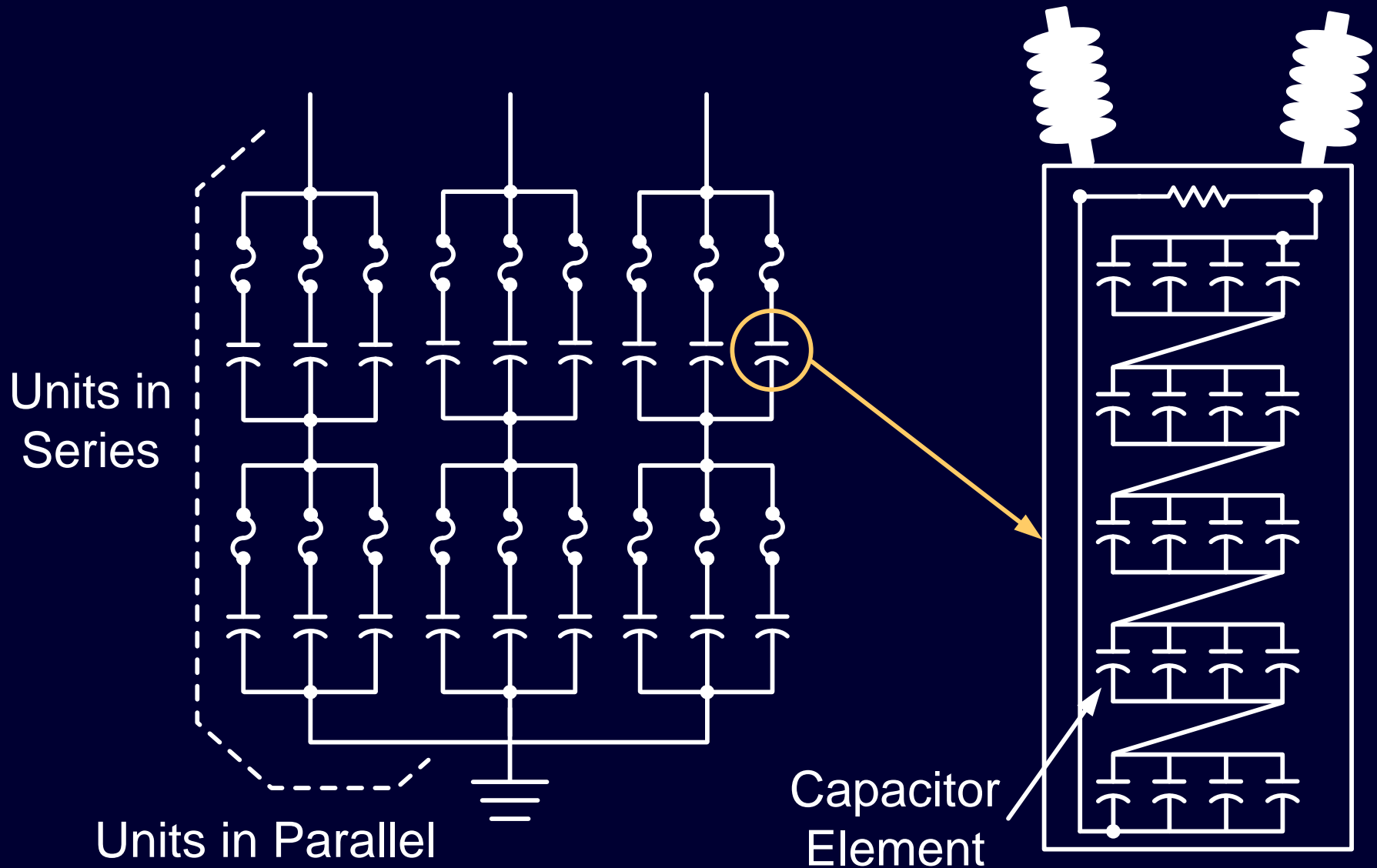
Joseph Schaefer

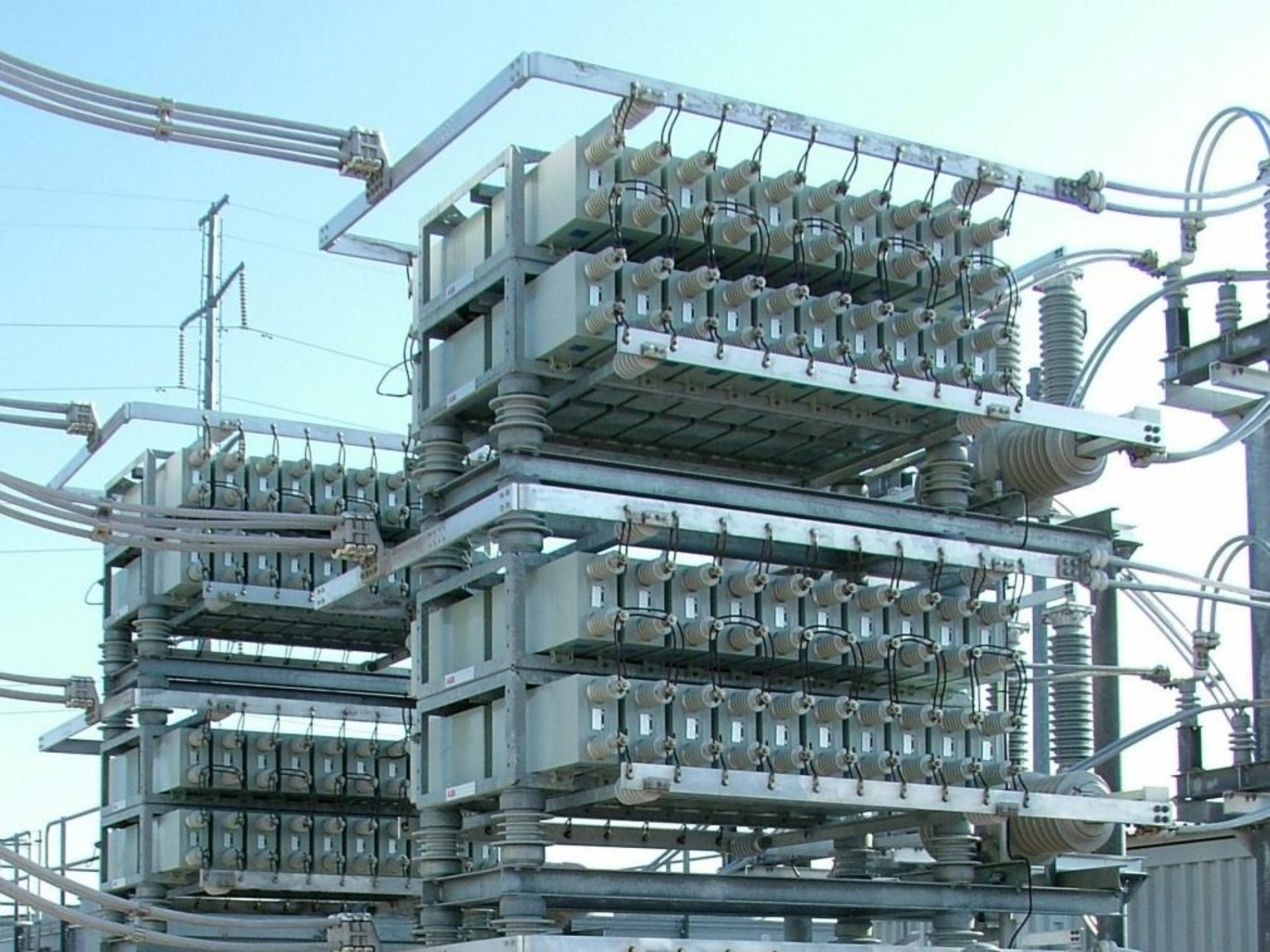
Florida Power & Light Company

Satish Samineni, Casper Labuschagne,
Steven Chase, and Dereje Jada Hawaz

Schweitzer Engineering Laboratories, Inc.

Capacitor Bank Configuration





Problem Statement

- Unit or element failures result in overvoltages
- Unbalance protection usually trips bank if overvoltages are too high
- Locating faulty unit is time-consuming process, resulting in long outage time

Steps to Put Bank Back in Service

- Take bank out of service
- Isolate and ground bank
- Disconnect each unit
- Measure capacitance across each unit
- Replace faulty unit
- Balance bank
- Energize bank

Fault Location Technique

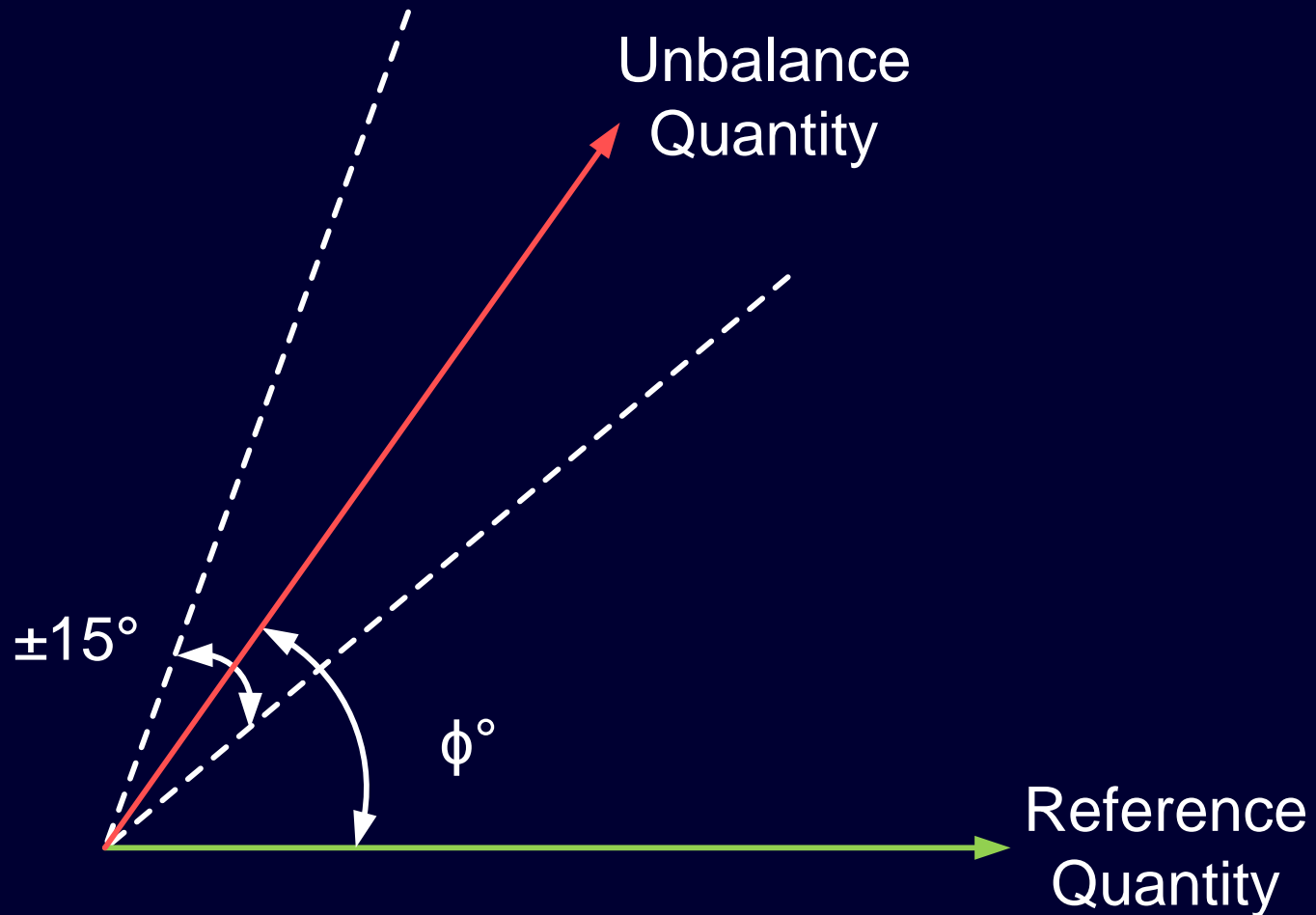
- Unbalance protection provides primary protection against unit or element failures in capacitor banks
- Unbalance protection methods
 - ◆ Phase voltage
 - ◆ Neutral voltage
 - ◆ Phase current
 - ◆ Neutral current

Fault Location Technique

- Unbalance protection uses measured quantities from instrument transformers to calculate unbalance quantity
- Unbalance quantity is phasor
 - ◆ Magnitude
 - ◆ Phase angle

Fault Location Technique

Phase and Section With Faulty Unit



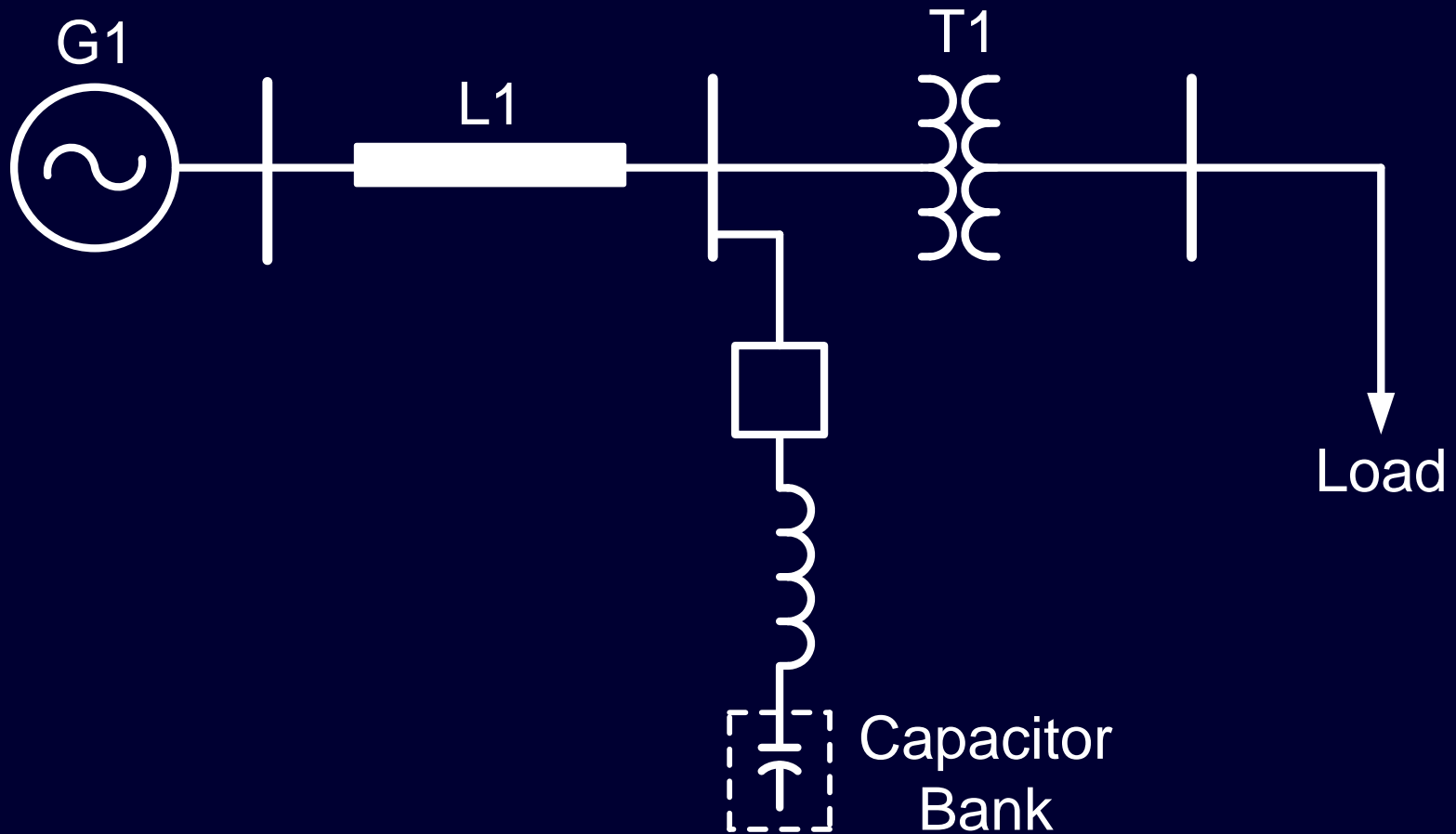
Fault Location Technique

- Supervised by alarm or trip for sensitivity
- $\pm 15^\circ$ blinder applied for security
- Affected by fusing method
- Immune to inherent unbalance

Advantages of Proposed Fault Location Technique

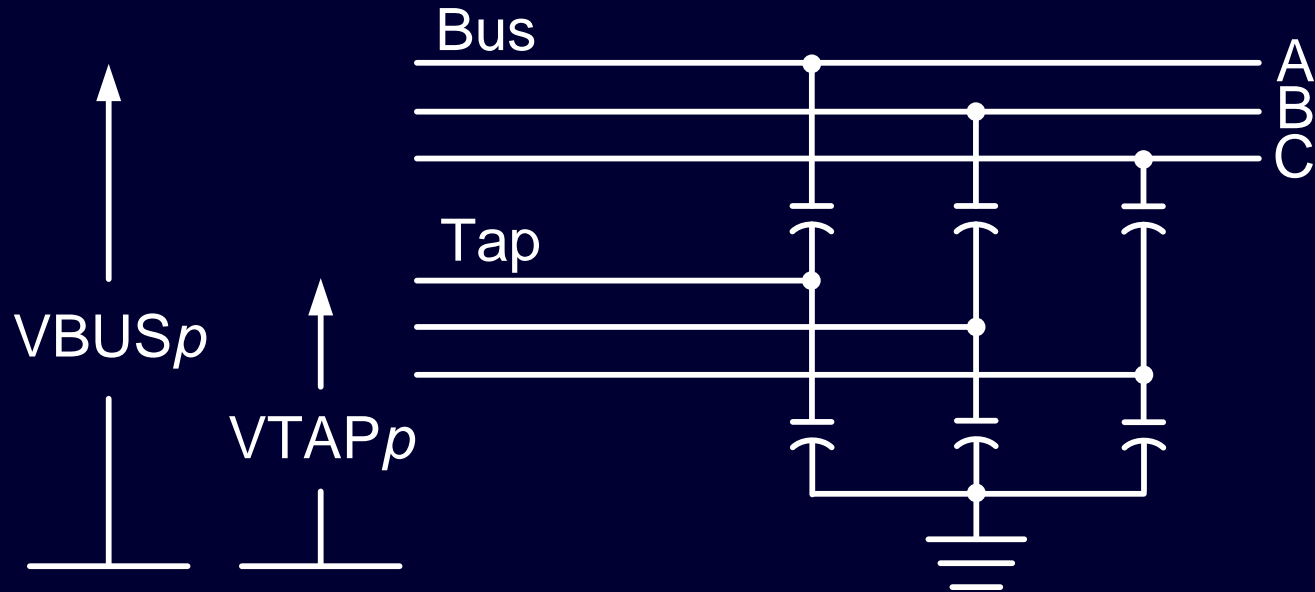
- Minimal outage time – by identifying phase and section
- Economical – embedded in protection
- Versatile – can be applied to wide range of bank configurations

Power System Modeled in RTDS



Phase Voltage Unbalance Protection

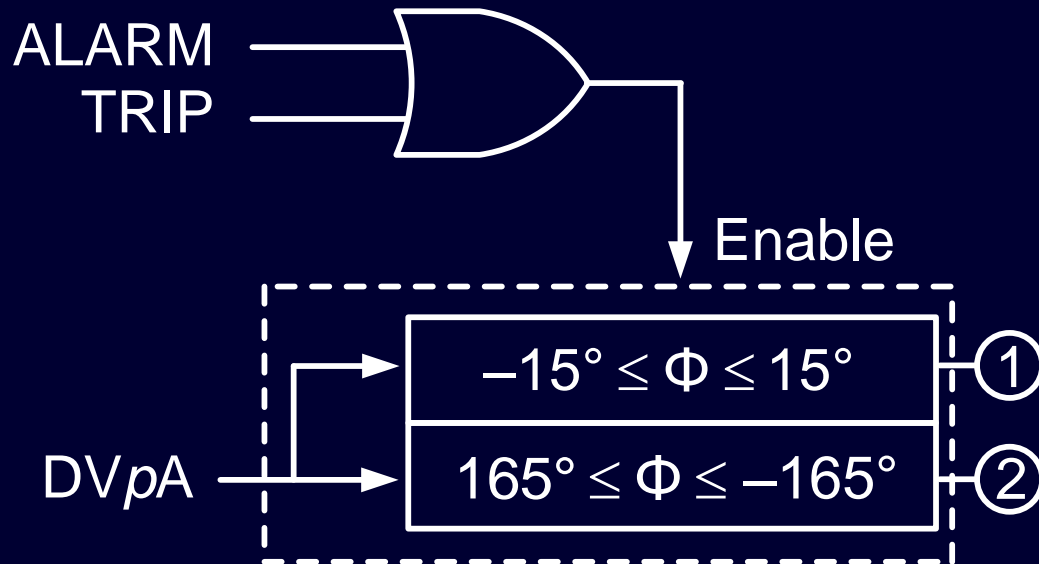
Single-Wye Bank



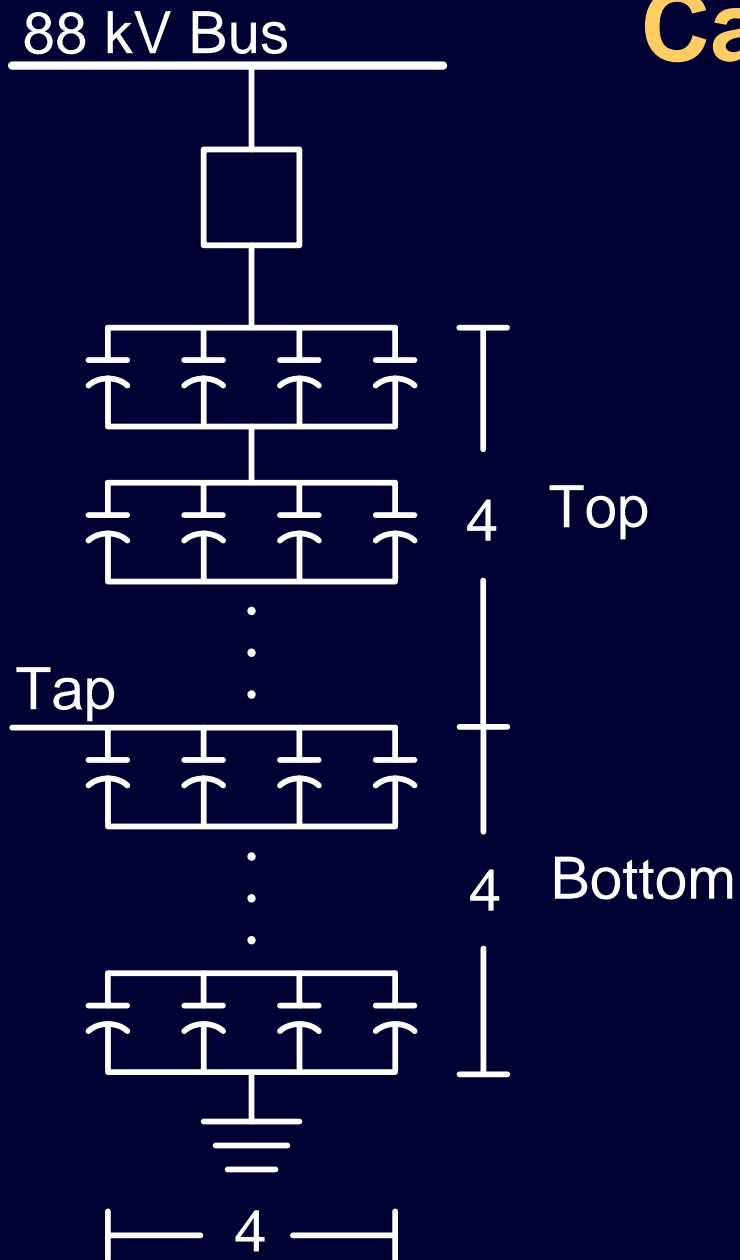
$$DV_p = V_{BUSp} - K_p \cdot V_{TAPp}$$

Fault Location Principle

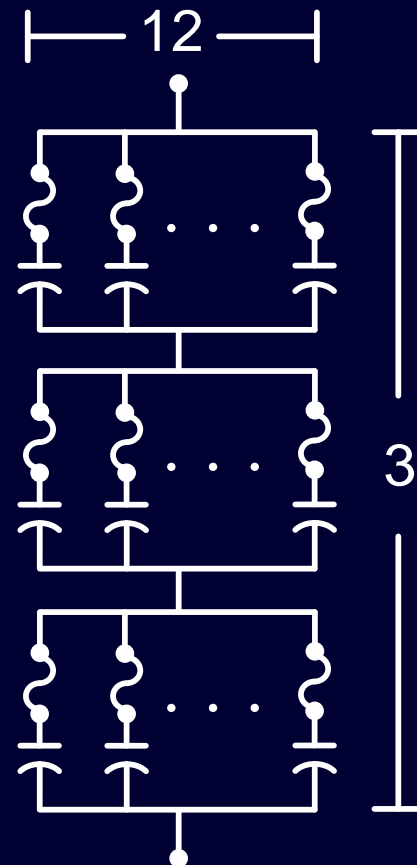
Switch at Position *a* if Bank Is Fuseless
Switch at Position *b* if Bank Is Fused



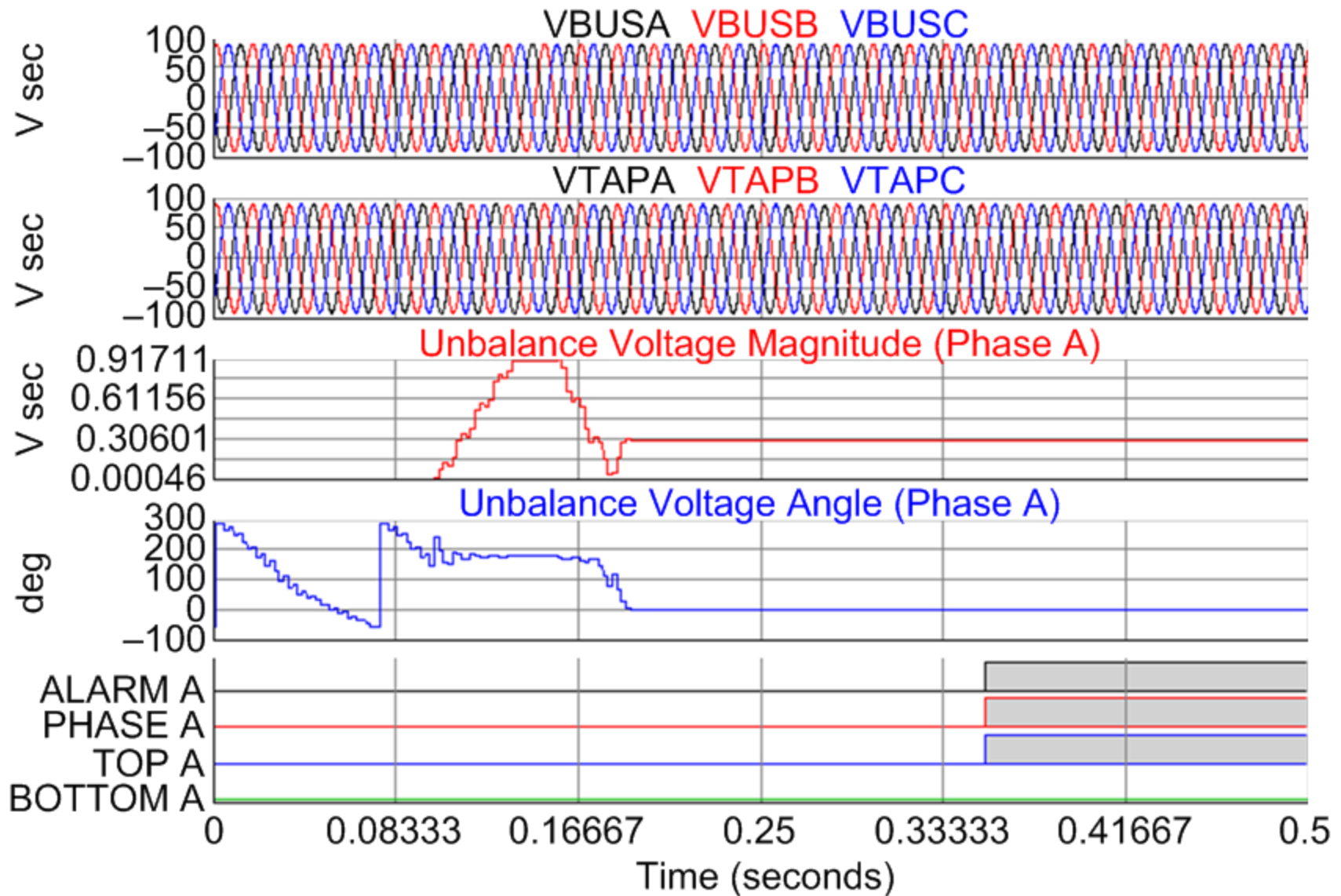
Capacitor Bank Model



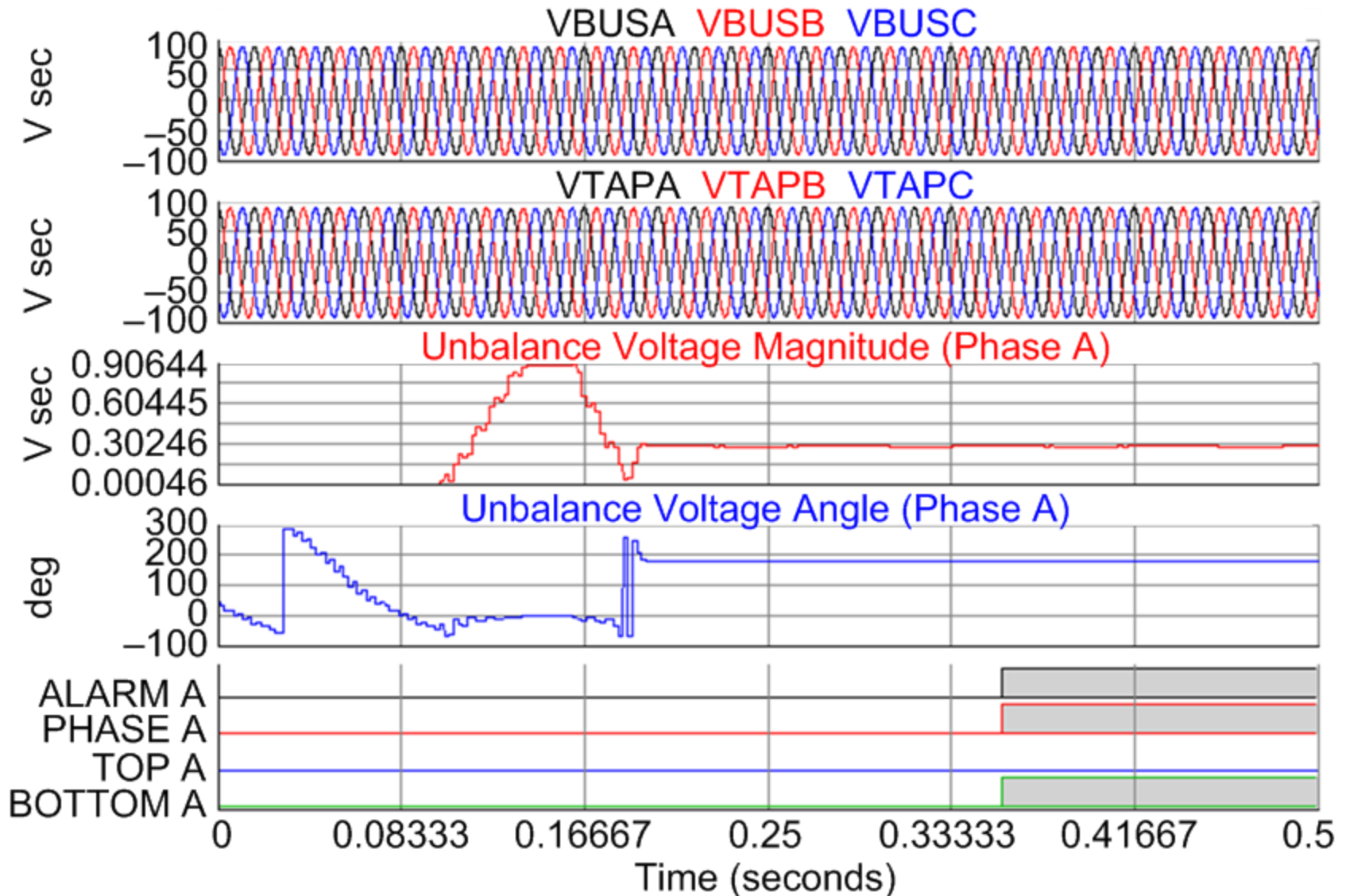
Single Capacitor Unit



Fault in Phase A and Top Section

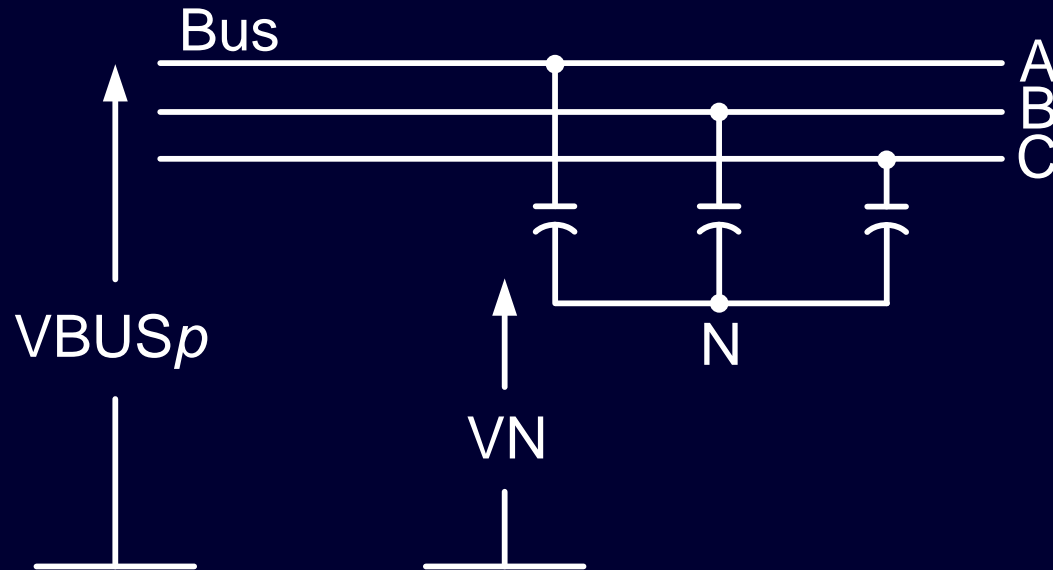


Fault in Phase A and Bottom Section



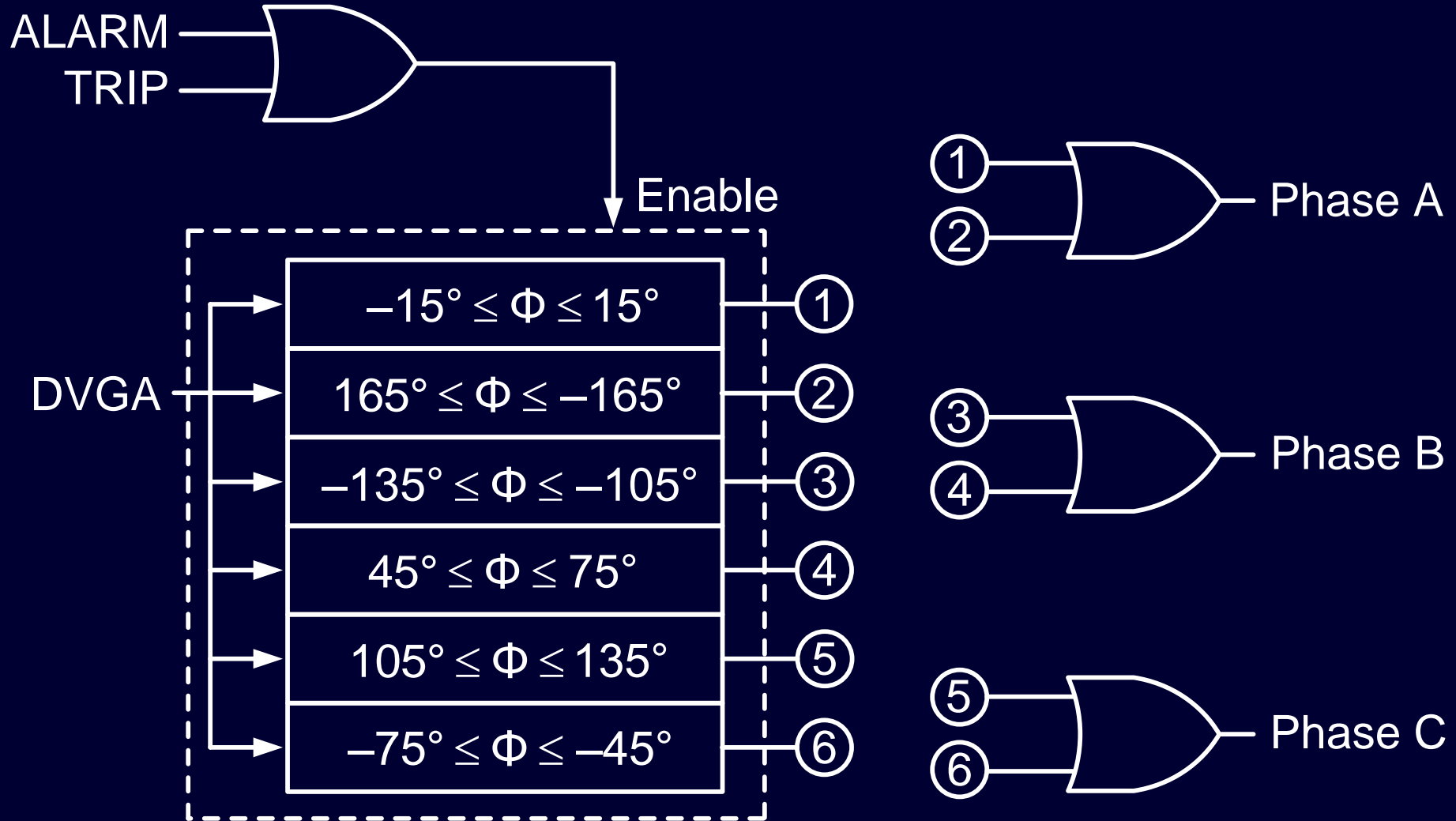
Neutral Voltage Unbalance Protection

Single-Wye Bank

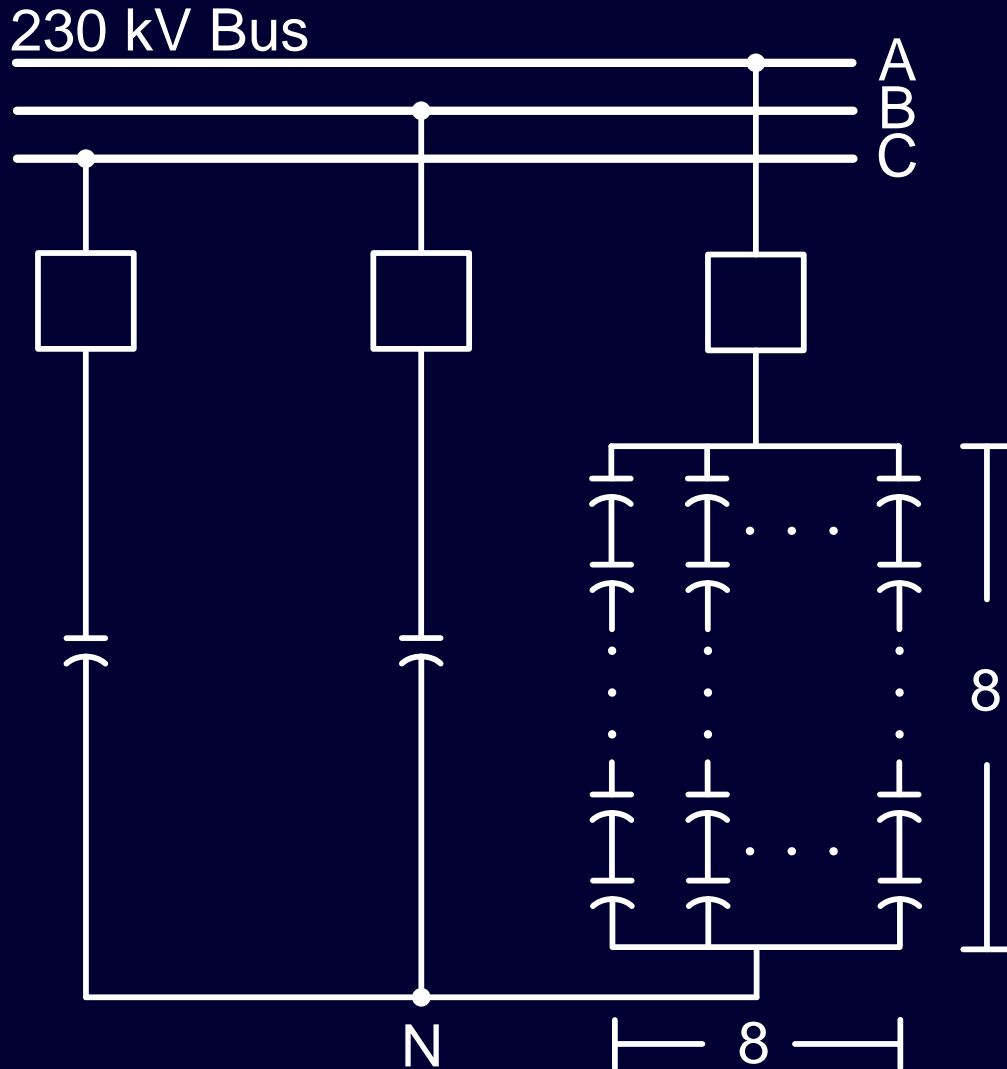


$$DVG = VBUSA + VBUSB + VBUSC - 3 \cdot VN - (K1 \cdot (VBUSB - VN) + K2 \cdot (VBUSC - VN))$$

Fault Location Principle



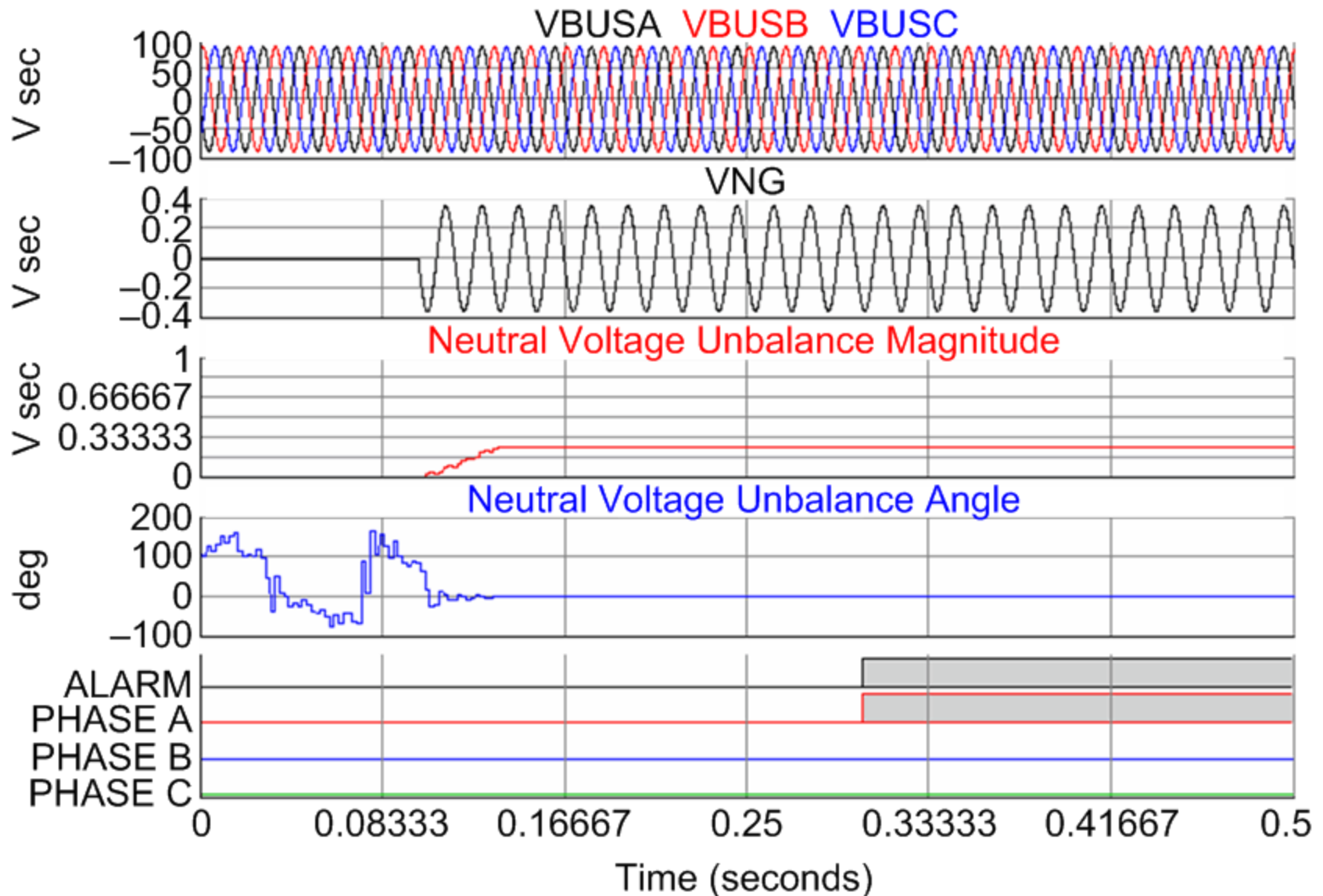
Capacitor Bank Model



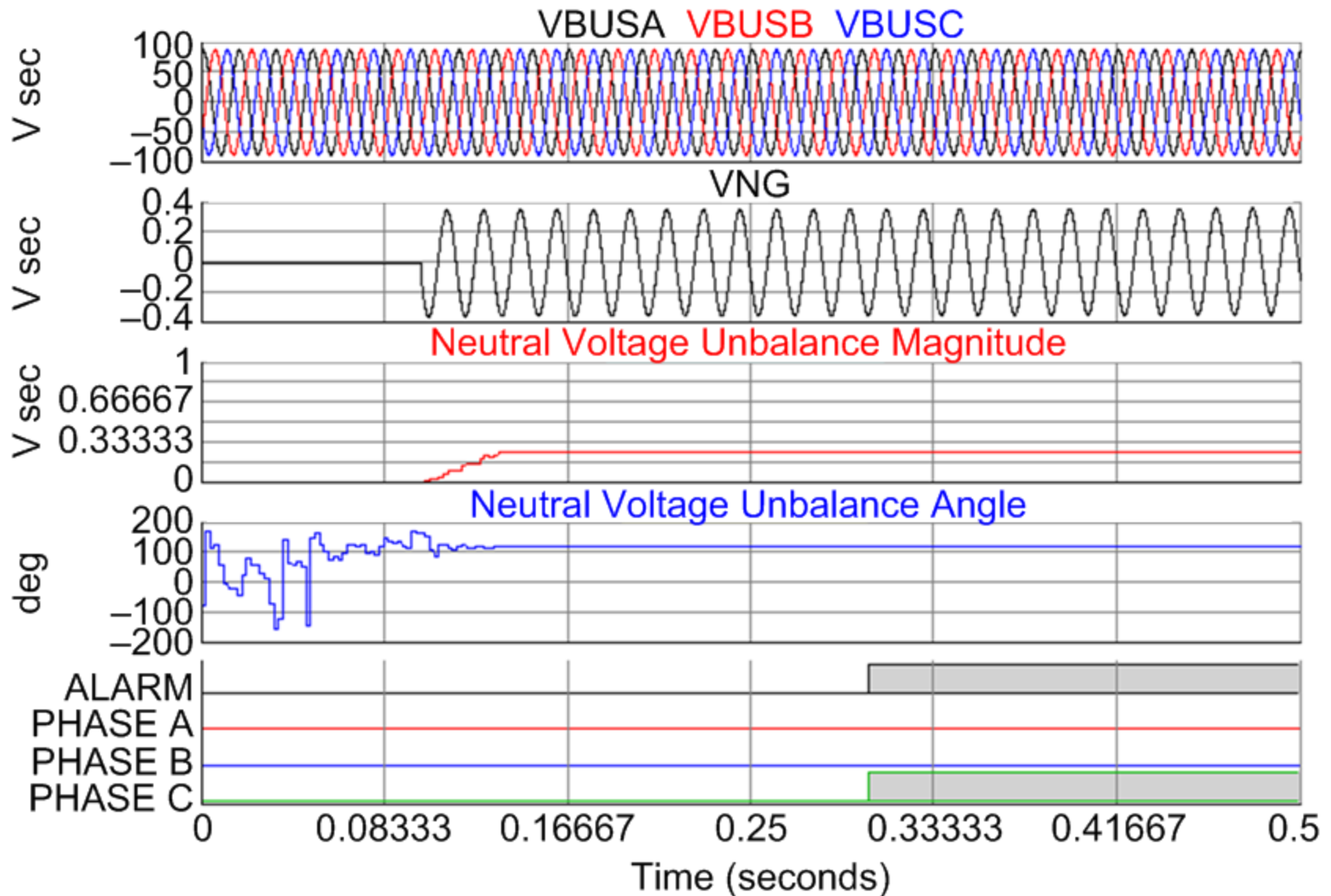
Single Capacitor Unit



Fault in Phase A

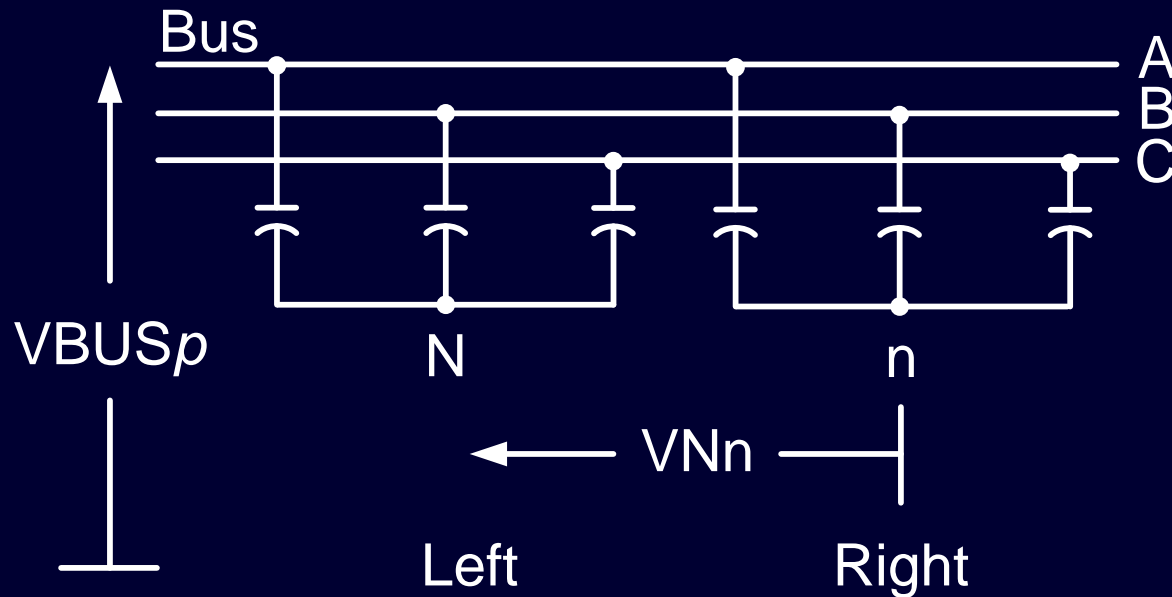


Fault in Phase C



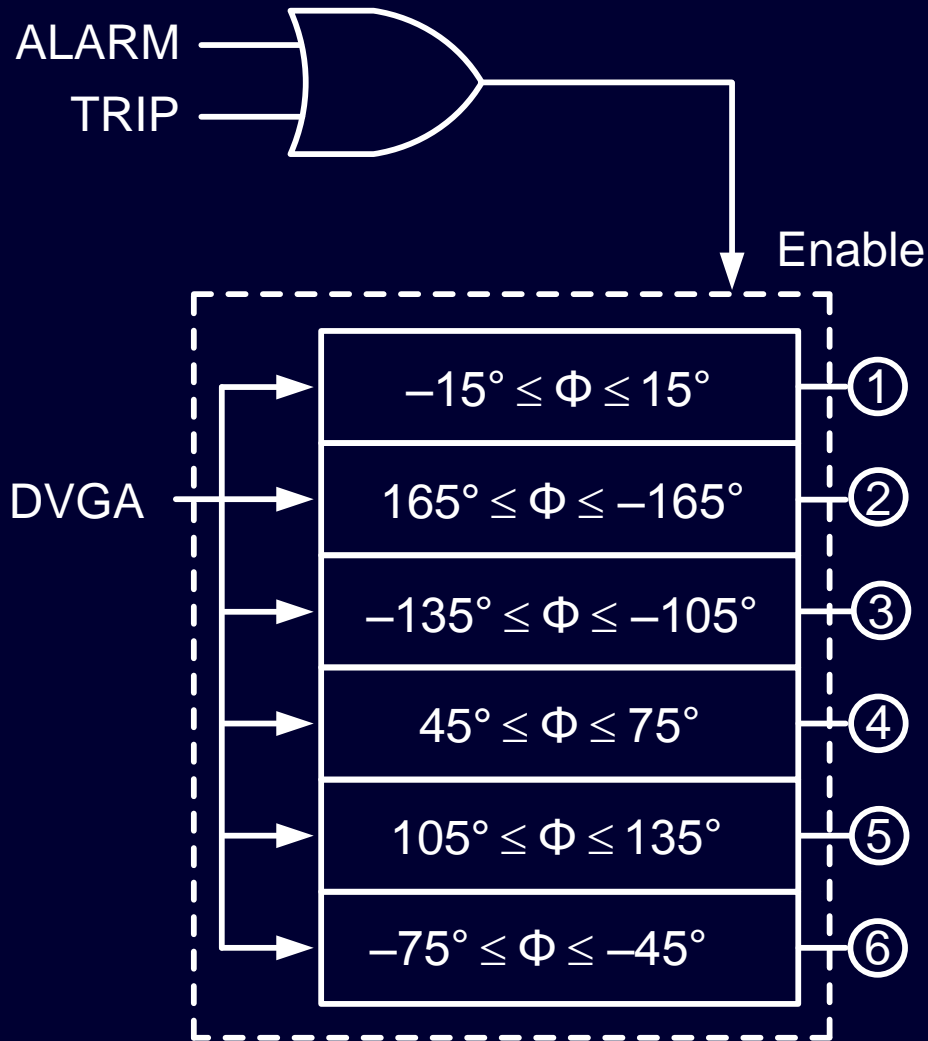
Neutral Voltage Unbalance Protection

Double-Wye Bank

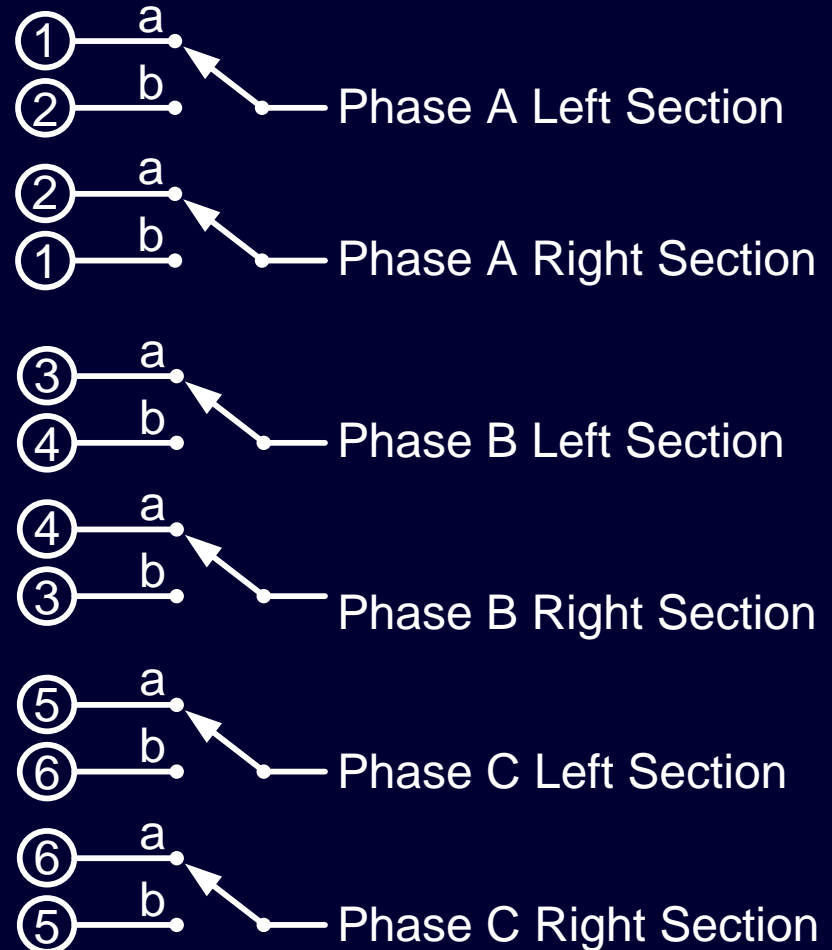


$$DVG = V_{Nn} - K_n \cdot V_{1BUS}$$

Fault Location Principle

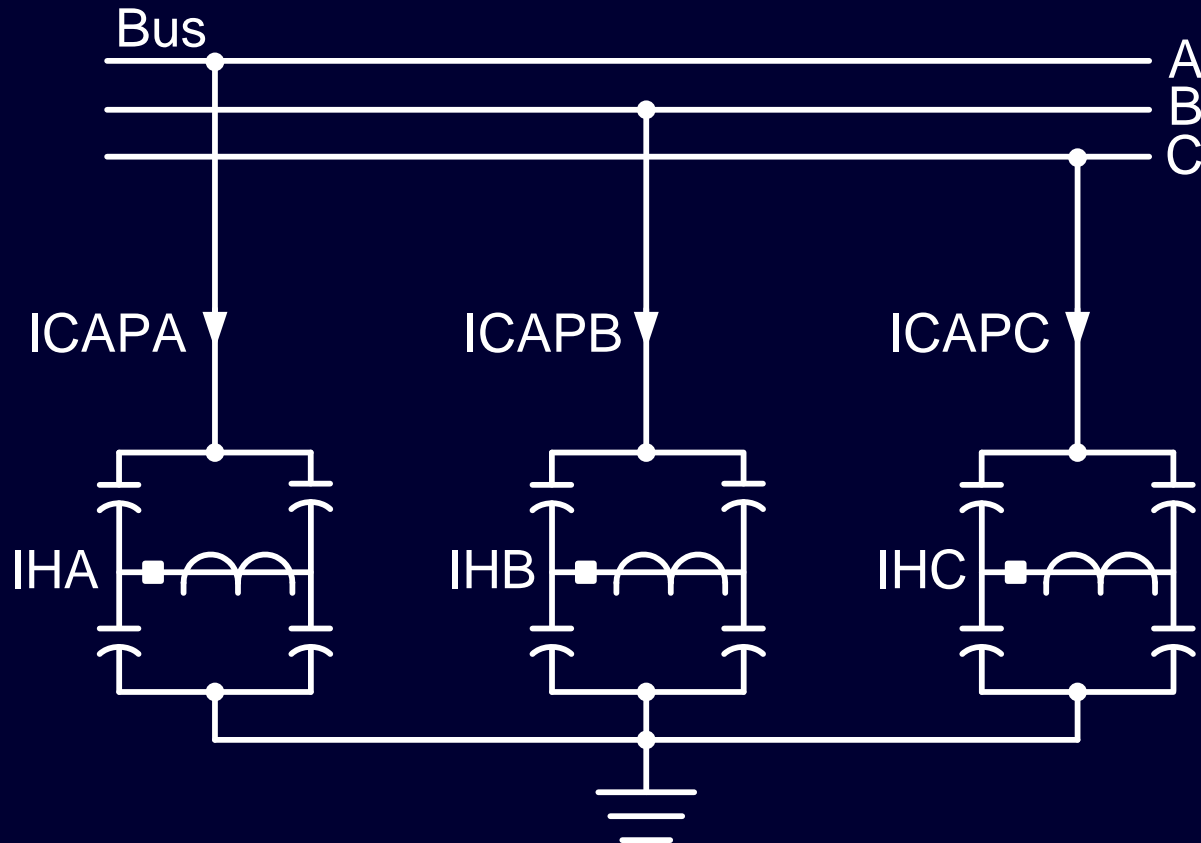


Switch at Position *a* if Bank Is Fuseless
Switch at Position *b* if Bank Is Fused



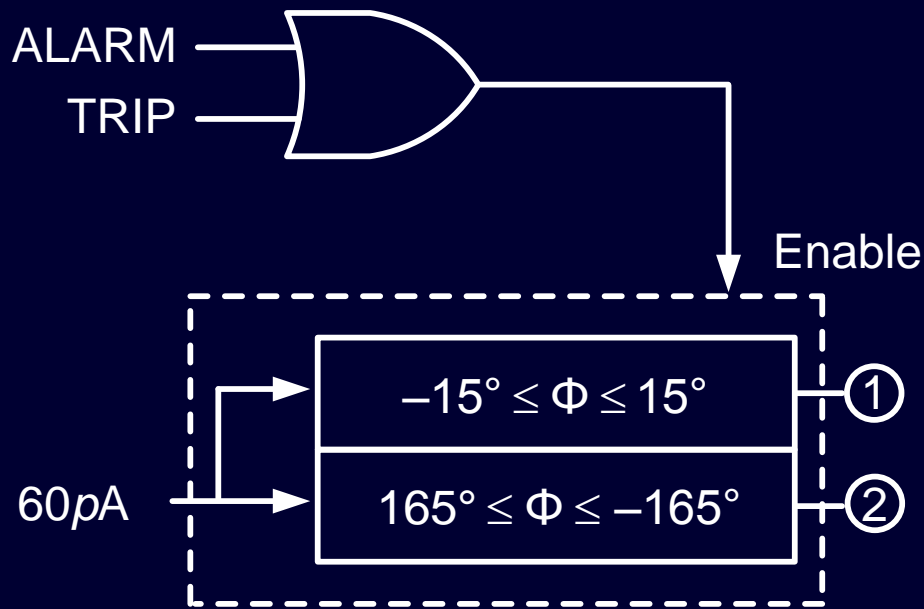
Phase Current Unbalance Protection

H-Bridge Bank

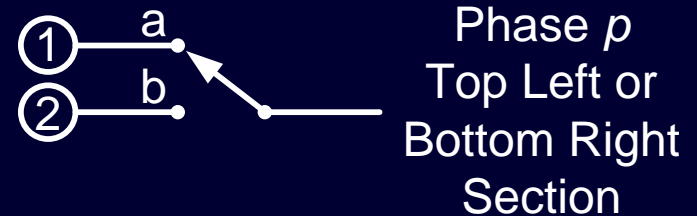


$$60p = IHp - Kp \cdot ICAPp$$

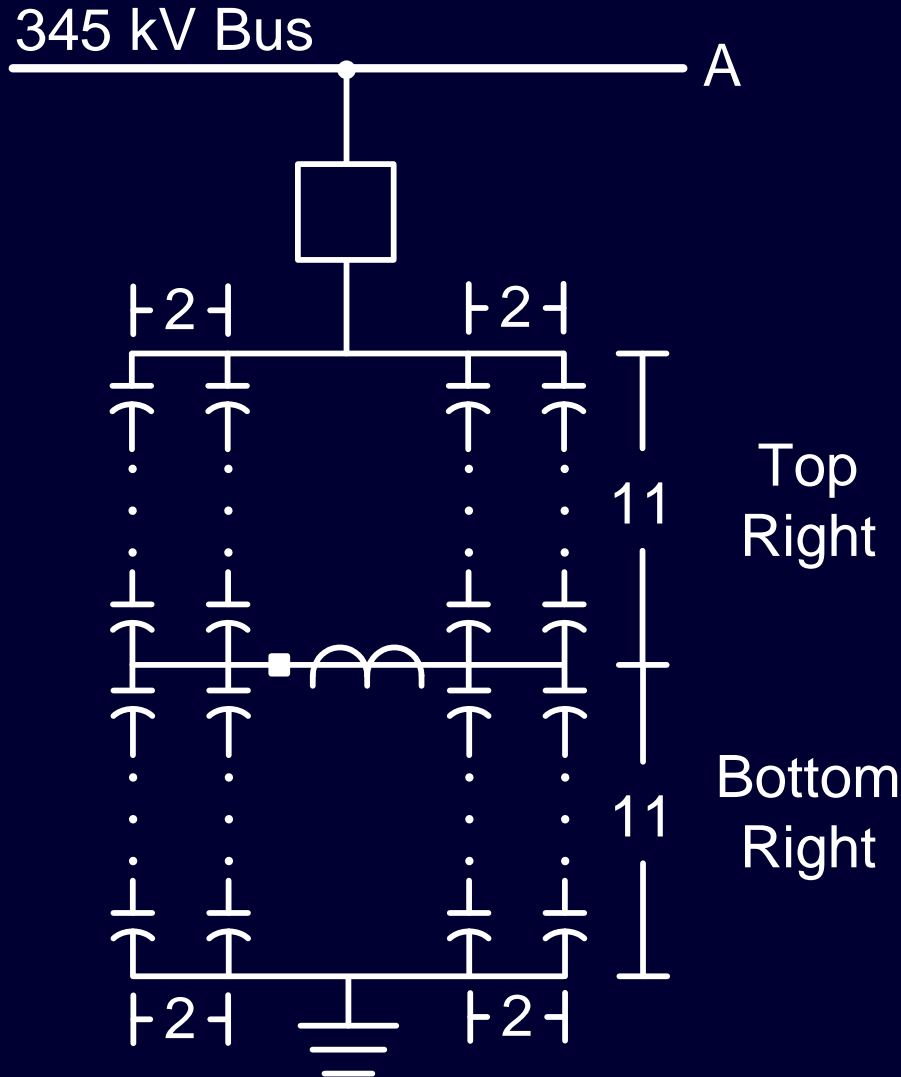
Fault Location Principle



Switch at Position *a* if Bank Is Fuseless
Switch at Position *b* if Bank Is Fused



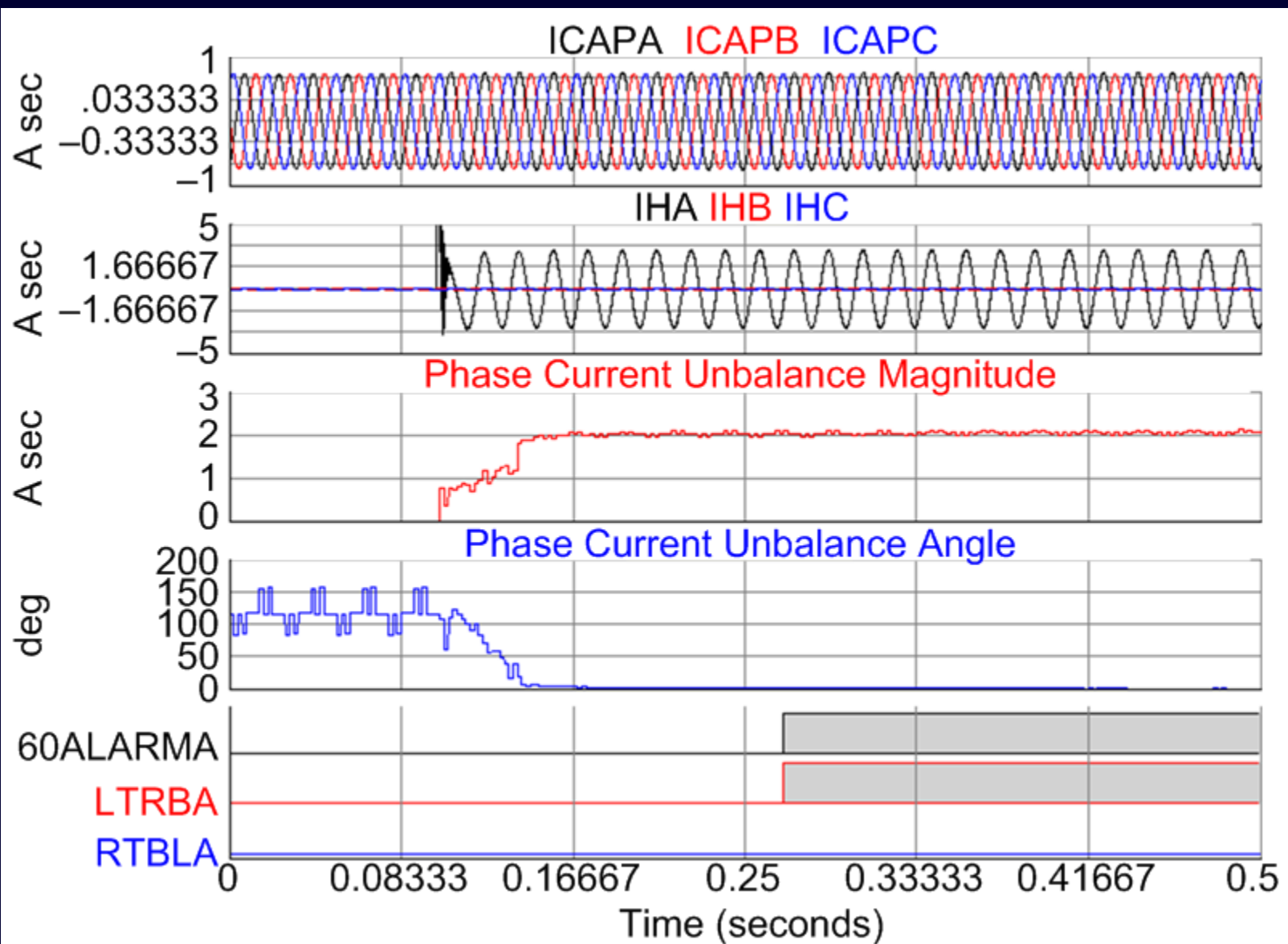
Capacitor Bank Model



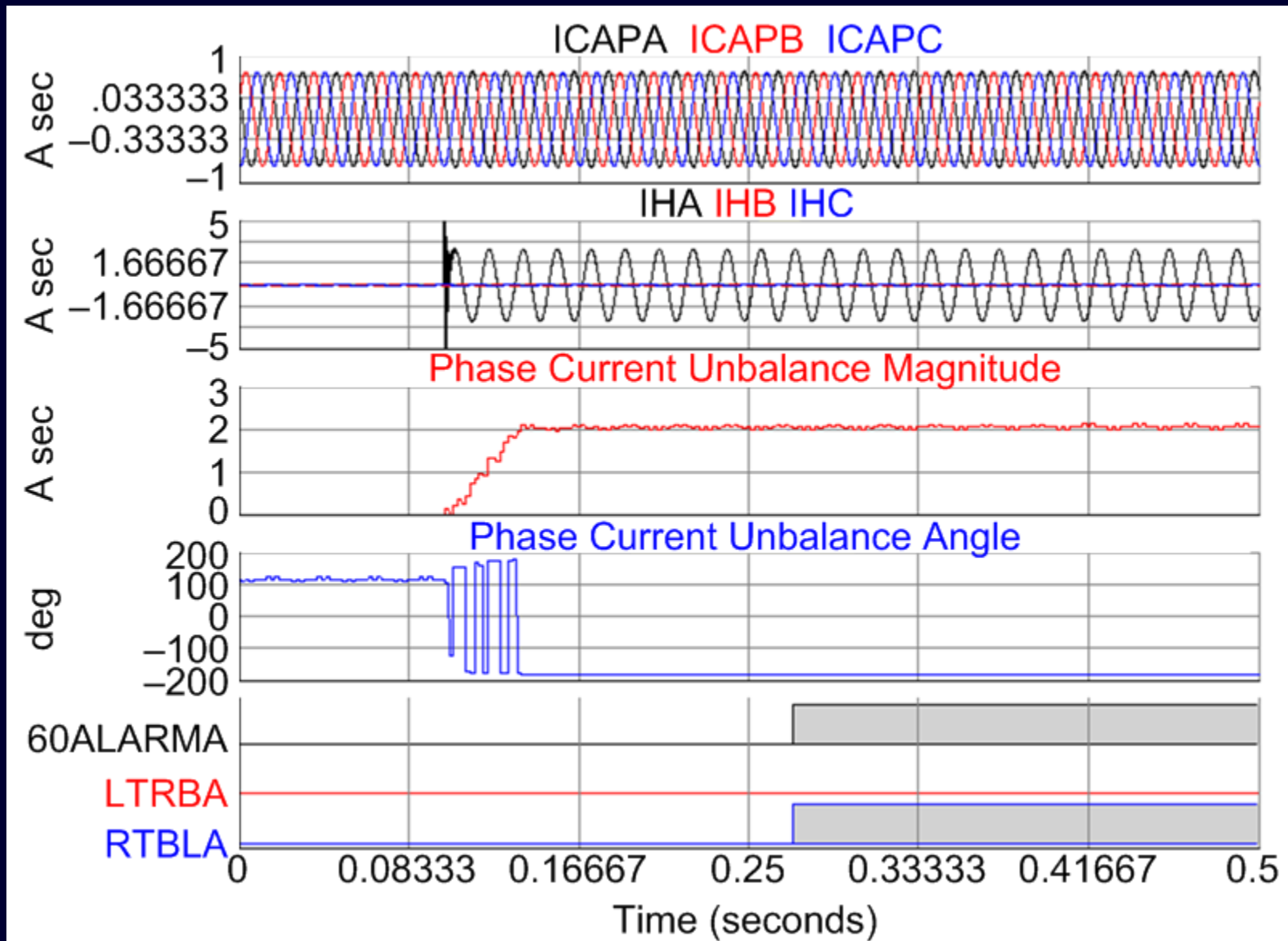
Single Capacitor Unit



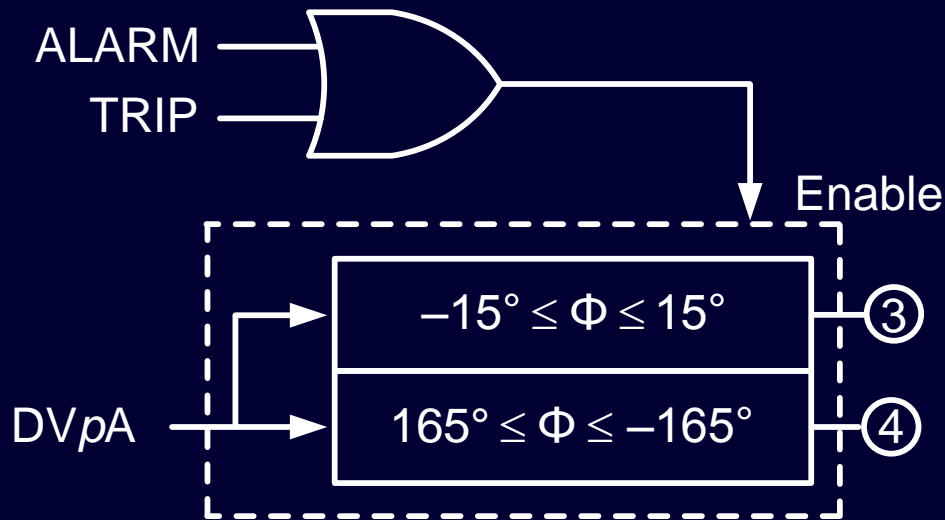
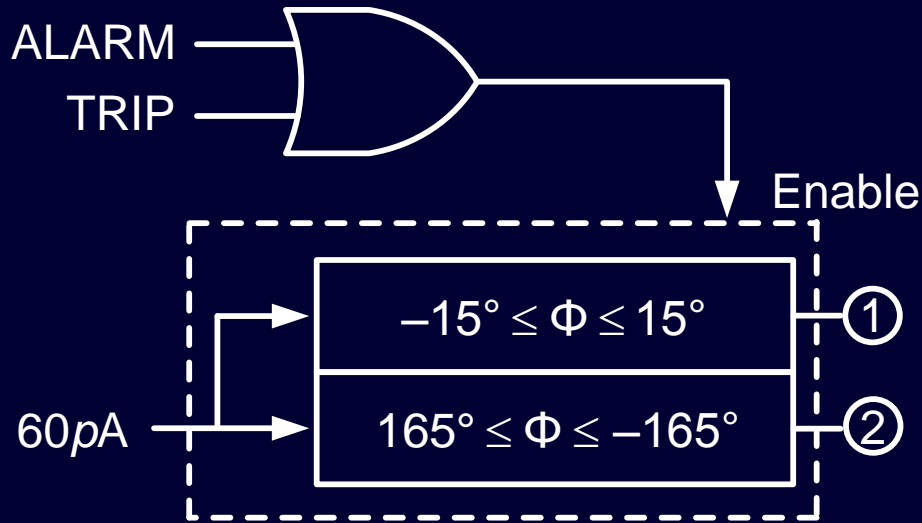
Fault in Top Left Section of Phase A



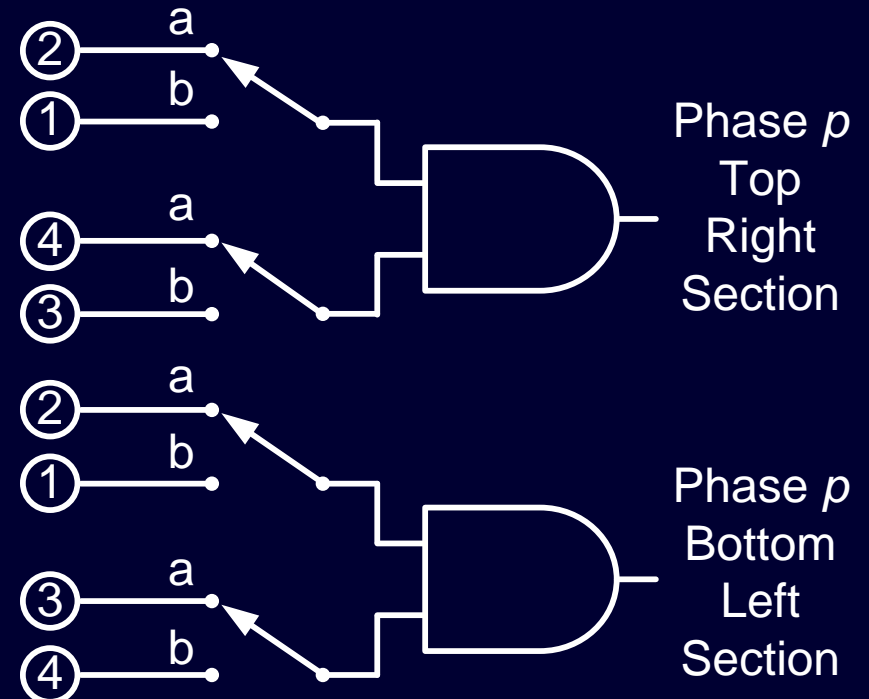
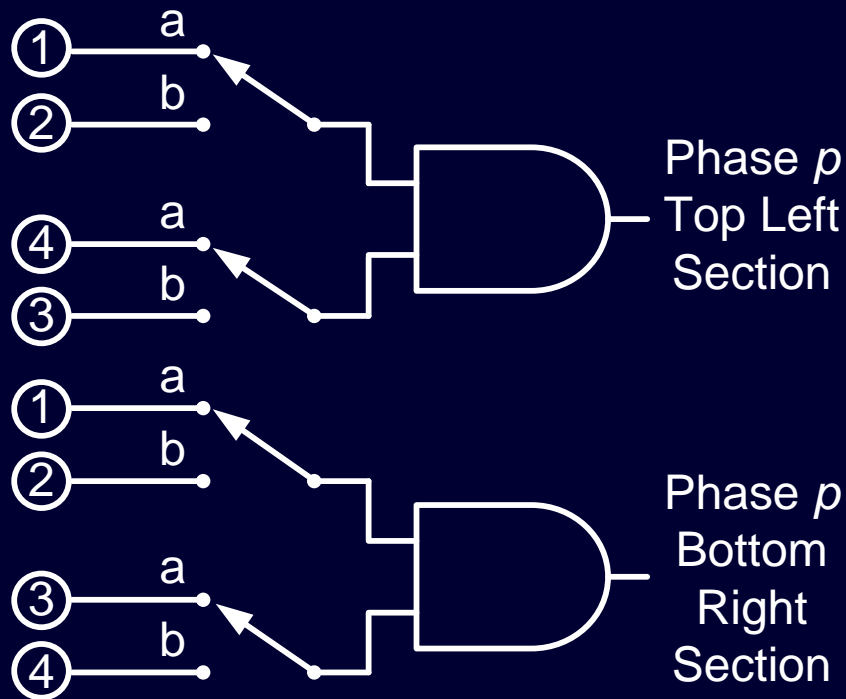
Fault in Bottom Left Section of Phase A



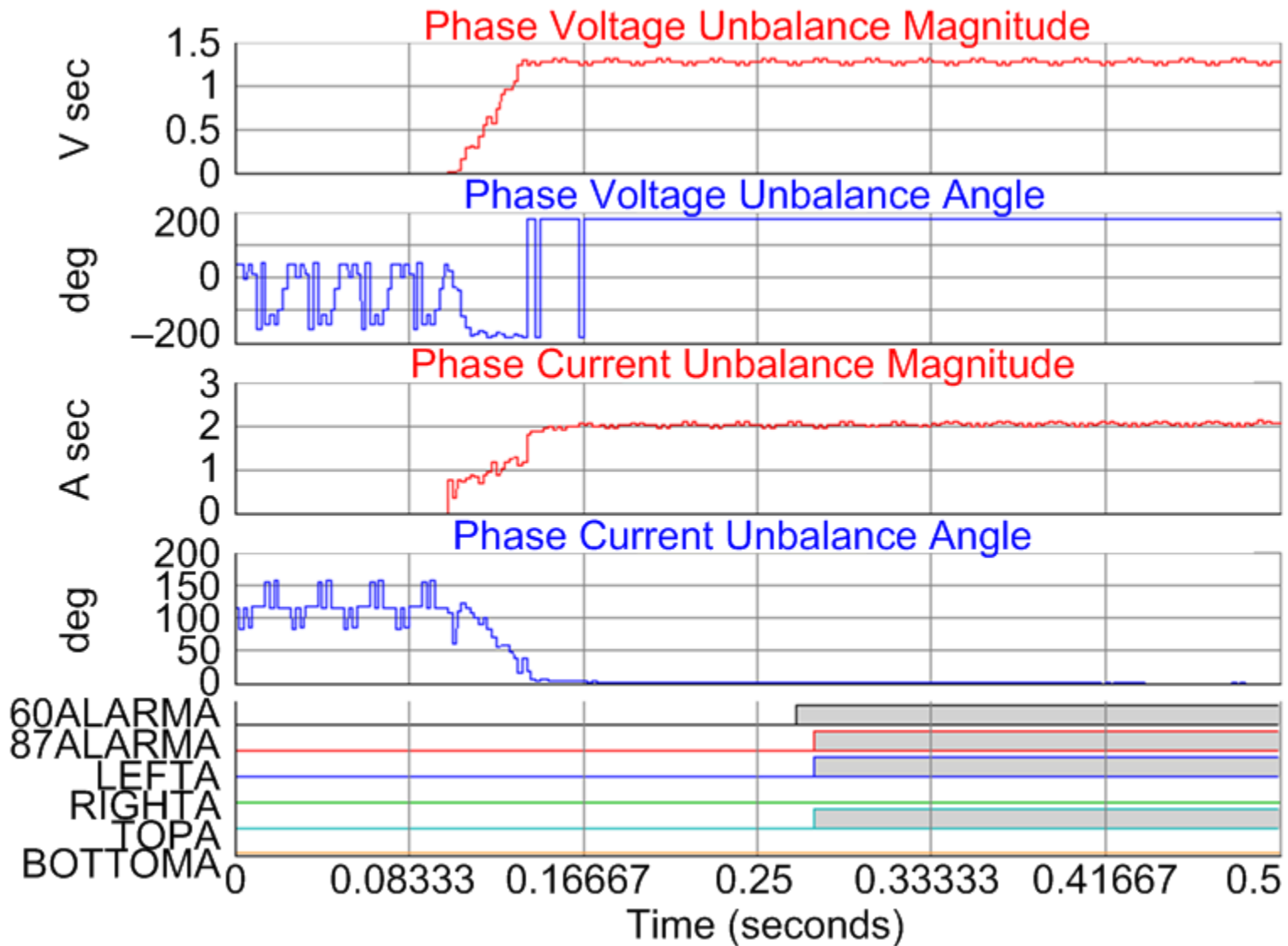
Phase Current and Voltage Unbalance Protection Fault Location Principle



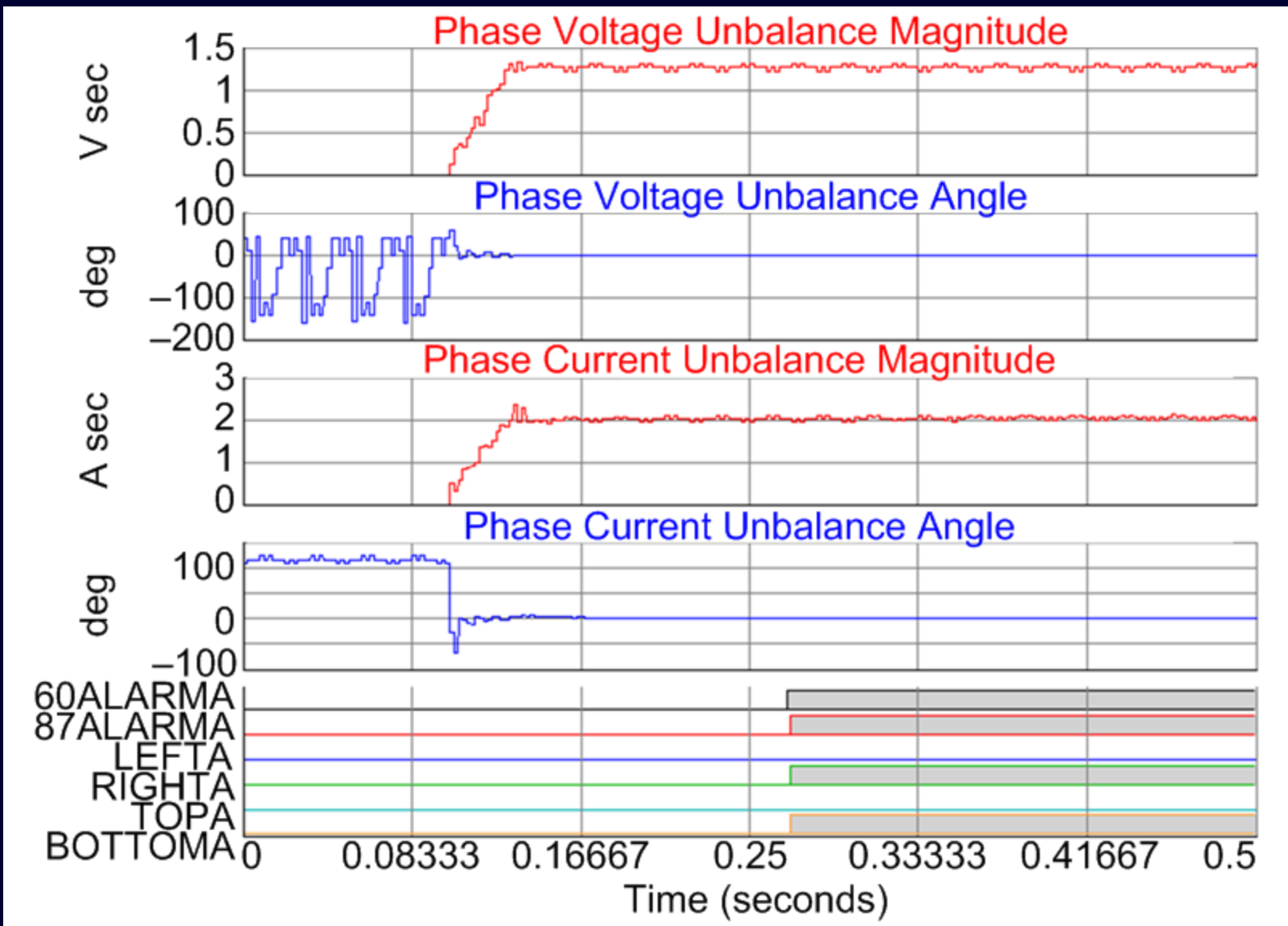
Switch at Position *a* if Bank Is Fuseless
Switch at Position *b* if Bank Is Fused



Fault in Top Left Section of Phase A

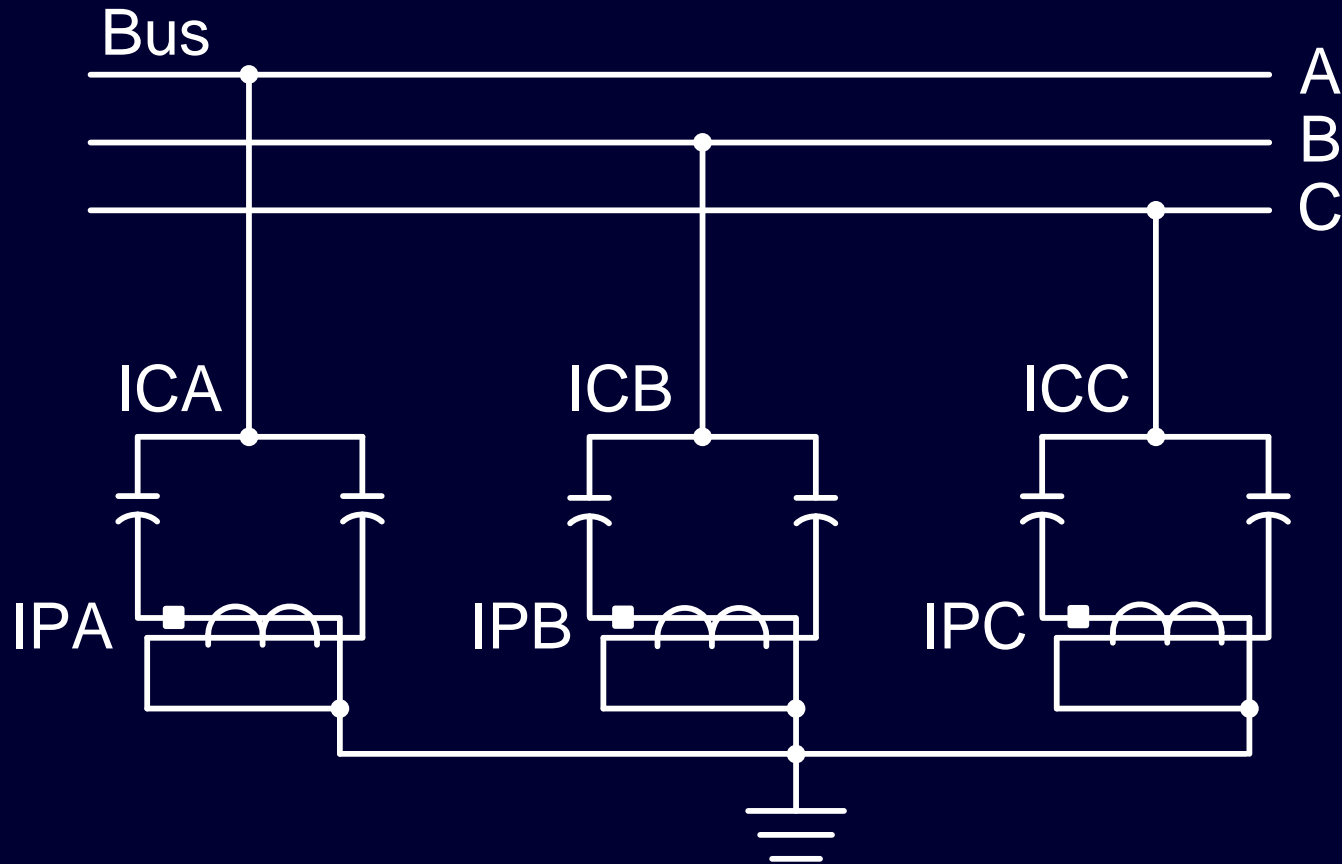


Fault in Bottom Right Section of Phase A

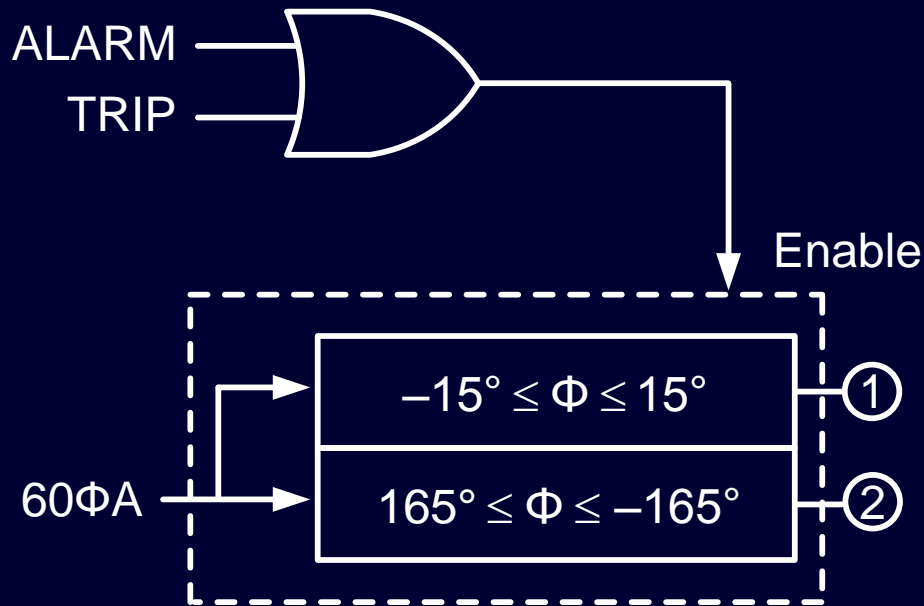


Phase Current Unbalance Protection

Double-Wye Bank



Fault Location Principle

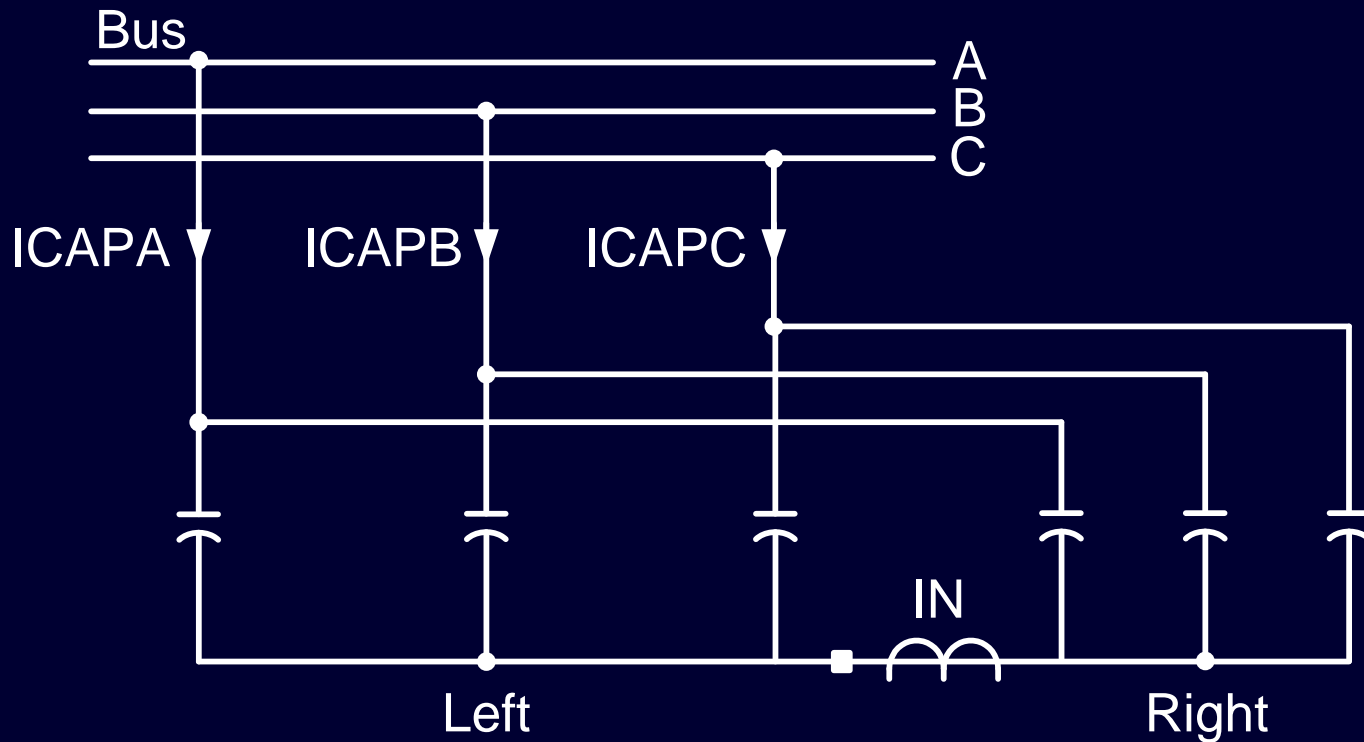


Switch at Position *a* if Bank Is Fuseless
Switch at Position *b* if Bank Is Fused



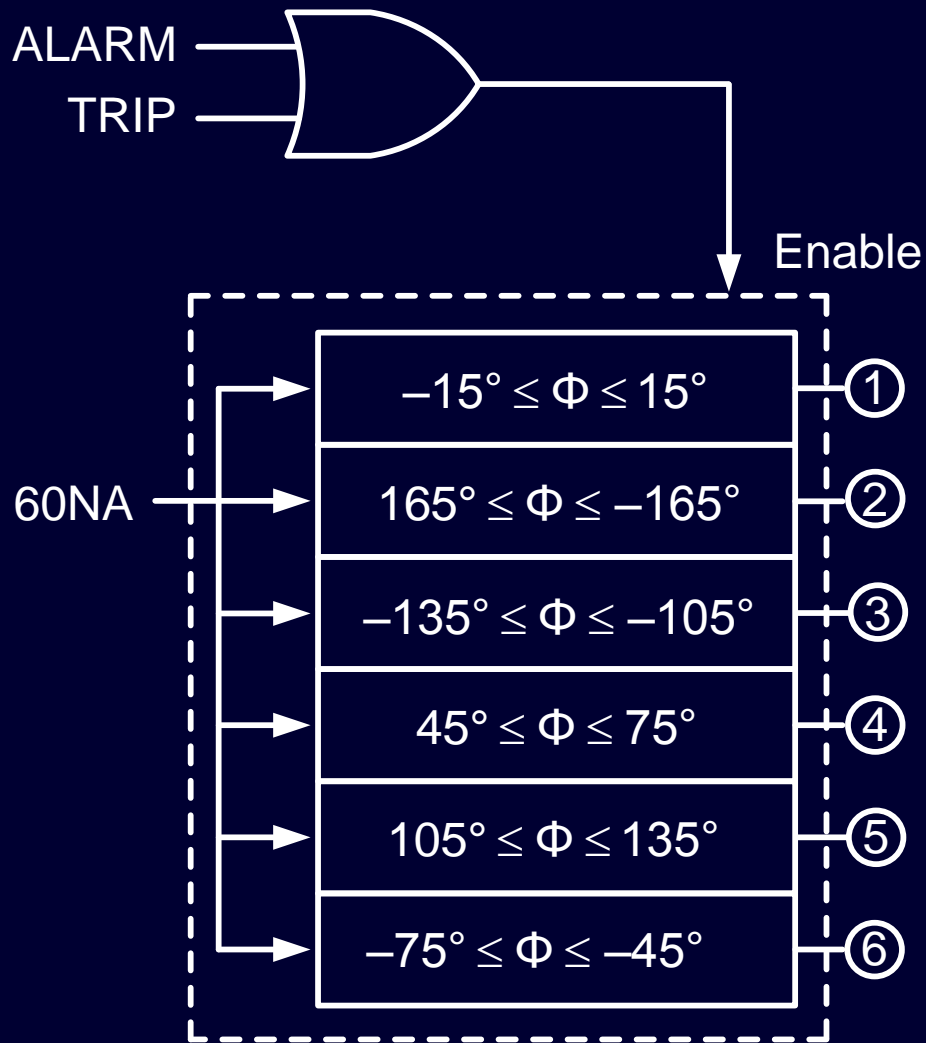
Neutral Current Unbalance Protection

Double-Wye Bank

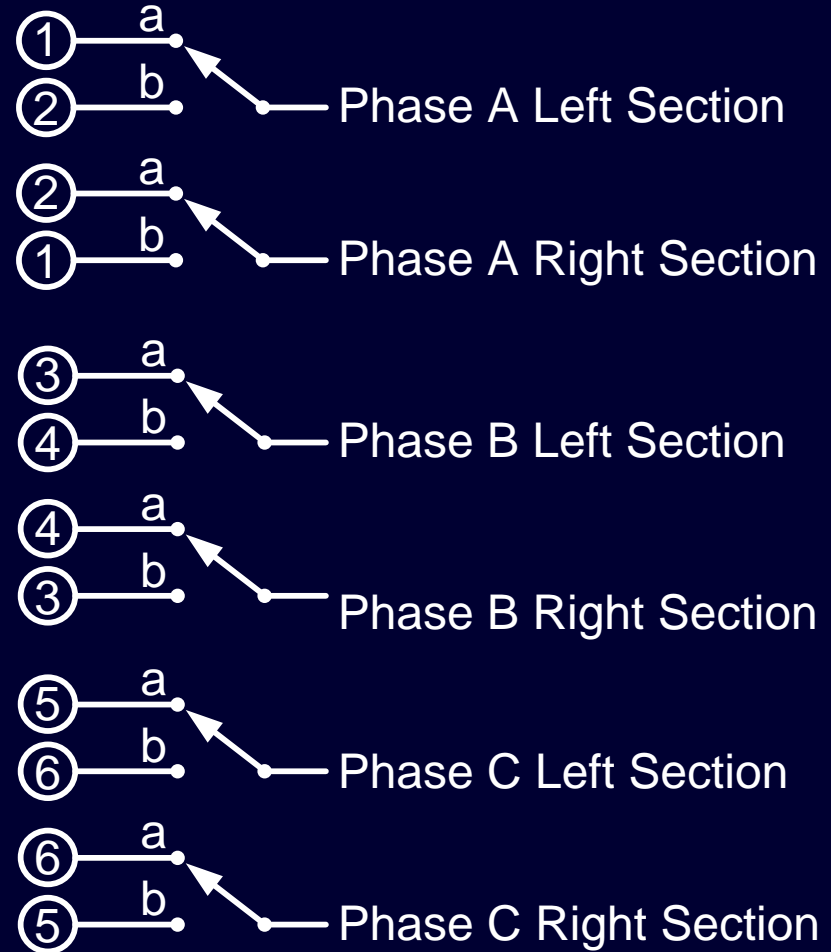


$$60N = IN - (K1 \cdot ICAPB + K2 \cdot ICAPC)$$

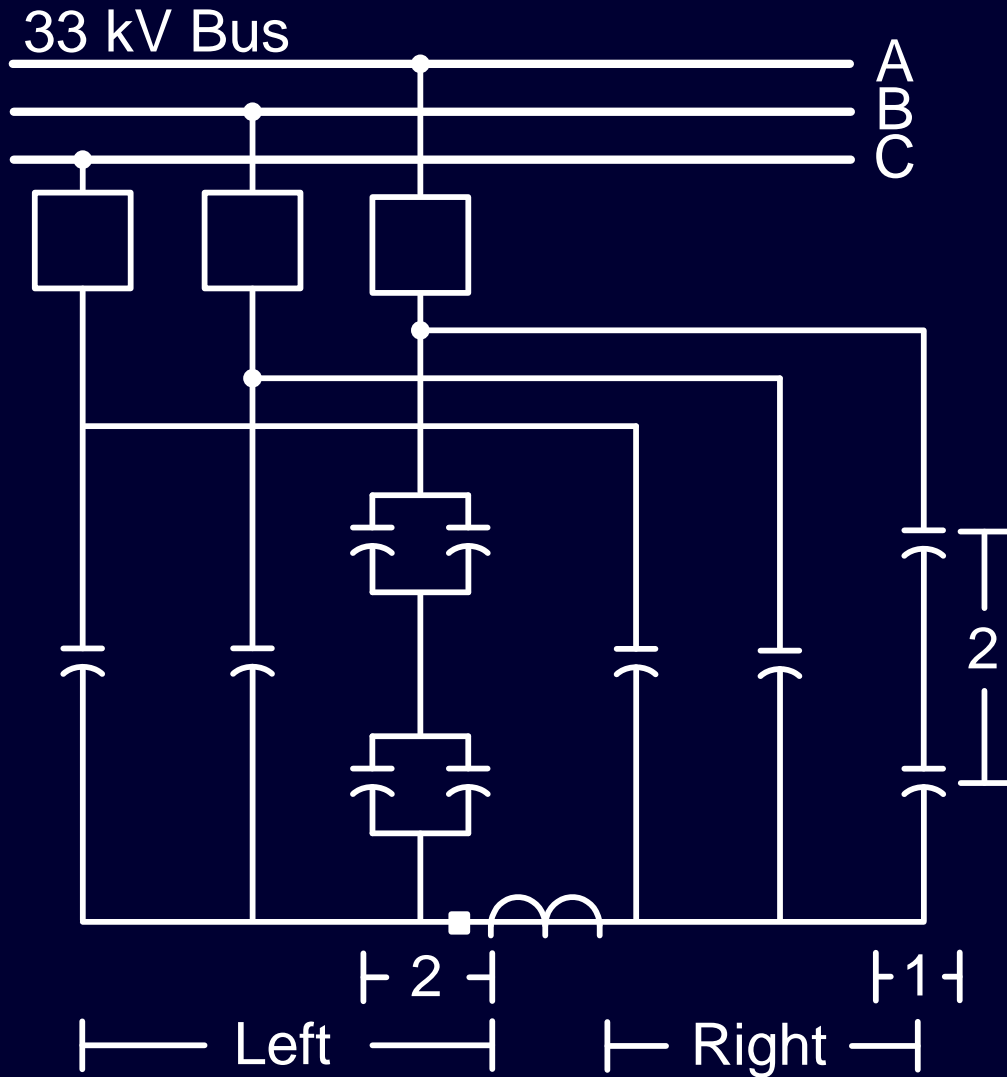
Fault Location Principle



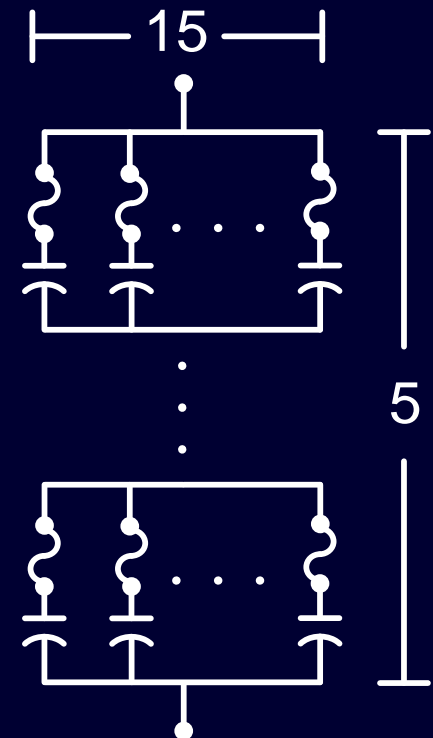
Switch at Position *a* if Bank Is Fuseless
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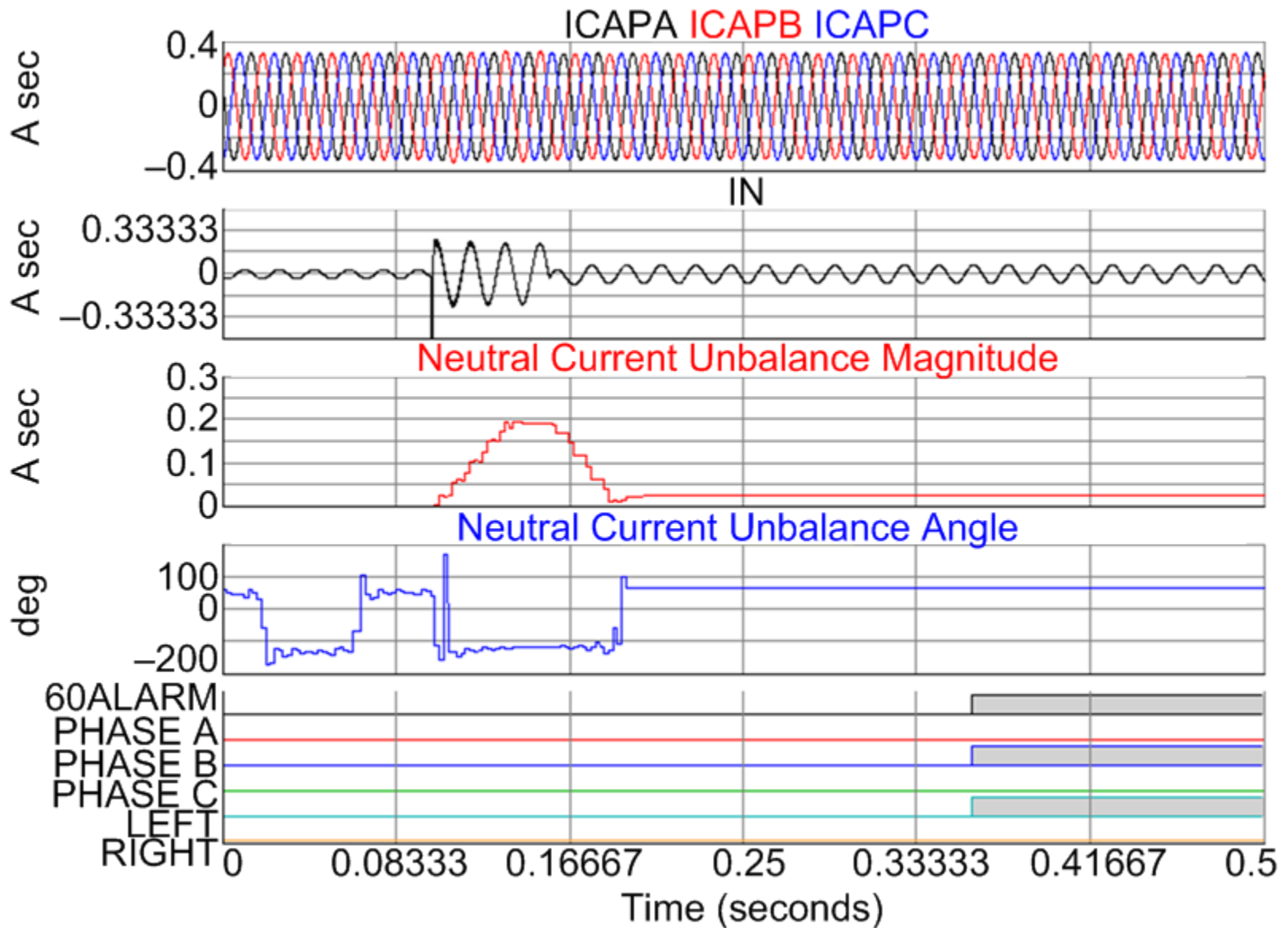
Capacitor Bank Model



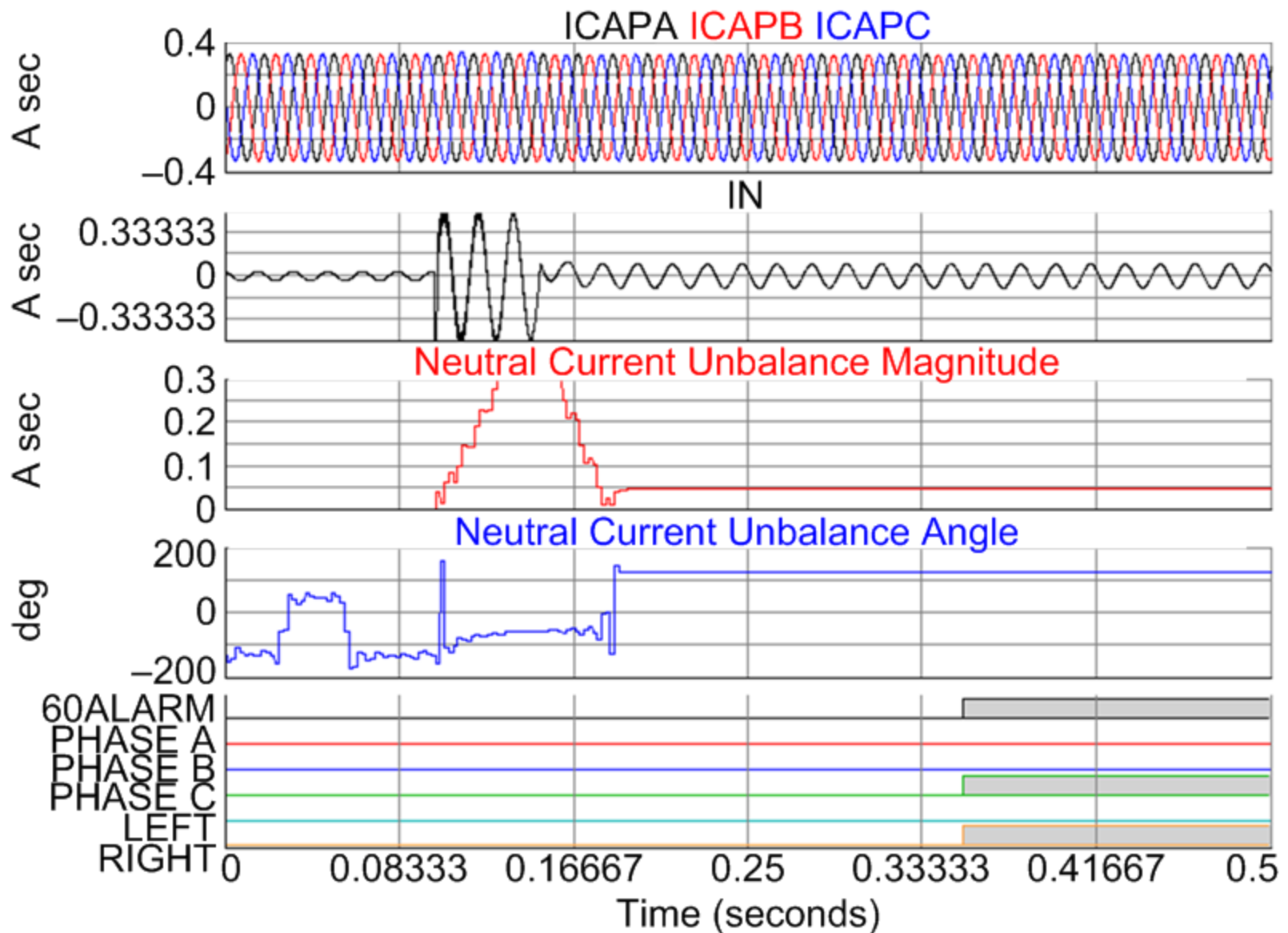
Single Capacitor Unit



Fault in Left Section of Phase B



Fault in Right Section of Phase C



Conclusion

- Locating faulty unit is time-consuming
- Proposed fault location technique
 - ◆ Reduces investigating time by 50 to 92%
 - ◆ Minimizes capacitor bank outage time
 - ◆ Is embedded in unbalance protection, making it economical
 - ◆ Can be applied to any bank configuration and fusing method

Conclusion

- Proposed fault location technique
 - ◆ Is not affected by inherent unbalance
 - ◆ Provides advanced alarms for planned maintenance
 - ◆ Provides fuse savings in externally fused bank
- Using multiple unbalance protection methods improves protection reliability and fault location

Questions?