

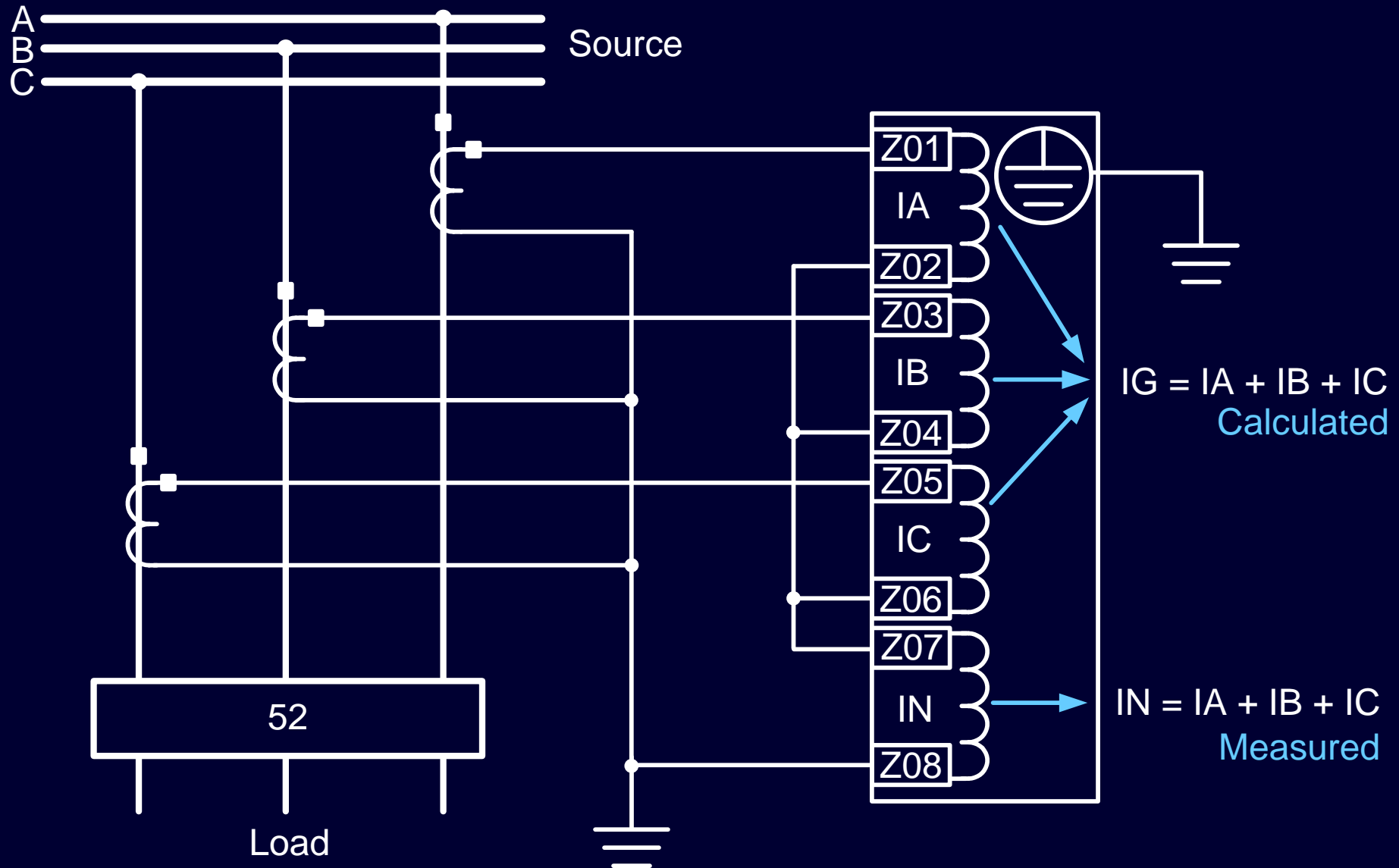
Open-Circuited CT Misoperation and Investigation

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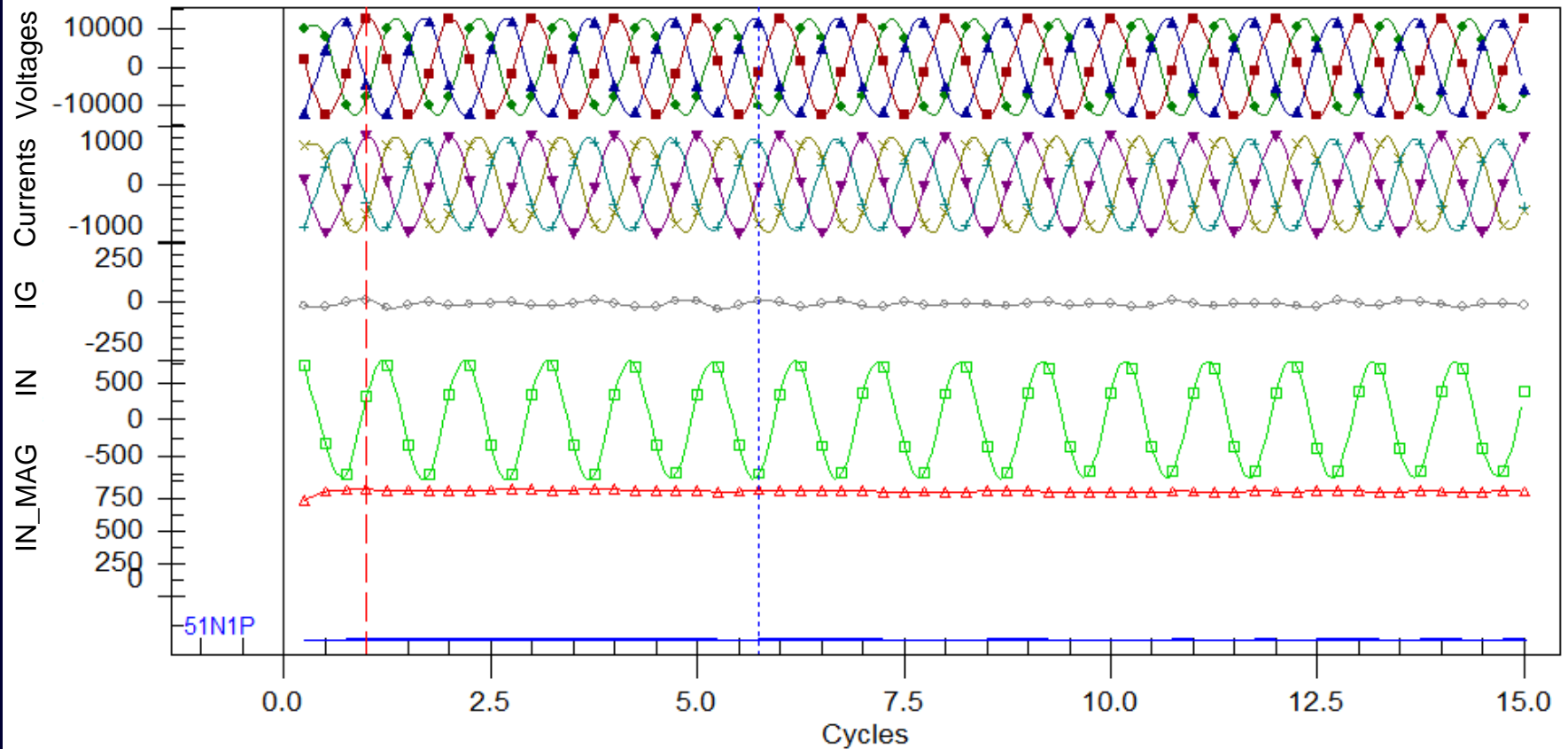
Initial Sequence of Events

- Main breaker relay has operated without incident for about 1 year
- Serial cables are added to all relays to enable SCADA
- About 2 weeks later, relay trips during normal, balanced load

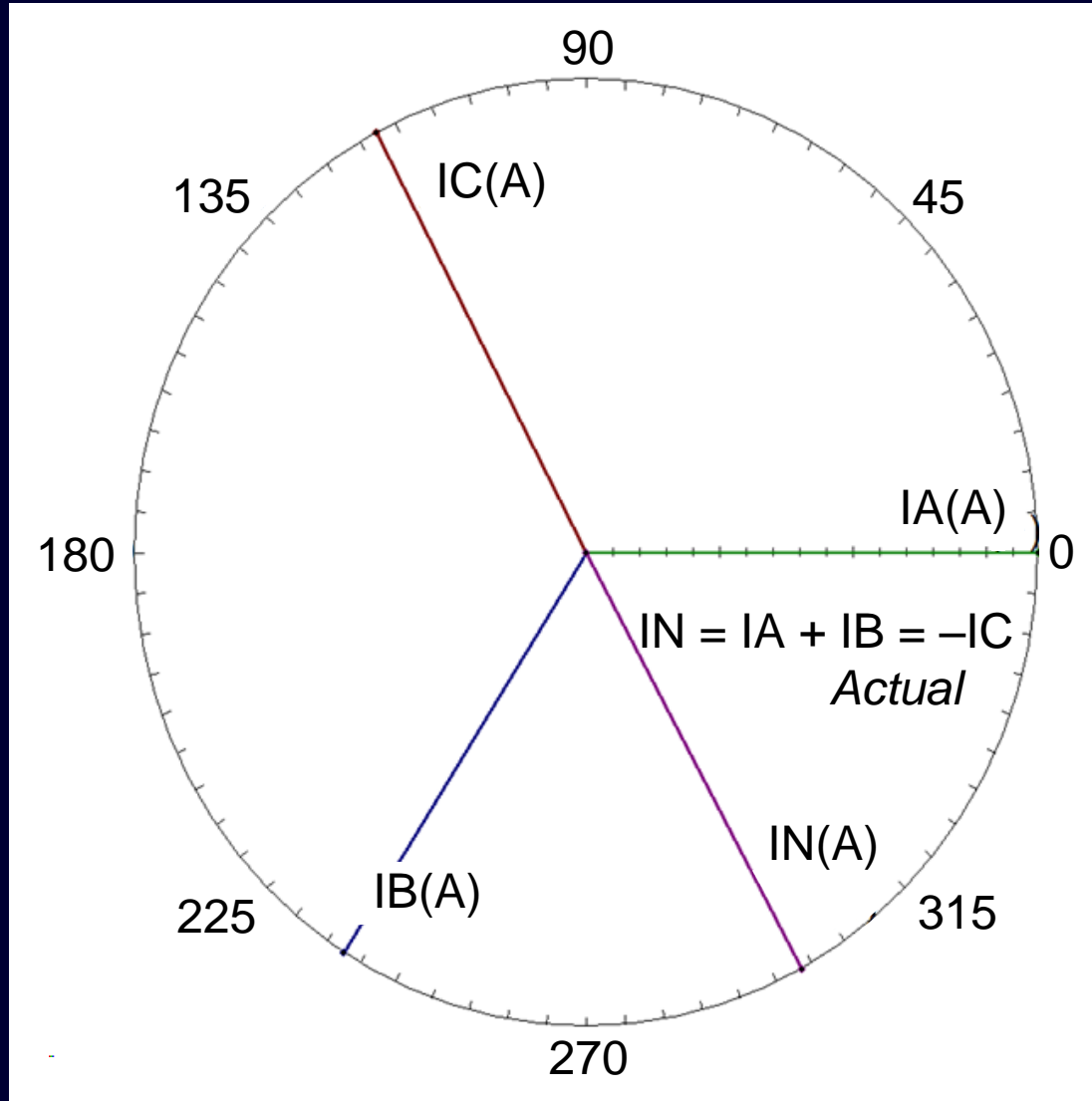
Simplified Connection Diagram



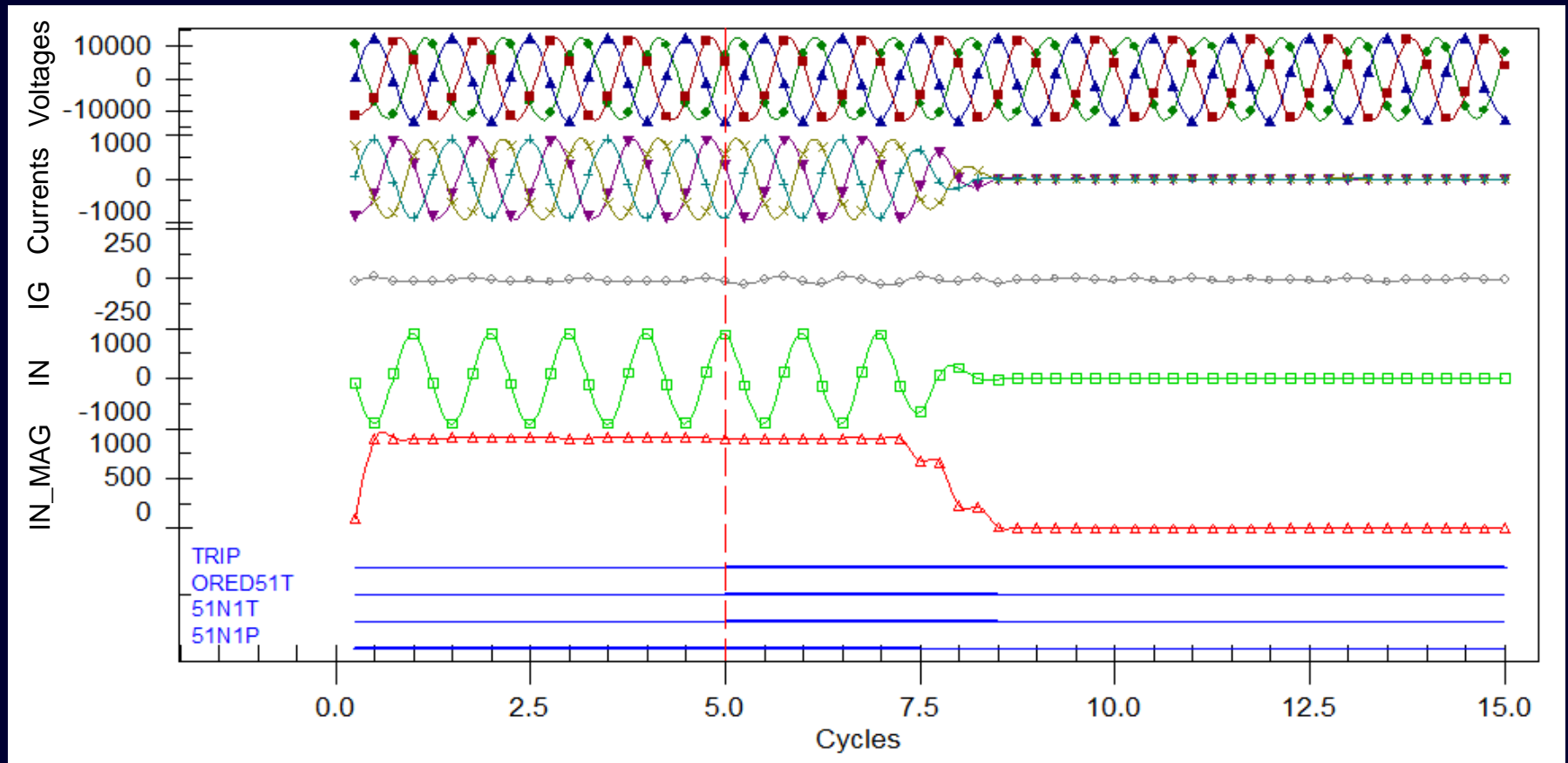
During Event $I_N = 800\text{ A}$, $I_G = 0\text{ A}$?



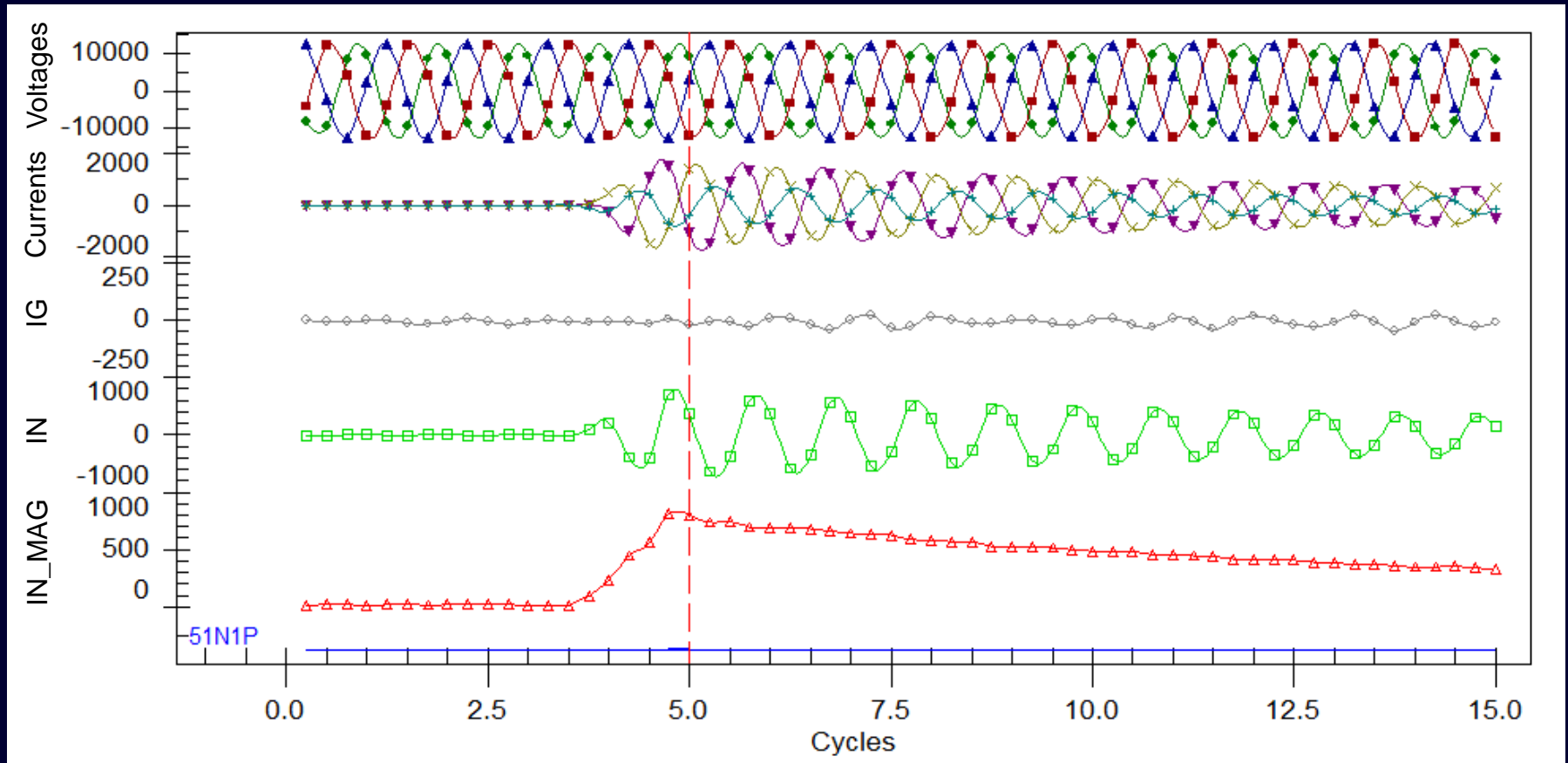
Phasor Diagram at Cycle 5.75



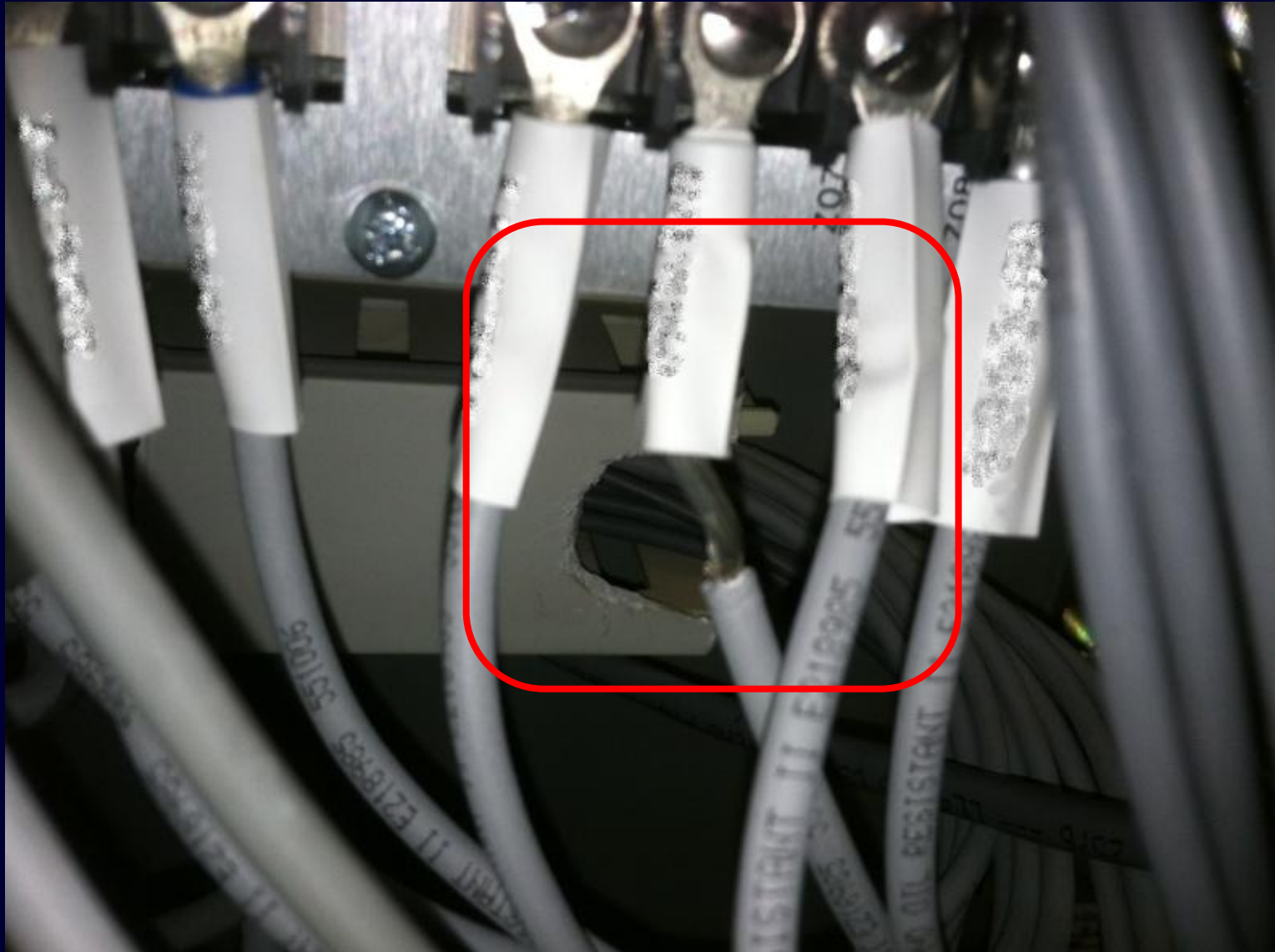
Eventual Trip and Plant Outage



Breaker Closed Manually, Trips Again

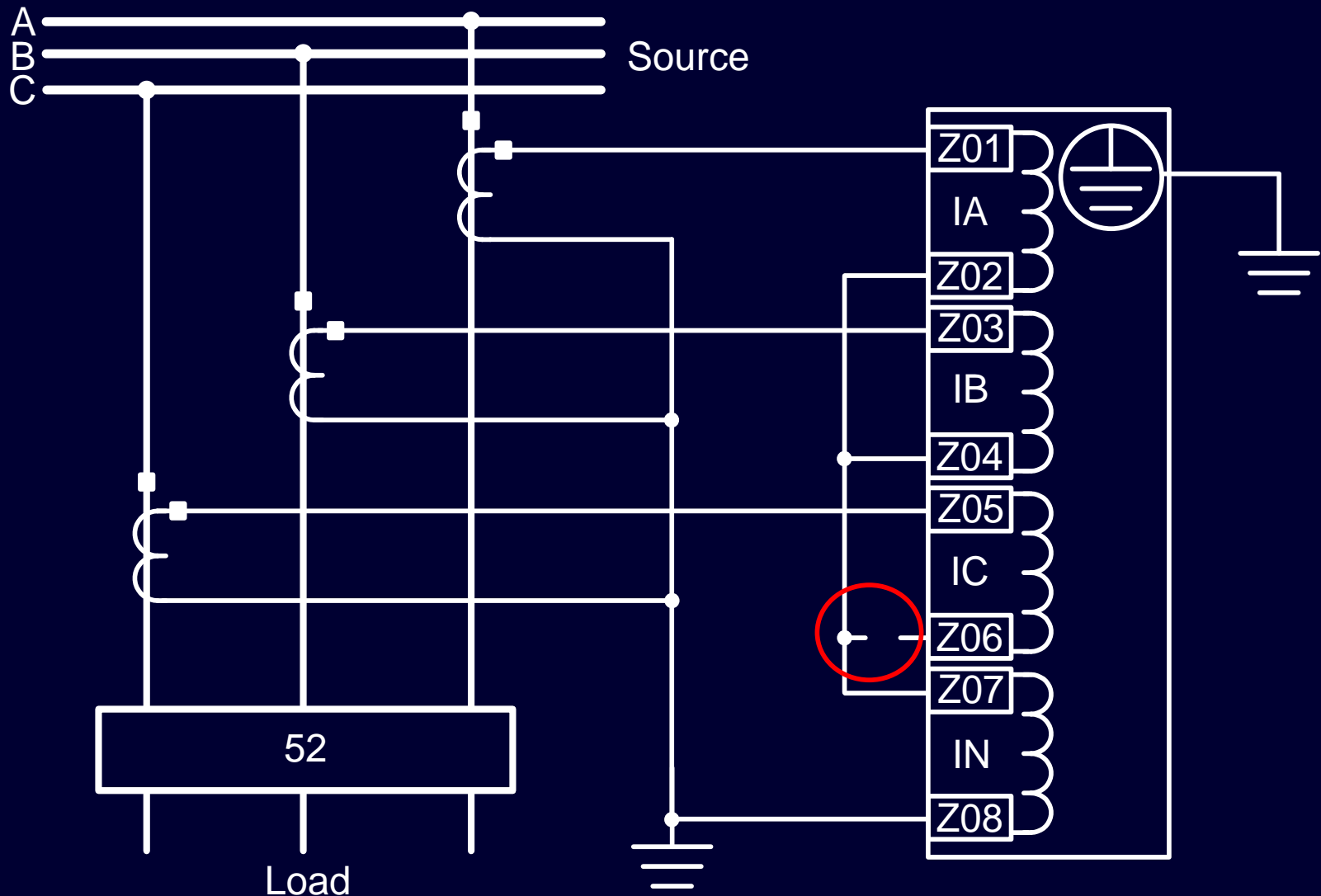


IC Nonpolarity Found Open-Circuited



Open Circuit Found

Explains Why $I_N = I_A + I_B$



Failure to Crimp *One* Terminal

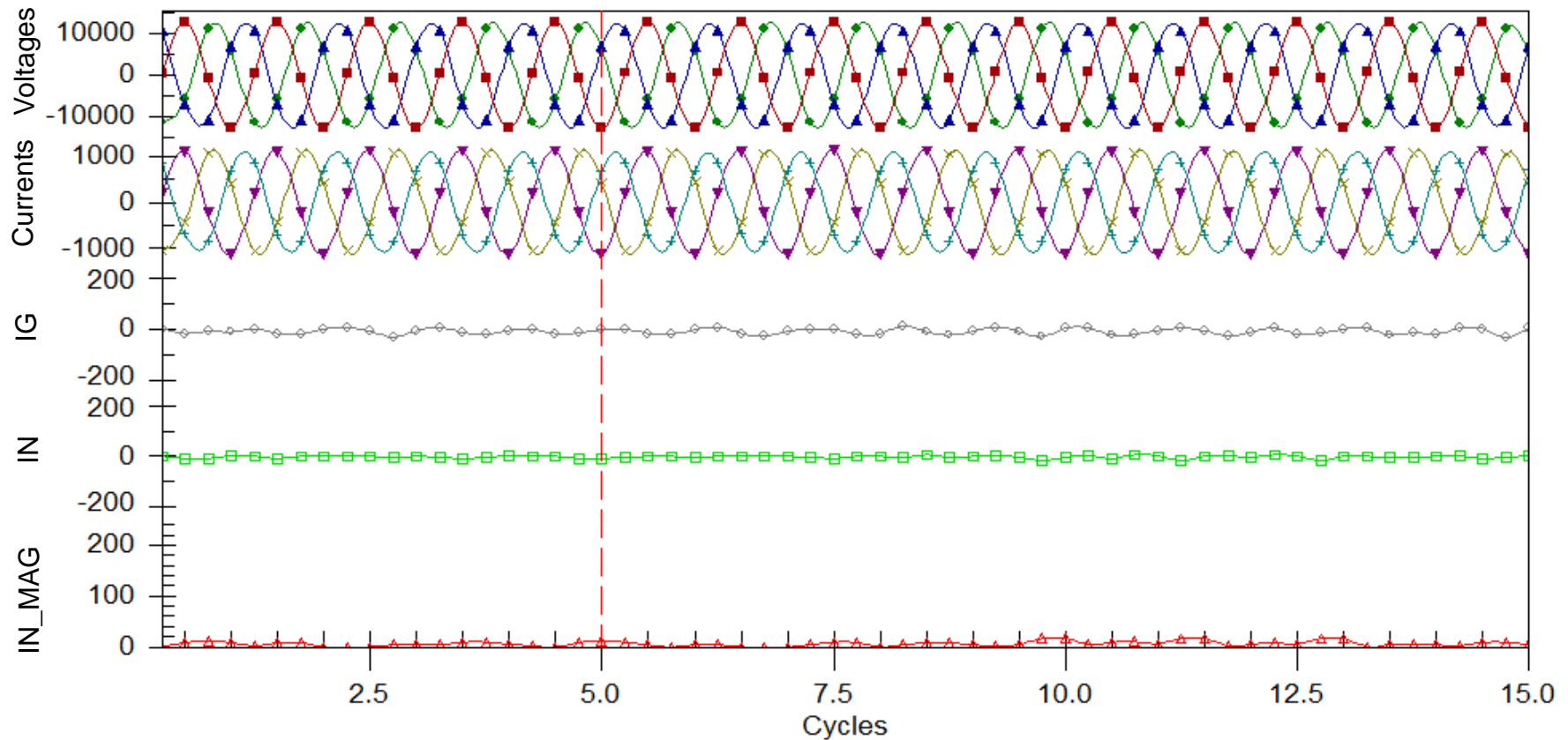
Suspect that SCADA wiring added enough pressure to cause wire to fall free of ring lug



- Explains
 $IN = IA + IB$
- Does NOT explain
 $IN \neq IG$

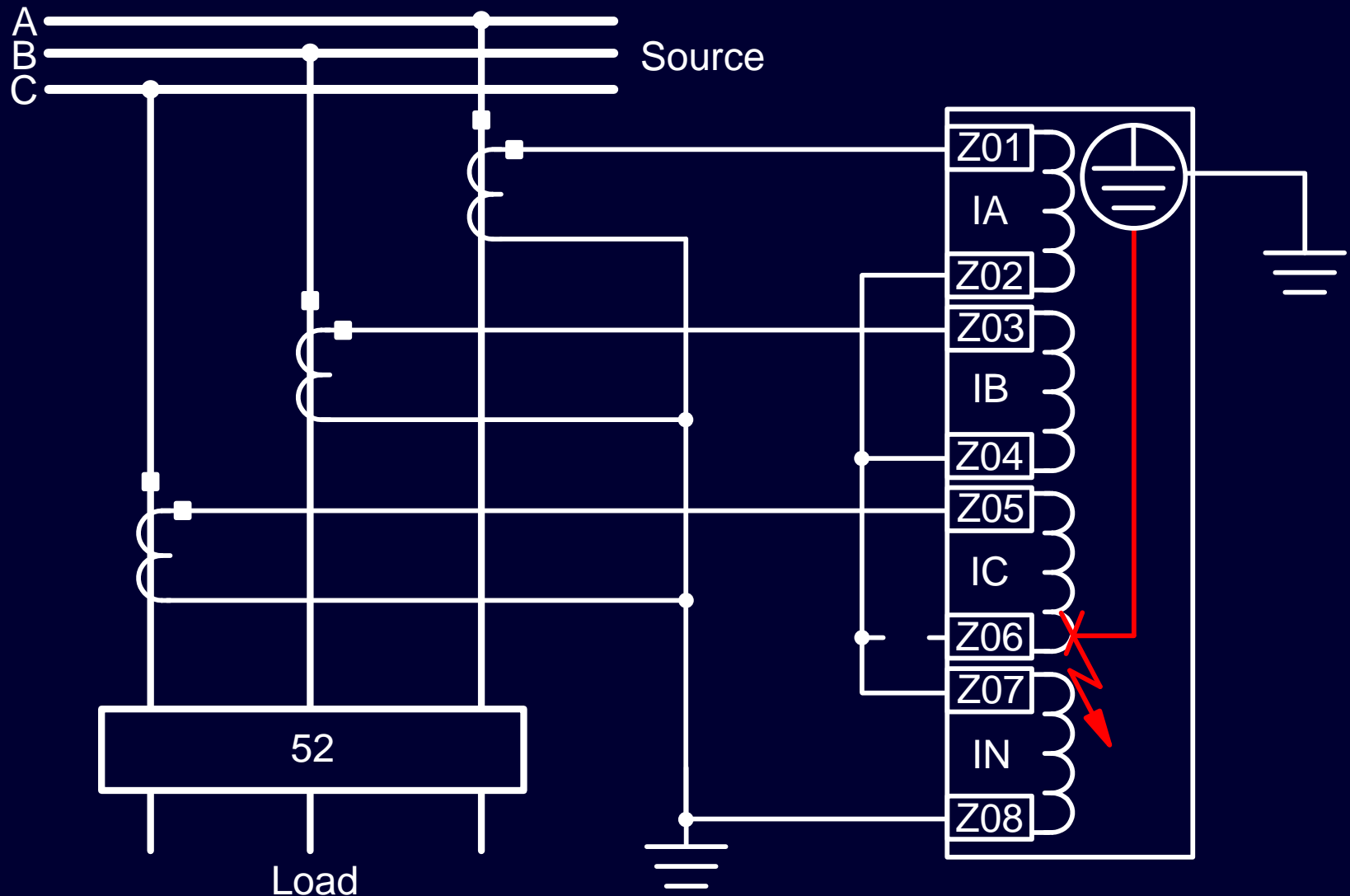
IN \approx IG \approx 0 A After Crimp Fixed

Why Did They Disagree During Trip?

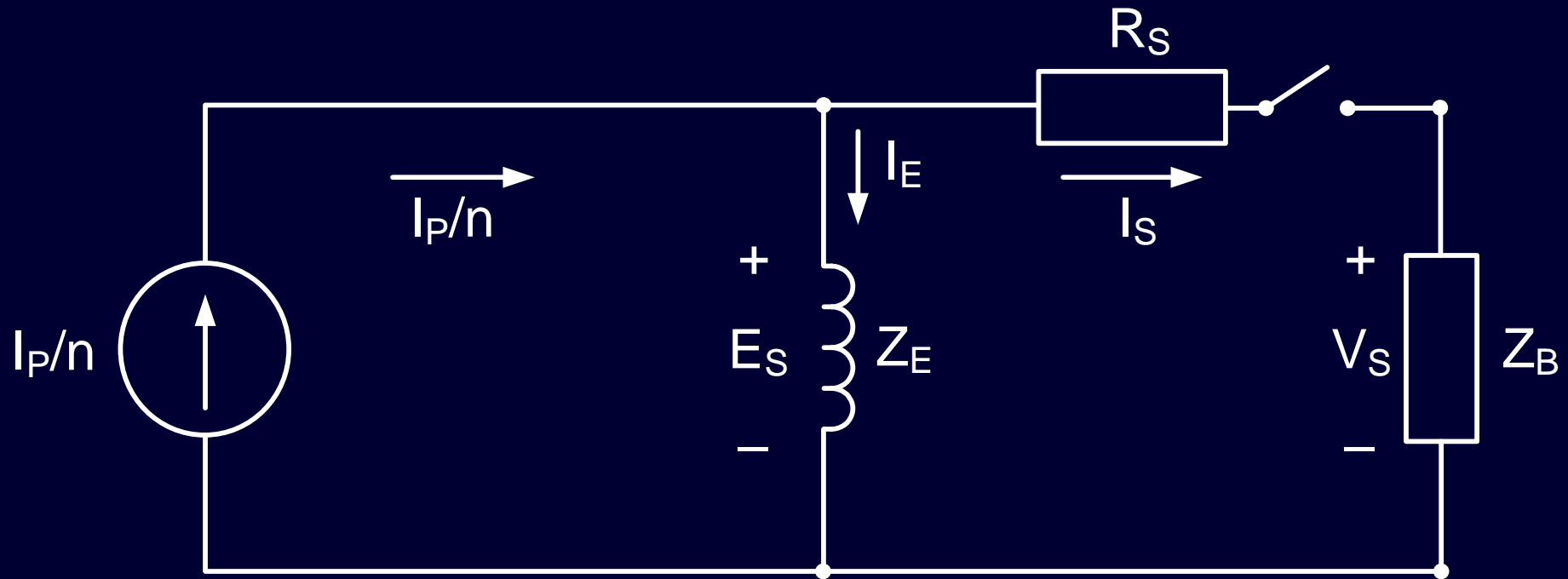


Theory of Why IG and IN Did Not Match

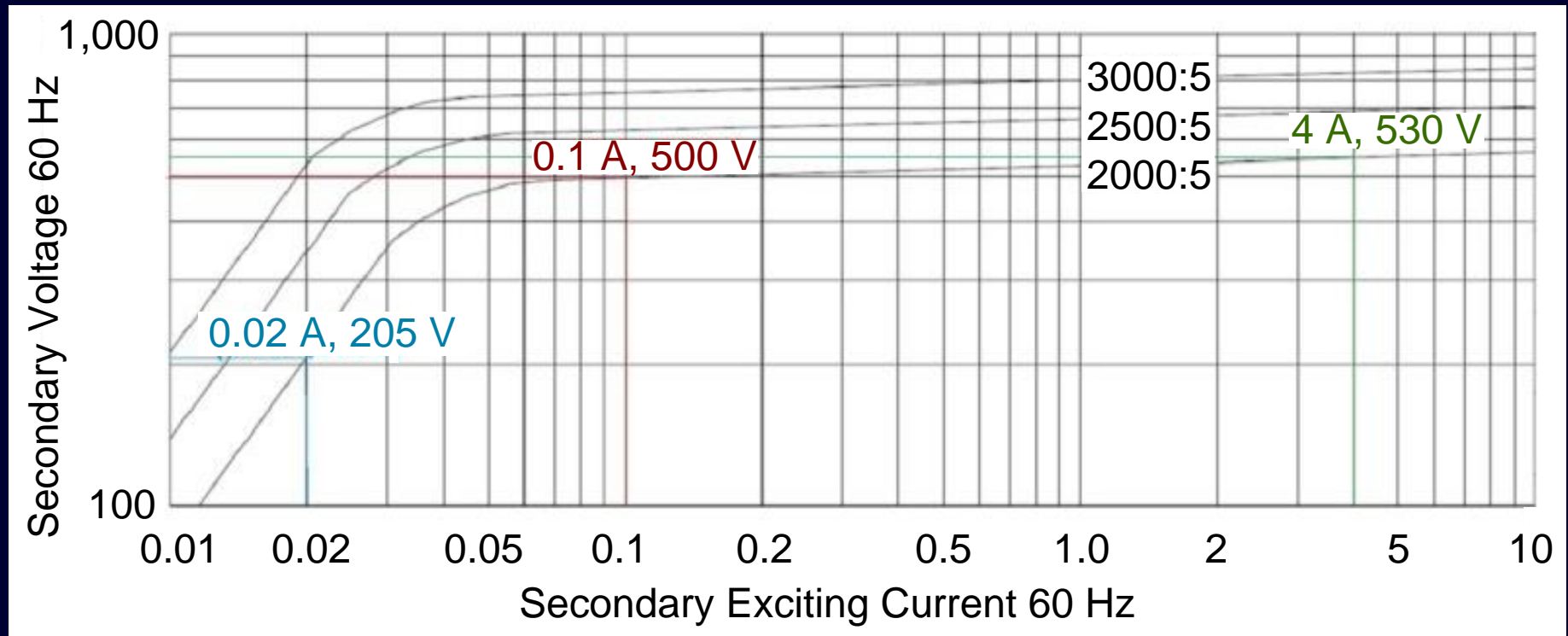
Open-Circuited CT Damaged Relay



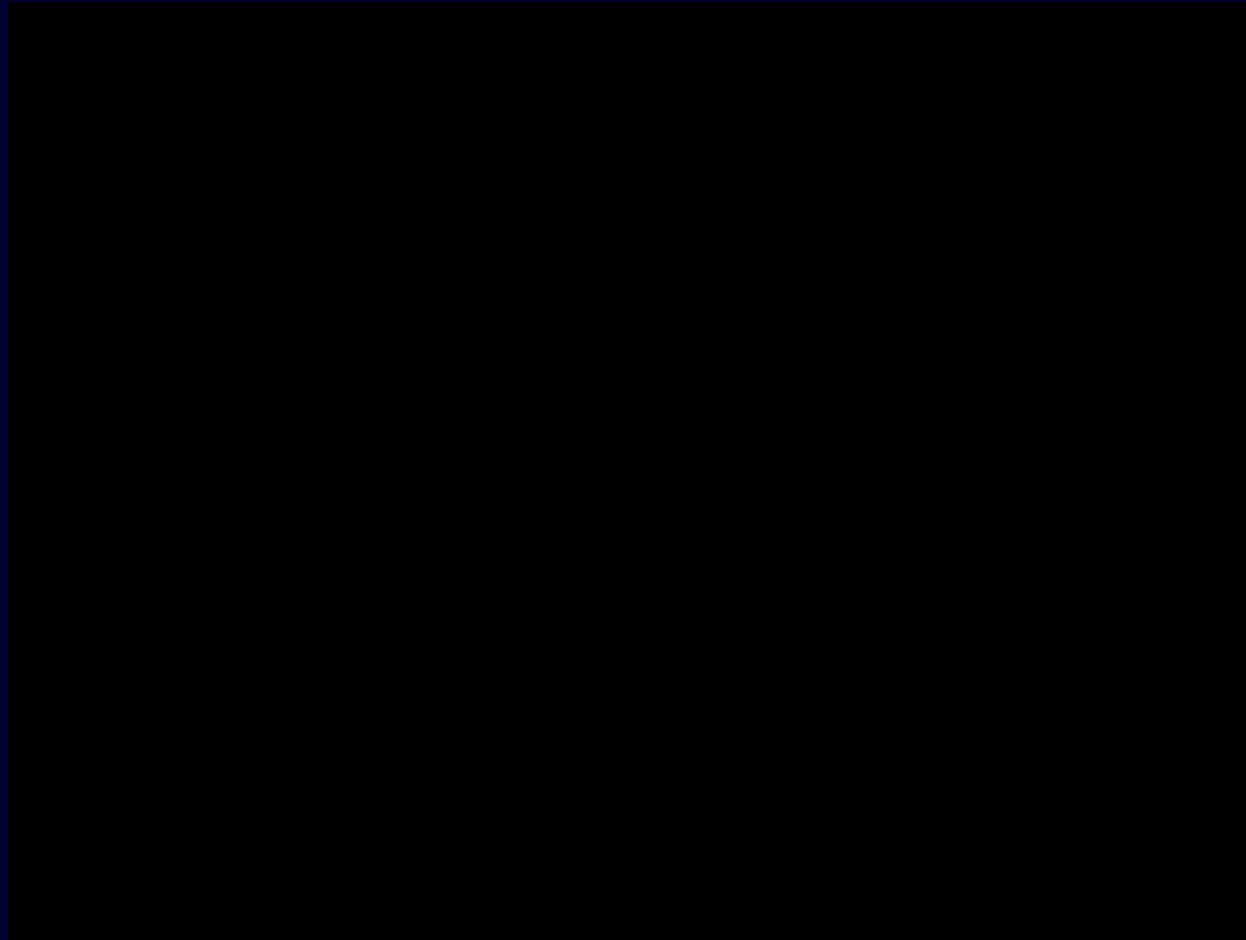
Open CTs Create HIGH Voltage



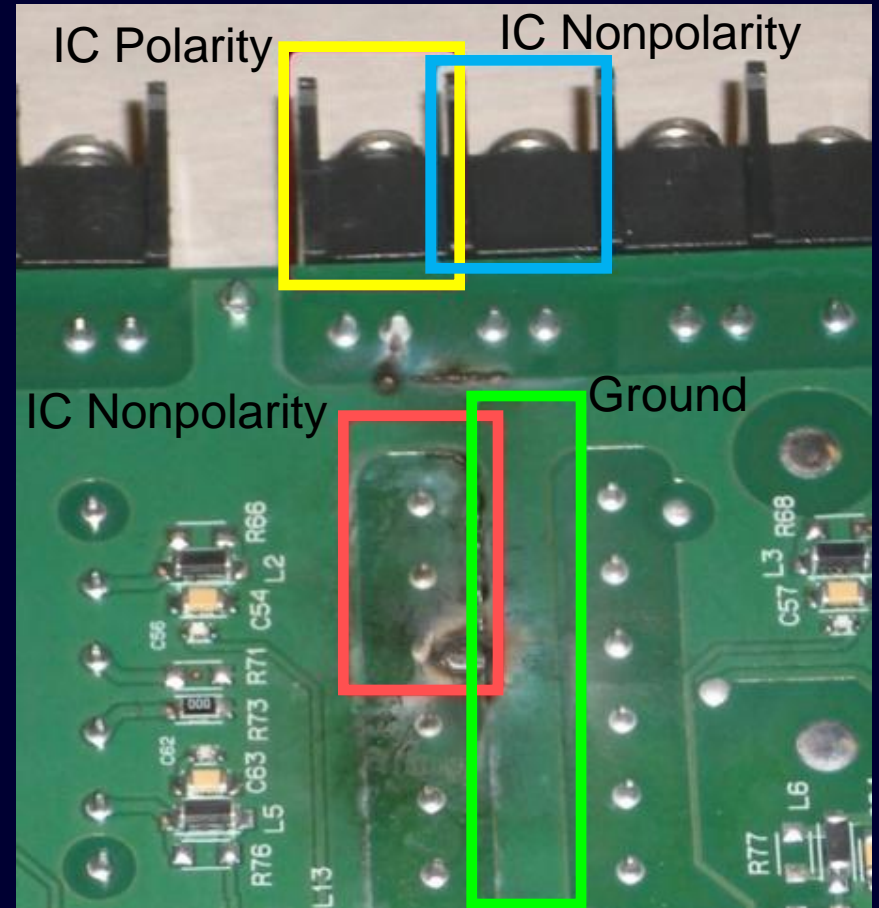
Open CTs Create HIGH Voltage



HiPot Test of Similar Board

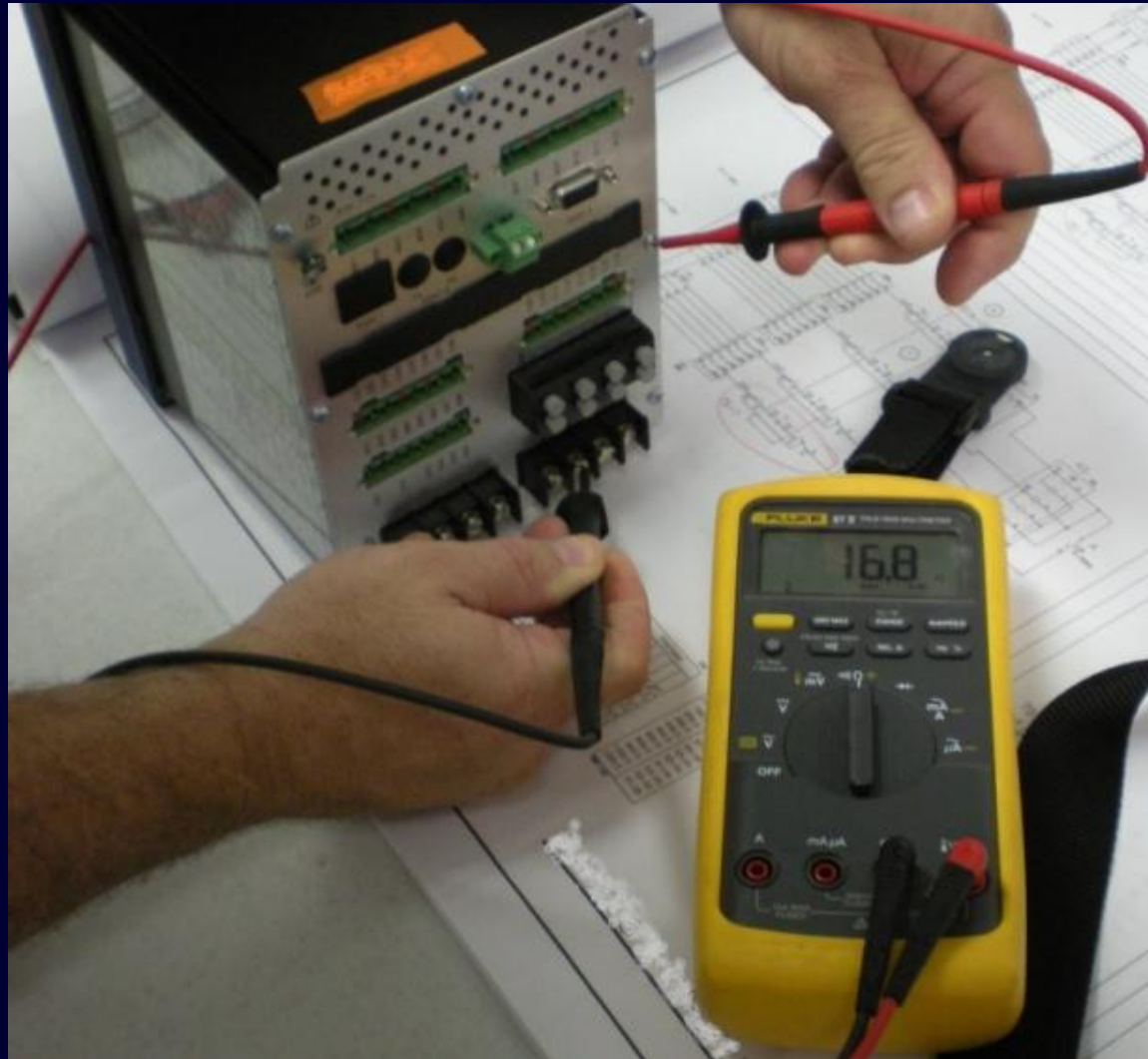


Damage Confirmed on In-Service Relay

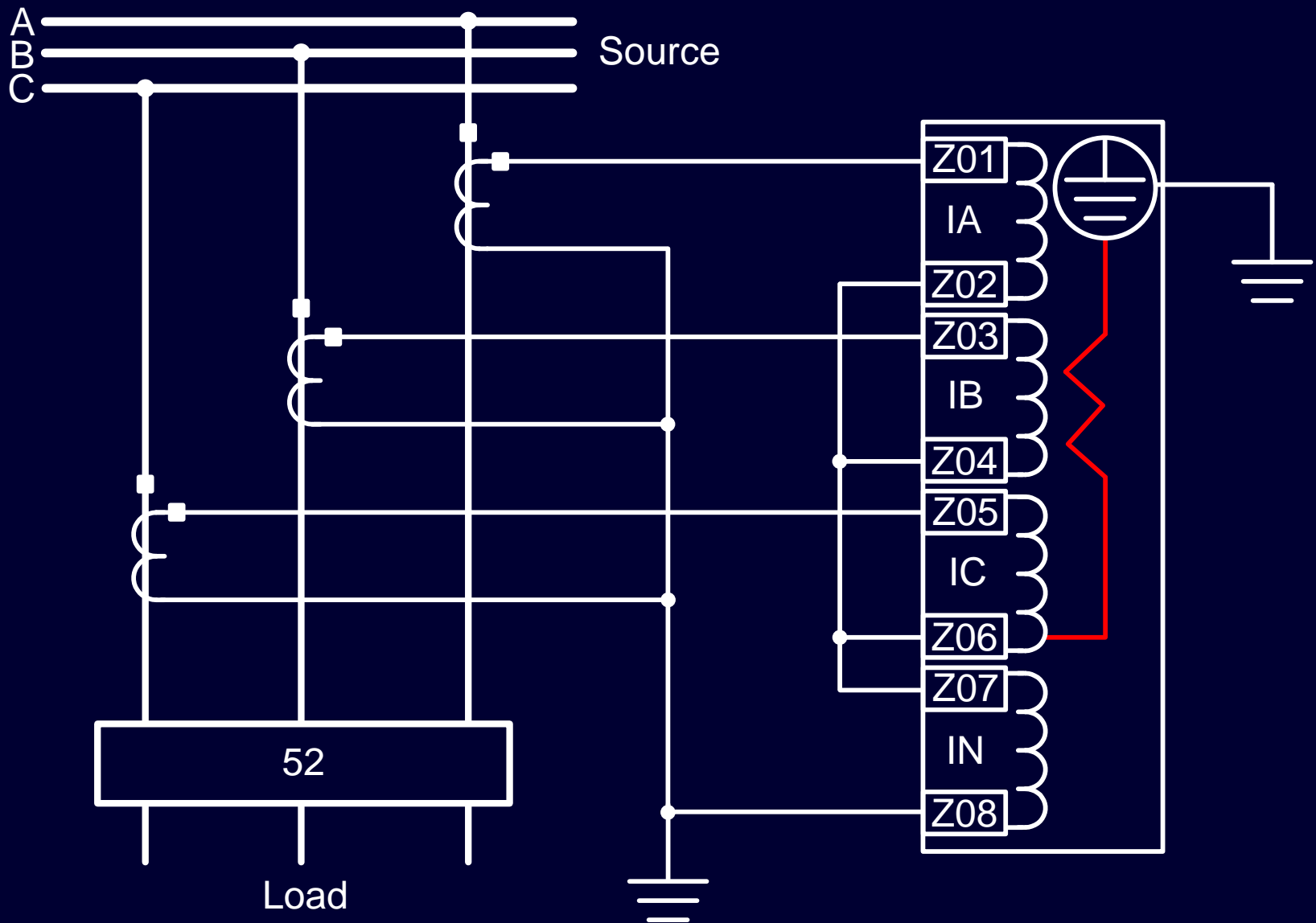


Path Through Damaged Board 17 Ohms

Reason $I_N \approx I_G \approx 0$ A After Crimp Fixed



State of In-Service, Damaged Relay



Conclusions

- Standards and robust designs ensure protection systems operate reliably when exposed to fault-induced transients
- Even relays designed and tested to greatly exceed IEEE and IEC dielectric standards fail if subjected to primary-level voltages
- Open-circuited CTs can create dangerously high voltage spikes

Conclusions

- In this case study, a crimp failure
 - ◆ Went undetected for about a year
 - ◆ Was exposed after new cabling put pressure on wiring harness
 - ◆ Caused relay trip, plant outage, and equipment damage
- Relay put back into service before root cause was known

Conclusions

- Subsequent event analysis
 - ◆ Discovered discrepancy between IG and IN
 - ◆ Proposed that in-service relay was damaged
 - ◆ Confirmed root cause
- There are *thousands* of wires and terminations – just *one* incorrect can damage equipment and cause dangerous working conditions and power outages

Questions?