Solidly Grounded Shipboard Systems

IEEE 45.1 Quarterly Meeting

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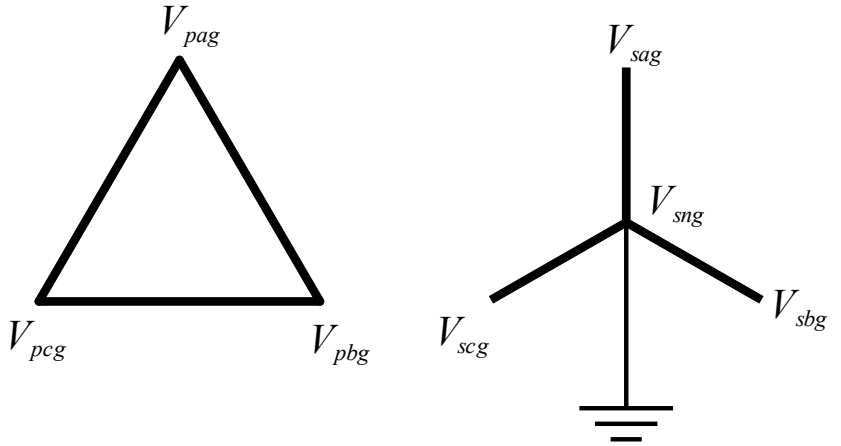
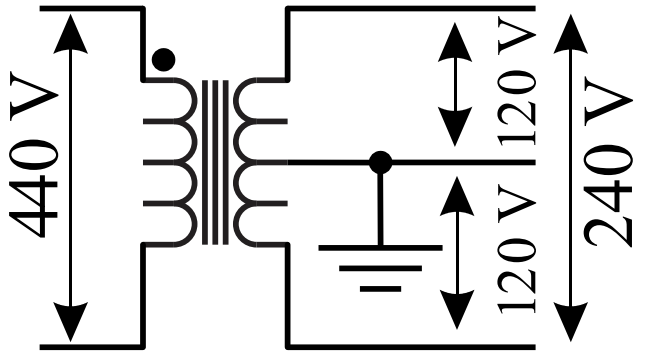
Solidly Grounded Shipboard Systems

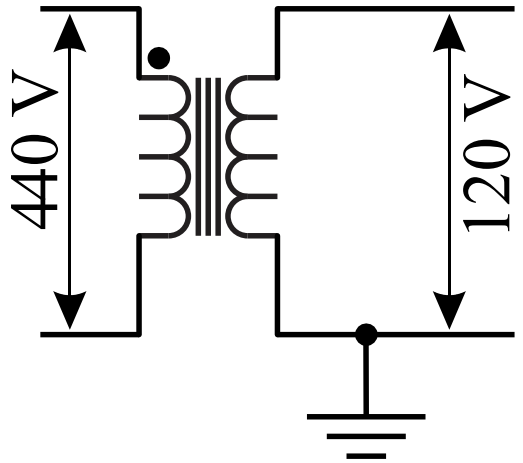
- IEEE Std 45.1-2023 Section 25.2 states
  - “Secondary buses powering non-critical loads should be solidly grounded”
- Rationale
  - Promote use of COTS equipment designed for solidly grounded terrestrial applications
- Solidly ground system normally provided by:
  - Delta Wye transformer
    - 3 phase 208 volt line to line (120 volts line to neutral) secondary
    - Transformer Neutral Conductor solidly grounded
  - Single phase transformer connected line to line on primary
    - Secondary can be 120 volts with one conductor solidly grounded (neutral)
    - Secondary can be 240 volts with center tap solidly grounded (neutral)

Transformer Configurations

- Delta-Wye
  - 208 volts line to line
  - 120 volts line to ground
- Single Phase 240/120 Volt
  - Line to line on primary
  - Secondary center tap grounded.
- Single Phase 120 volt
  - One conductor grounded

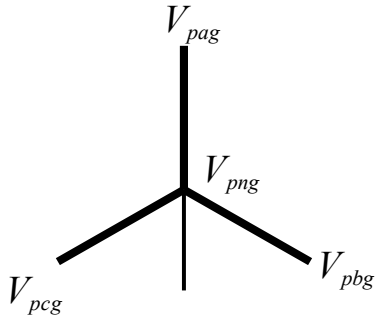


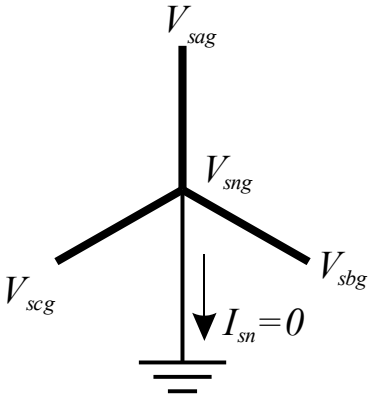


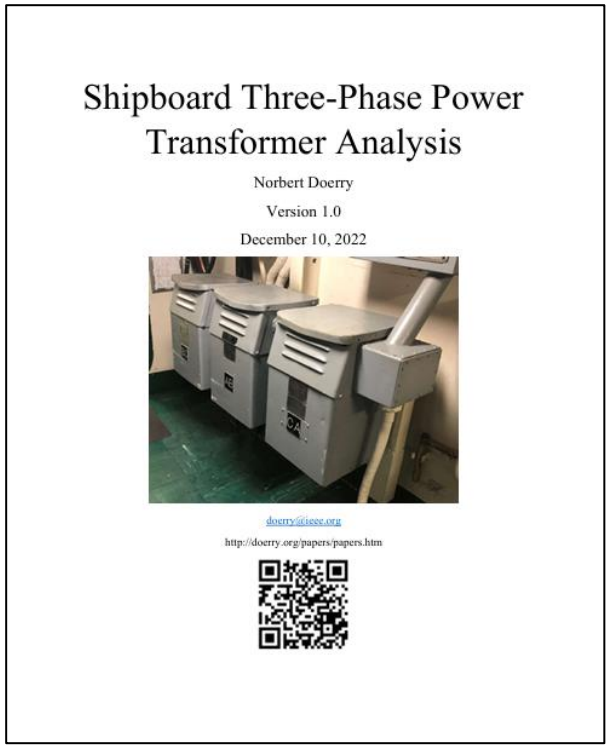


Wye-Wye transformers are NOT recommended for solidly grounded secondary:

- With neutral of primary ungrounded, the current in neutral to ground connection of secondary is always zero.
- Line to ground fault on secondary results in
  - No current flows in the neutral of either transformer.
  - The neutral conductor on the secondary will have a voltage proportional to the faulted phase voltage.
  - The primary and secondary currents for the faulted phase will be in phase with the phase voltage.
  - The primary and secondary currents for the unfaulted phases will not be in phase with their respective phase voltages.
  - The fault current is limited by the load resistance






Shipboard Three-Phase Power Transformer Analysis

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Version 1.0

December 10, 2022

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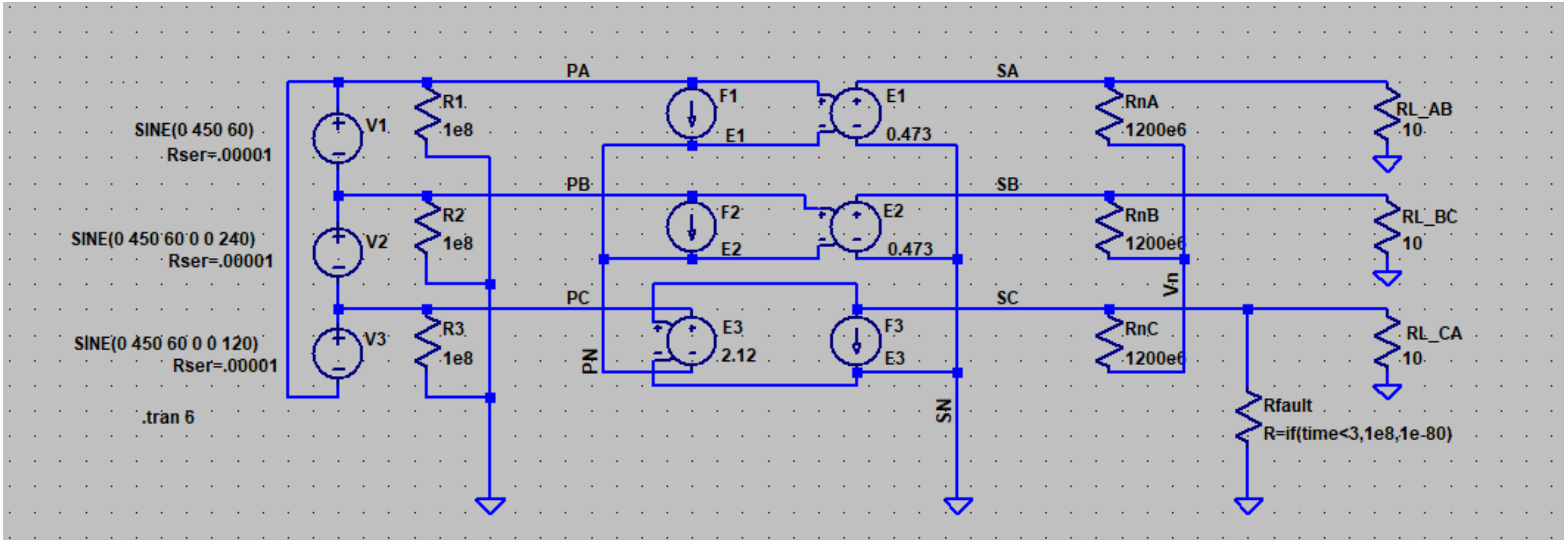
http://doerry.org/papers/papers.htm

Simulation: Line to Ground Fault on Wye-Wye



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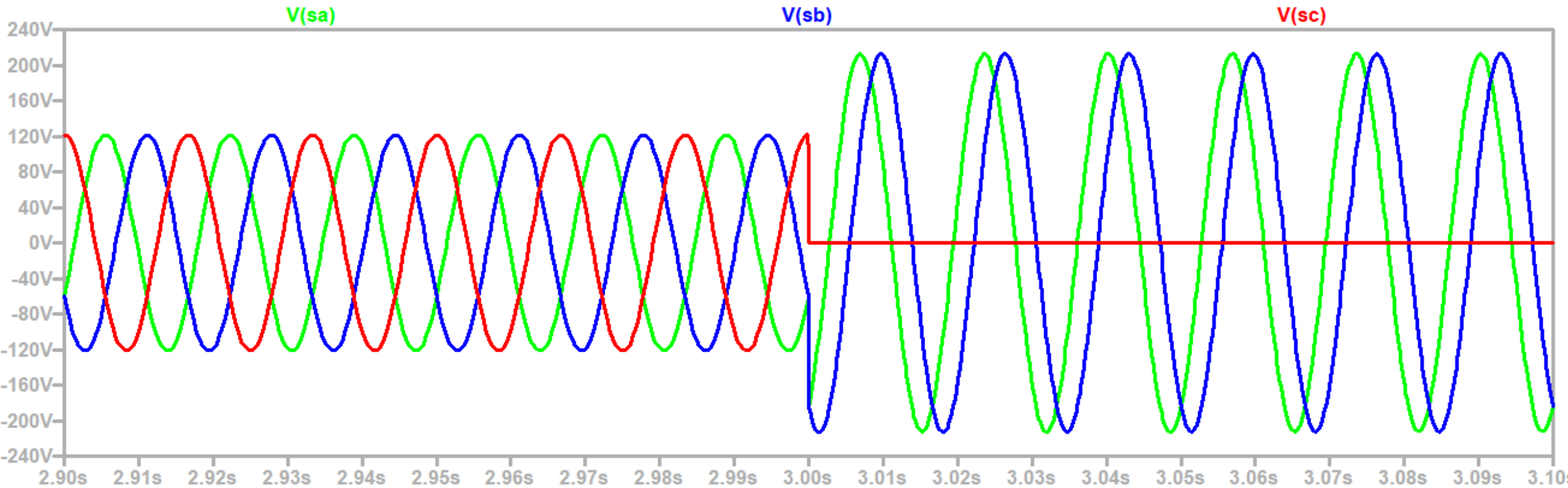
Line to Ground Fault: Wye-Wye Secondary Voltages



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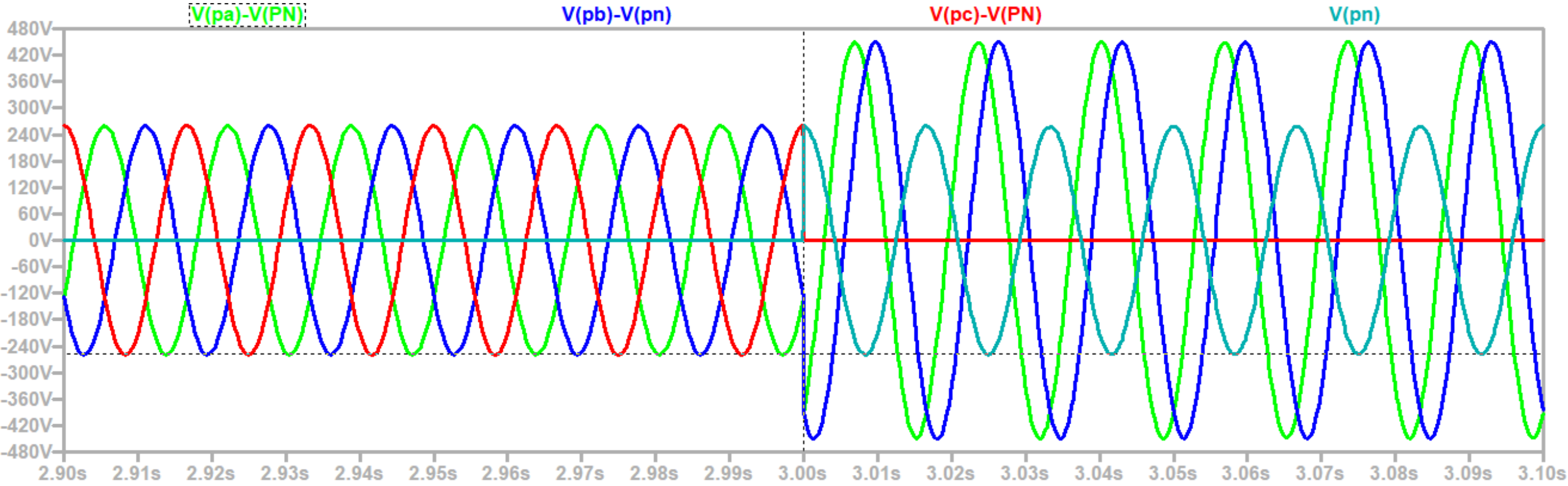
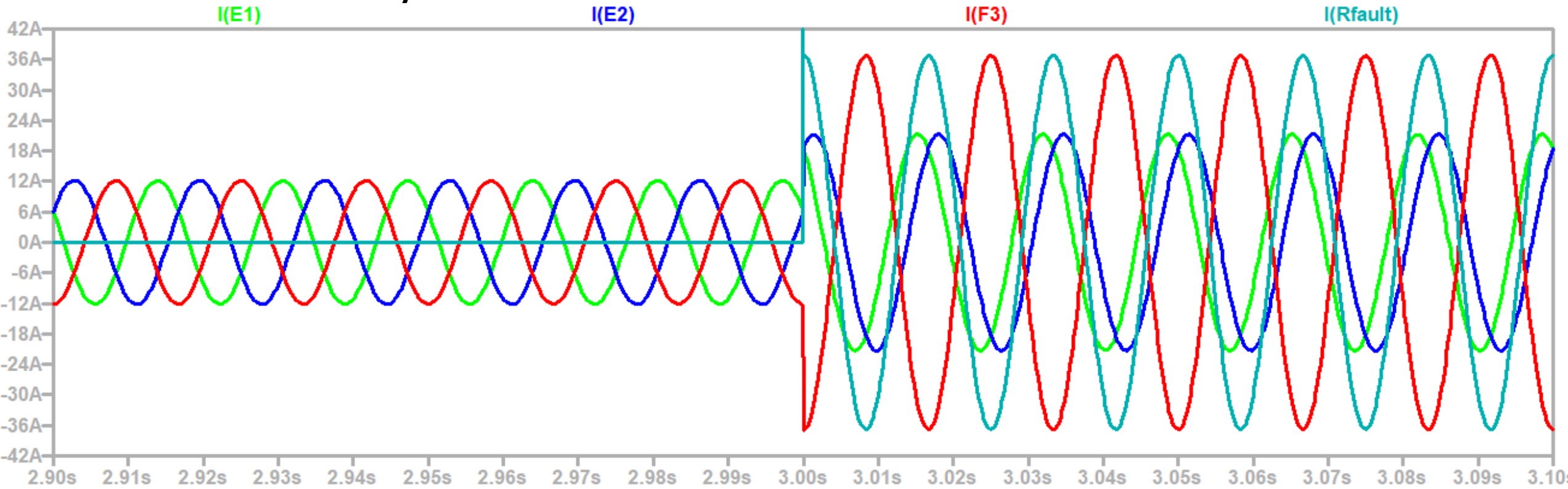


Line to Ground Fault: Wye-Wye Secondary Currents



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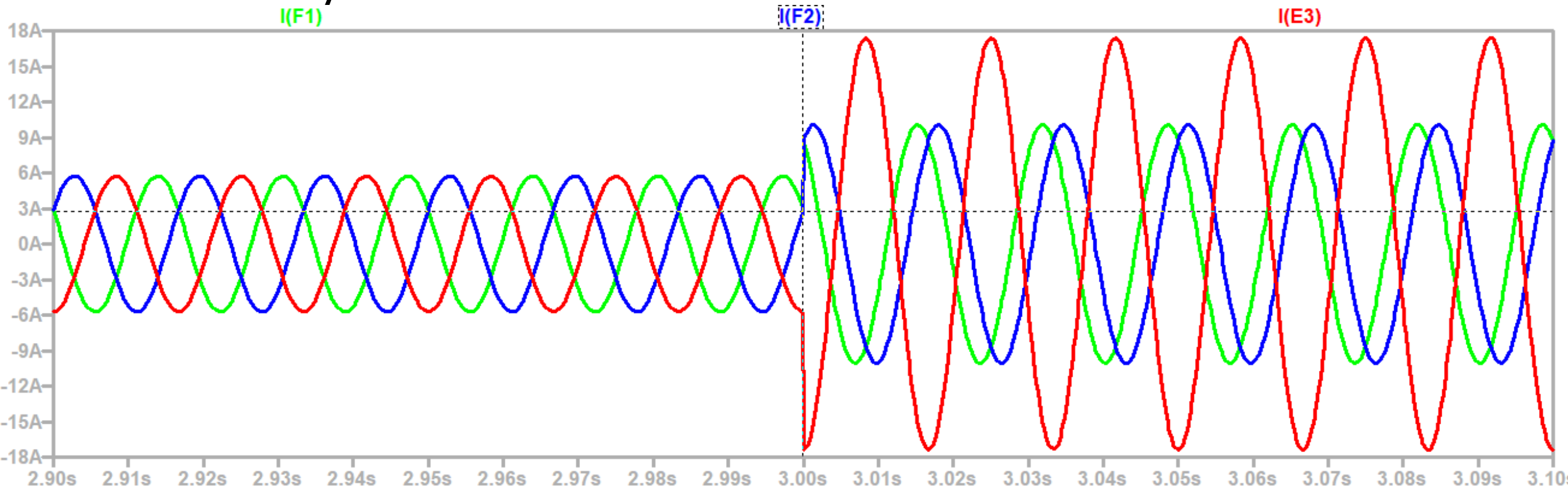
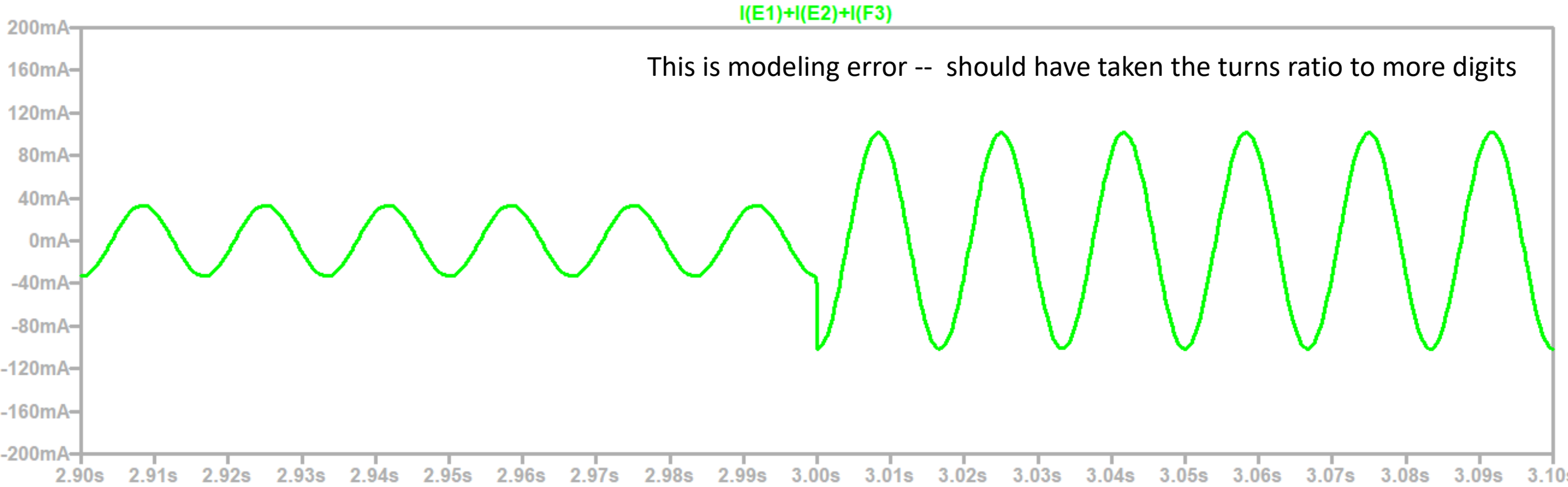
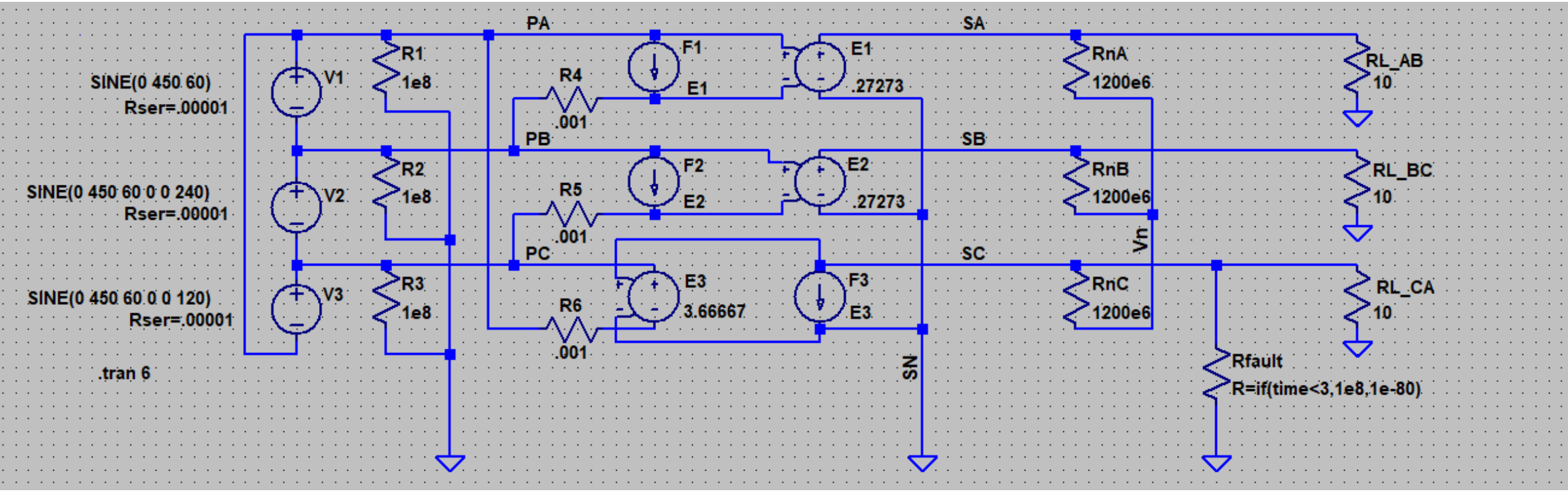


Line to Ground Fault: Wye-Wye Secondary Neutral Current



Line to Ground Fault: Delta-Wye



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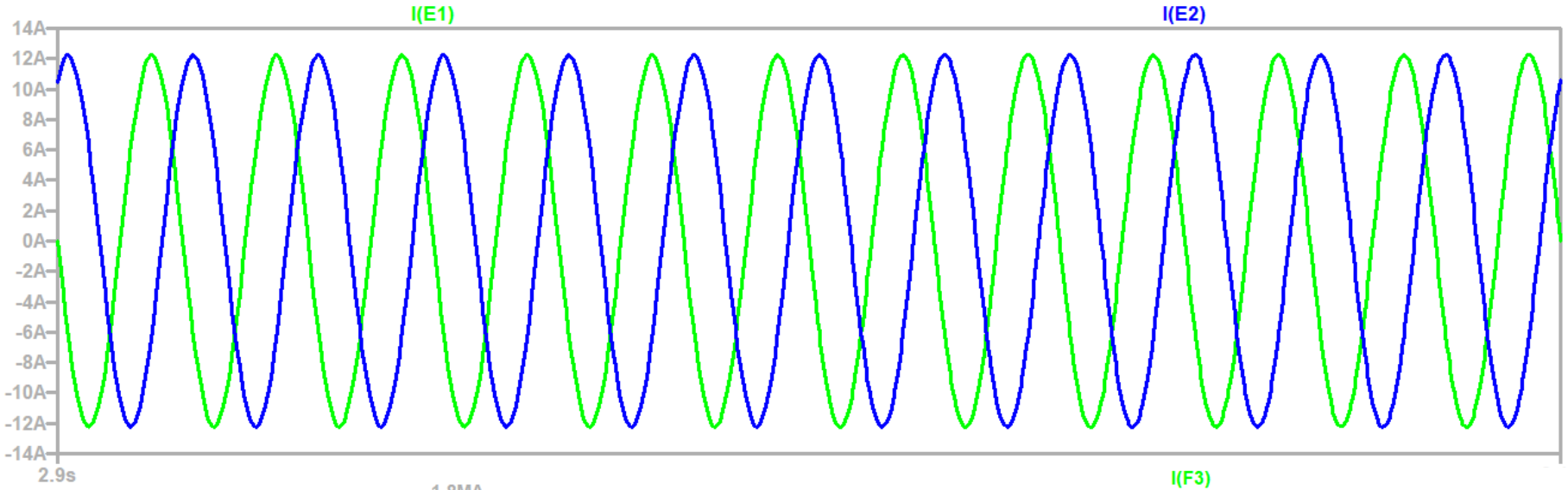
Line to Ground Fault: Delta-Wye Secondary Currents



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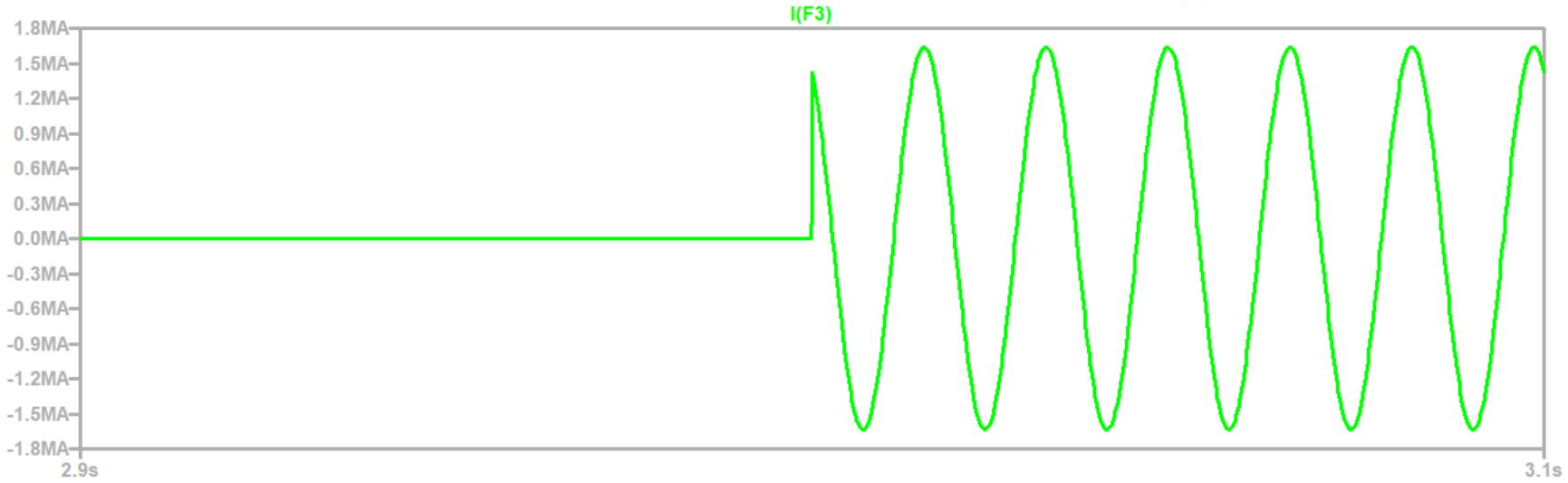
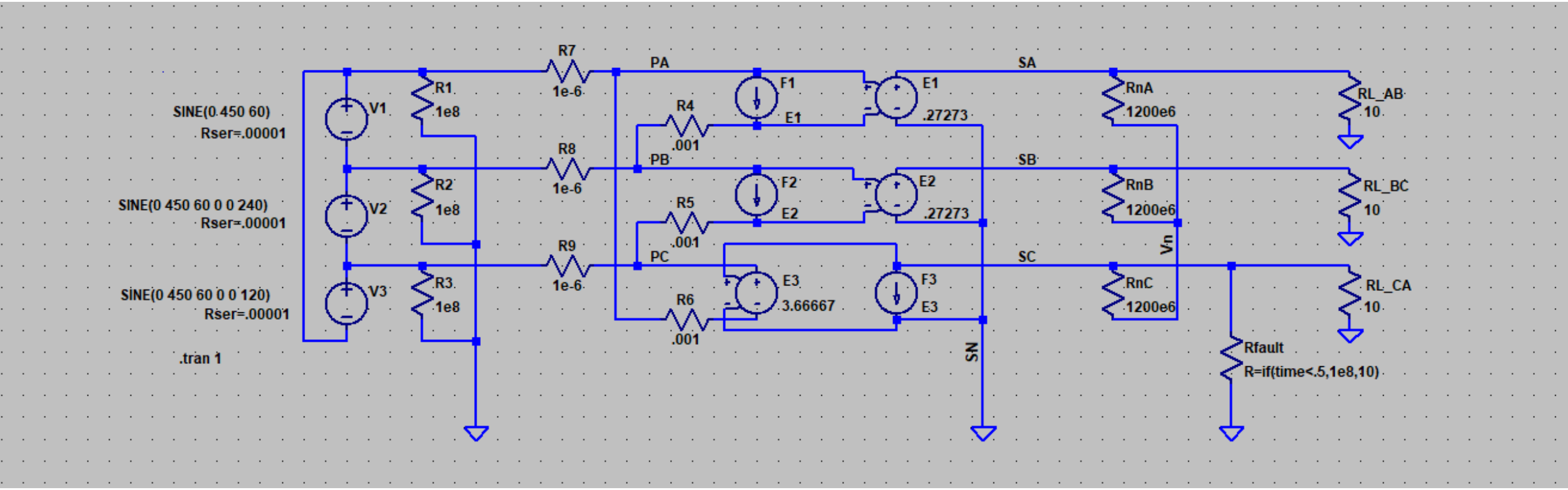


Impact of unbalanced phase loads Delta-Wye Transformers

- Greater impact on secondary phase currents than on primary phase currents.
- Conductor current rating could be exceeded for one conductor on secondary while all conductors on primary are below their conductor current rating
- If unbalanced loads are possible, should provide circuit breakers on both primary and secondary side of transformer
  - Primary side protects transformer
  - Secondary side protects cable from transformer

Unbalanced Phase Loads



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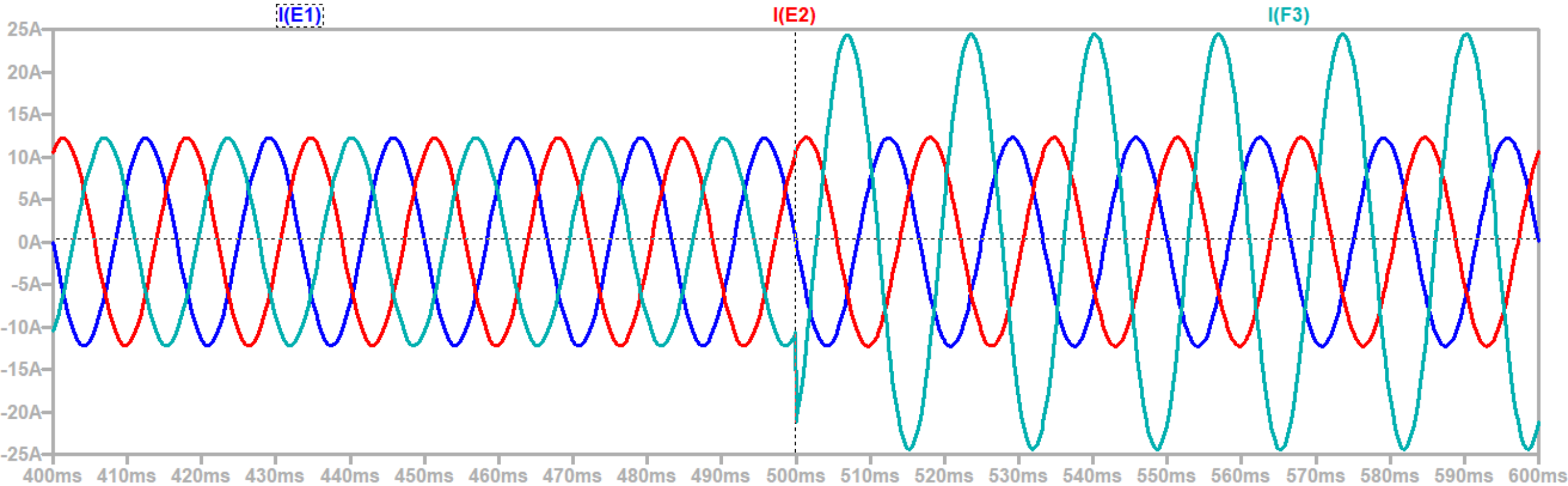
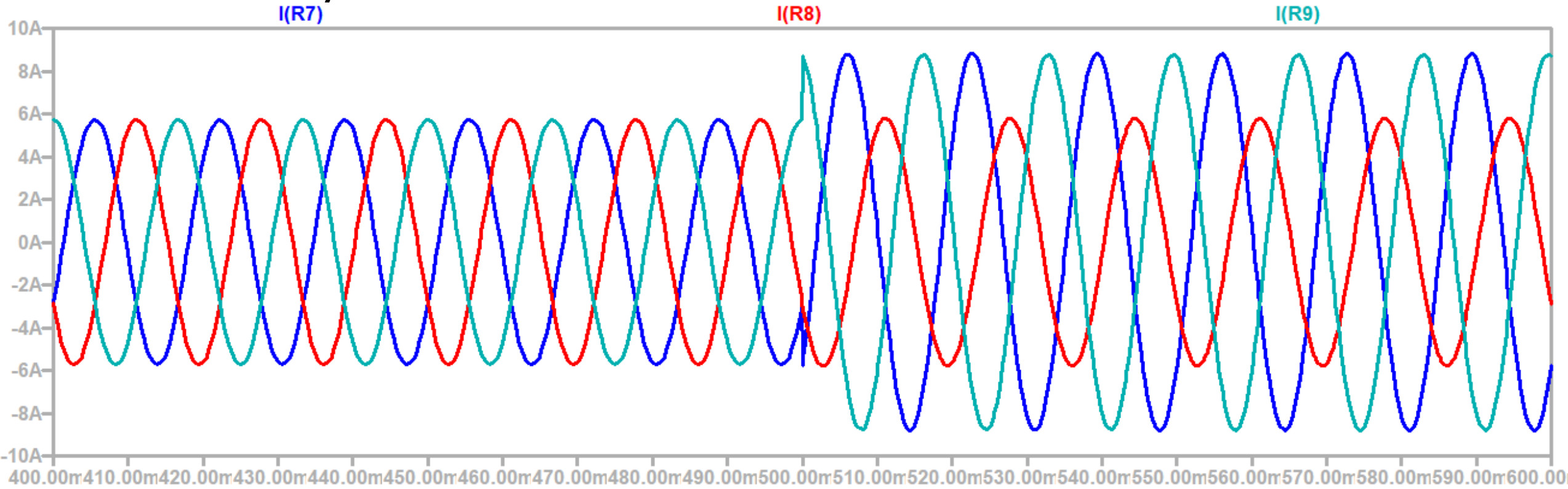
Unbalanced Phase Currents
Secondary Phase Currents



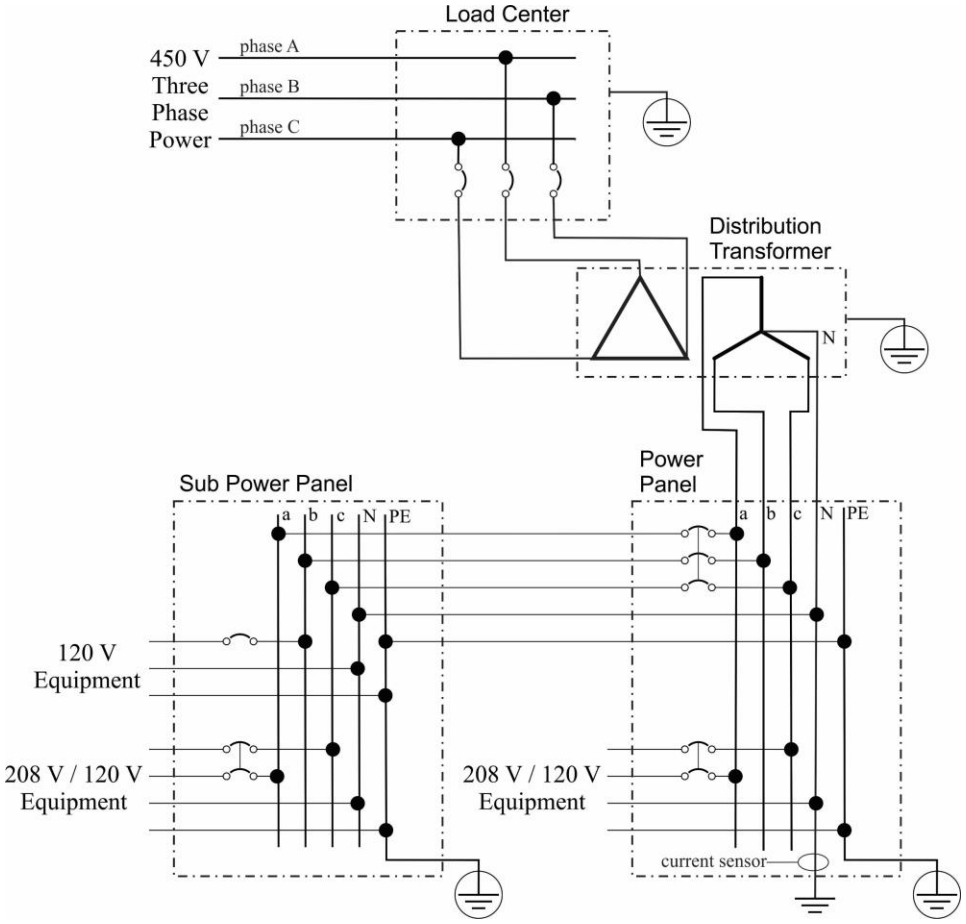
Phase C current is twice the other phases

Unbalanced Phase Loads
Primary Phase Currents



Phase A and C currents are about 150% of Phase B current

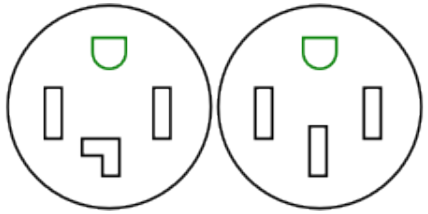
Grounding of panels and sub-panels

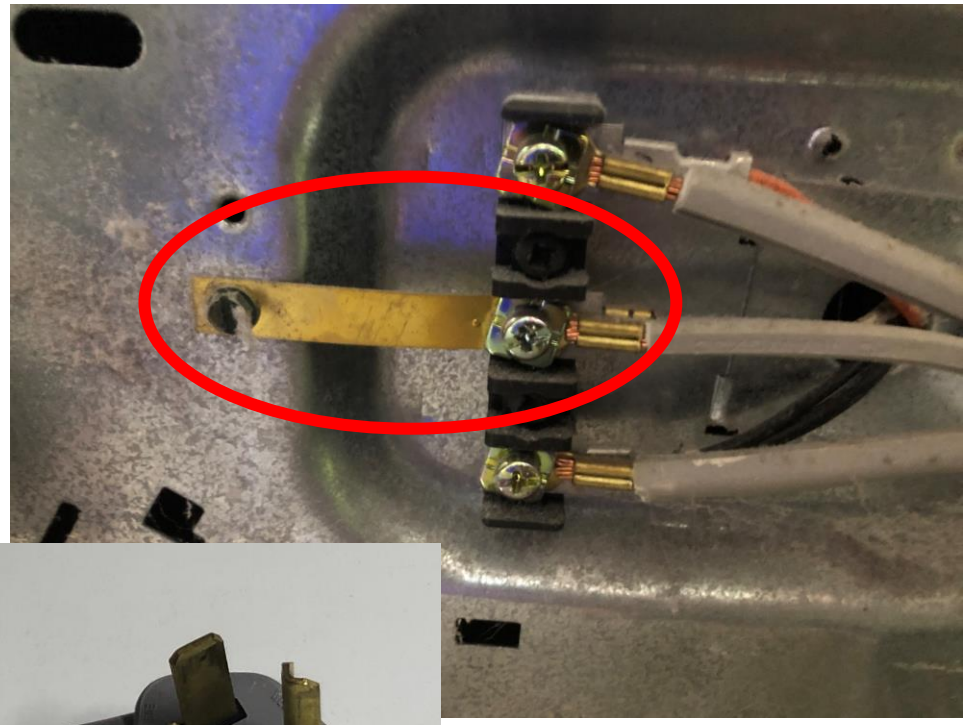


- IEEE 45.1-2023 Section 9.2
  - Ship structure should not be used as a normal current-carrying conductor for the electrical power supply distribution systems.
- System neutral should only be grounded at the Main Power Panel
  - Neutral is a current-carrying conductor
- Sub panels should not ground the system neutral.
  - Doing so will cause a portion of the neutral current to flow through the ship's structure
- Phase conductors, System neutral Conductor, and Equipment Ground Conductor (PE) should be part of the same cable
  - Maximize mutual inductance to minimize current through structure during a ground fault

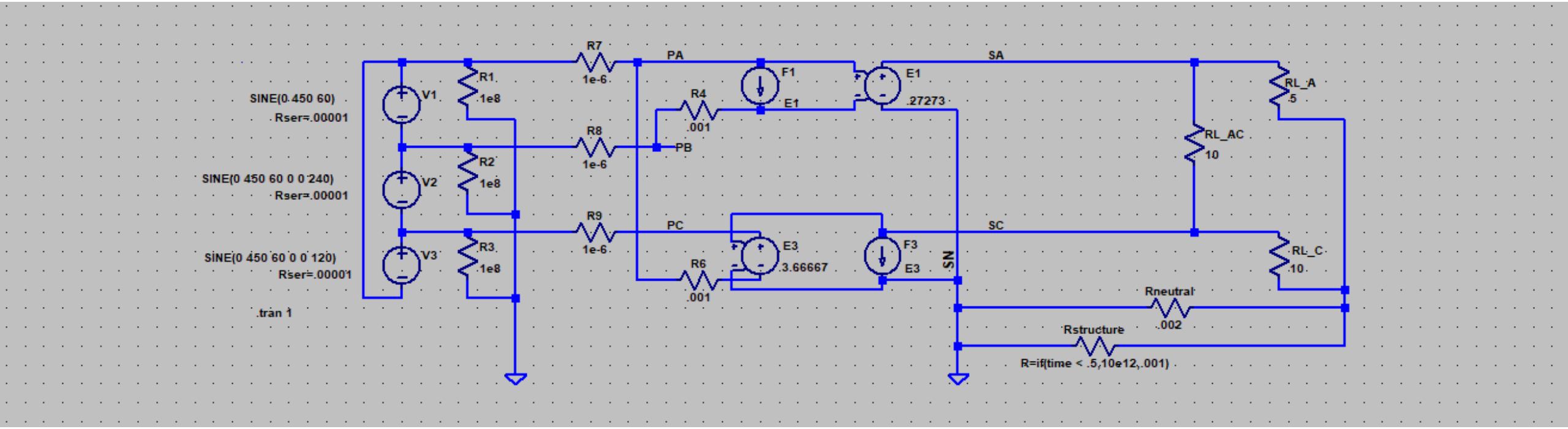
Ground Fault on Neutral Conductor with NEMA 6-XX connectors

- Uses same conductor for neutral and equipment ground (PE) in terrestrial applications.
  - Commonly found on electric clothes dryers and kitchen stoves
- Important to use this conductor only for neutral in shipboard system.
  - Equipment ground (PE) provided by connection to hull.
  - Remove jumper from neutral to equipment chassis
  - Failure to remove jumper can result in large currents through the ship's hull.
- Instead, use NEMA 14-XX connectors with dedicated equipment ground (PE)





Simulation of grounded neutral on 208/120 volt system



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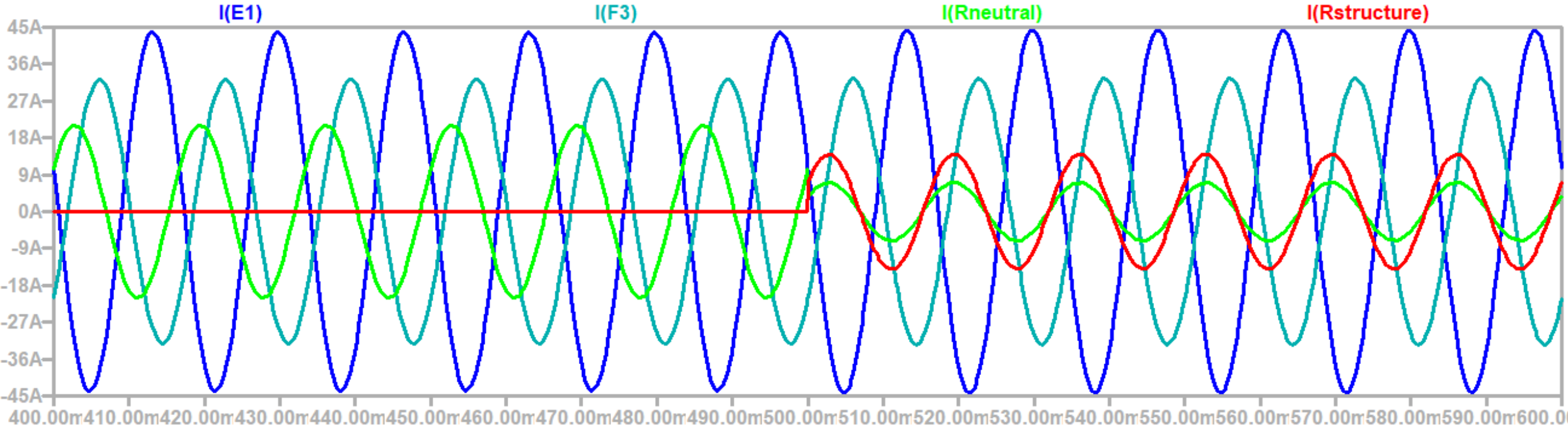
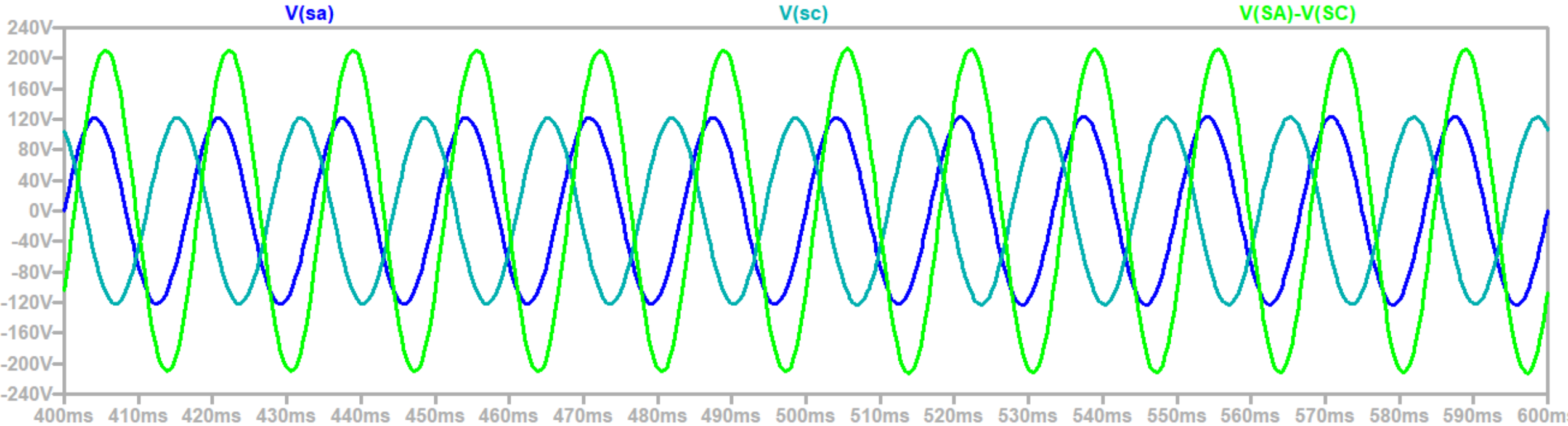
Simulation of grounded neutral on 208/120 volt system: Currents

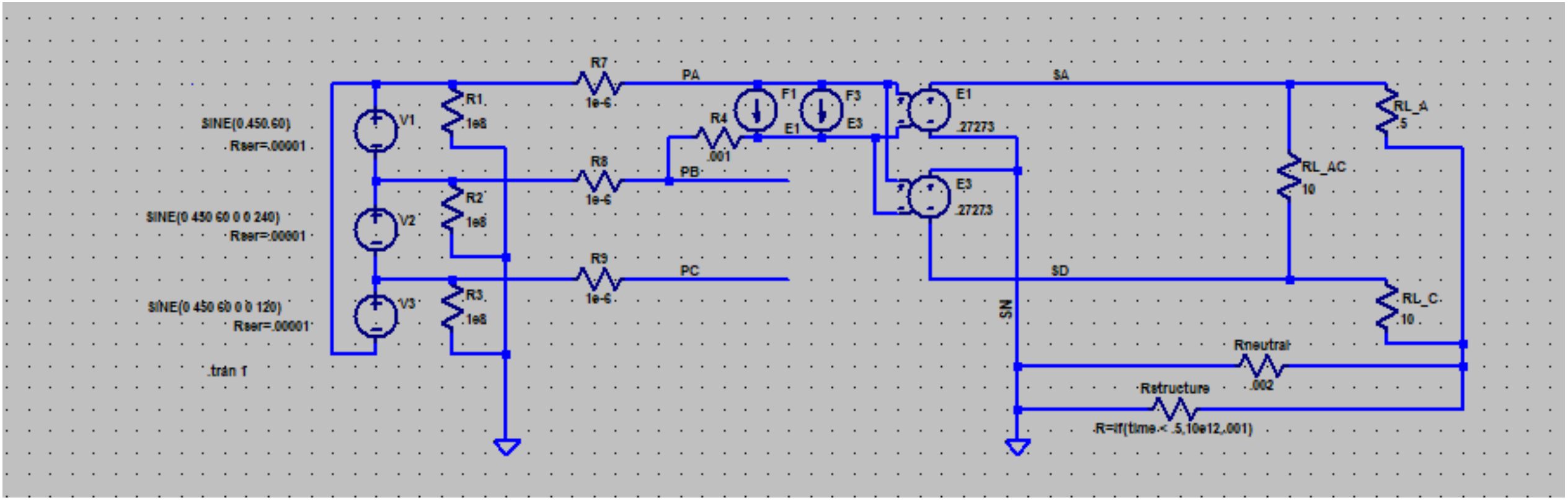


When Neutral is grounded at Load > .5 seconds, large structure current

Simulation of grounded neutral on 208/120 volt system: Voltages



Simulation of grounded neutral on 240/120 volt system



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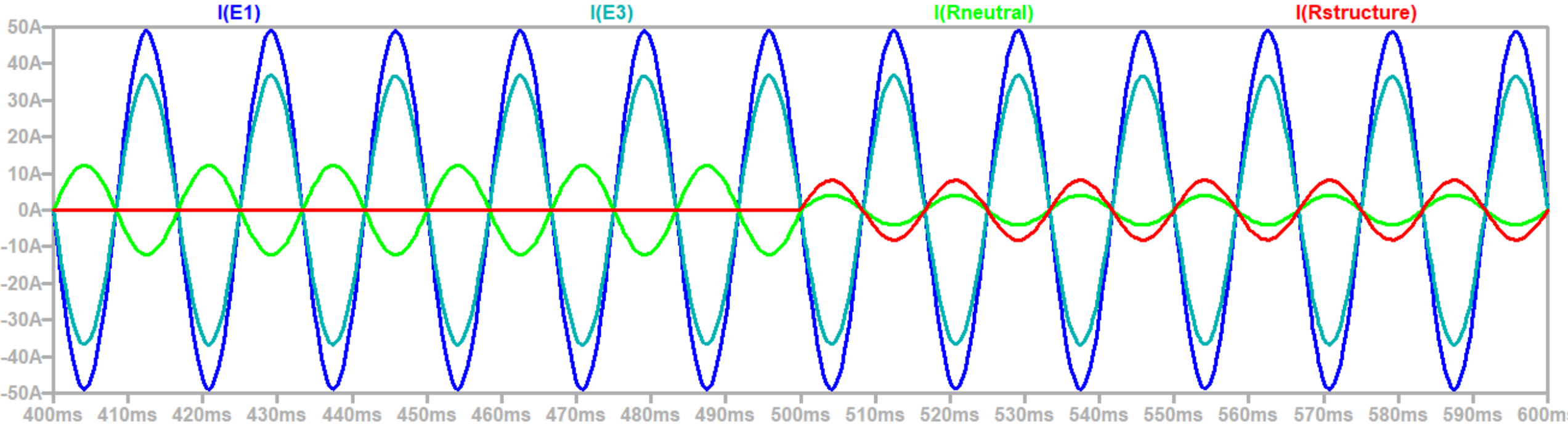
Simulation of grounded neutral on 240/120 volt system: Currents



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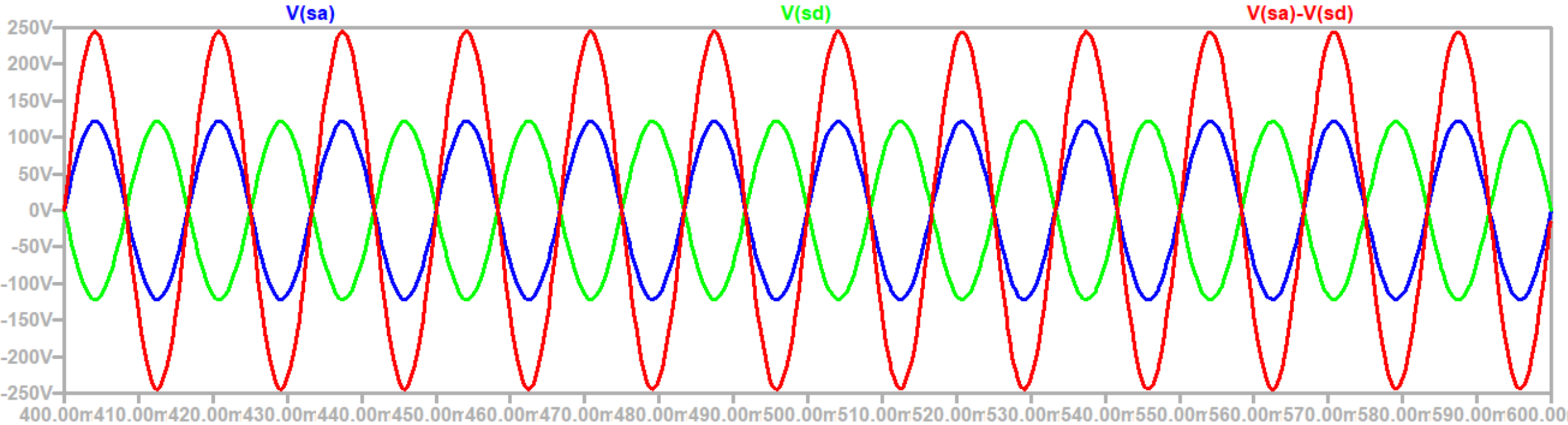

Ground Fault Detection

- Low impedance line to ground faults cleared by traditional circuit protection
- Low impedance neutral to ground faults are not cleared by traditional circuit protection
  - Can be detected by measuring current in transformer ground conductor
  - Can be cleared with GFCI
  - Not discussed in IEEE 45.1-2023
- High Impedance ground faults can be cleared with GFCI
- Traditional ground detection lamps should not be used on solidly grounded systems.