Transient Simulation of Ground Faults in Ungrounded Power Systems

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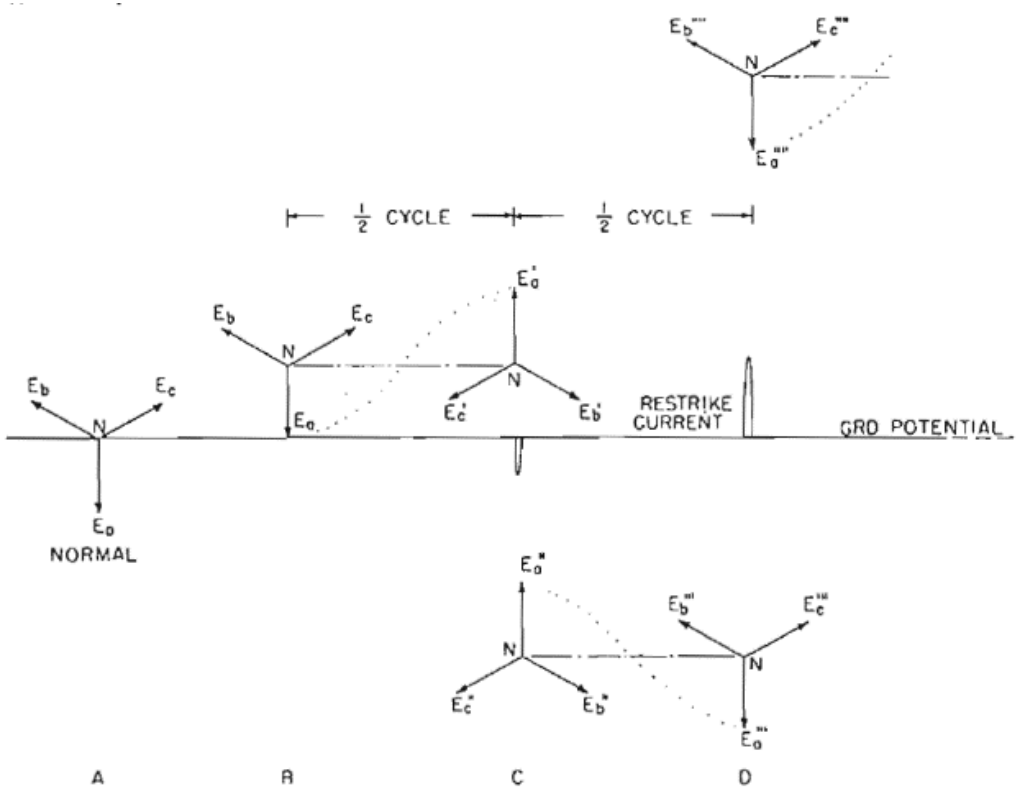
Motivation

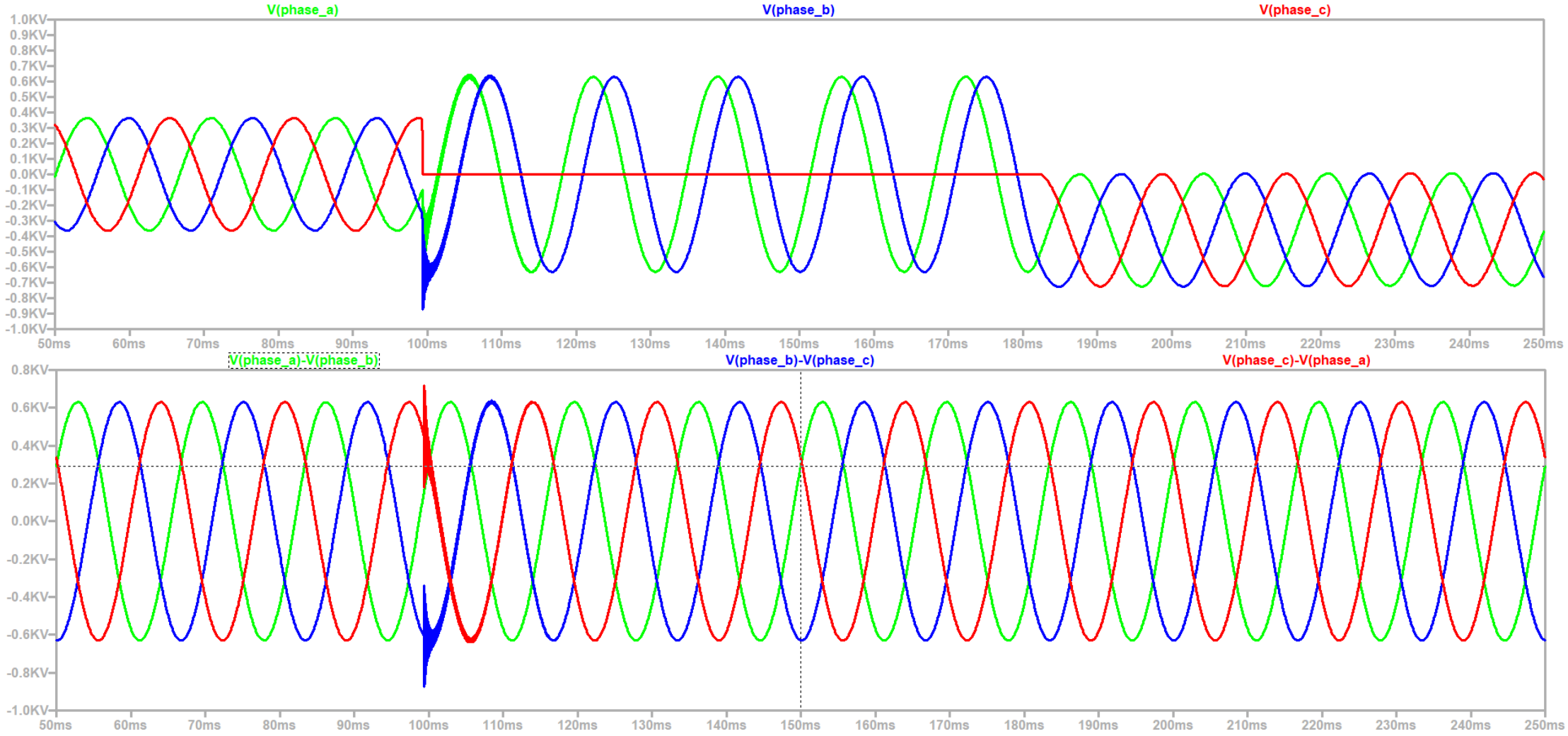
- Ungrounded power system used extensively in industrial power systems up to 1950s.
  - Transient over-voltages due to intermittent ground fault reported
    - One case involved loss of over 40 motors during the 2 hours required to locate fault
  - Charge pumping of the neutral to ground parasitic capacitance has traditionally been the explanation
- Solidly grounding or resistance grounding has largely replaced ungrounded power systems in industry
- Ungrounded systems still widely used onboard ships.
  - High resistance grounding is becoming more prevalent.



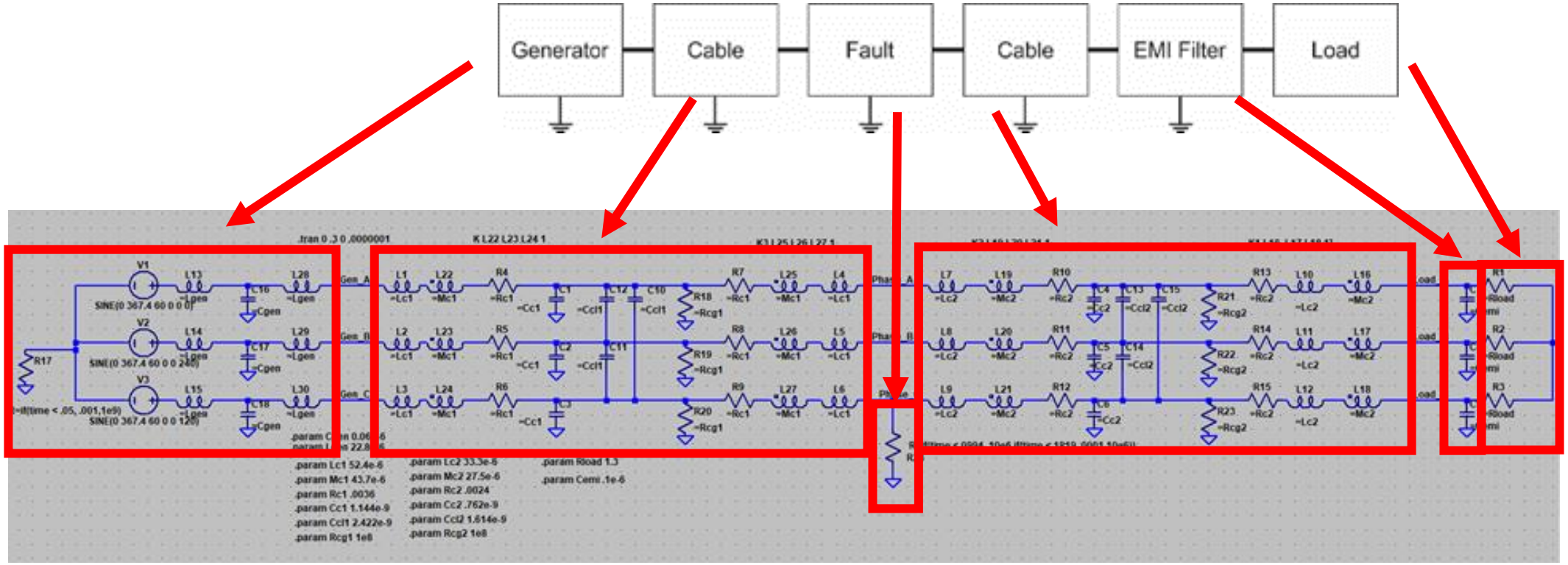
Kaufmann and Maynord 1955

Charge Pumping does not make sense as typically explained

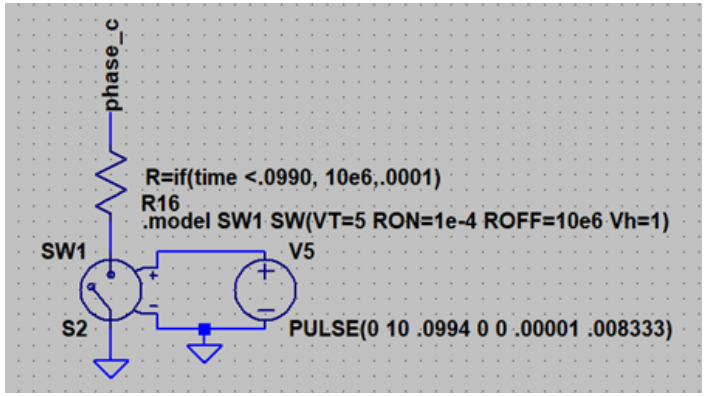
Simulation of a long duration ground fault



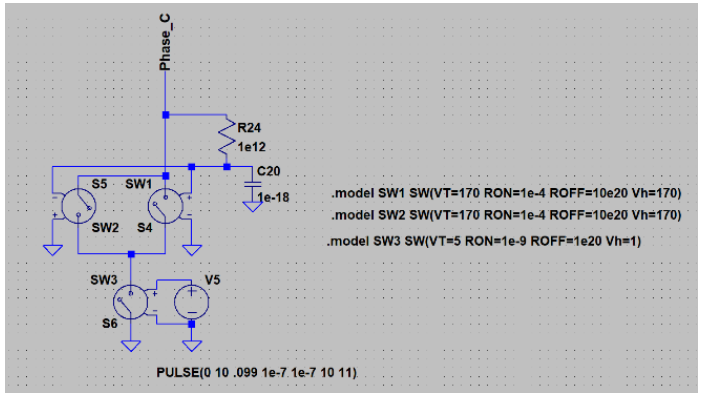
System Modeling (using LTSpice)



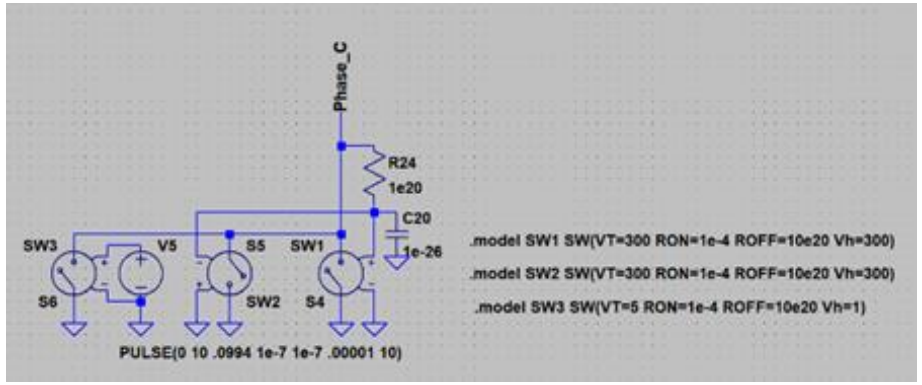
Alternate Fault Models



recurring ground fault



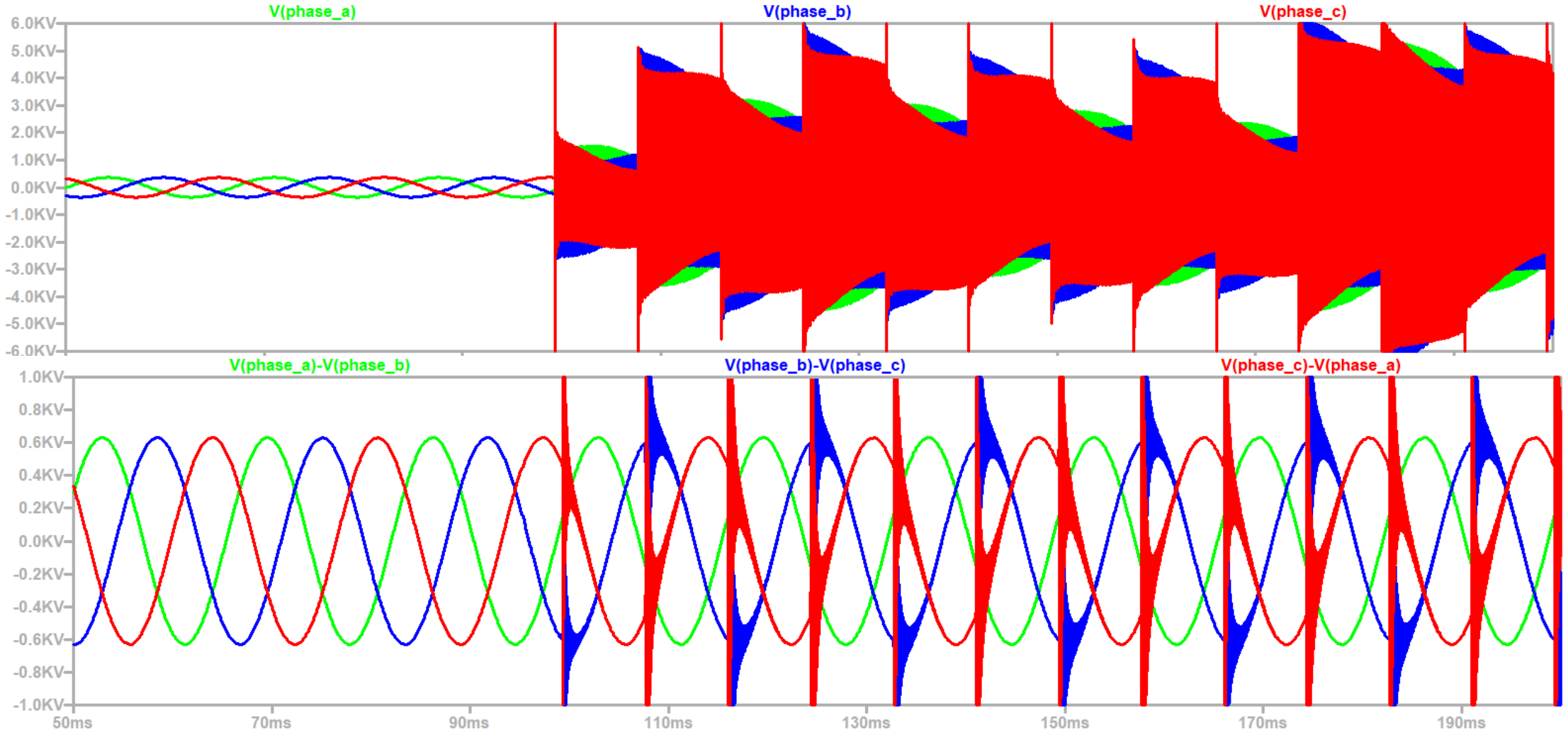
intermittent ground fault with arc threshold voltage less than nominal line to neutral voltage



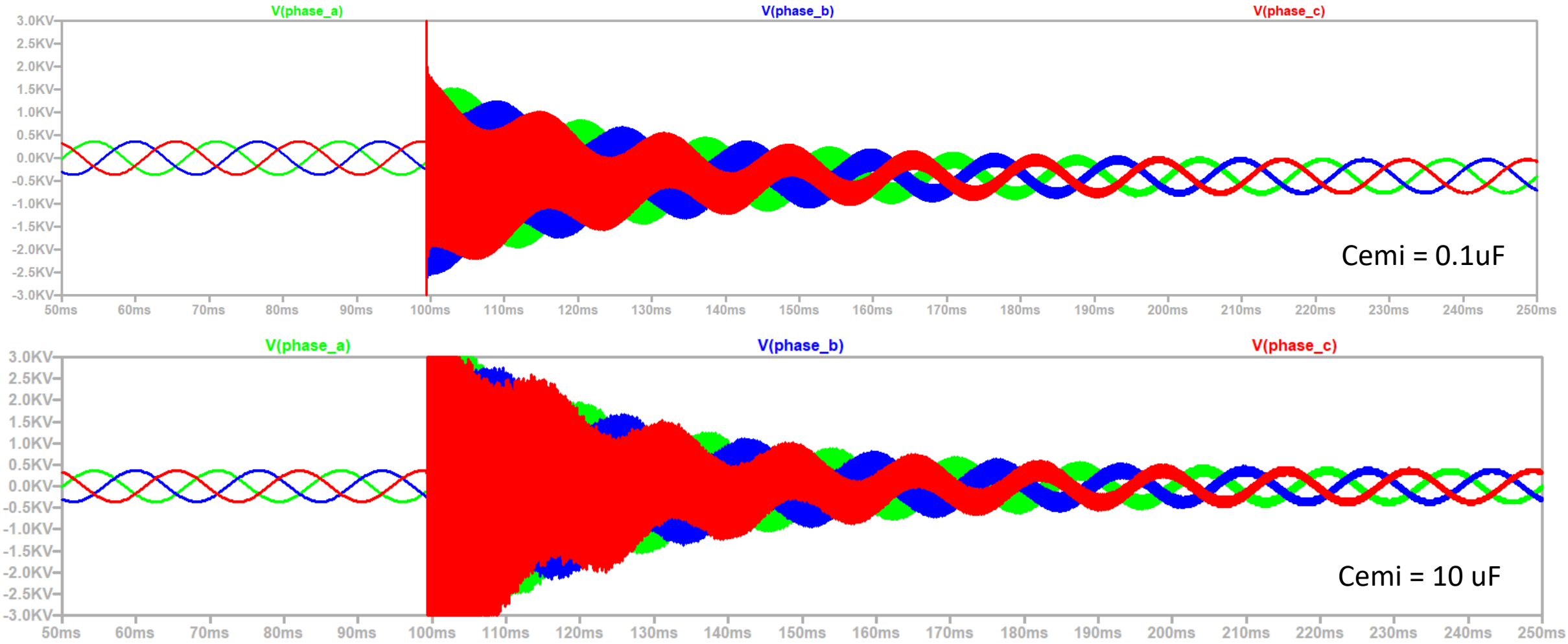
intermittent ground fault with arc threshold voltage greater than nominal line to neutral voltage

How one models the ground fault matters

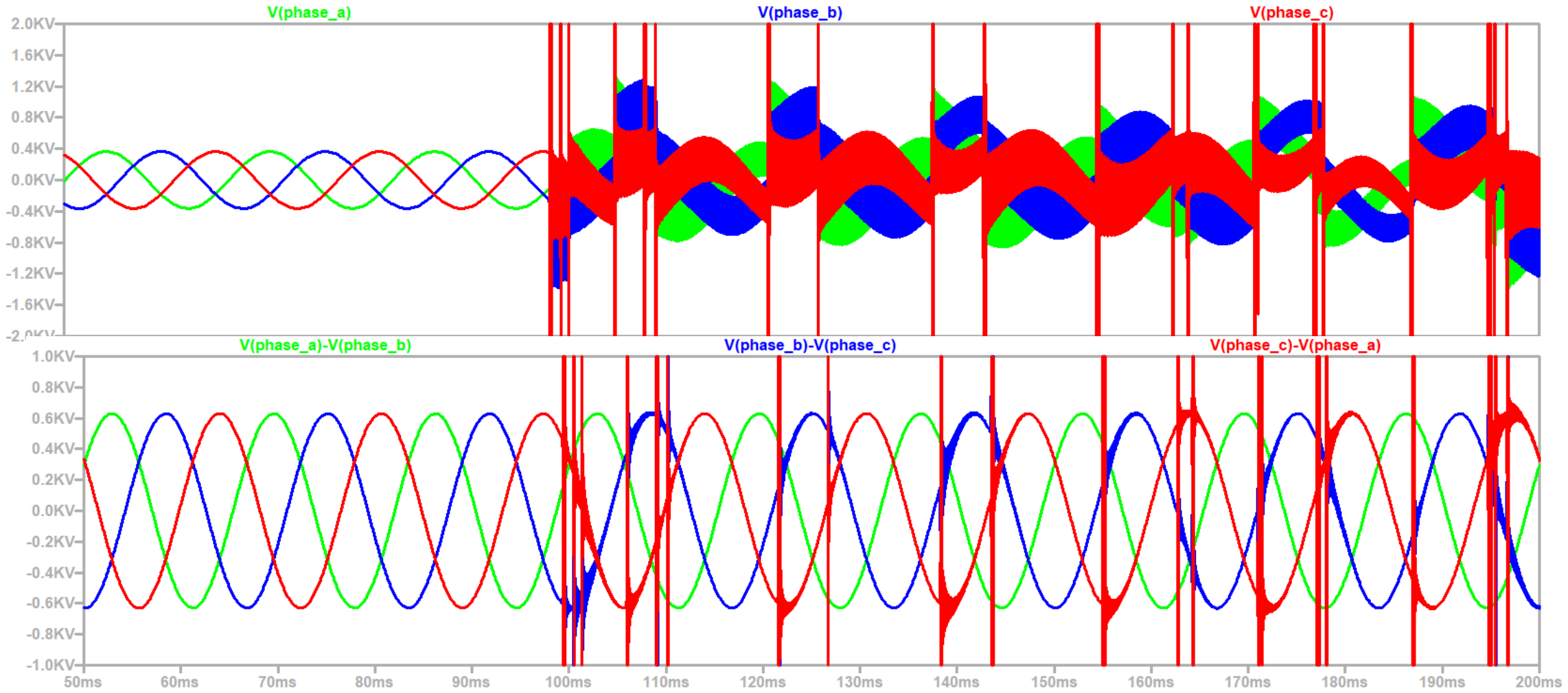
10 microsecond ground fault every ½ cycle



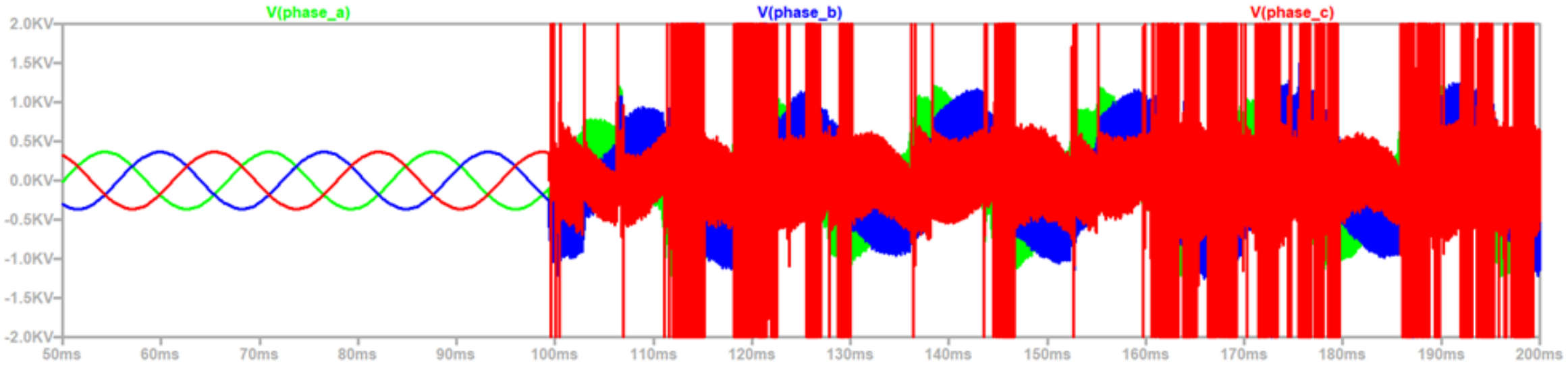
Impulse Response:
Single 10 microsecond ground fault



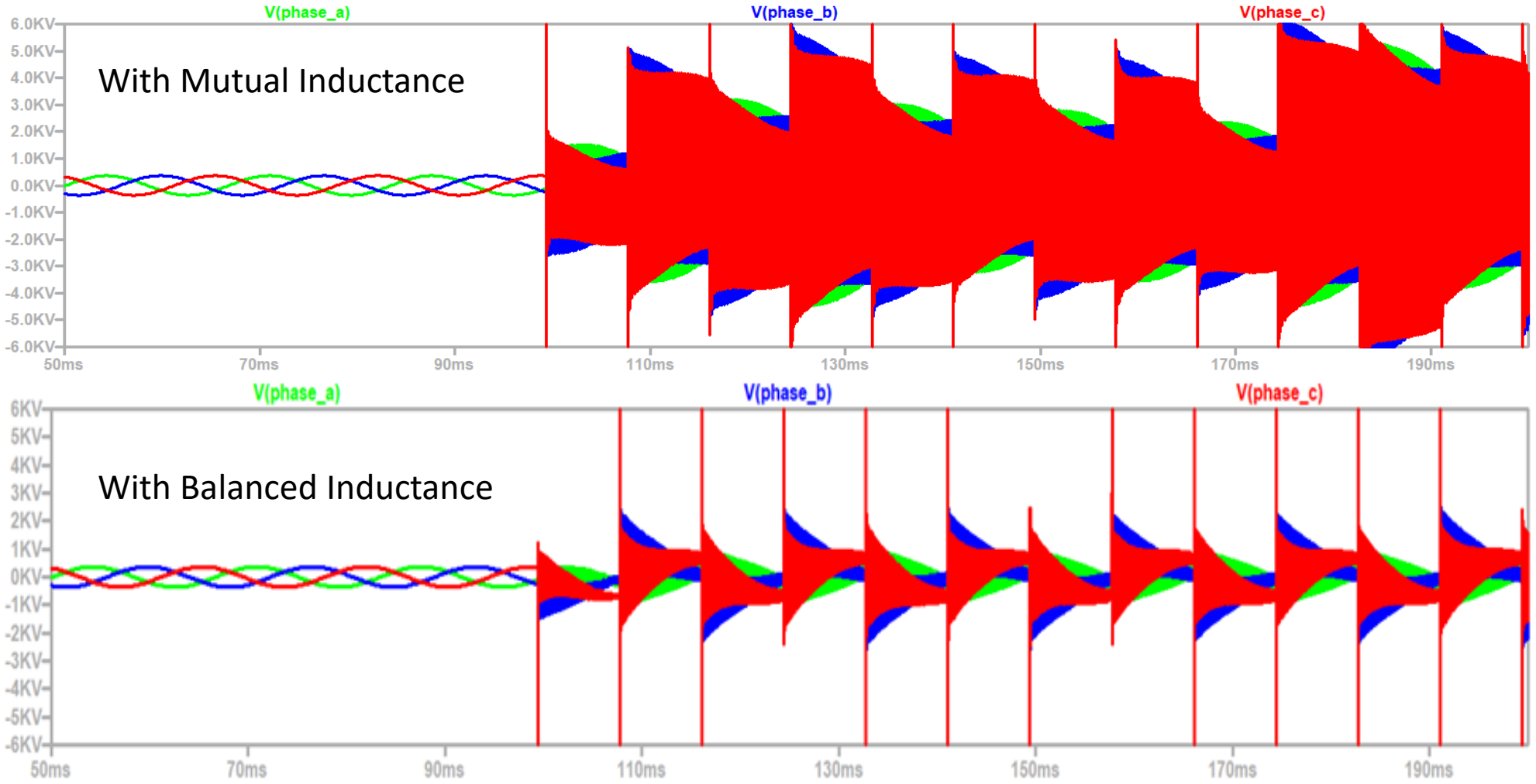
Arc Fault Model with arc threshold of 400 V



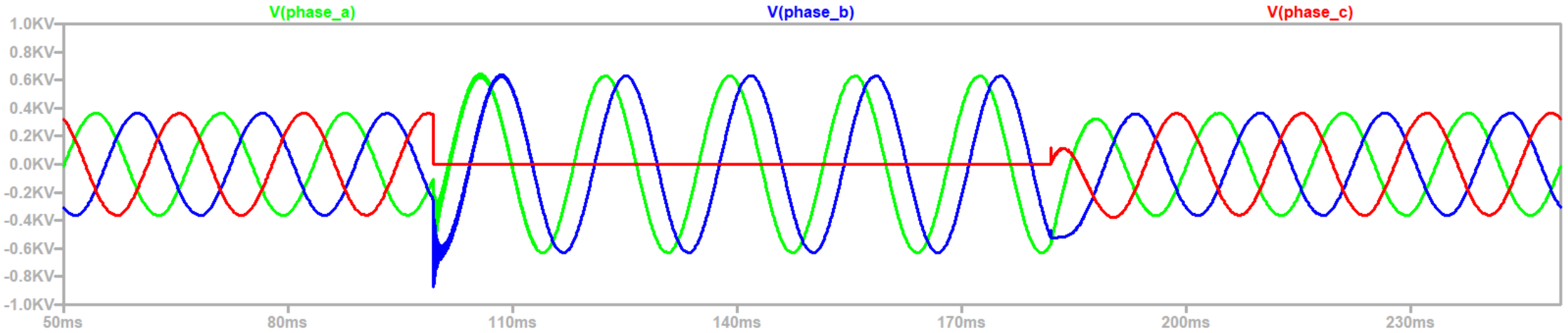
Arc Fault Model with arc threshold of 400 V Cemi = 10 uF

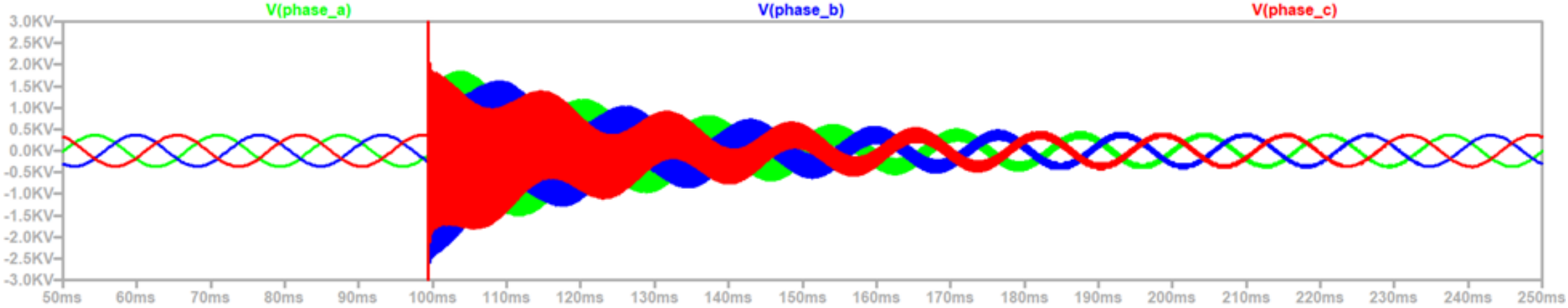


Modeling Cable Mutual Inductance is Important



High Resistance Grounding





Conclusions

- High frequency ringing results in large over-voltage due to intermittent grounds of ungrounded power systems.
- When line to ground fault clears, charge is trapped on the parasitic capacitances, resulting in a d.c. neutral offset
- High line to ground capacitances make things worse
- Modeling the cable mutual and self-inductance is important
- High Resistance Ground effectively eliminates d.c. neutral offset when line to ground fault clears.
- High Resistance Ground has less of an impact on impulse response than intuitively expect.