

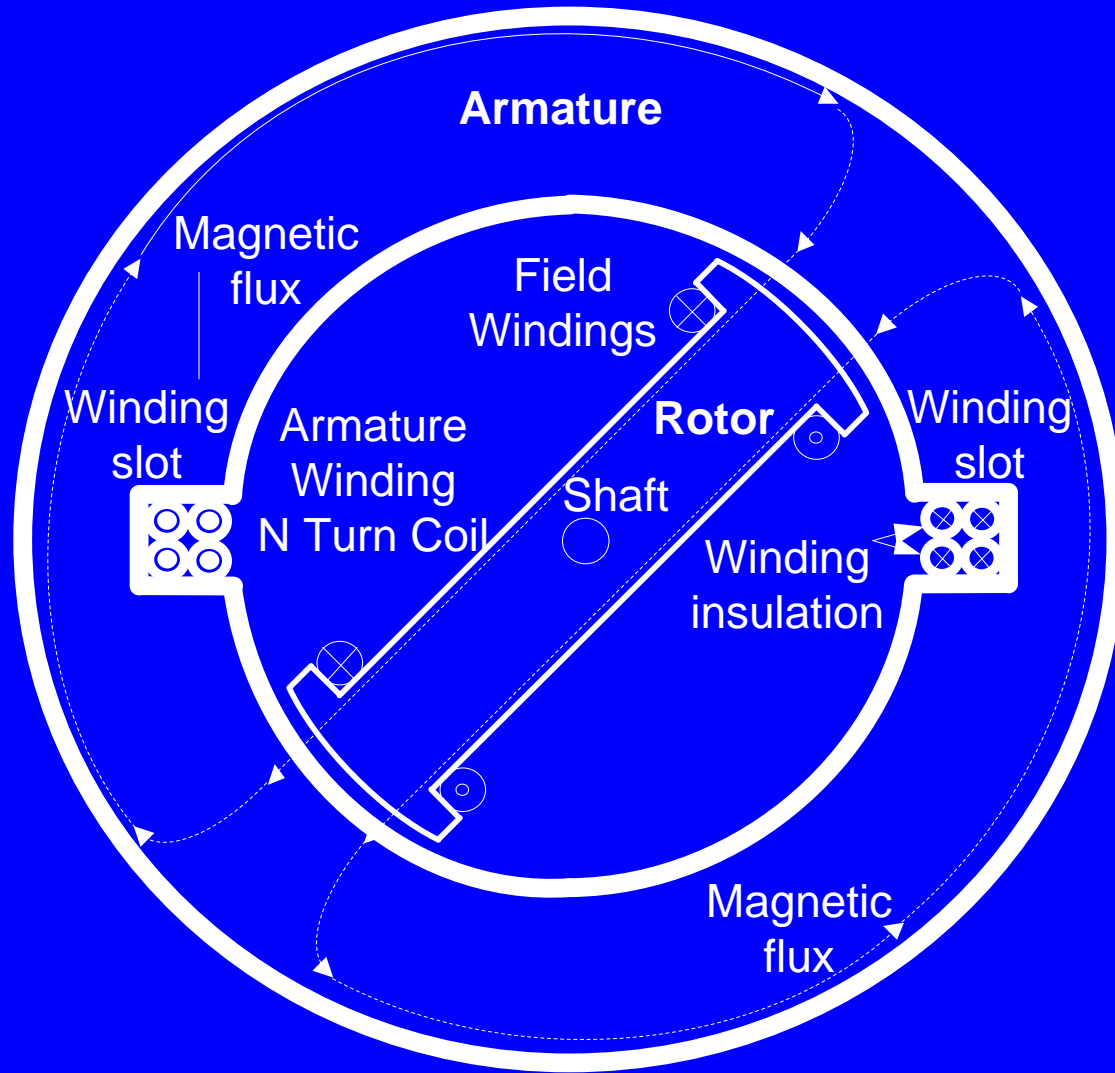
A Review of Synchronous Generator Stator Protection

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Topics

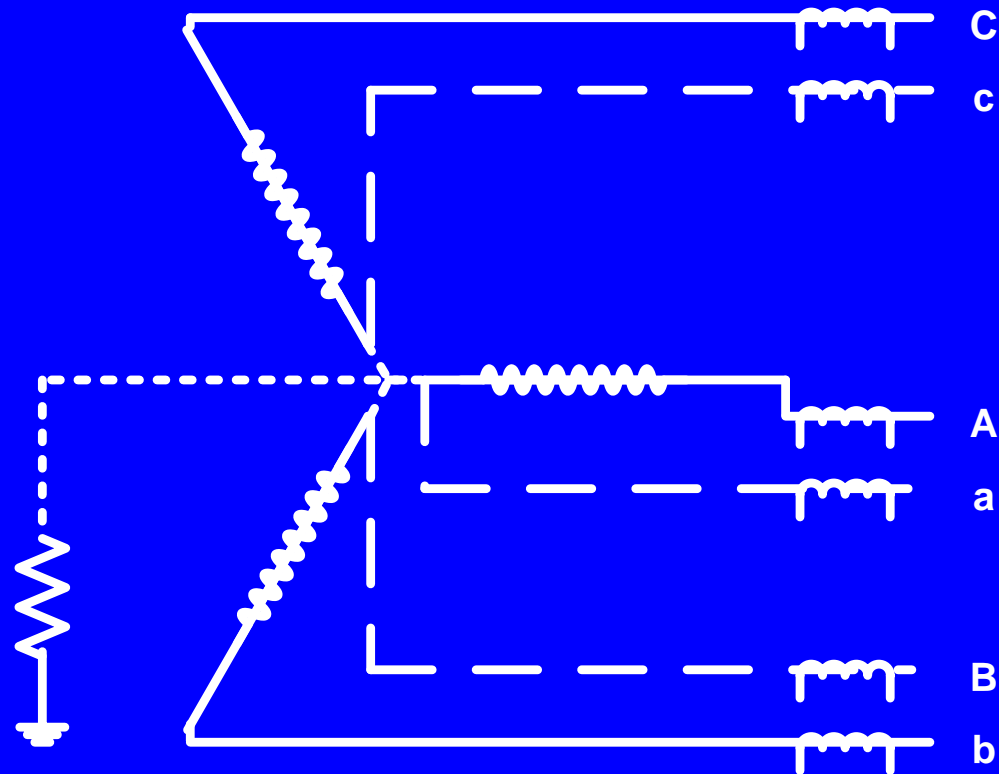
- **Synchronous generator principles**
- **Generator grounding systems**
- **Generator stator protection**

Synchronous Generator



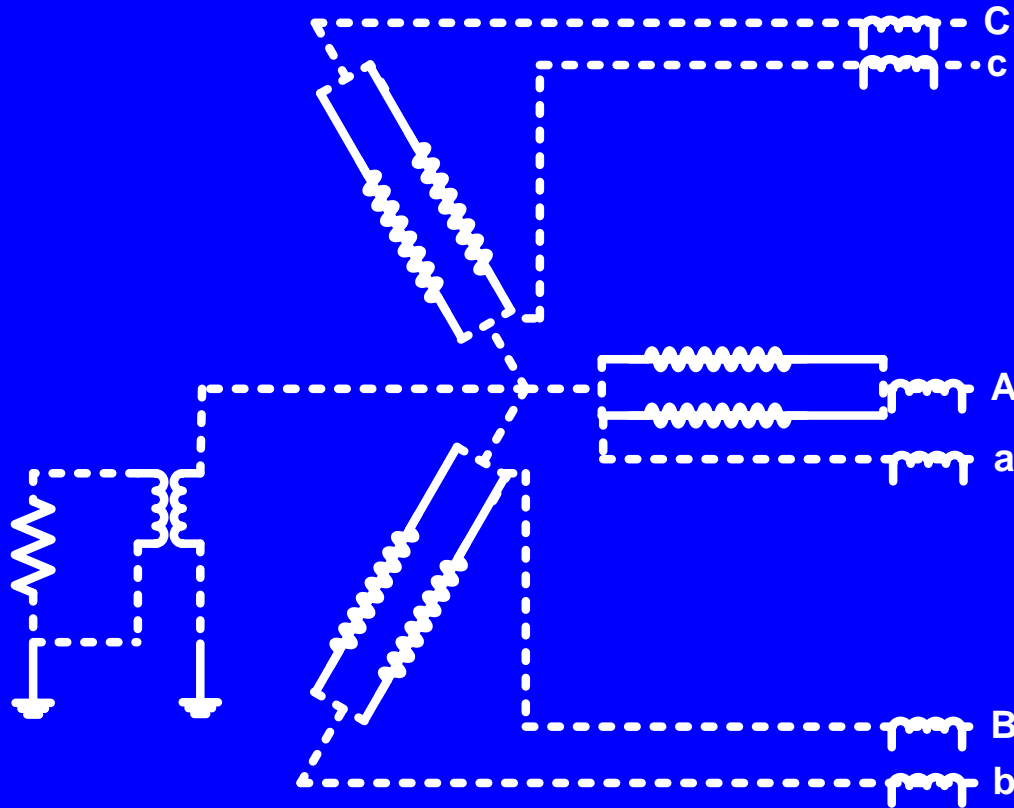
Single-phase generator, cross-section view

Generator Windings—1 Circuit



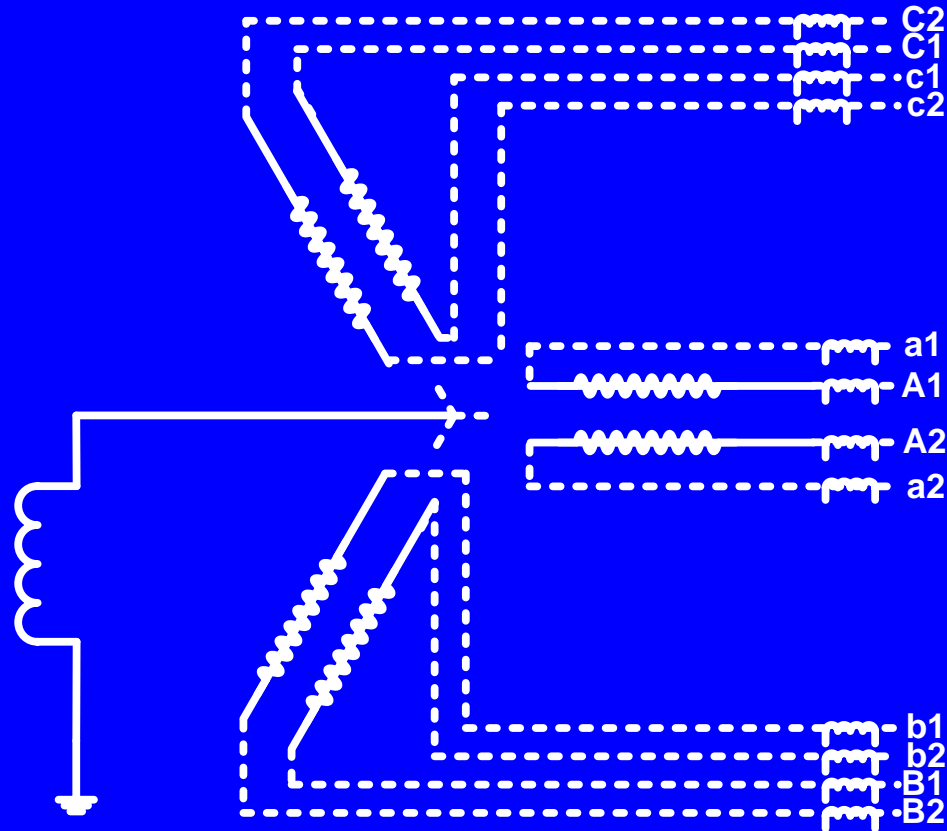
Three-phase generator—one circuit, six bushings, direct resistance grounding

Generator Windings–2 Circuits



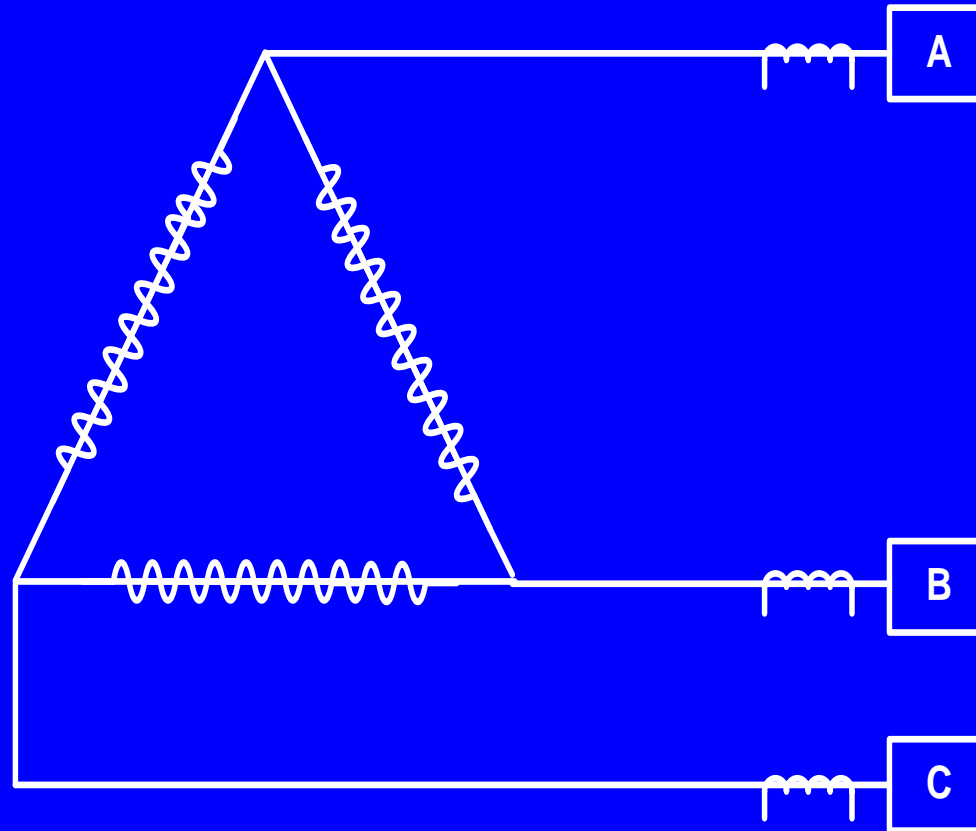
Three-phase generator—two circuits per phase,
six bushings, resistance grounding through
distribution transformer

Generator Windings–12 Bushings



Three phase generator, two generator circuits per phase, twelve bushings, reactance grounding

Generator Windings–Delta



Three-phase generator–delta connection, three bushings

Generator Faults and Design

- Stator temperature
- Winding insulation
- 3rd-harmonic voltage
- Frequency variations

Generator Grounding Systems

- Low-impedance (solid)
- Medium-impedance
- High-impedance
- Hybrid

Common Generator Faults

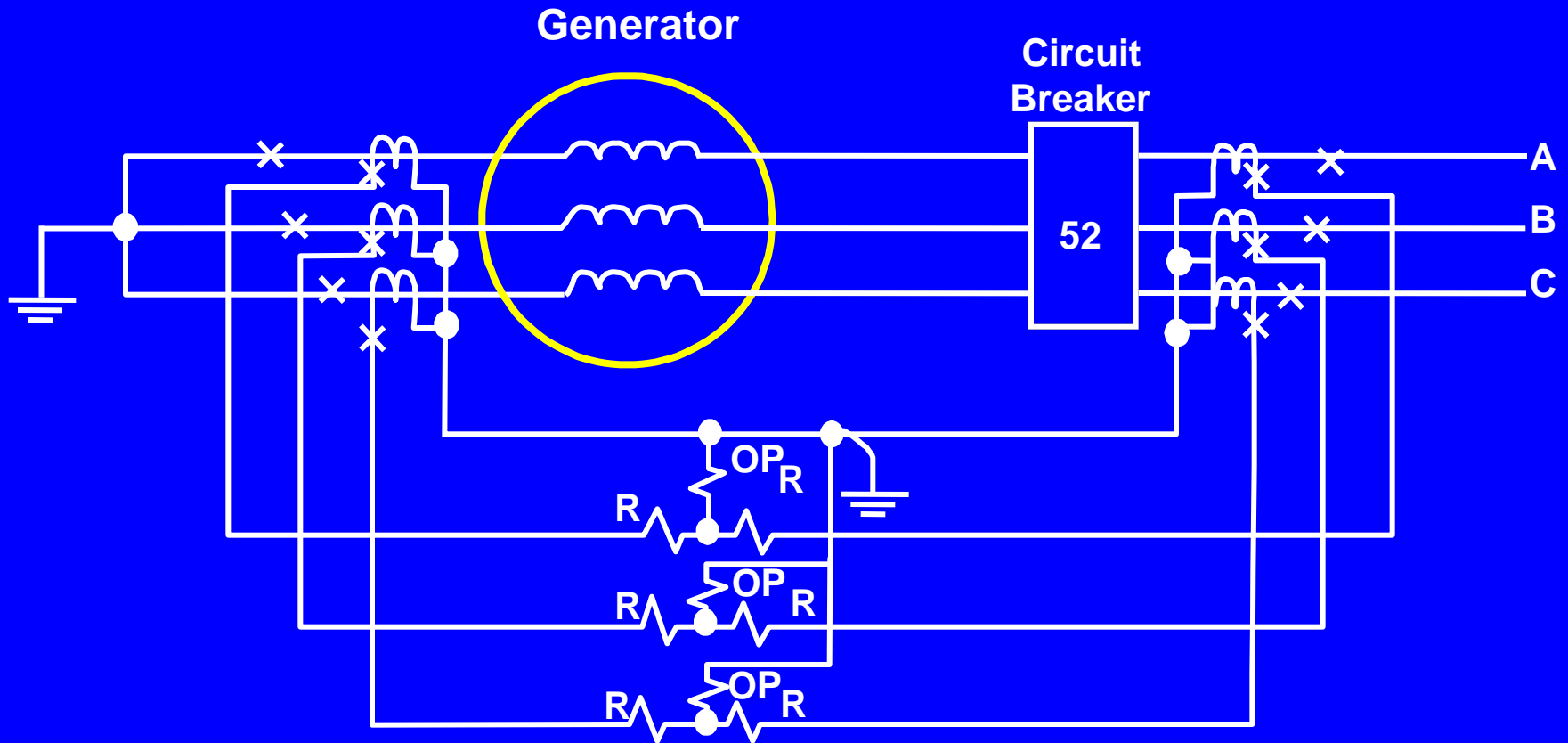
- Stator phase
- Turn-to-turn (phase-to-phase)
- Stator ground

Stator Phase-Fault Protection

Differential (87)

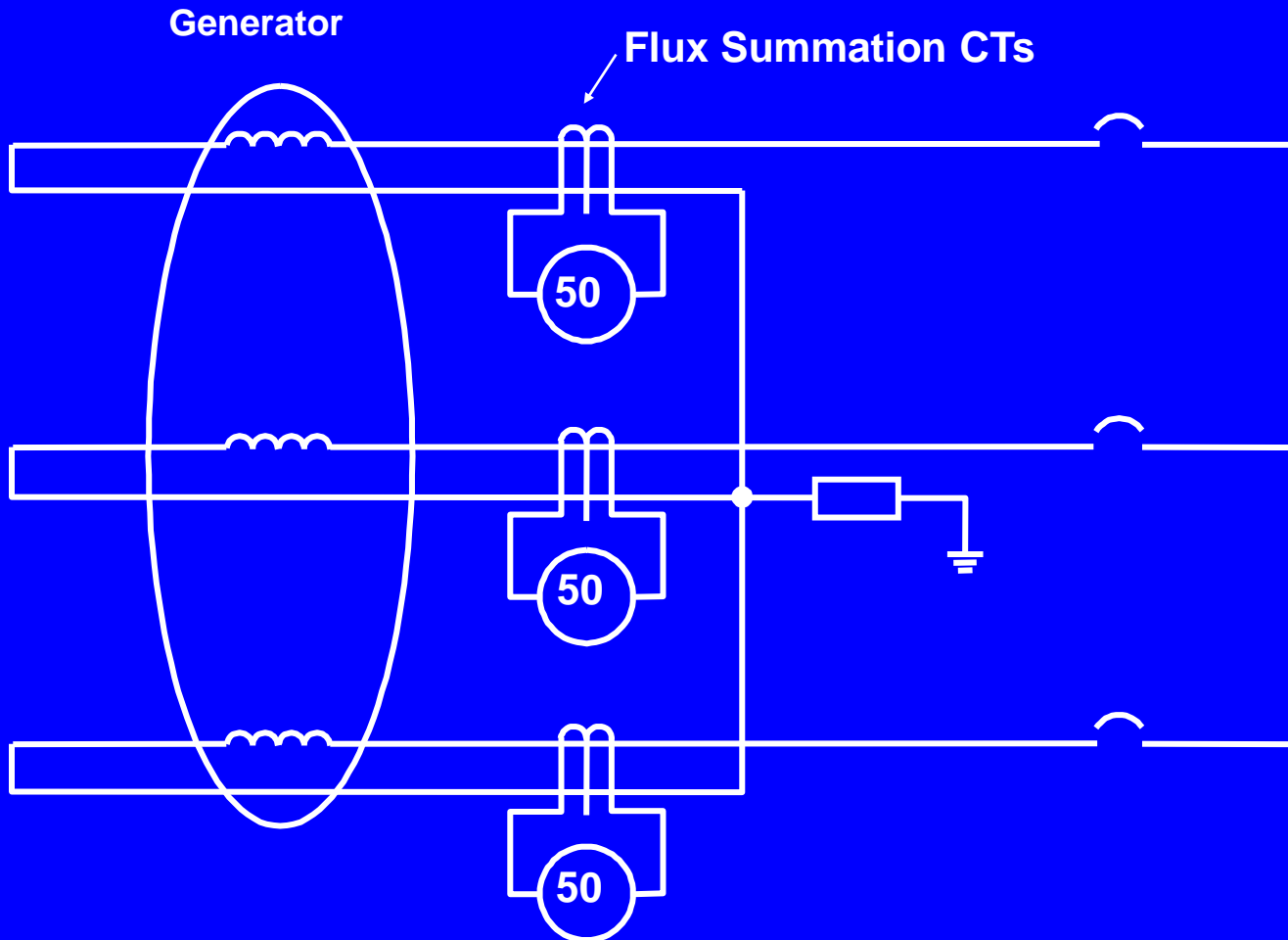
- Percentage
- Flux-balance
- High-impedance

Percentage Differential



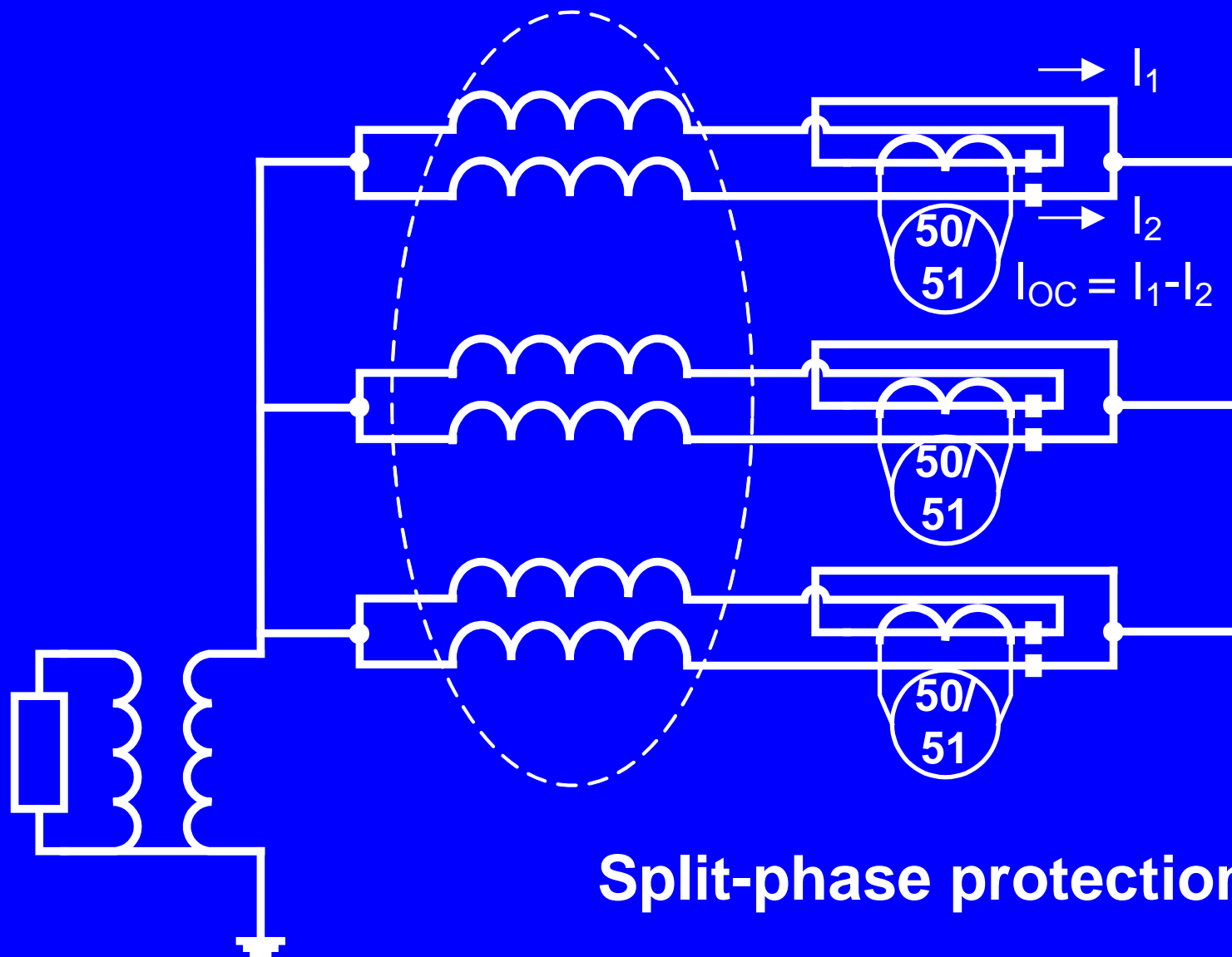
- 2006 "IEEE Guide for AC Generator Protection", IEEE Power Engineering Society,
- Sponsored by the Power Systems protection Committee, IEEE Std C37.102-2006.

Flux-Balance Differential

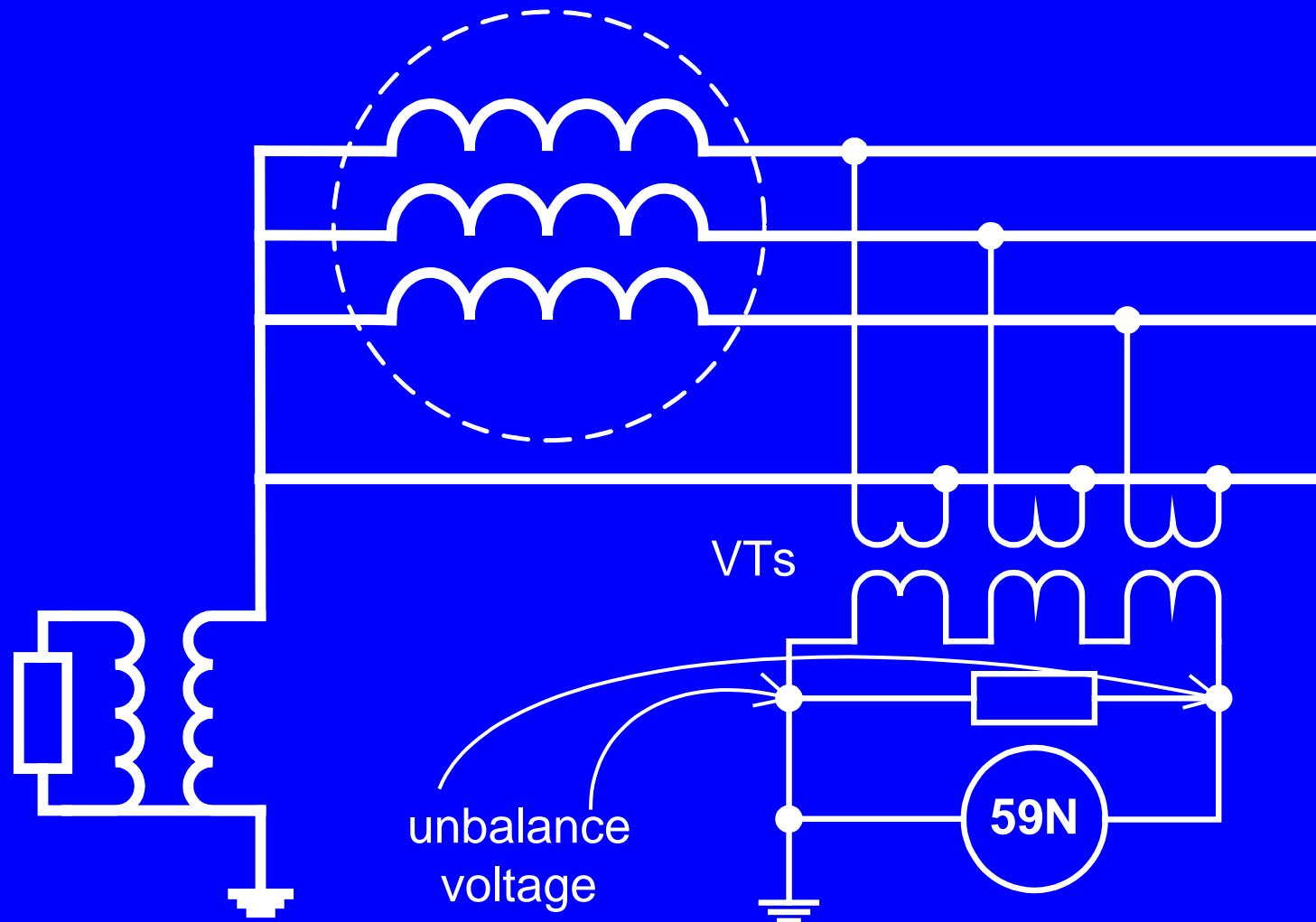


- 2006 "IEEE Guide for AC Generator Protection", IEEE Power Engineering Society,
- Sponsored by the Power Systems protection Committee, IEEE Std C37.102-2006.

Turn-to-Turn Faults–Split Phase



Turn-to-Turn: Neutral Overvoltage (59N)

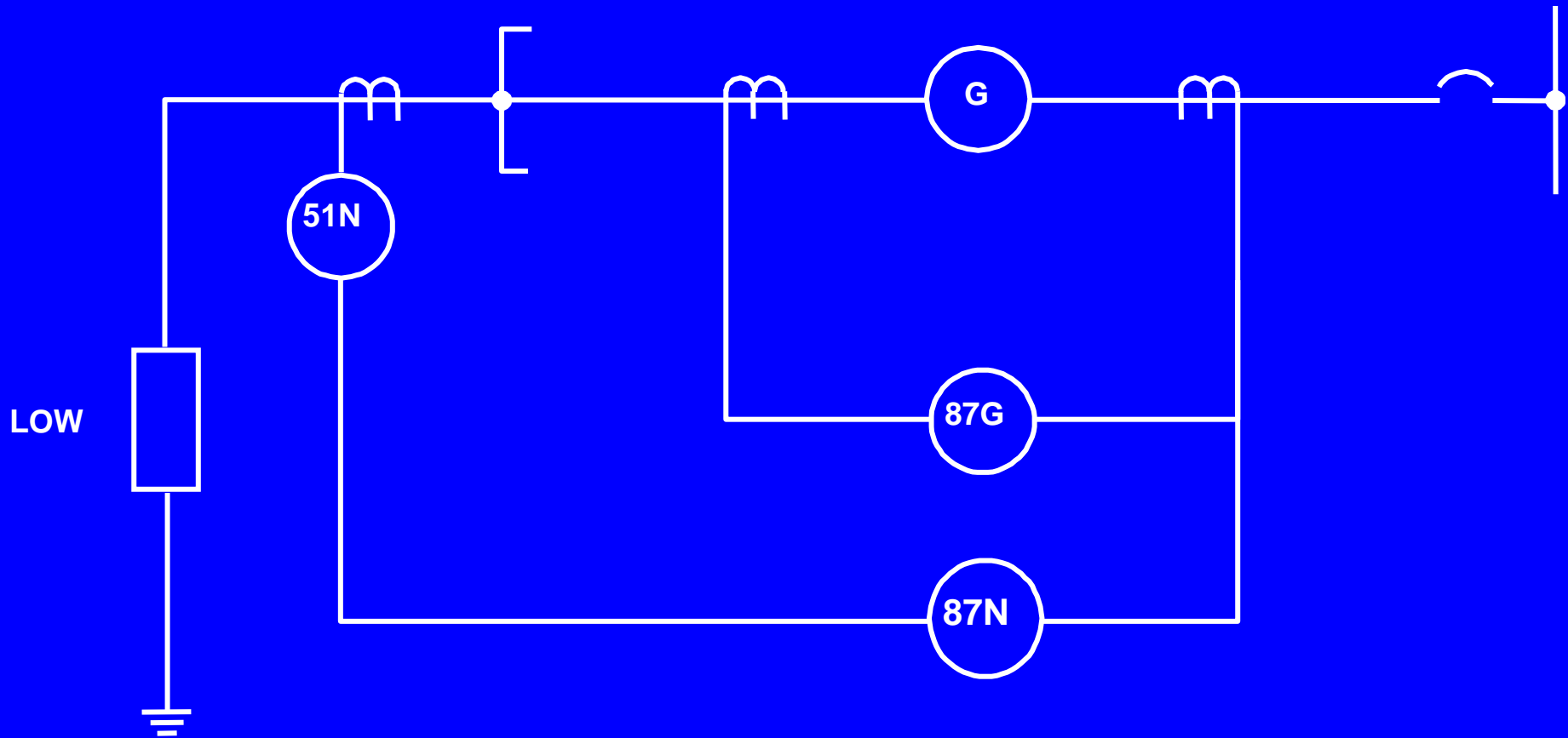


59N element detects turn-to-turn faults

Stator Ground-Fault Protection

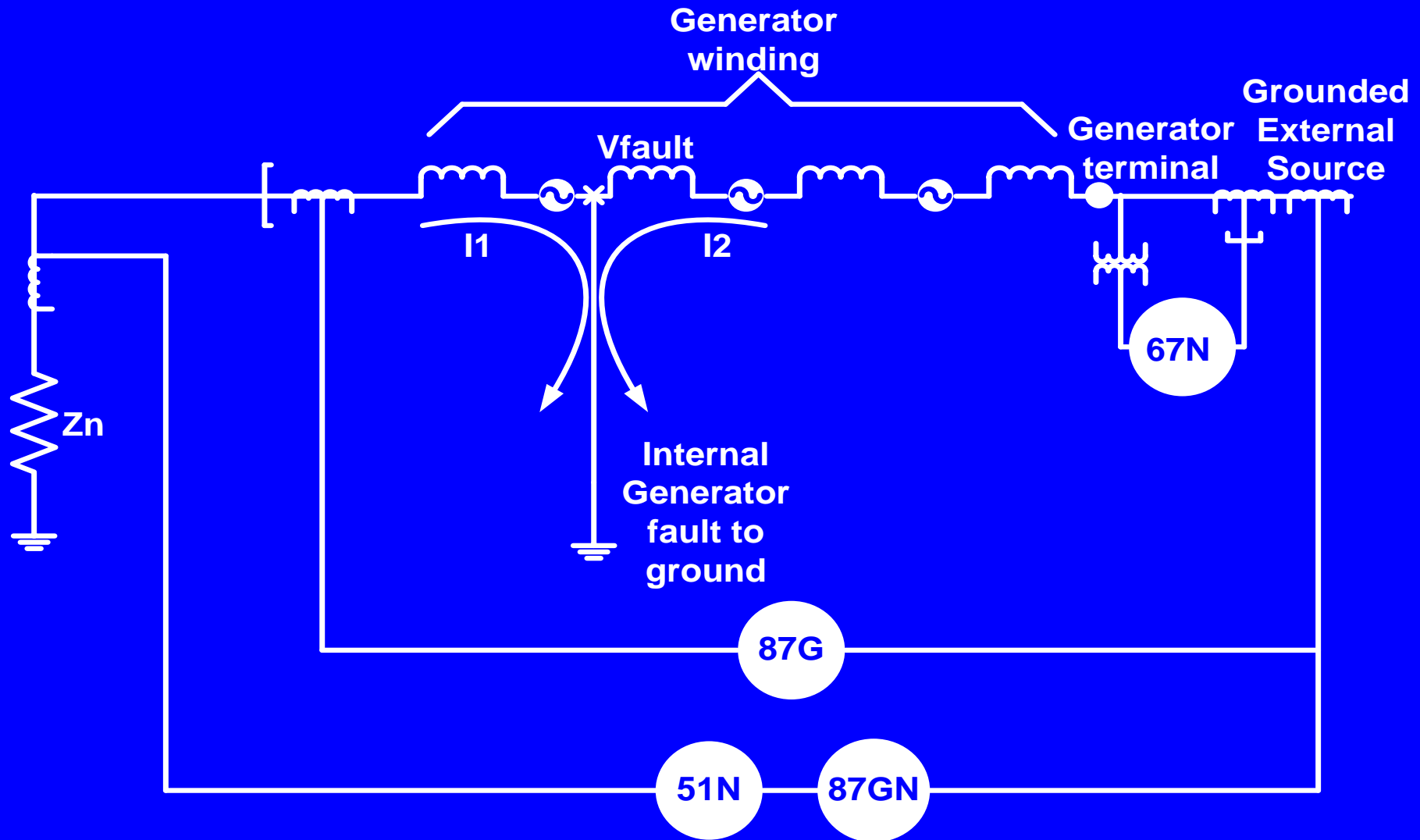
- Solid / low-impedance ground
- Medium-impedance ground
- High-impedance ground
- Subharmonic voltage injection

Solid / Low-Z Ground: Differential



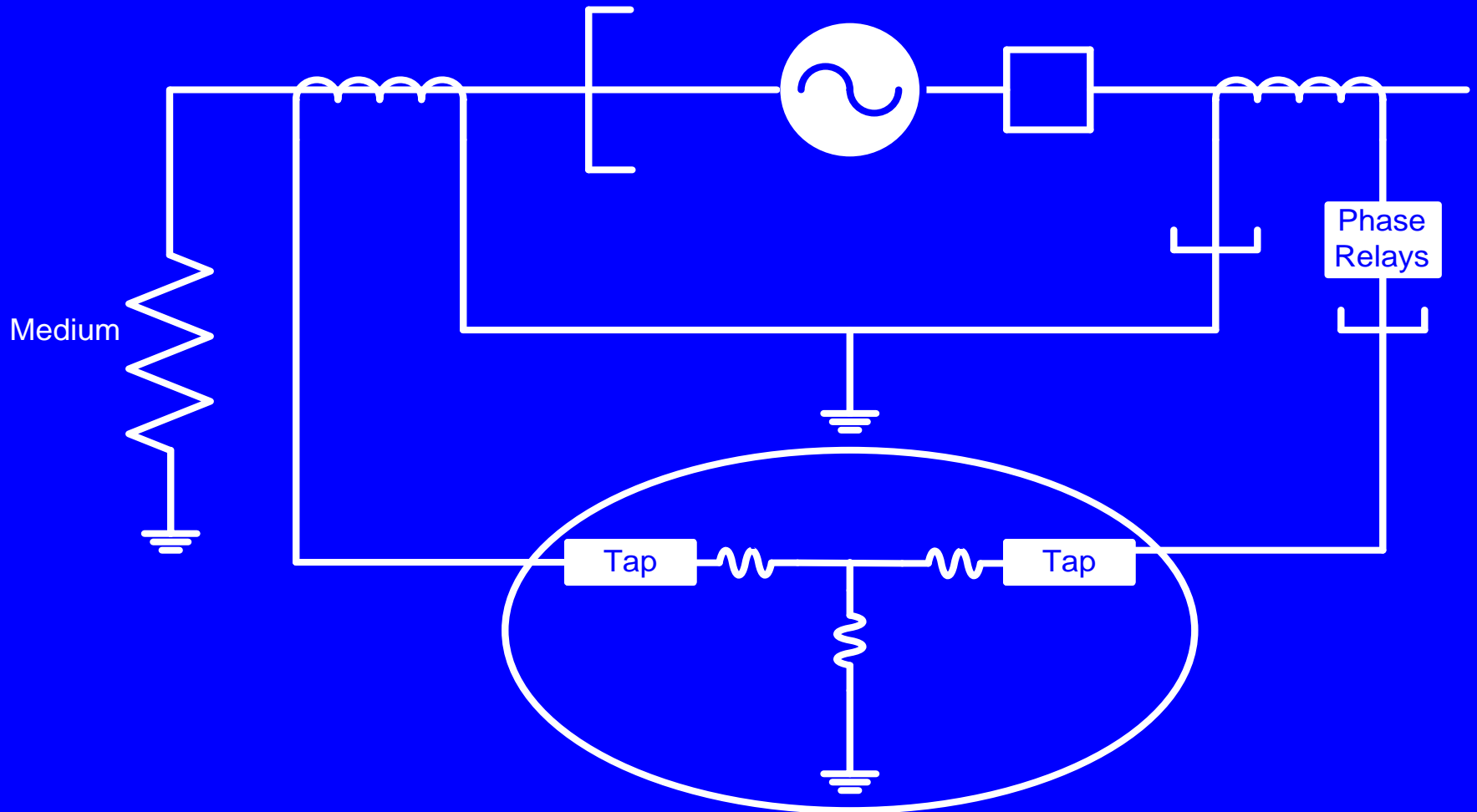
Sensitivity to 10 percent of generator winding

Solid / Low-Z Ground: Neutral Currents



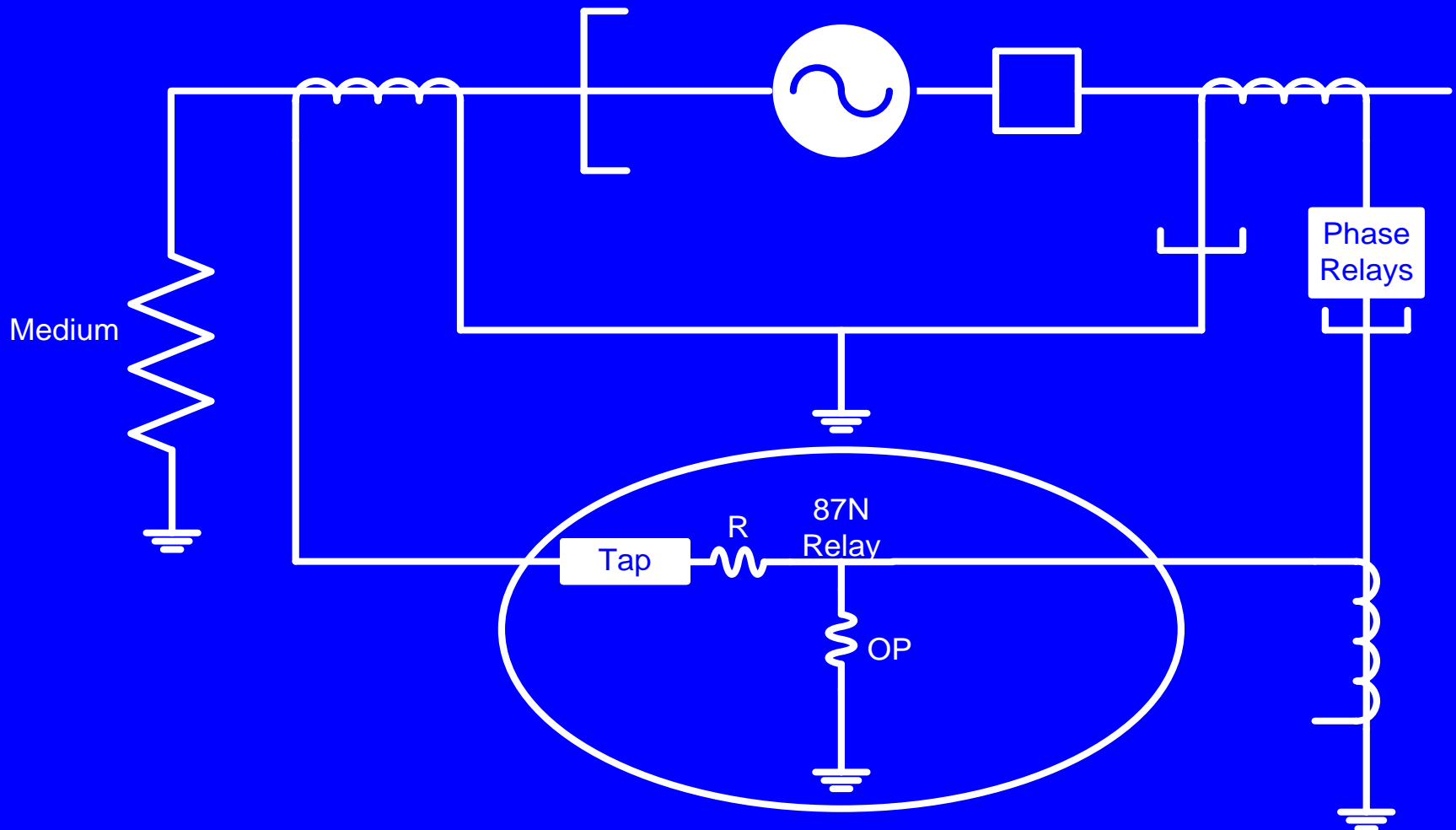
Sum the currents flowing to ground.

Medium-Z Ground: Phase Differential



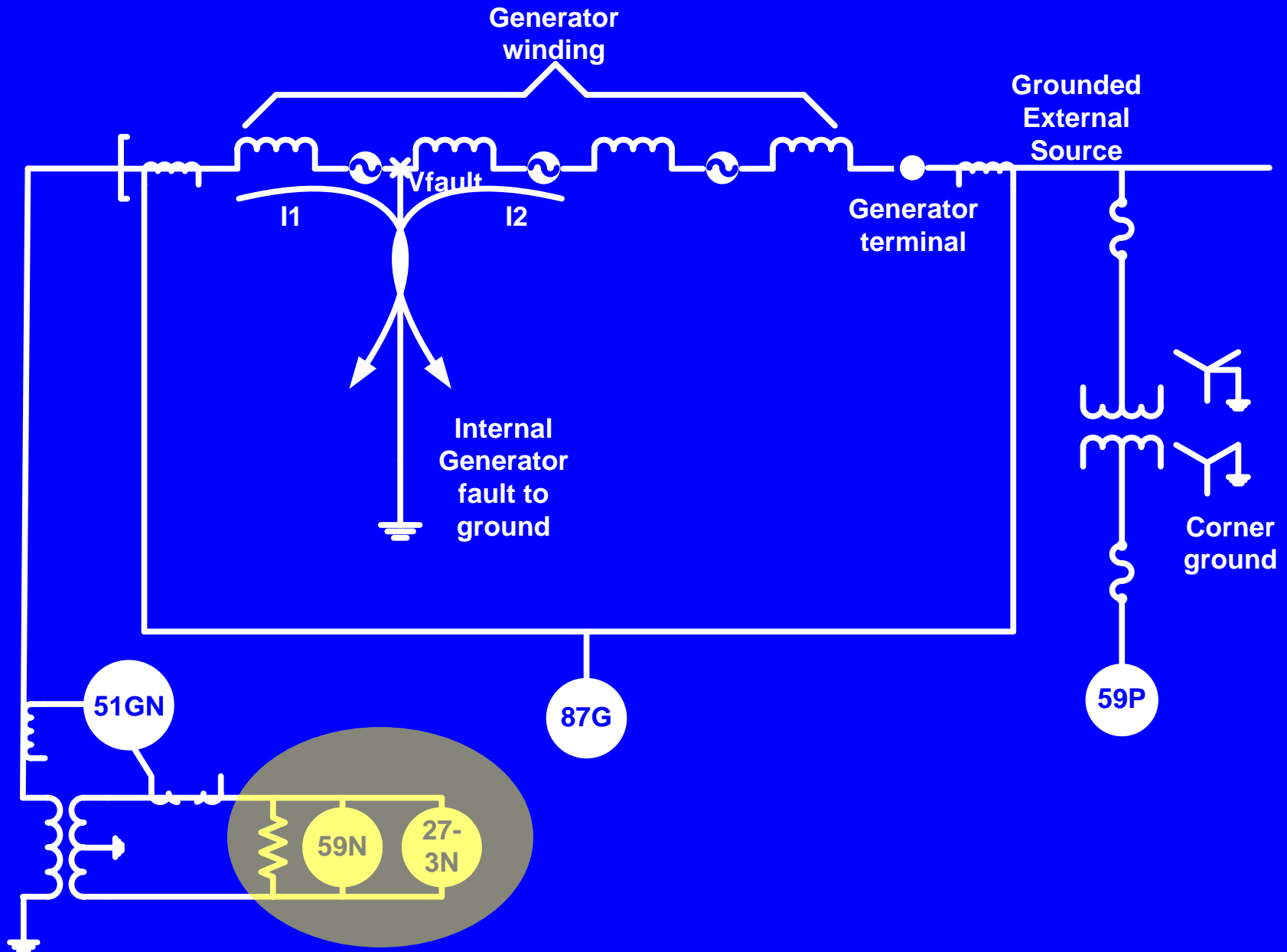
Limited sensitivity for ground faults

Medium-Z Ground: Diff w/ Aux CT

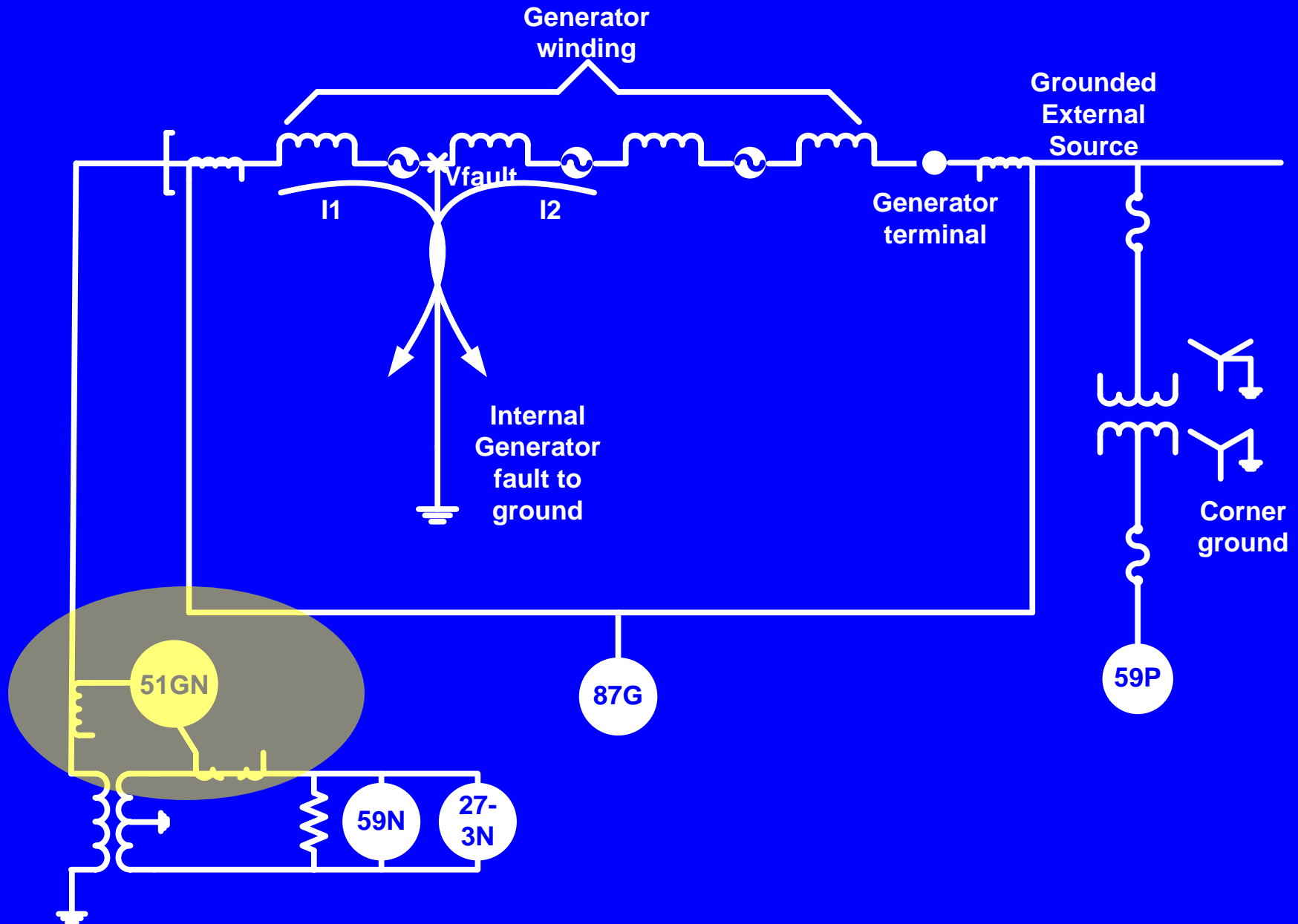


Auxiliary CT increases sensitivity ≈ 10 percent

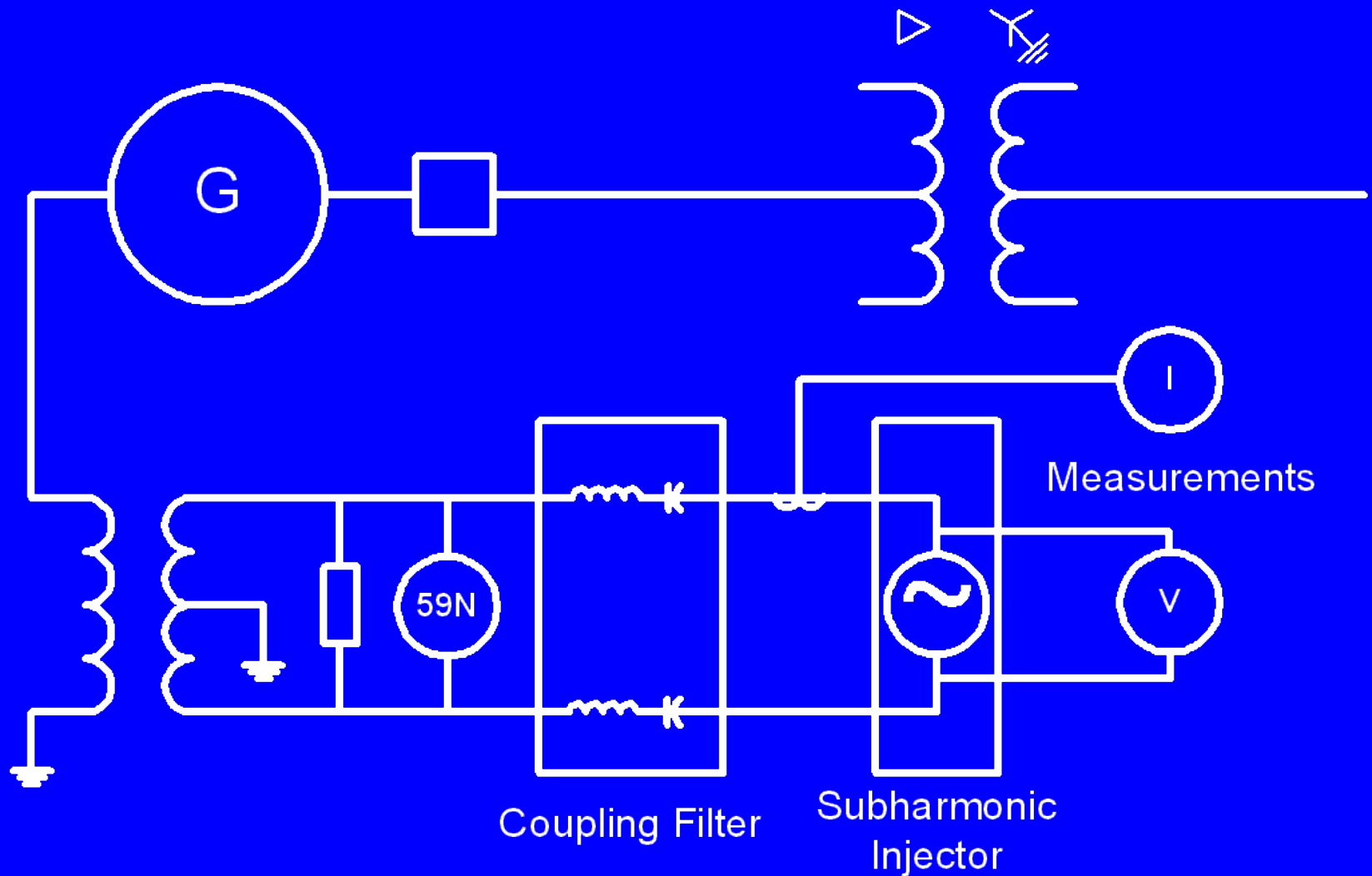
High-Z Ground: 59N and 27-3N



High-Z Ground: 51GN Backup



Voltage and Subharmonic Injection



2006 "IEEE Guide for Generator Ground Protection", IEEE Power Engineering Society, Sponsored by the Power Systems protection Committee, IEEE Std C37.101-2006.

Thank you