

# Distribution Bus Protection Upgrade Considerations When Integrating Distributed Generation

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# Bus Protection

- Isolates bus faults
- Is secure for external faults
- Minimizes arc-flash energy
- Provides backup protection for feeder faults

# Distributed Generation Sources

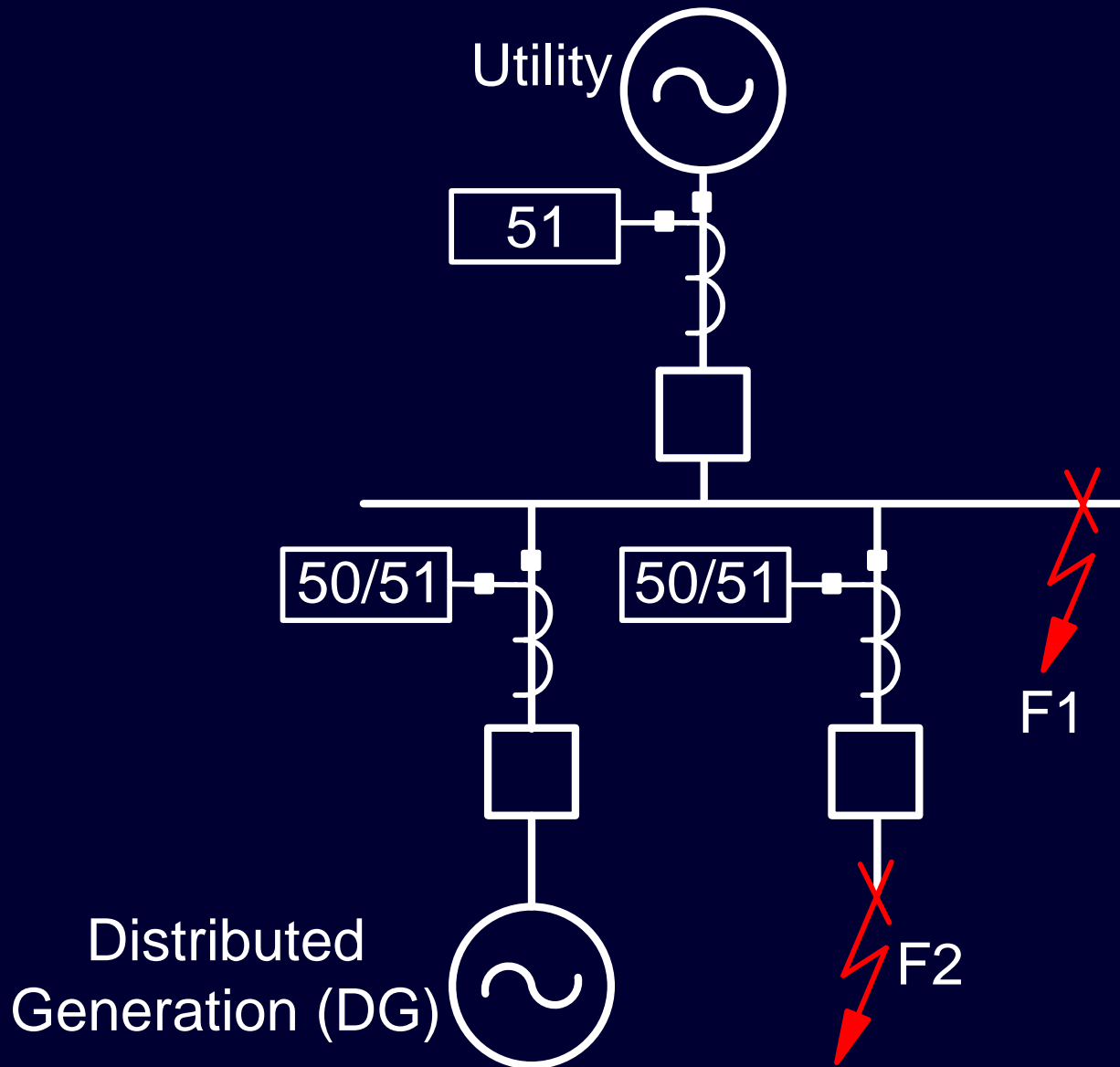
- Photovoltaic
- Fuel cells
- Wind
- Landfill gas
- Agriculture



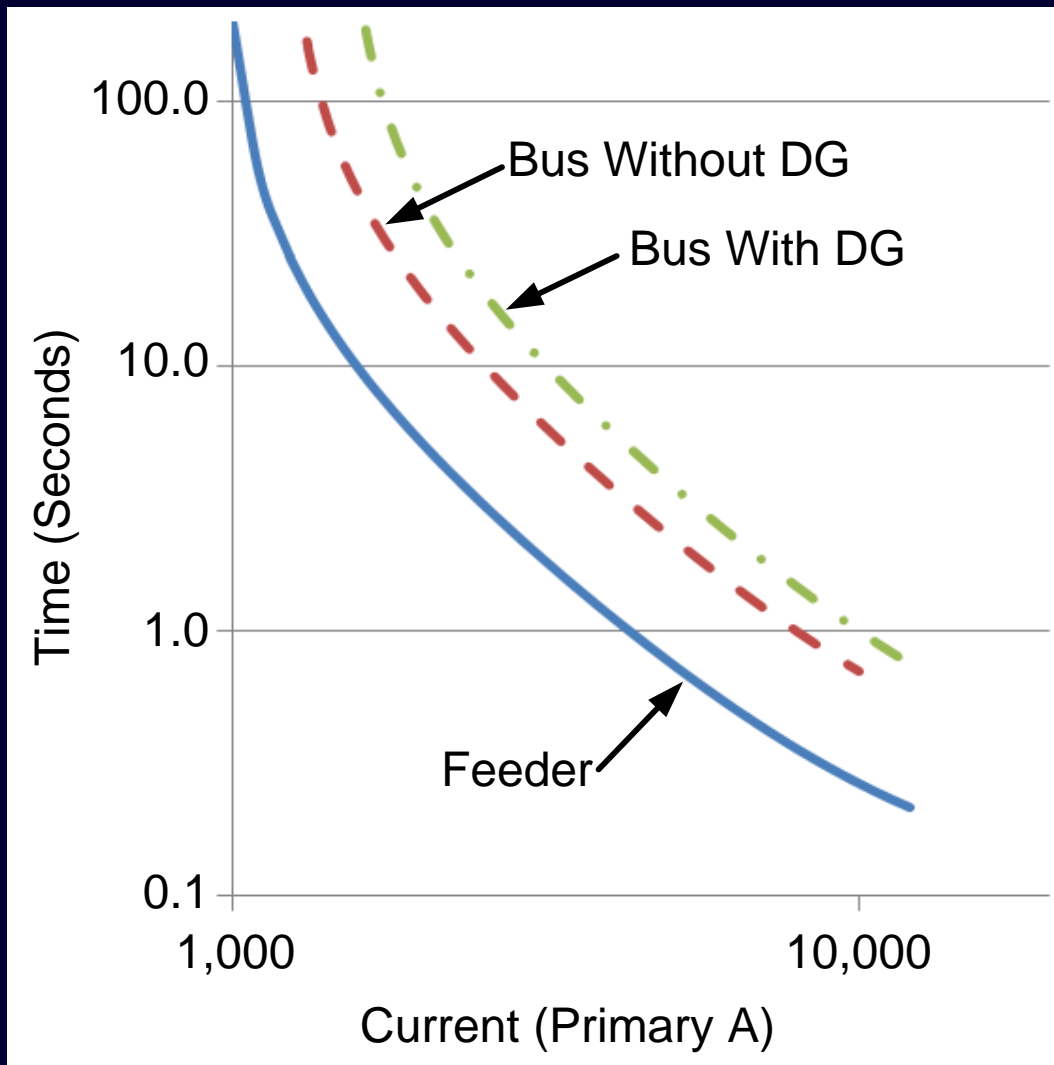
# Bus Protection Schemes

- Time-delayed overcurrent elements
- Zone sequencing
- Percentage differential relays with dedicated CTs
- Percentage differential relays with paralleled CTs

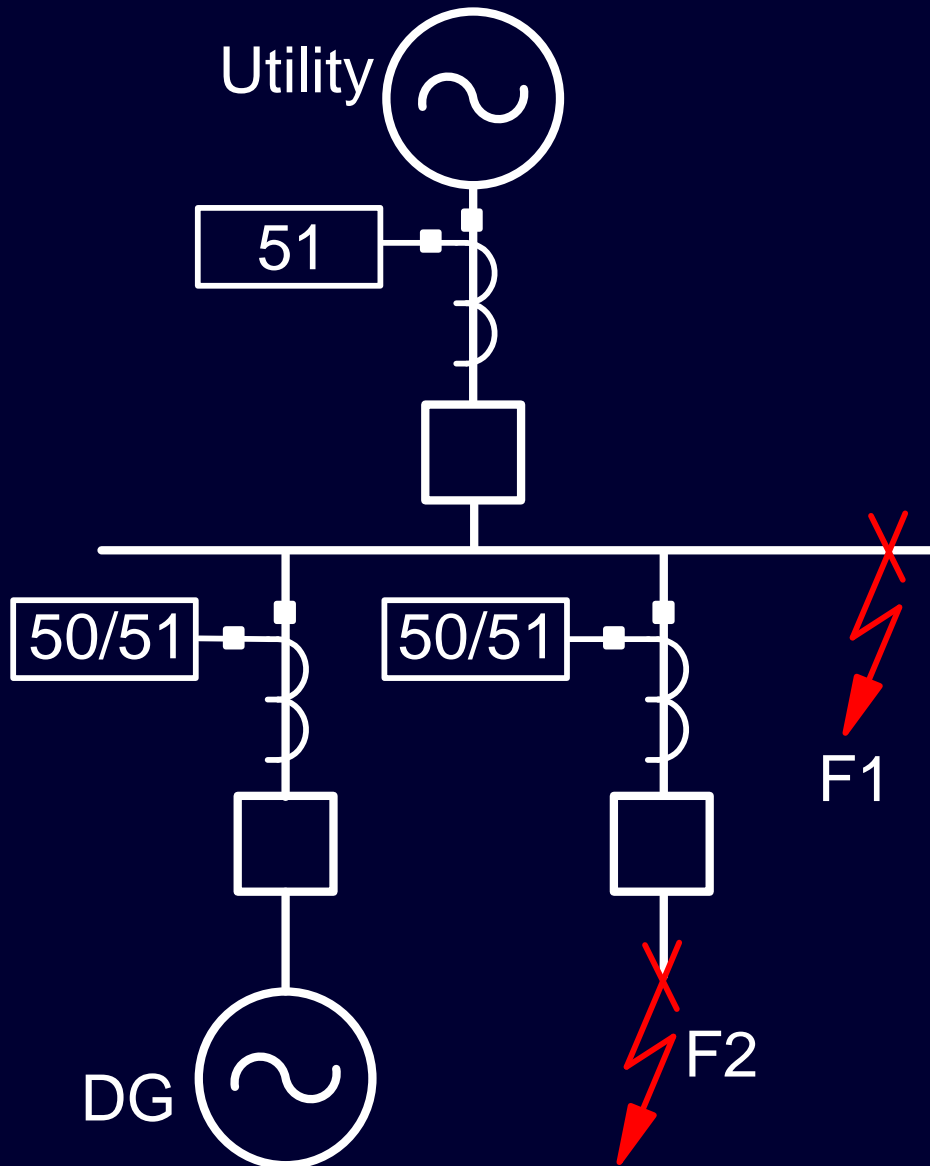
# Overcurrent Elements



# Coordination of Time-Delayed Overcurrent Elements



# Zone Sequencing



# Low-Impedance Percentage Differential Calculations

$$I_{OP} = |IW1 + IW2|$$

$$I_{RT} = |IW1| + |IW2|$$

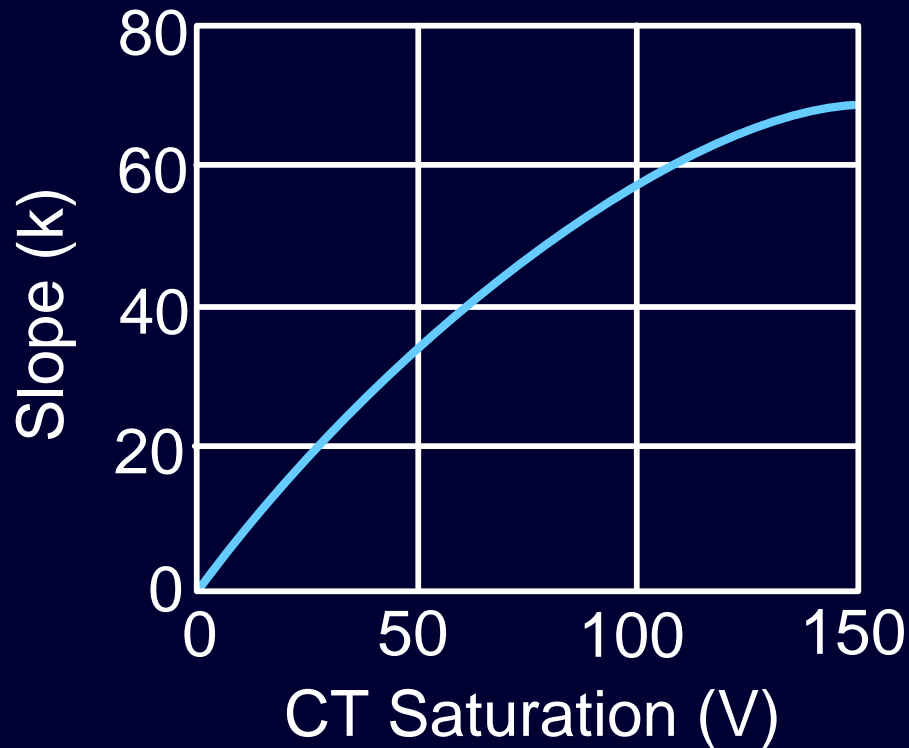
$$I_{OP} > k I_{RT}$$



# Calculating Secure Slope (k)

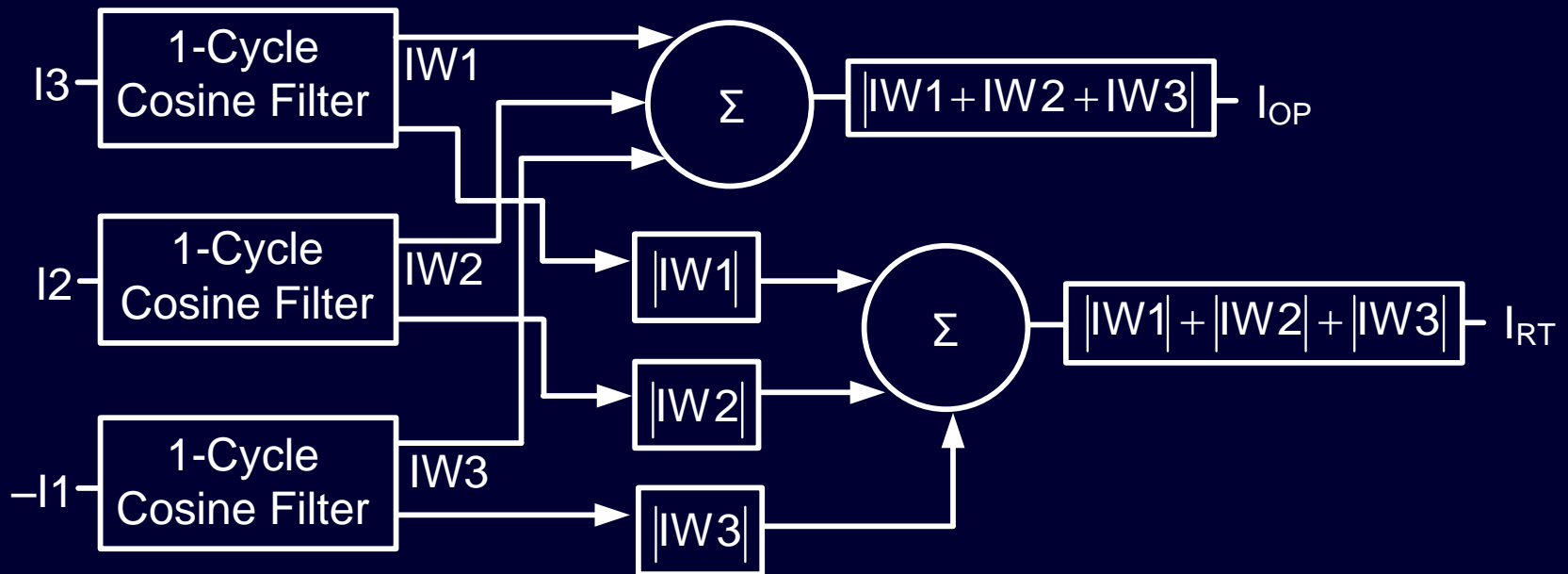
$$V_s = (1 + X/R)I_r Z_b$$

$$k = 0.824(V_s) - 0.00242(V_s)^2$$

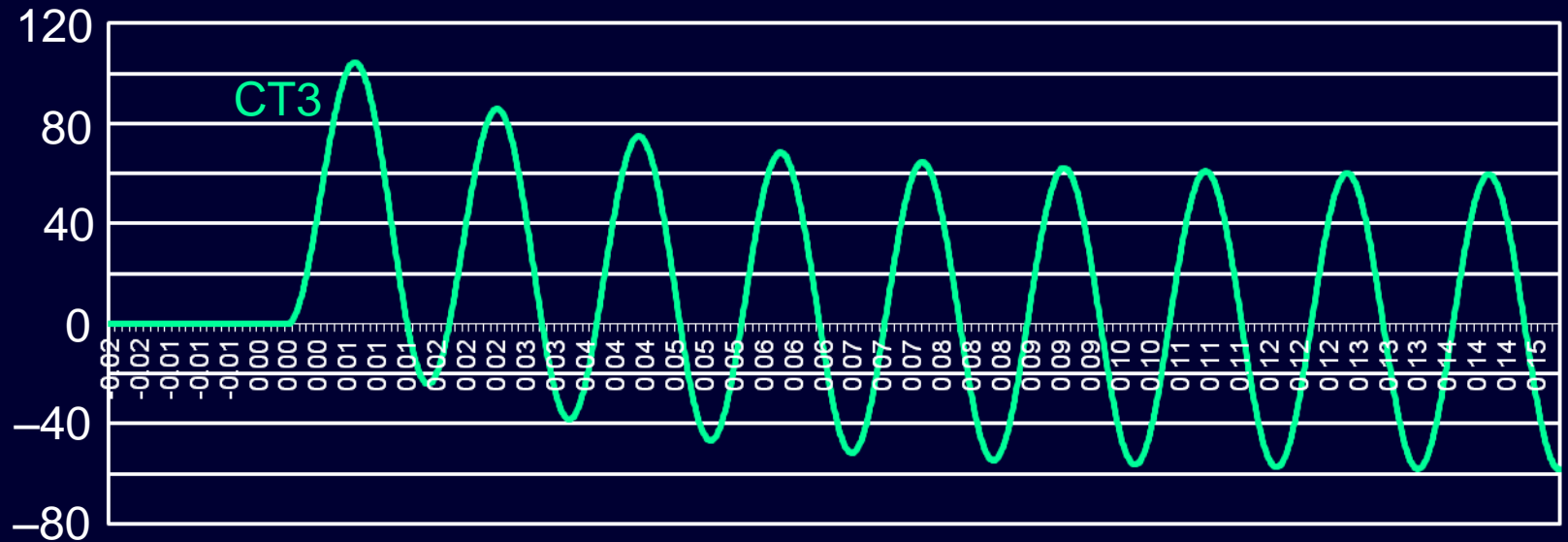
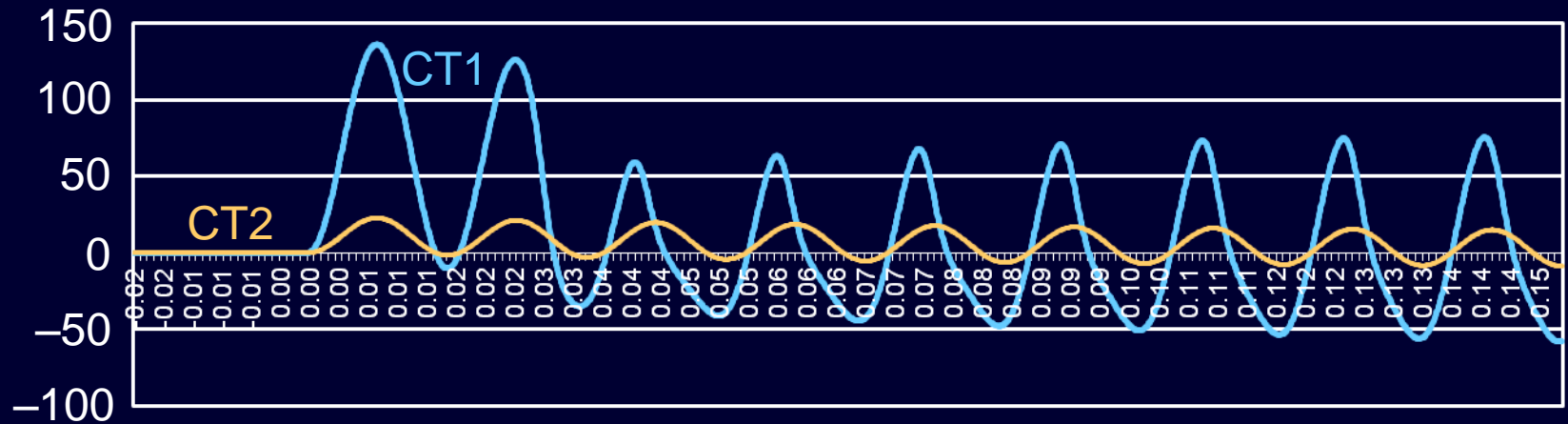




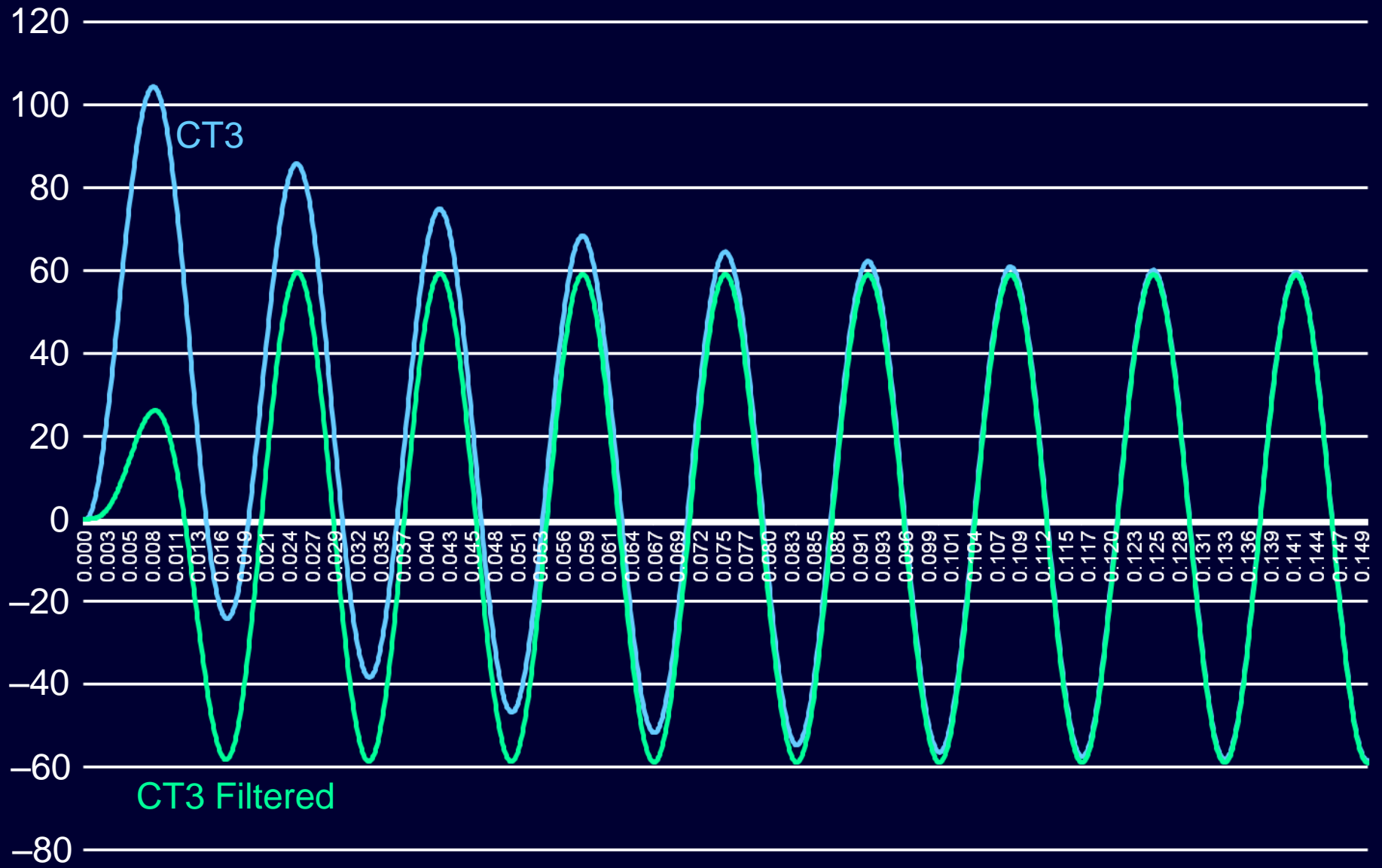
# Differential Calculation With Dedicated CTs



# Current Simulations



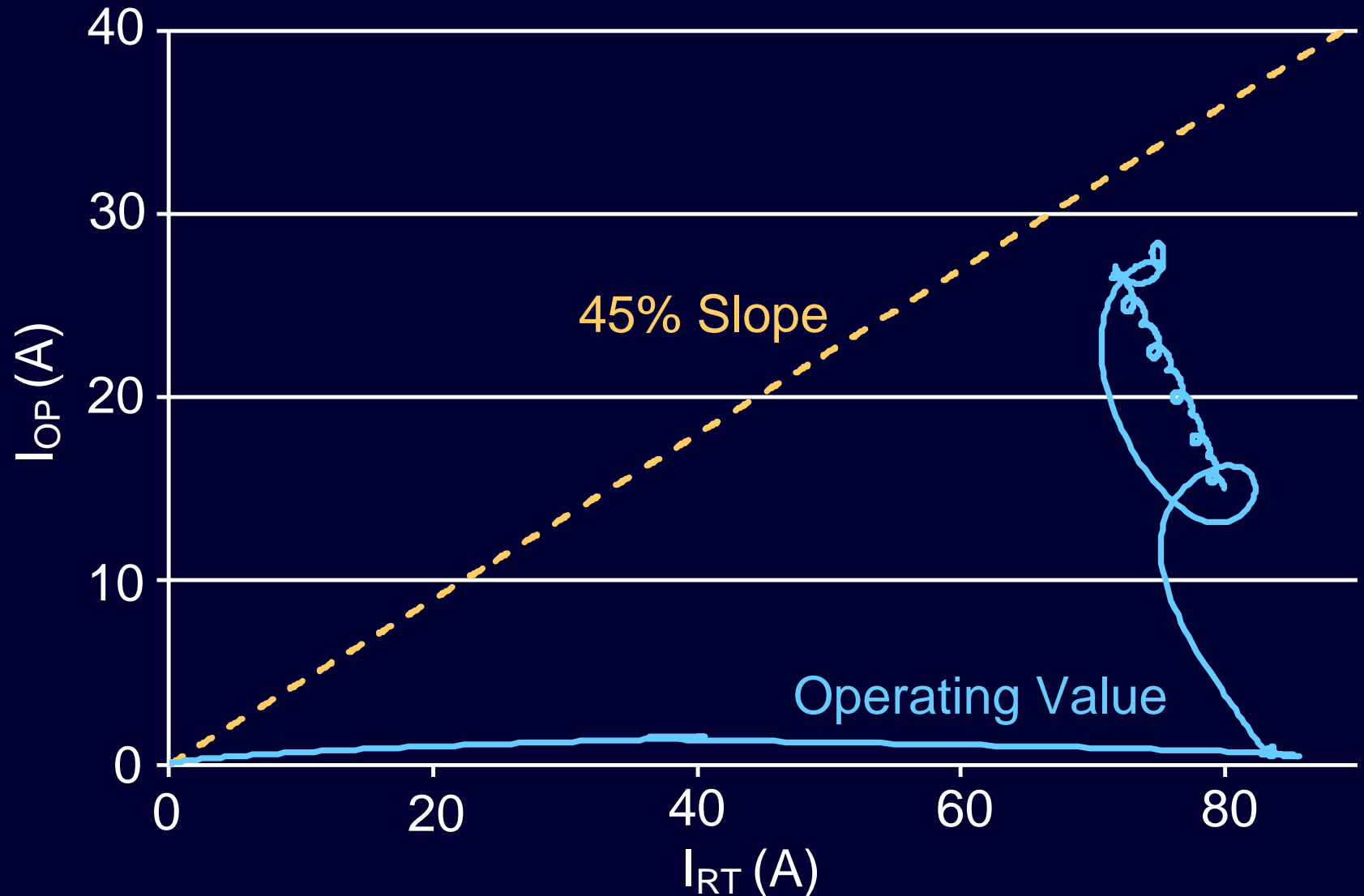
# Apply Digital Filtering



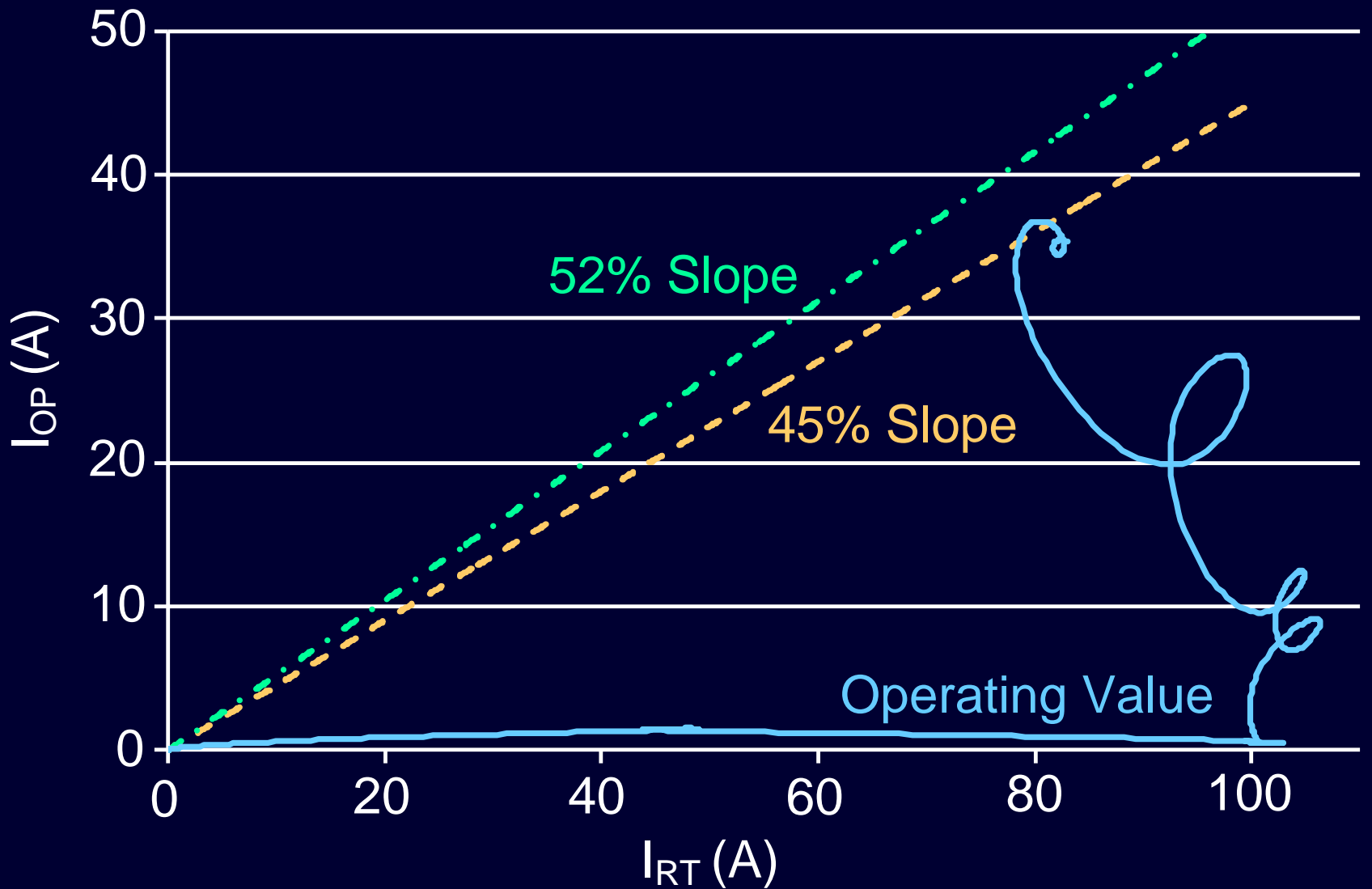
# Calculate Operate and Restraint Currents



# Differential Quantities Without DG

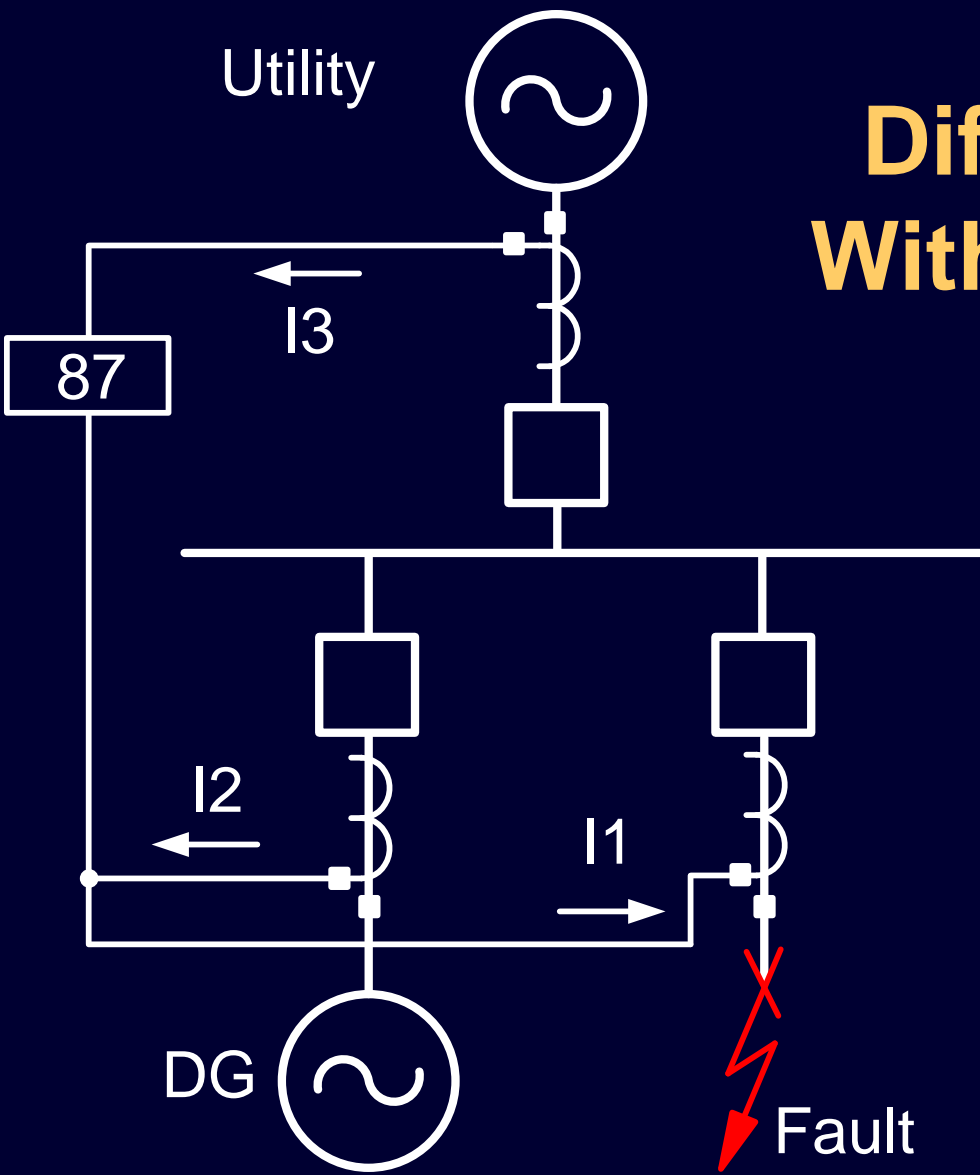


# Differential Quantities With DG

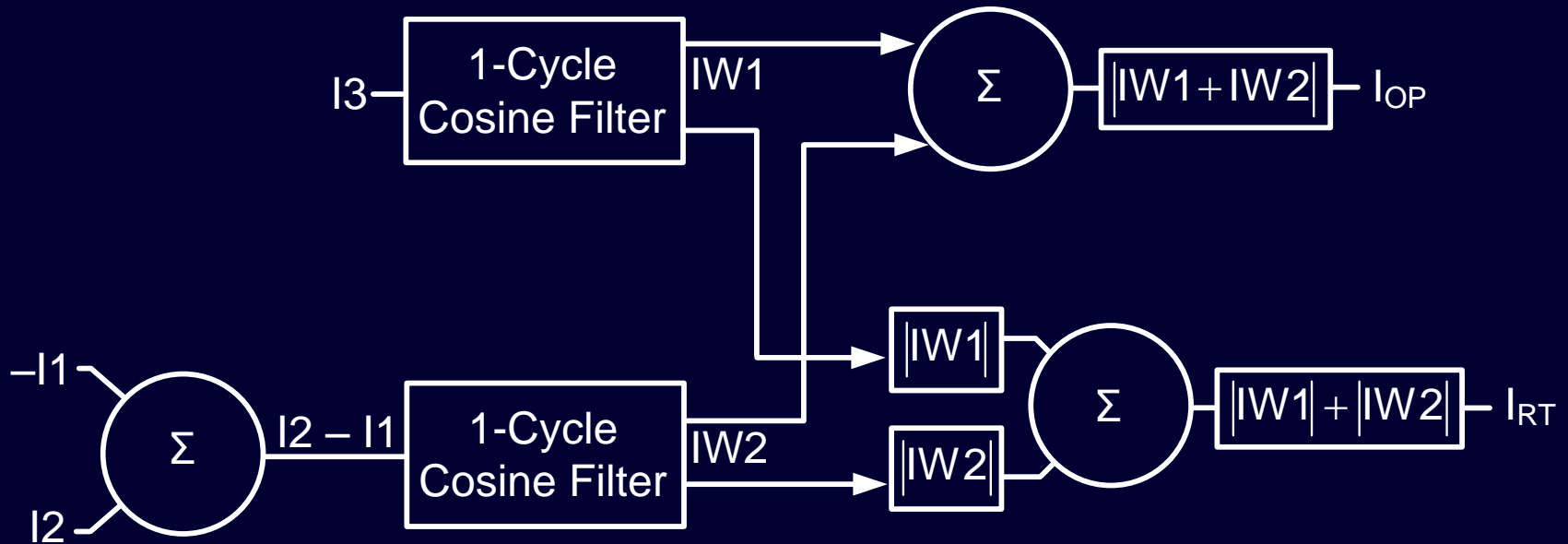




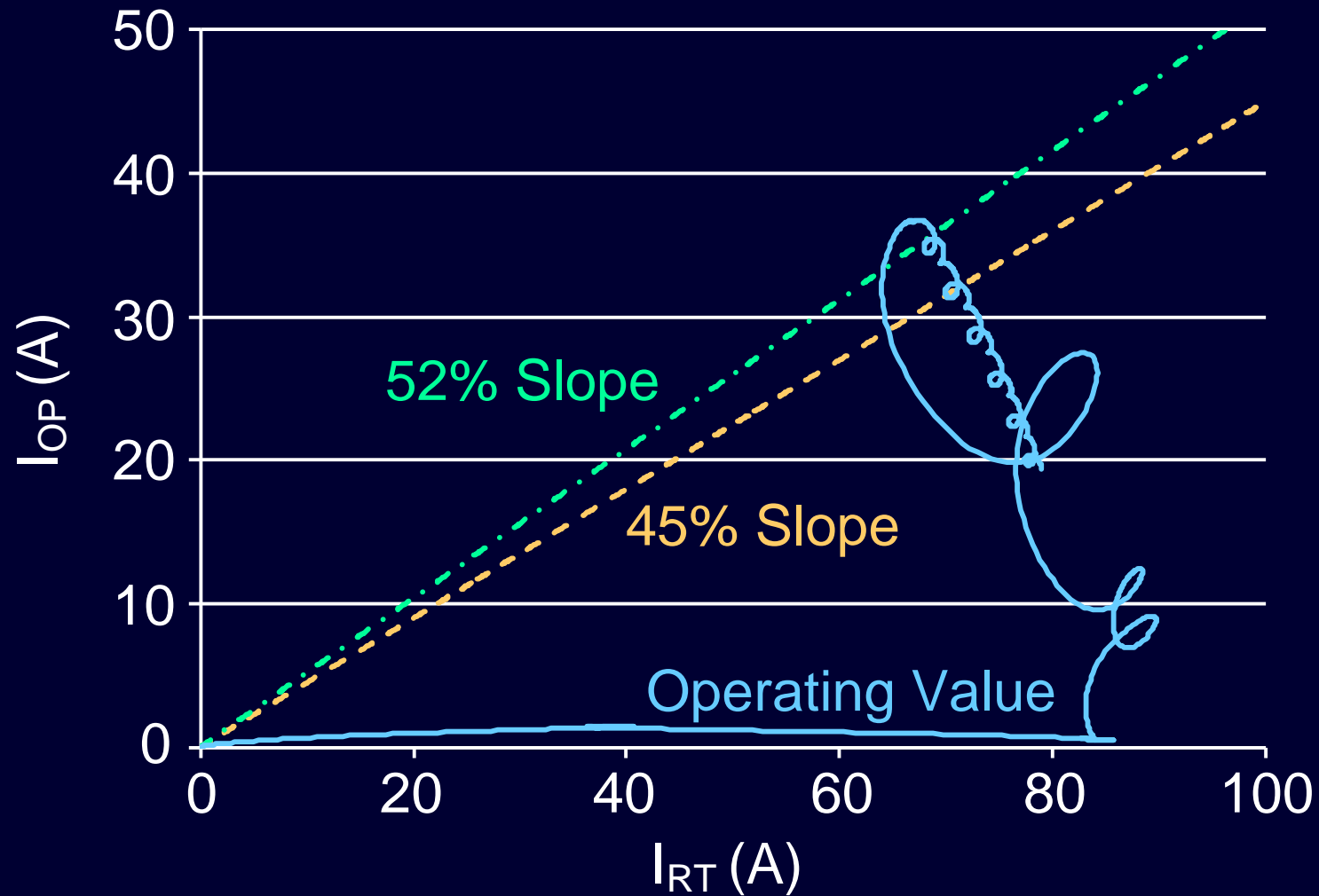
# Percentage Differential Relay With Paralleled CTs



# Differential Calculation With Paralleled CTs



# Differential Quantities With Paralleled CTs



# Conclusion

- Inverse-time overcurrent elements are delayed with DG
- Zone sequencing requires modifications
- Percentage differential relays require
  - ◆ Wiring modification
  - ◆ Settings adjustment
  - ◆ Relay replacement

**Questions?**