

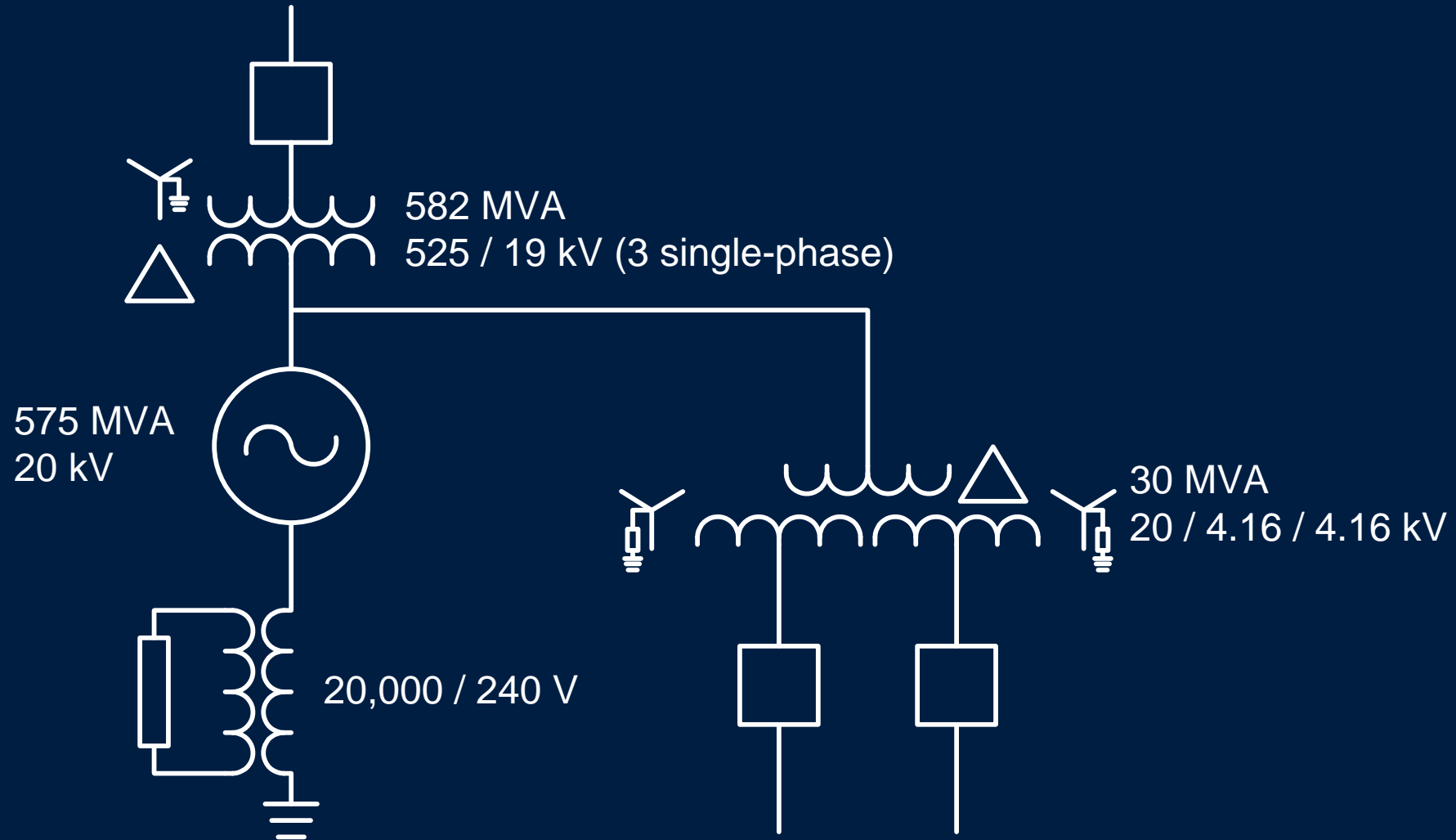
# How Transformer DC Winding Resistance Testing Can Cause Generator Relays to Operate

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# Outline

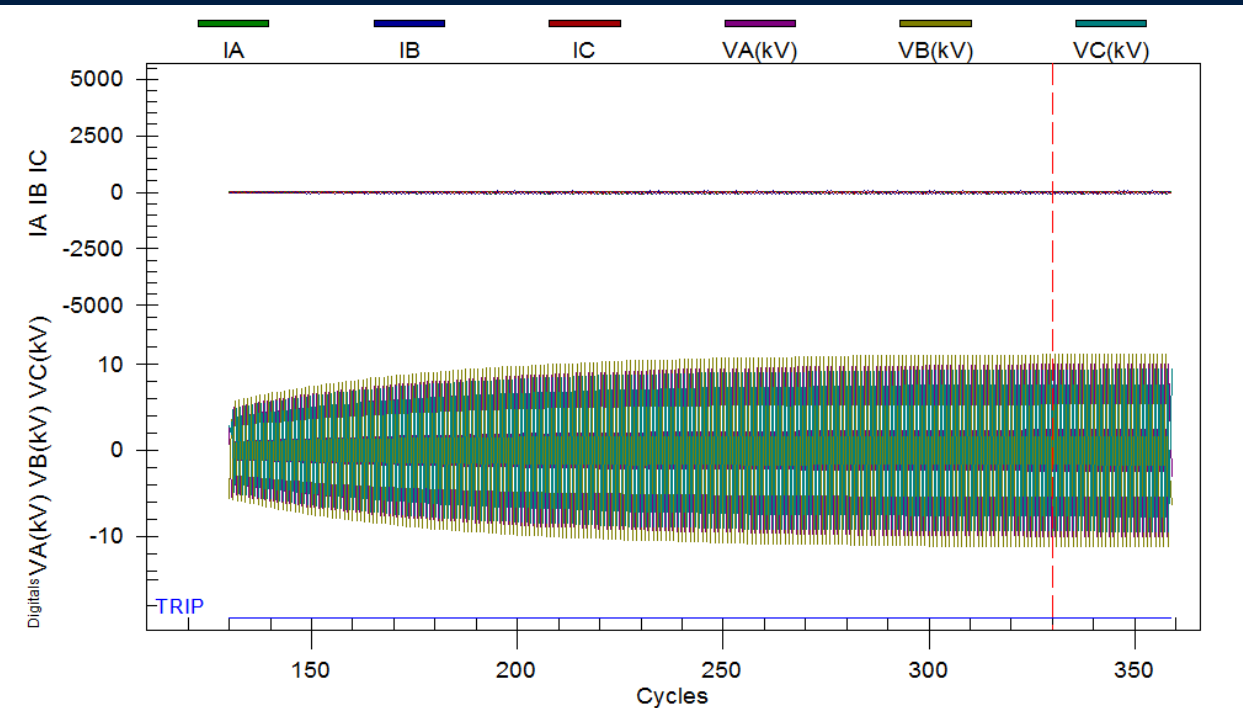
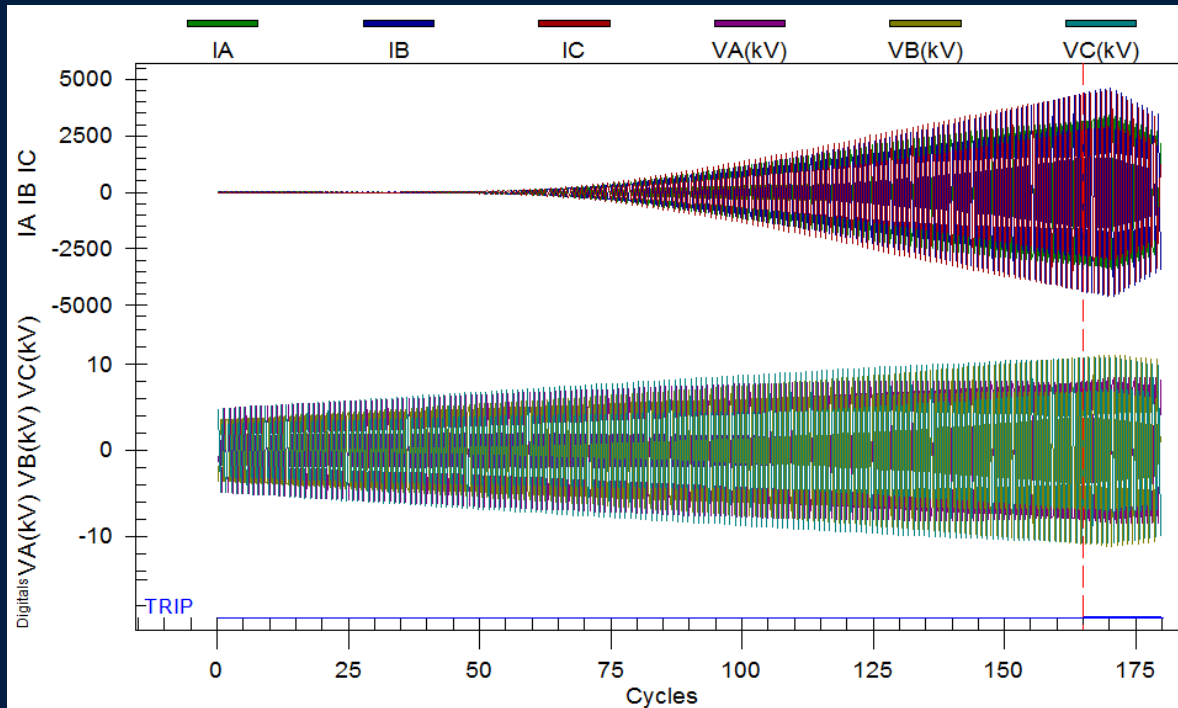
- Relay operation during return to service
- DC resistance testing and inrush
- Effect on generator protection elements
- Solutions

# One-Line Diagram

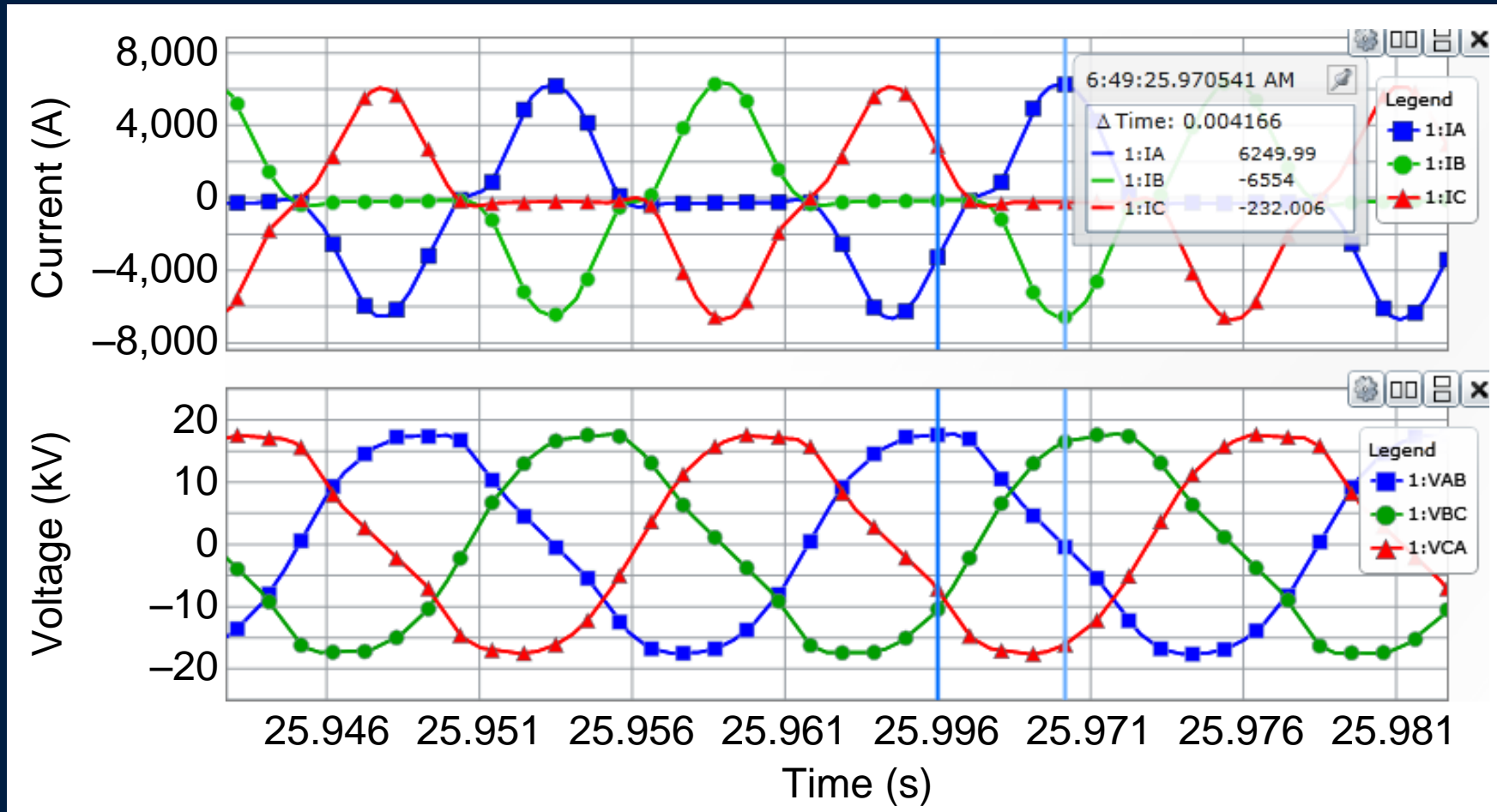


# Oscillography Captures

## Normal Energization vs. Relay Operation

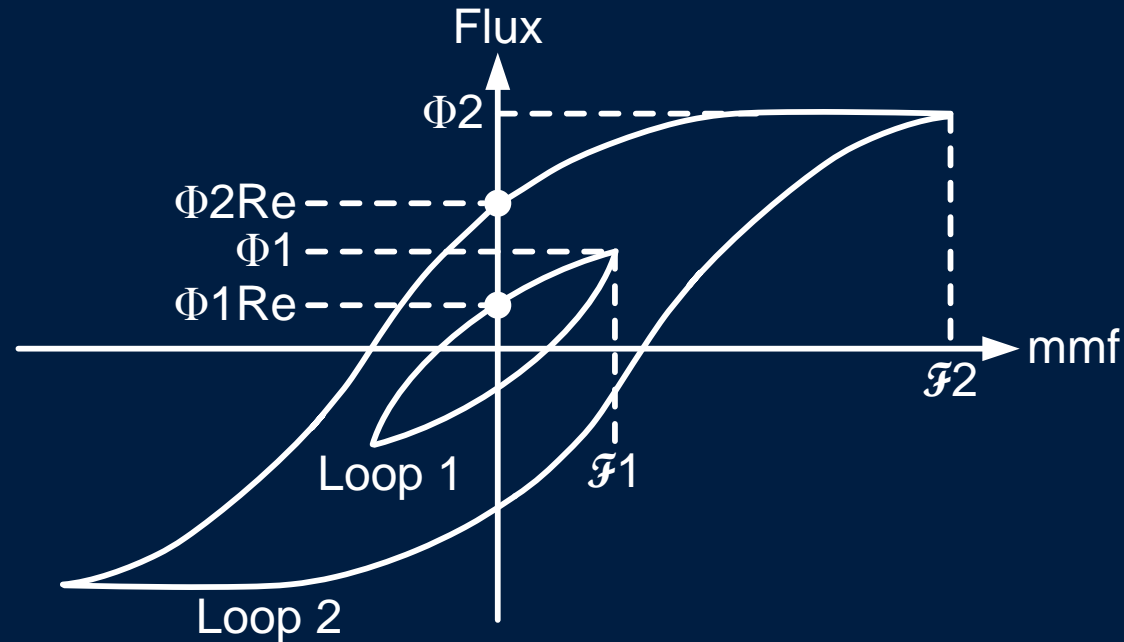
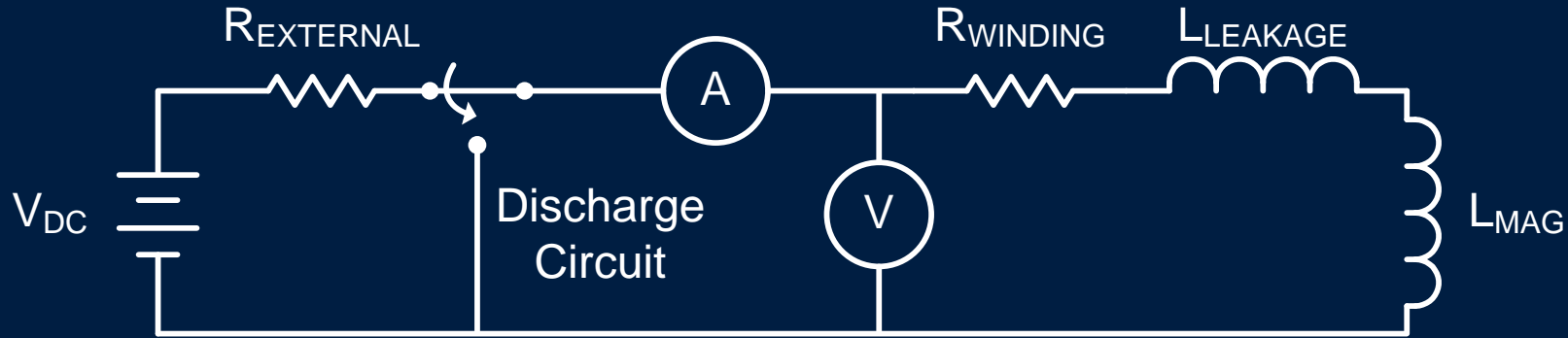


# Oscillography during Relay Operation

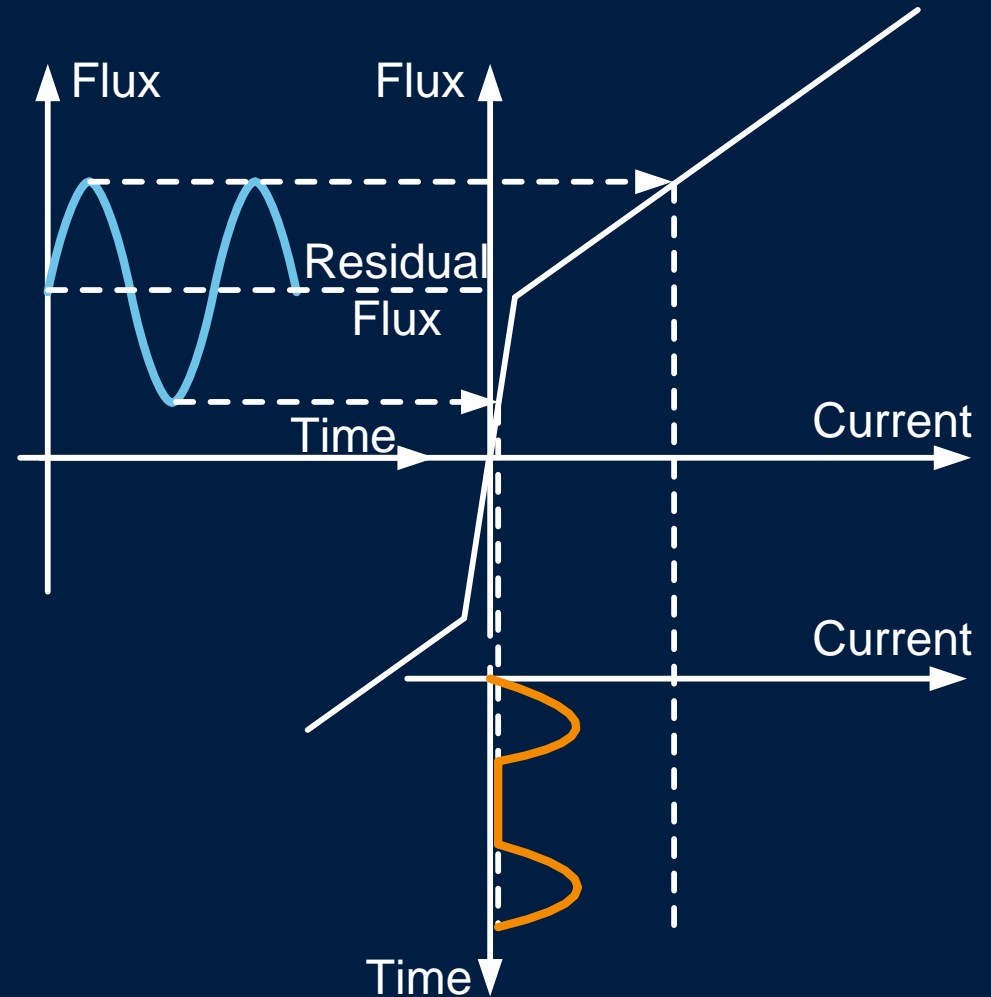
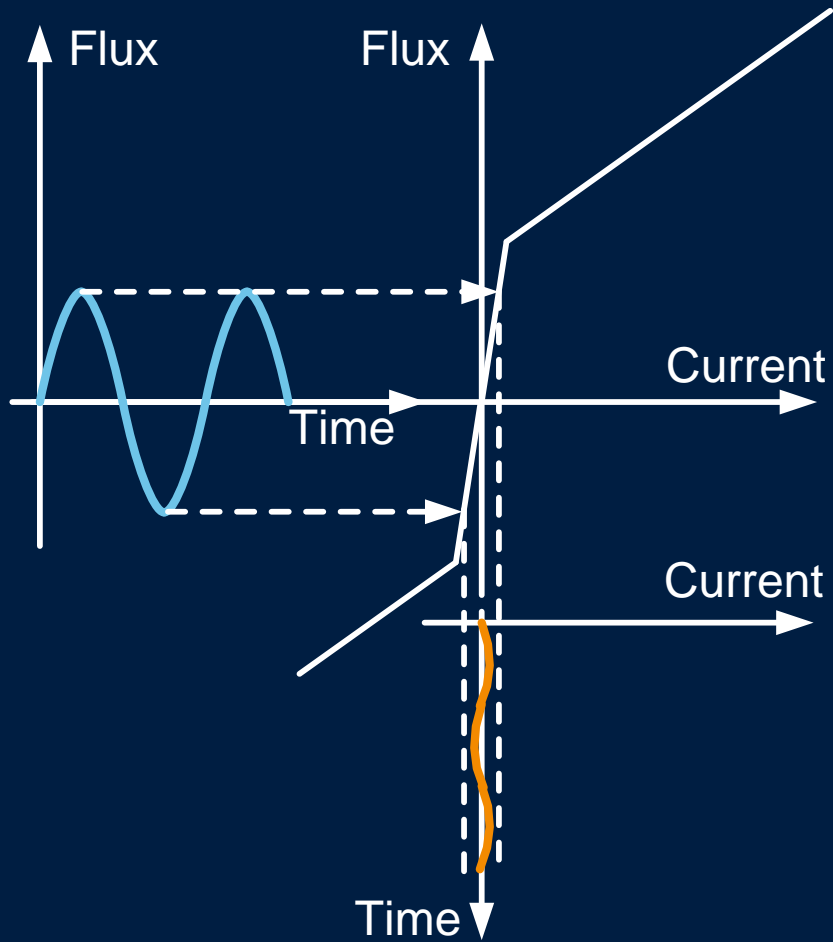


# DC Winding Resistance Testing

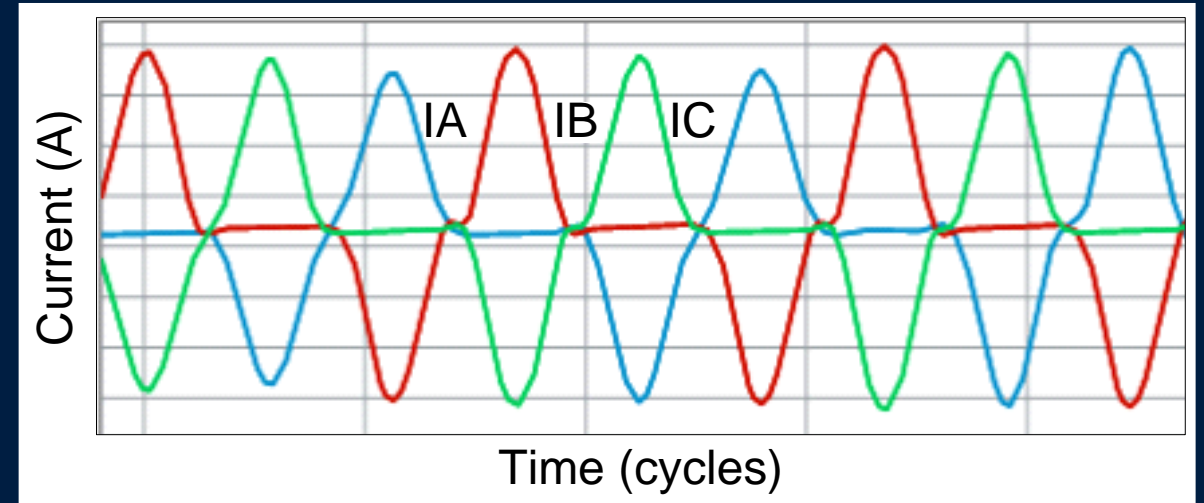
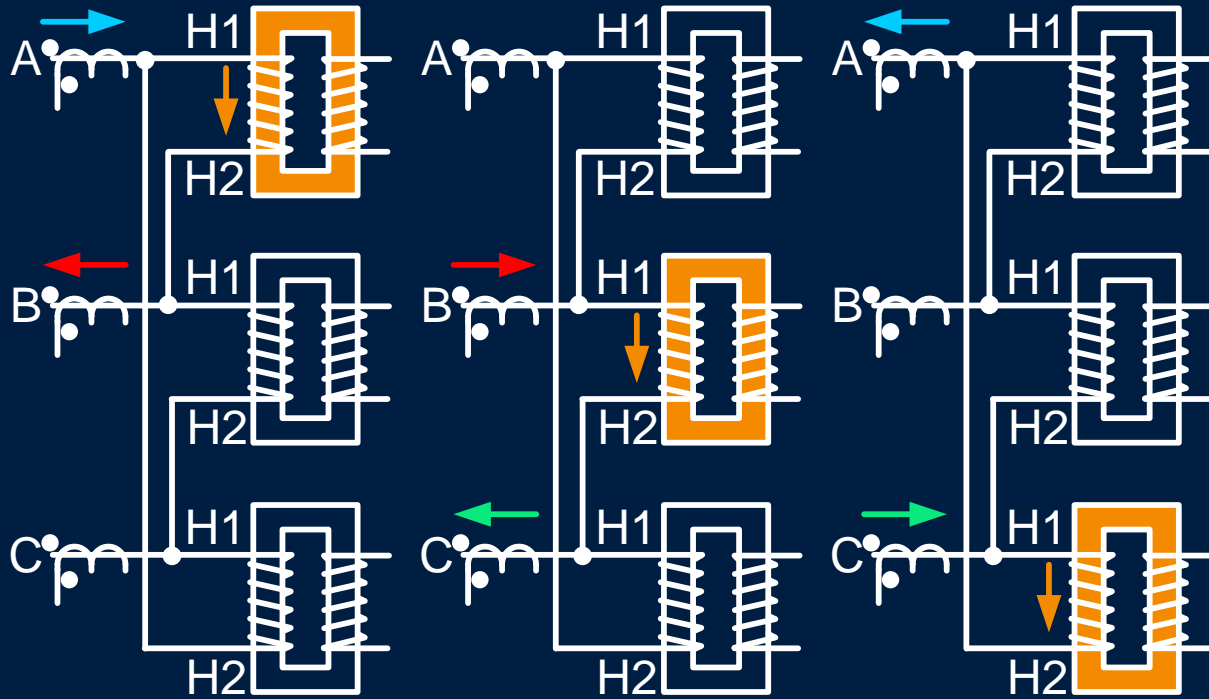
## Effect on Transformer Core



# Effect of Core Saturation on Inrush Currents

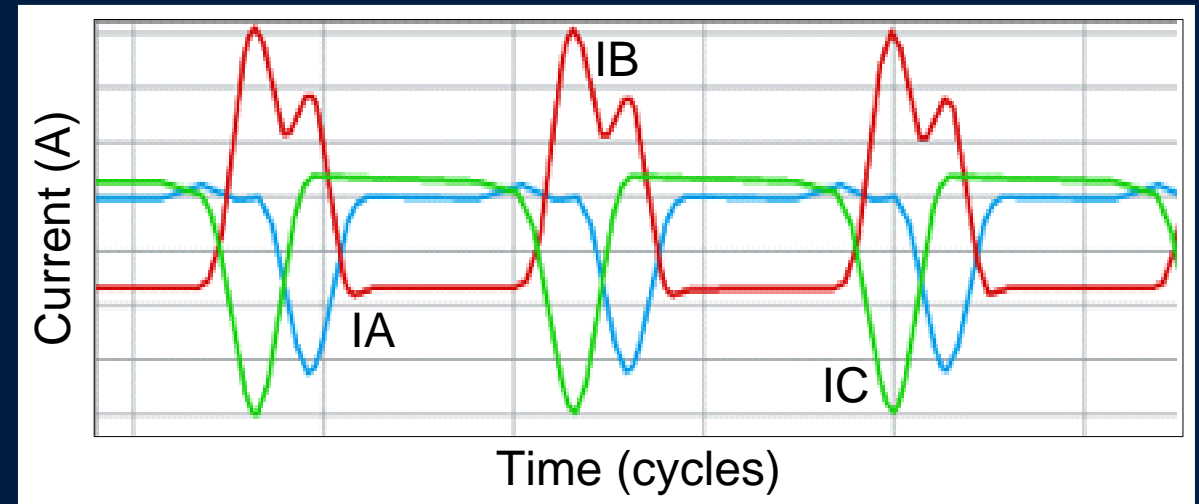
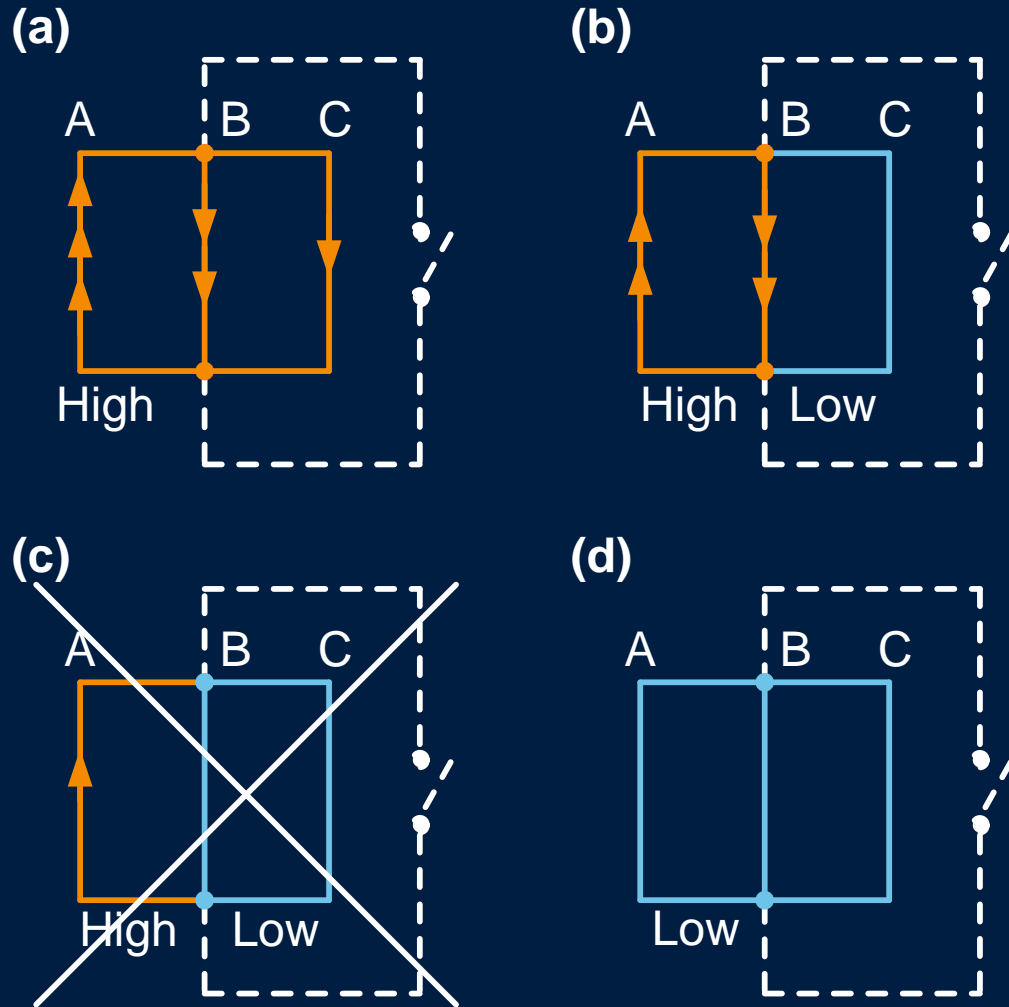


# Inrush Currents in Three Single-Phase Transformers



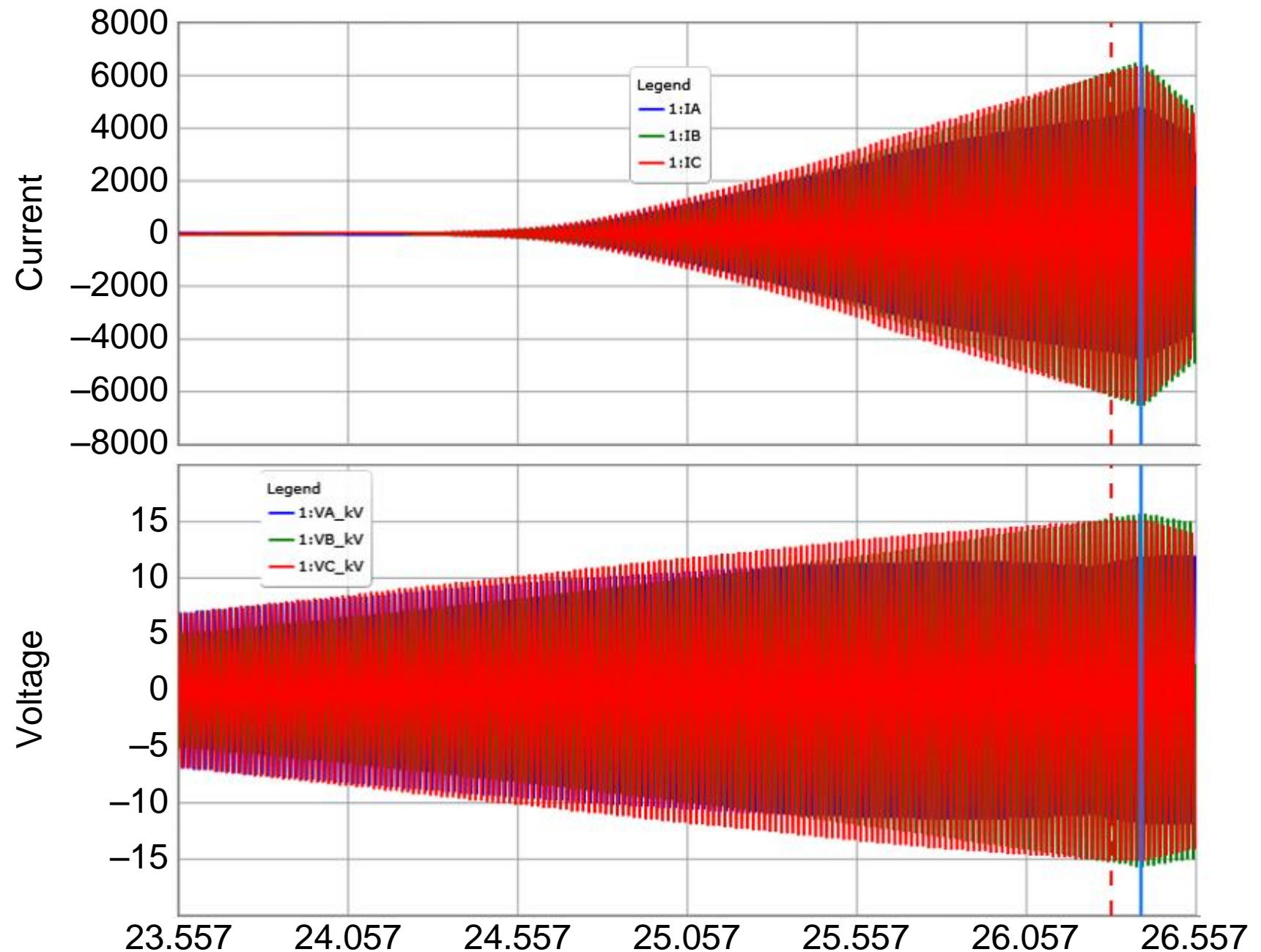


# Inrush Currents in a Three-Phase Transformer

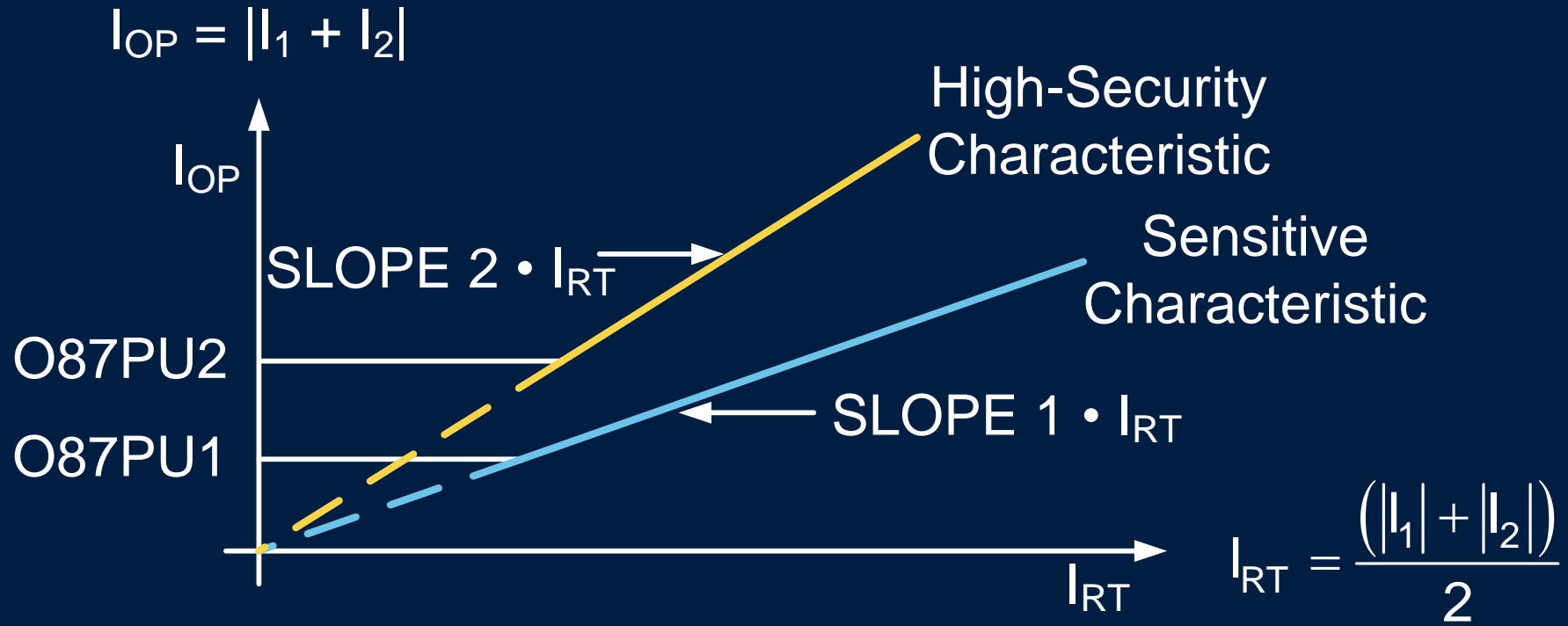


# Effect on Generator Protection

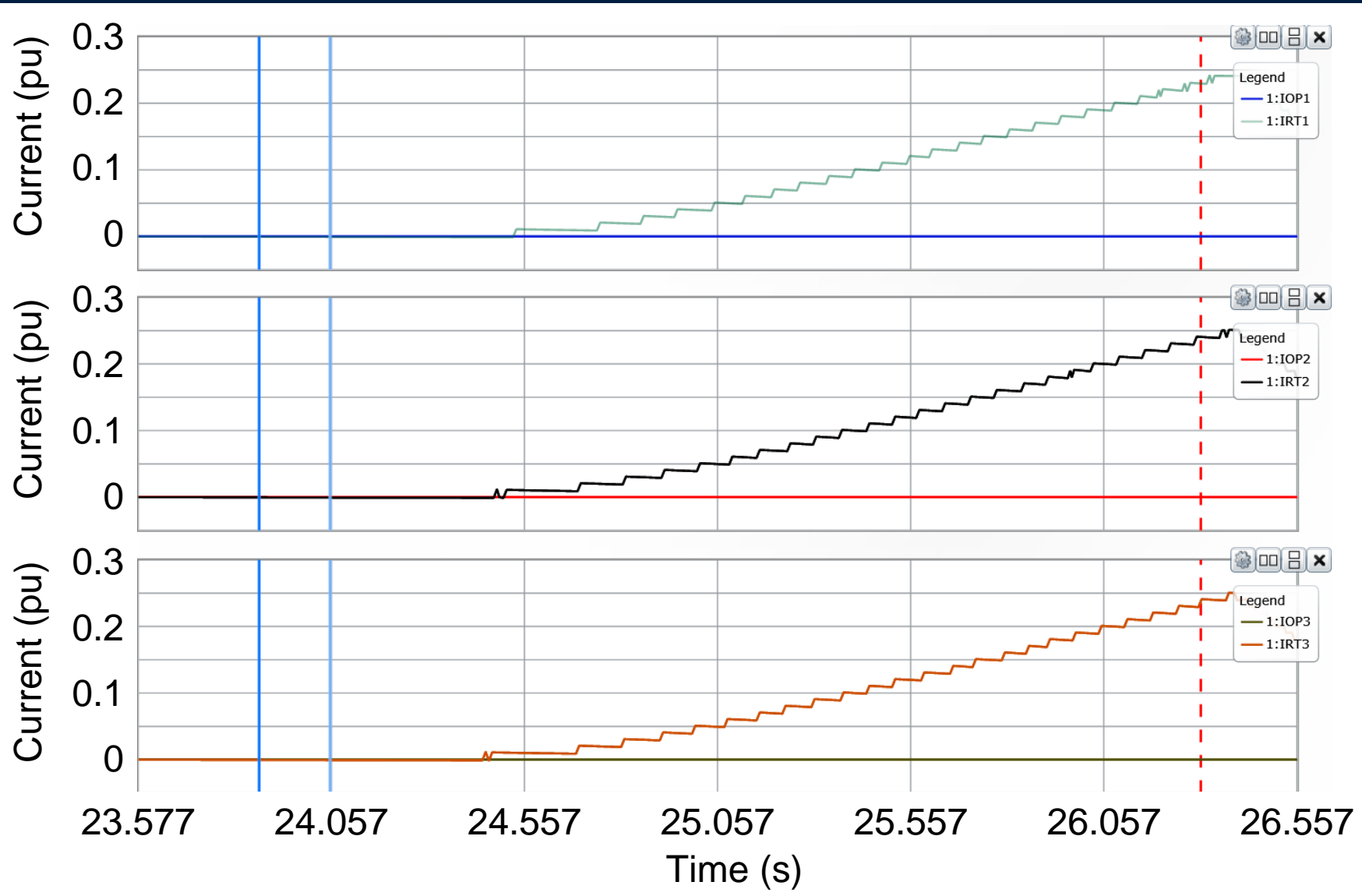
- Generator differential
- Inadvertent energization



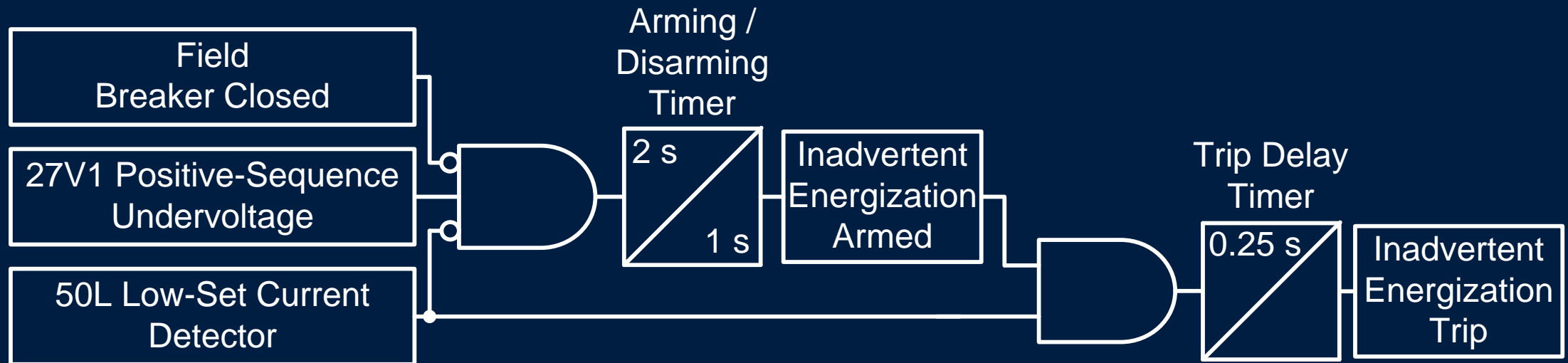
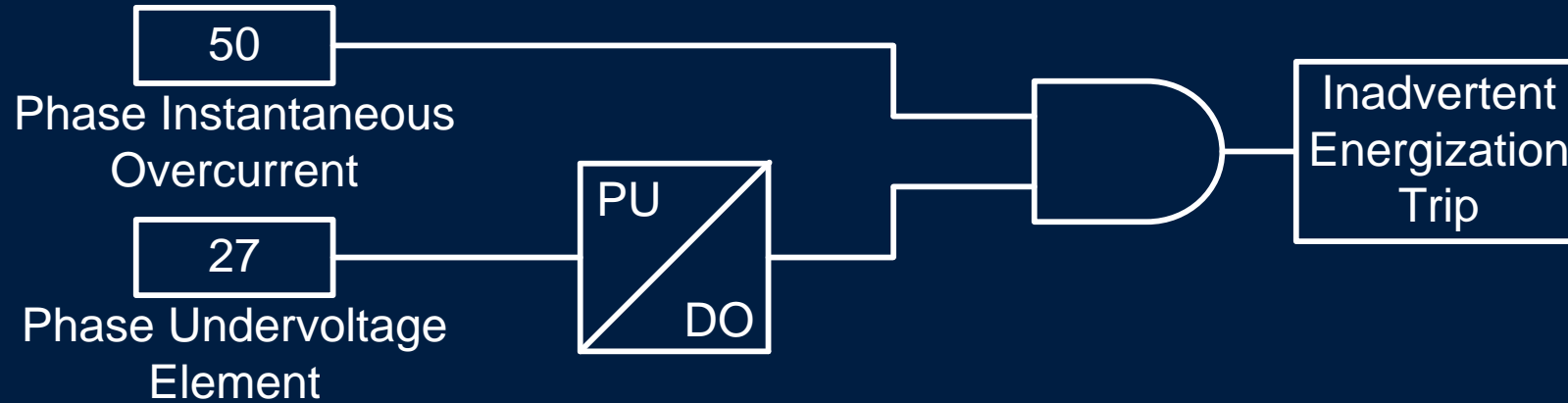
# Generator Differential



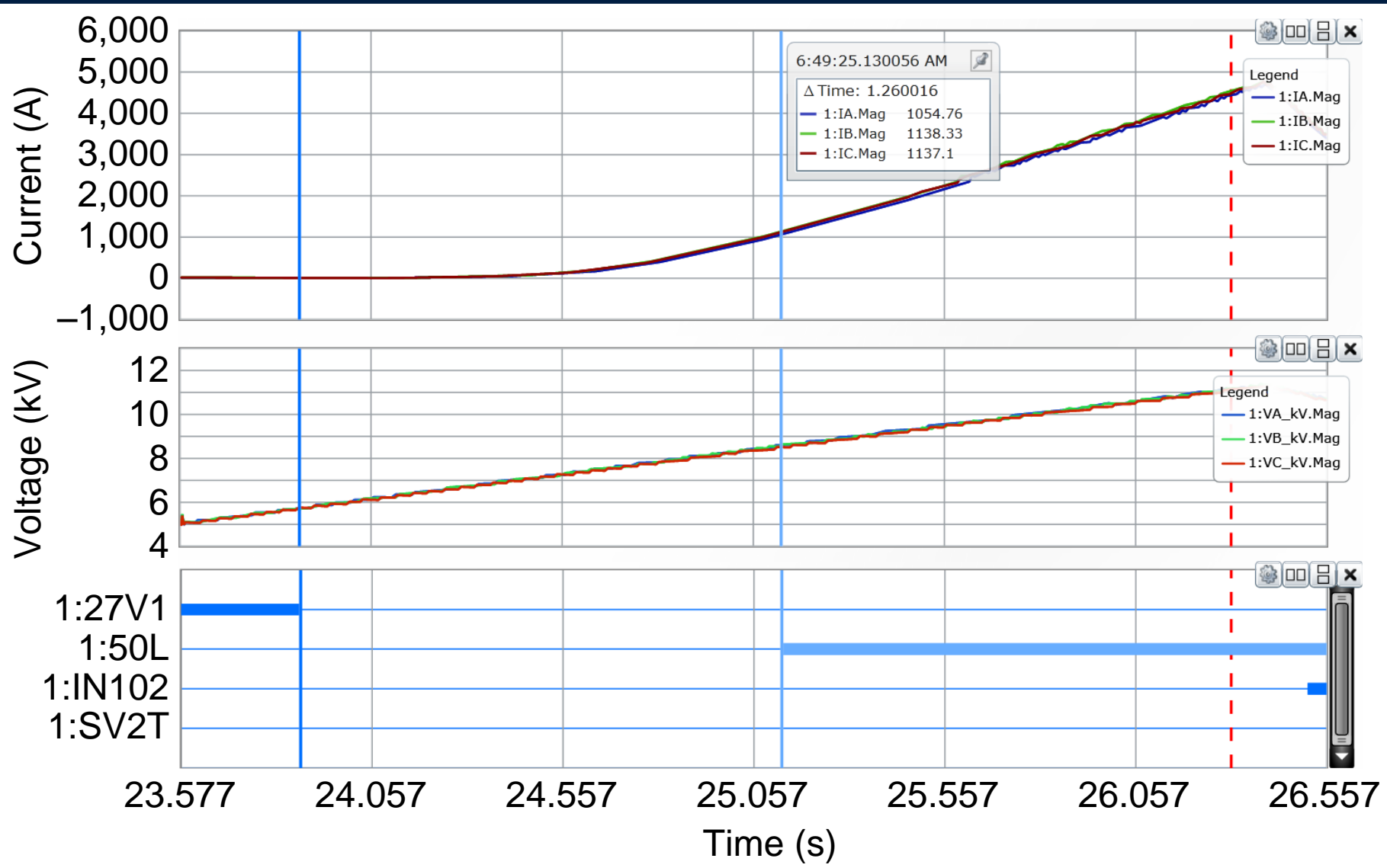
# Observed Differential Quantities



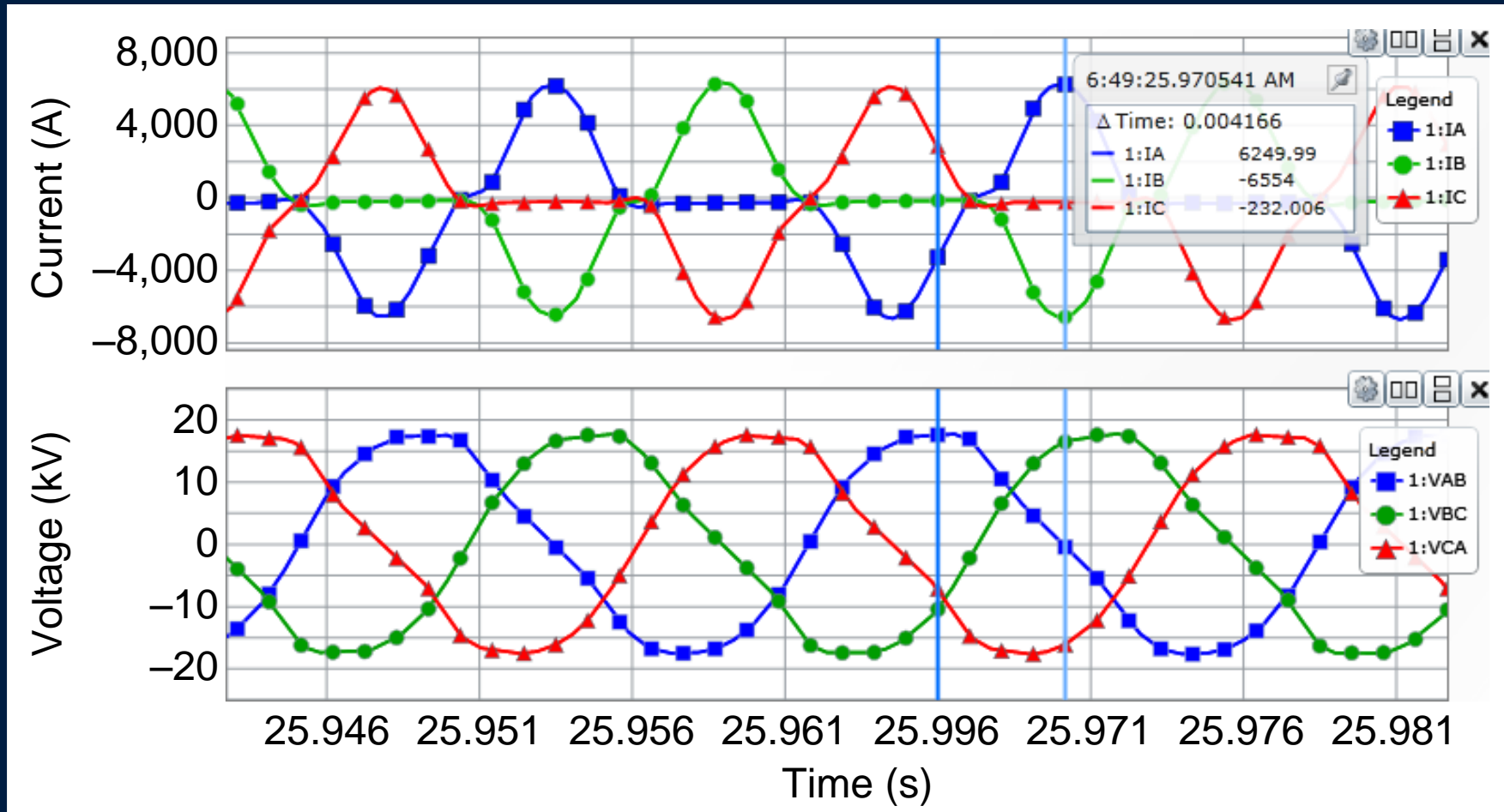
# Inadvertent Energization



# Inadvertent Energization Quantities

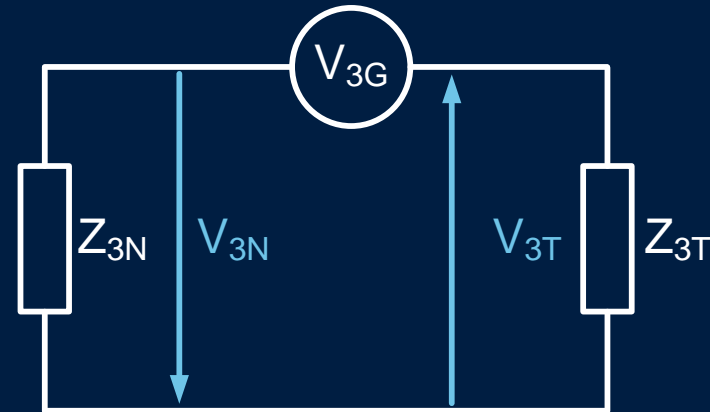
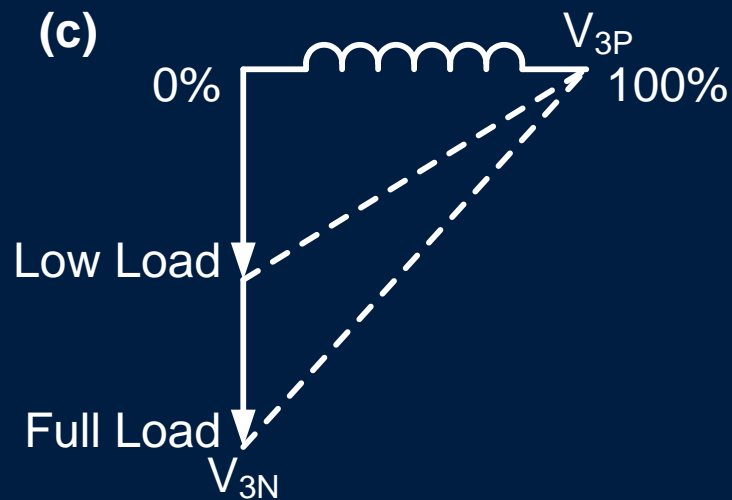
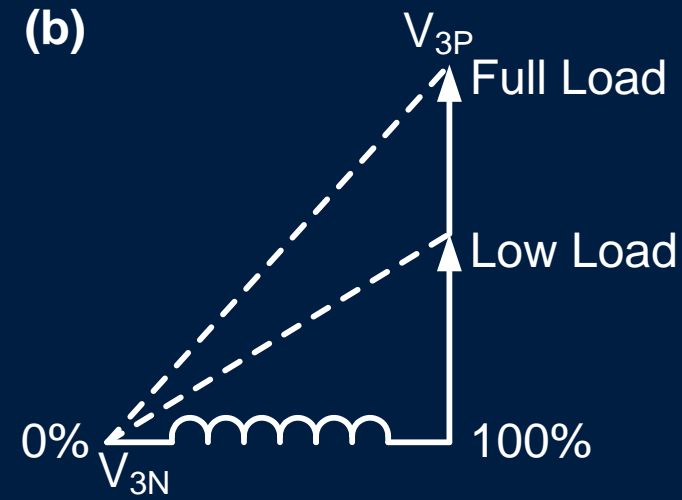
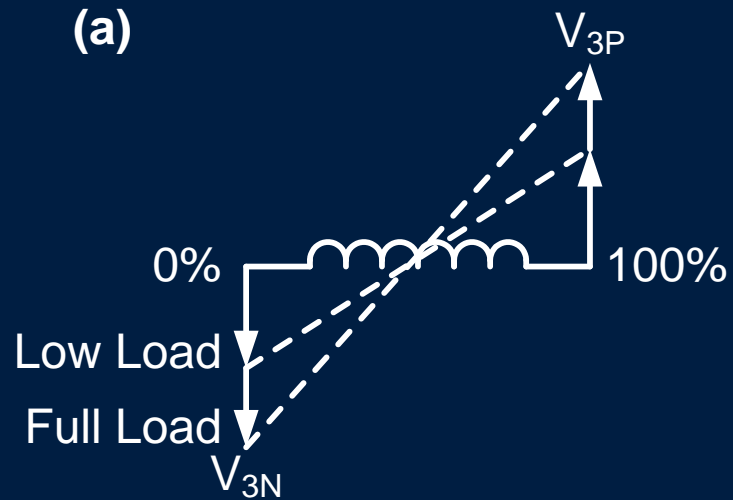


# Waveform Characteristics



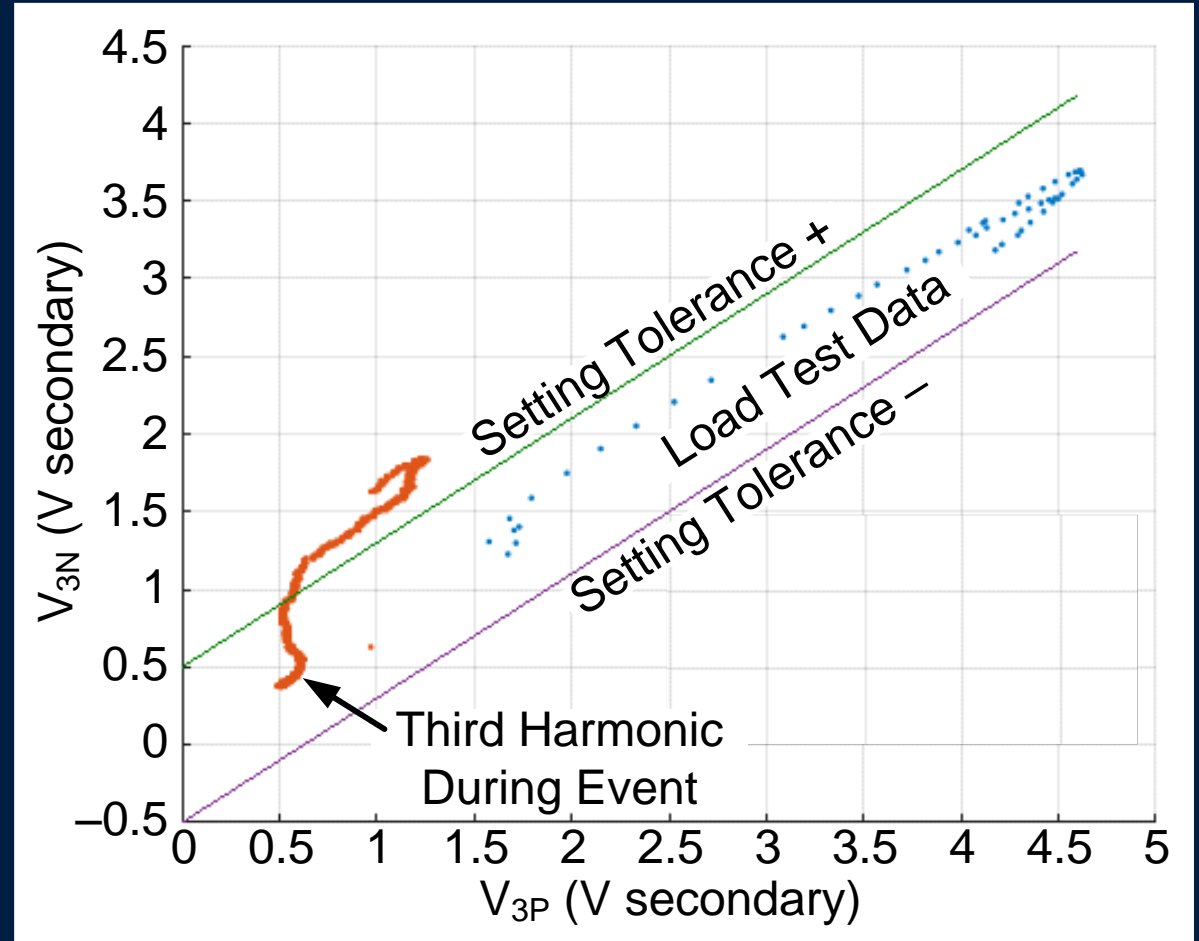
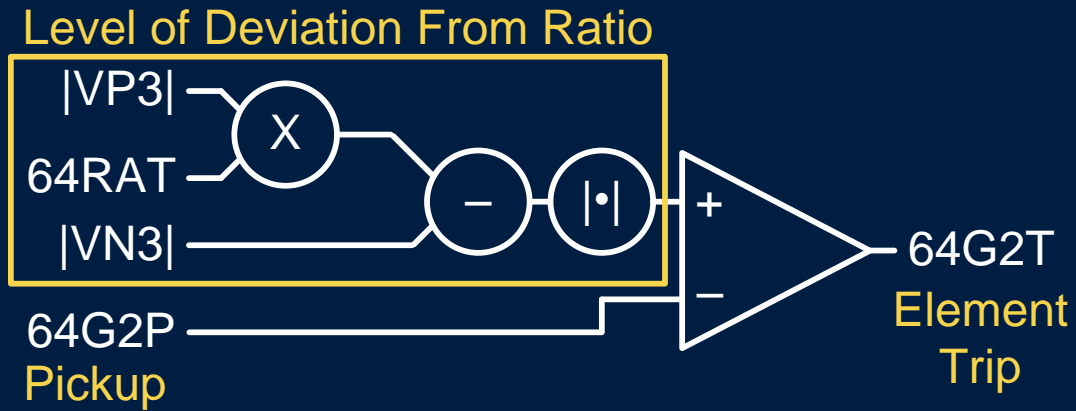
# Generator Protection Element

## 100% Stator Ground: Third-Harmonic Differential

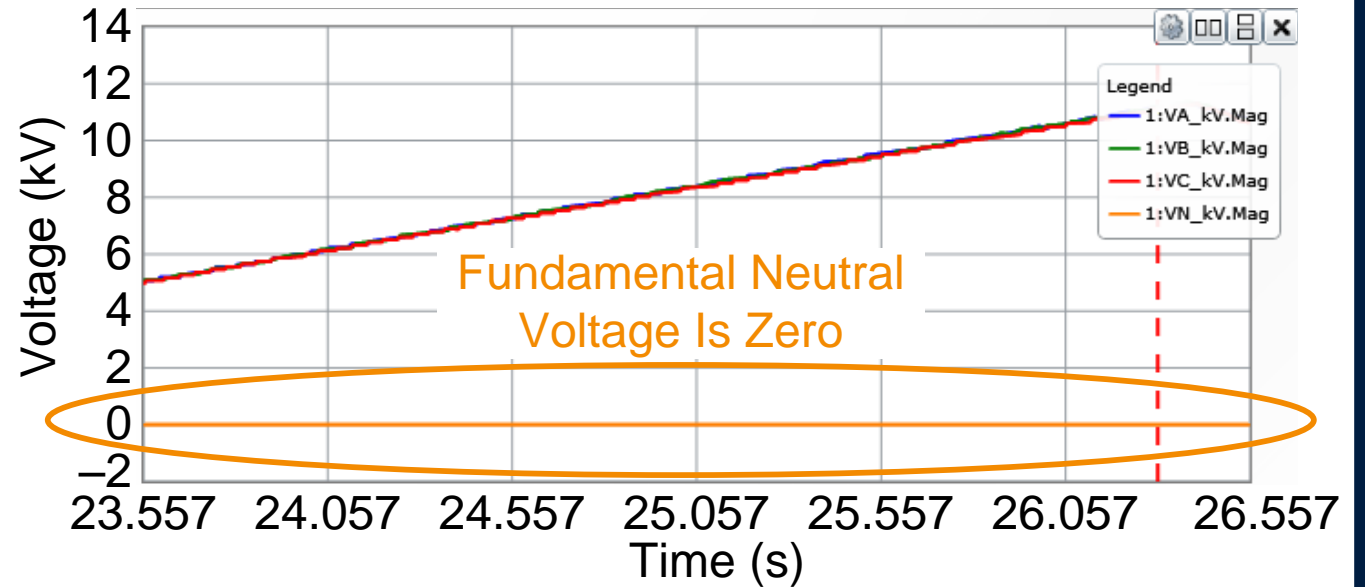
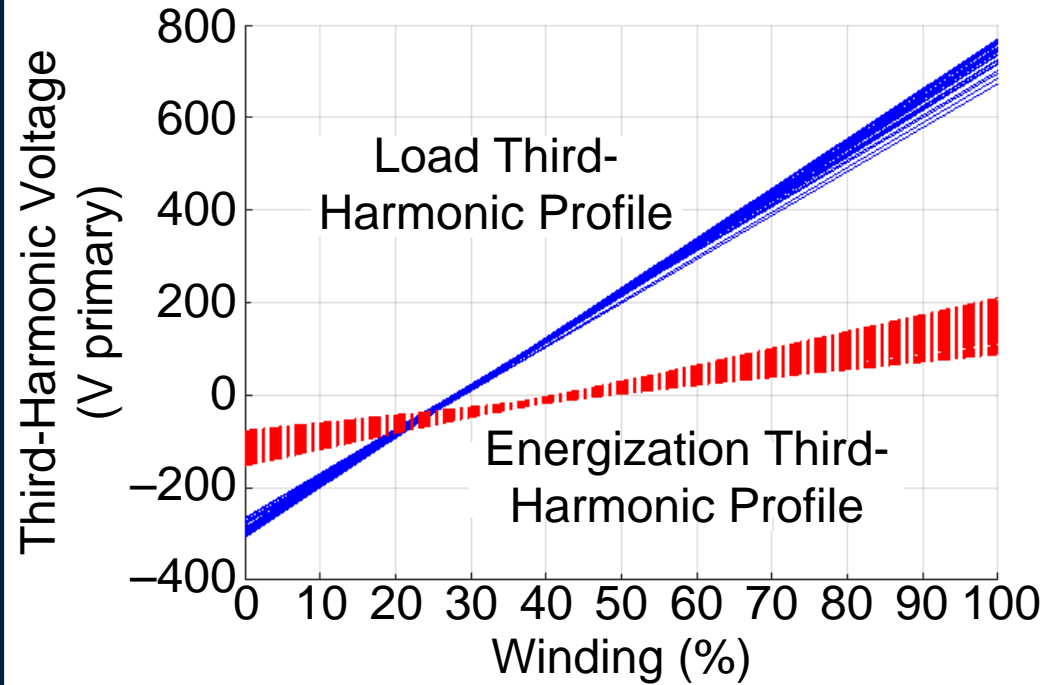




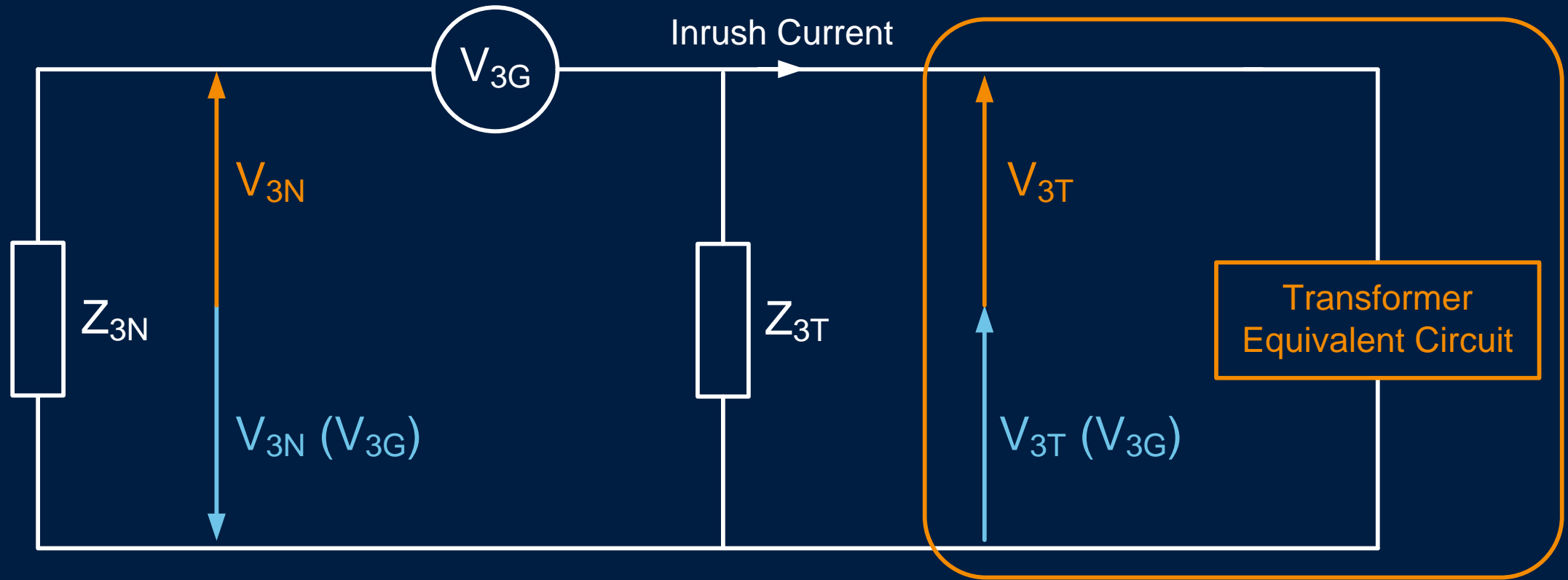
# Third-Harmonic Voltage Profile



# Is This a Generator Internal Fault?



# Equivalent Third-Harmonic Circuit



# Solutions

## Third-Harmonic Element

- Process
  - Demagnetize transformer
  - Modify procedure to perform other tests after dc resistance testing
- Algorithm settings
  - Pickup
  - Time delay
  - Supervision
- Alternate method – subharmonic injection

# Conclusion

- DC resistance testing can cause transformer core saturation
- Energization following testing can affect currents and voltages seen by generator relay
- Users should demagnetize transformers following testing or adopt other protection elements or settings



Questions?

