# Negative-Sequence Overcurrent Considerations for Induction Motor Loads

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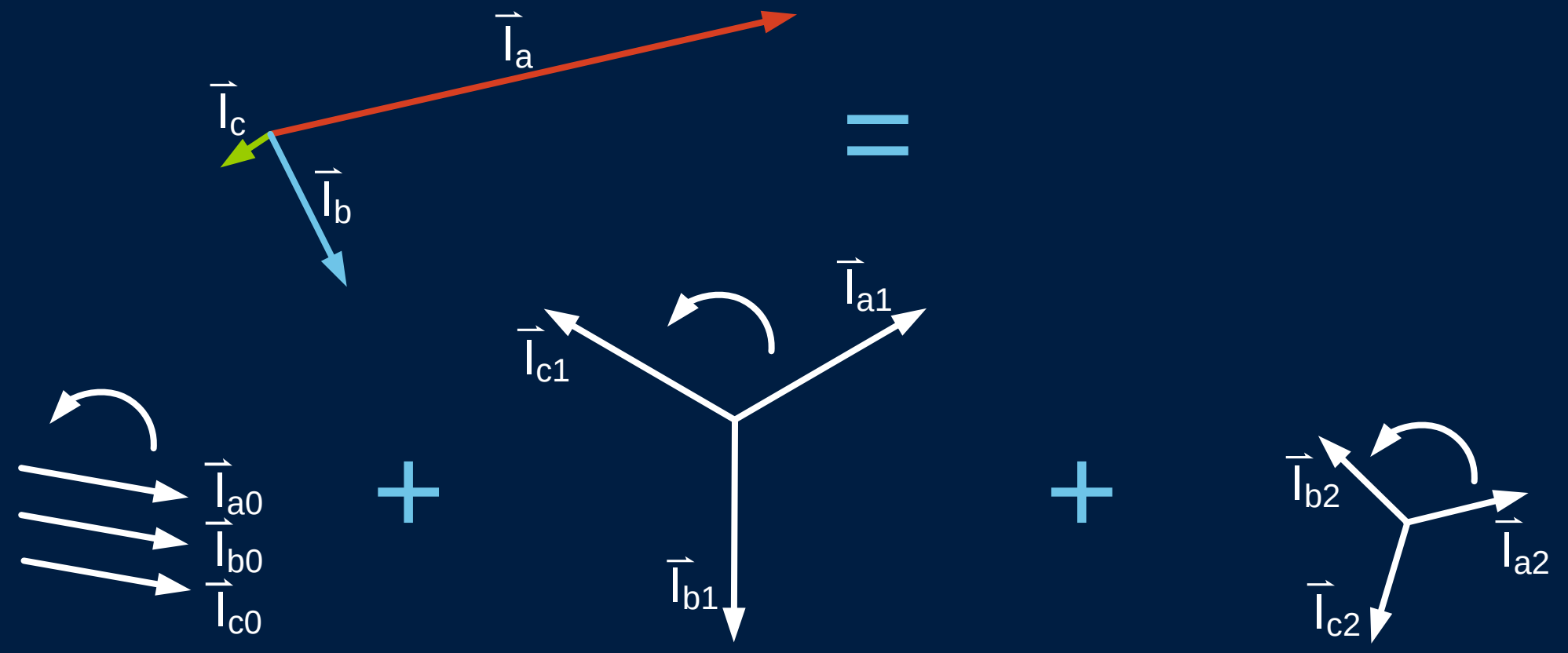
# Overview

- Sequence components
- Negative-sequence overcurrent protection
- Induction motor model and slip
- Real-world event analysis
- PSCAD simulations of event
- Settings recommendations
- Conclusion

# Introduction to Sequence Components




Zero-Sequence
Single-Phase

Positive-Sequence
Balanced

Negative-Sequence
Balanced

# Negative-Sequence Overcurrent Protection

## Why Use This Element?

| Element | Responds to Load? | Detects Phase-to-Phase Faults? | Detects Ground Faults? |
|---|---|---|---|
| Phase overcurrent | Yes | Yes | Limited |
| Ground overcurrent | No | No | Yes |
| Negative-sequence overcurrent | No | Yes | Yes |

# Negative-Sequence Overcurrent Protection

## When to Use This Element?

- Feeder protection
- Transformer protection
- Motor protection

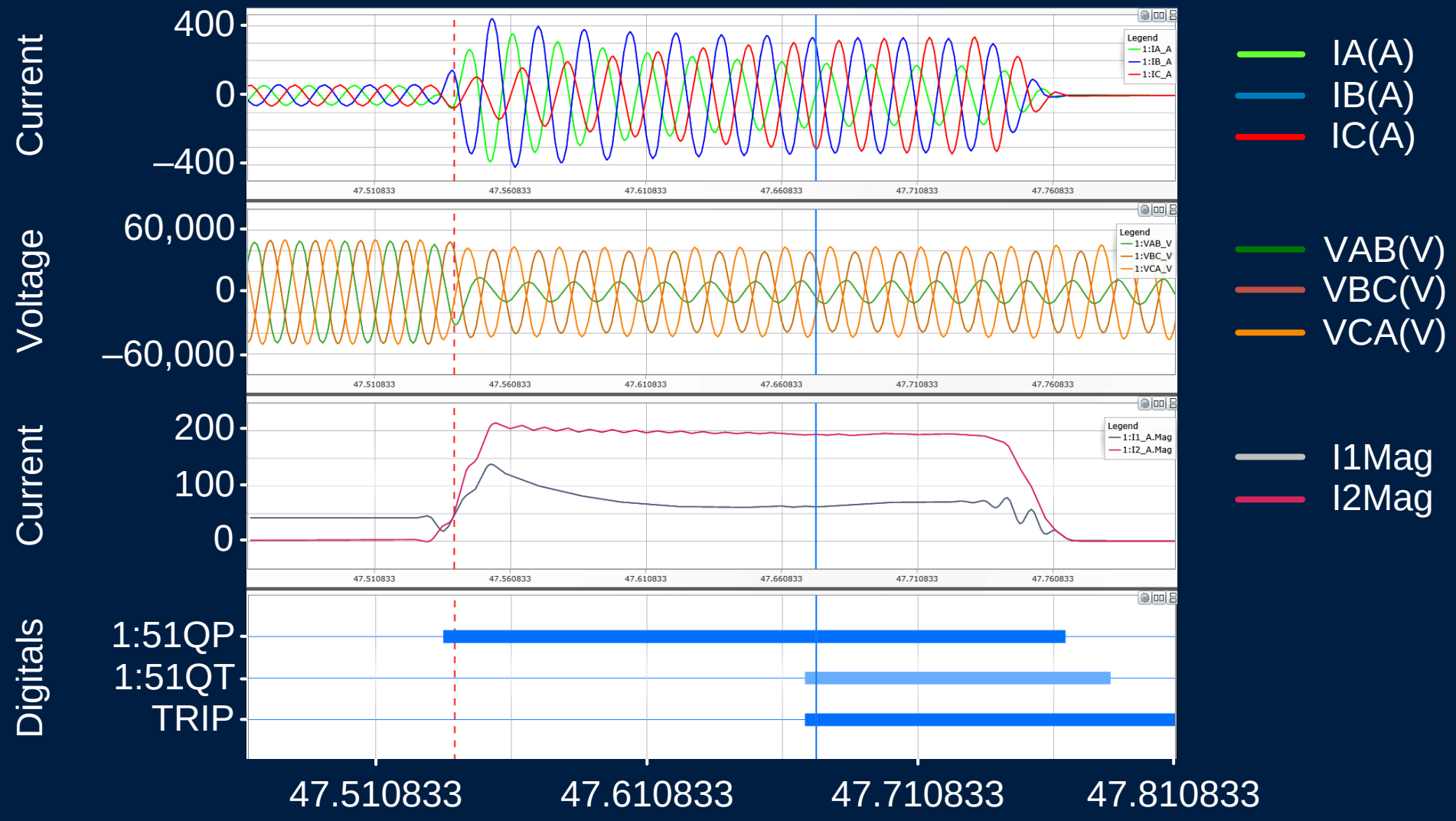
# Induction Motor Model

# Induction Motor Slip

- For positive-sequence current, $s = 1 - \left(\frac{Nr}{Ns}\right)$
- For negative-sequence current, $s2 = 1 - \left(\frac{Nr}{-Ns}\right) = 2 - s$
- Typically, $\frac{|Z1|}{|Z2|} \approx 6$

# Real-World Event System

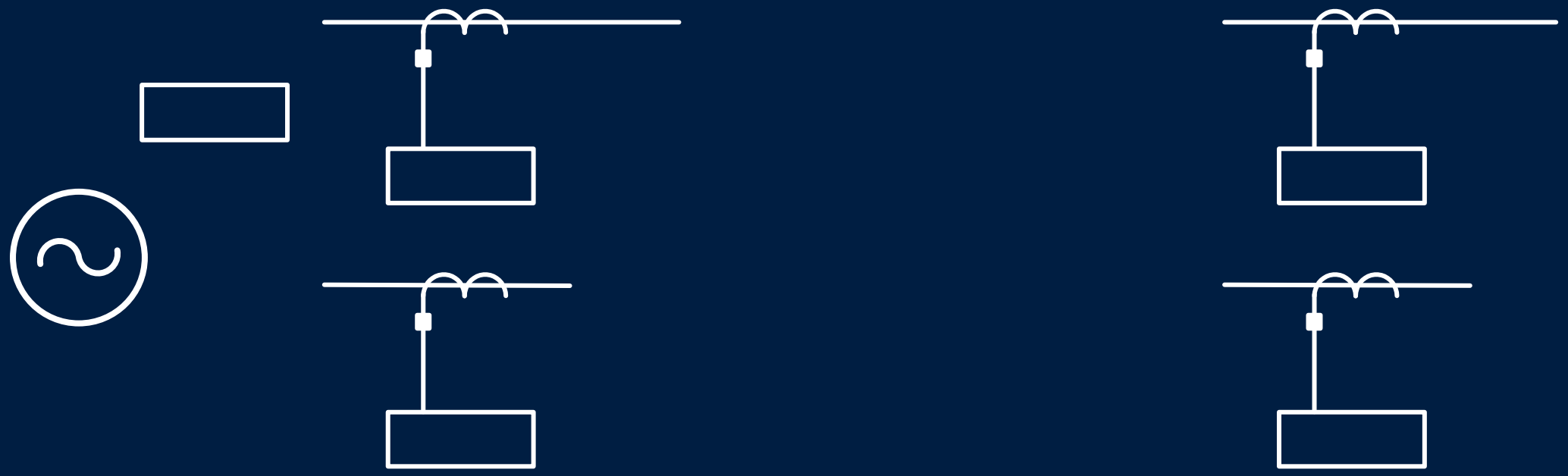
# Real-World Event Analysis



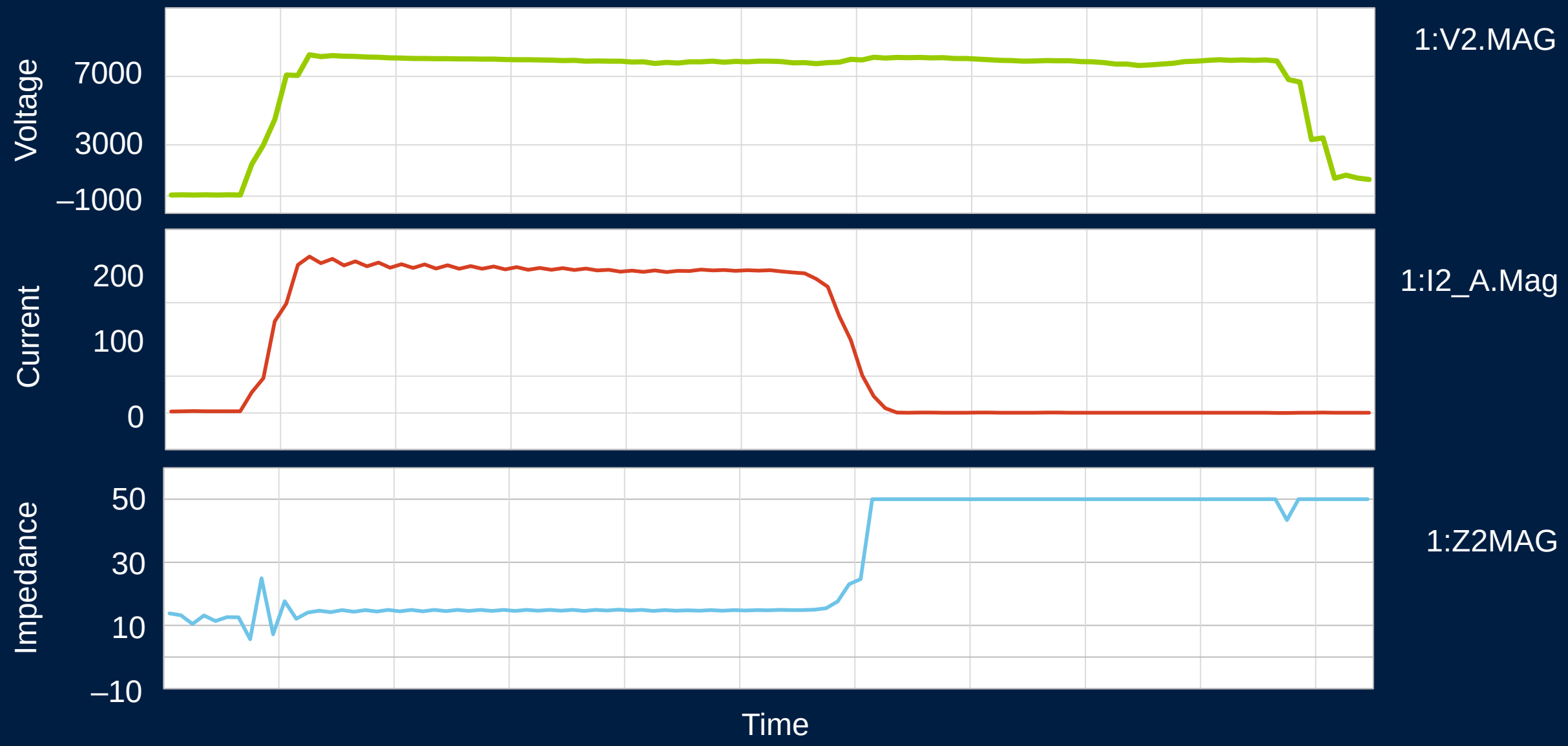
# Real-World Event Analysis

## Phase Relationship Before and During Fault

# Sequence Network During Fault

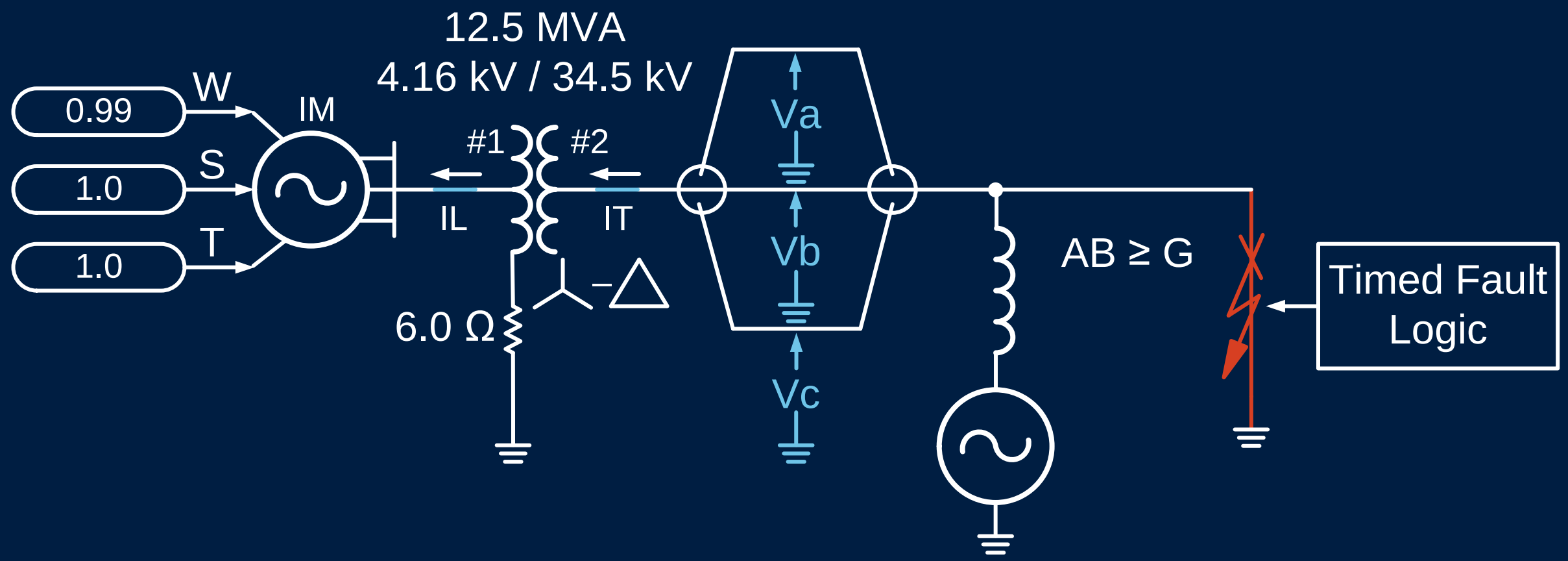


# Relay 2 Event Negative-Sequence Waveforms



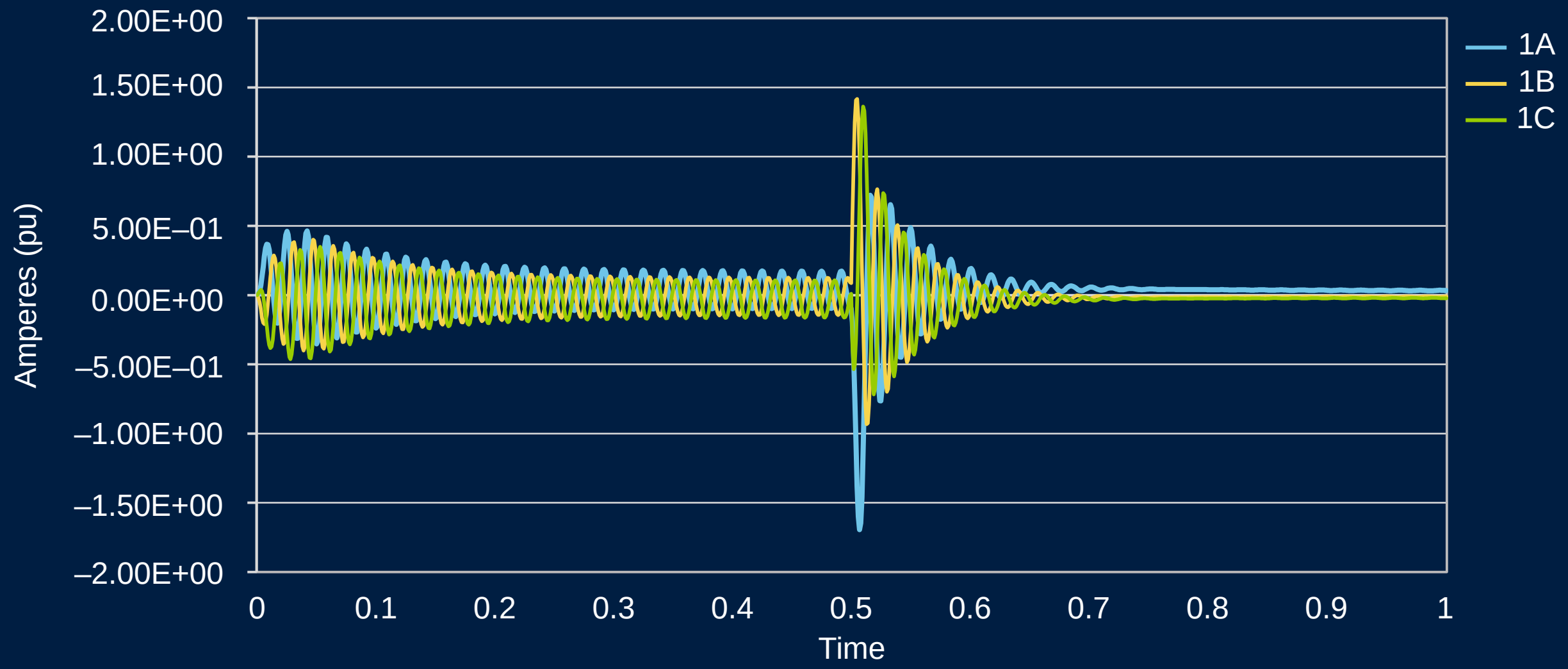
# PSCAD Simulations System Setup

## Single-Line Diagram



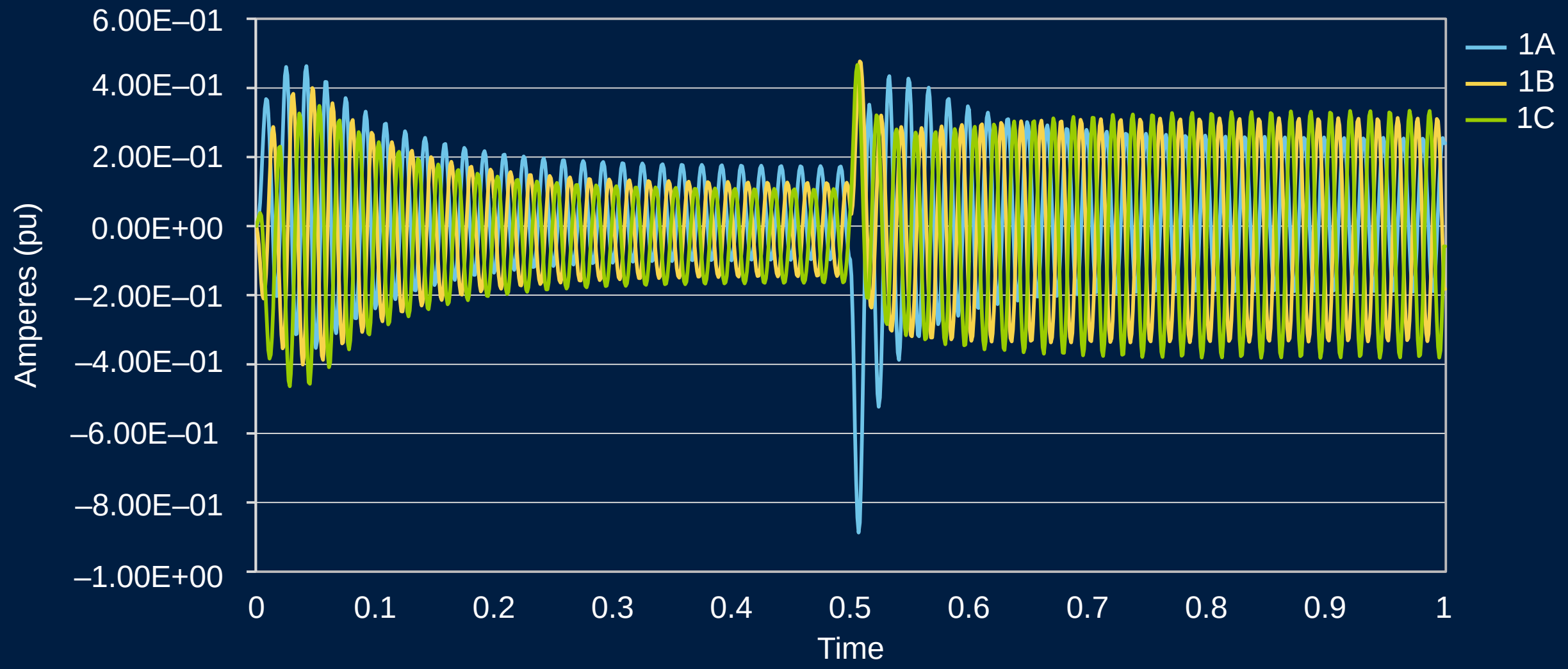
# PSCAD Simulated Waveforms

## Three-Phase Fault



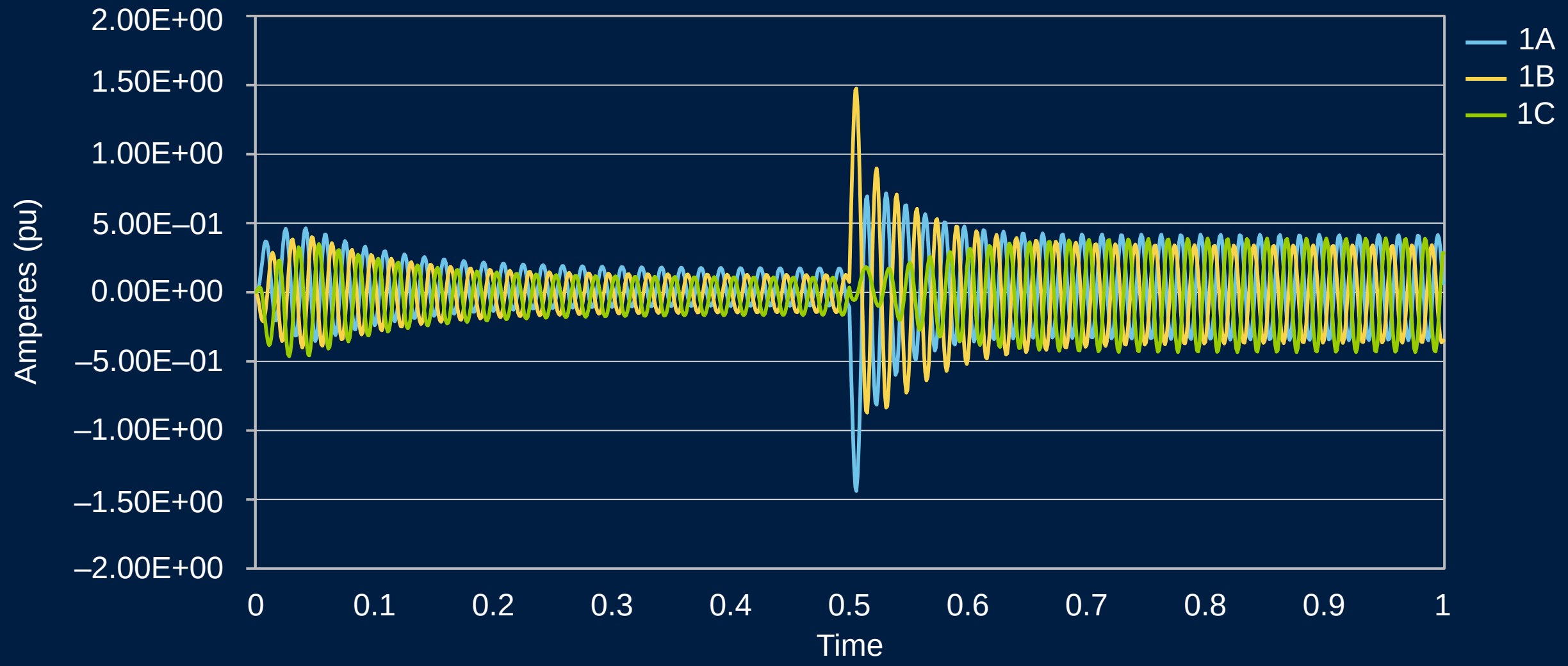
# PSCAD Simulated Waveforms

## Phase-to-Ground Fault



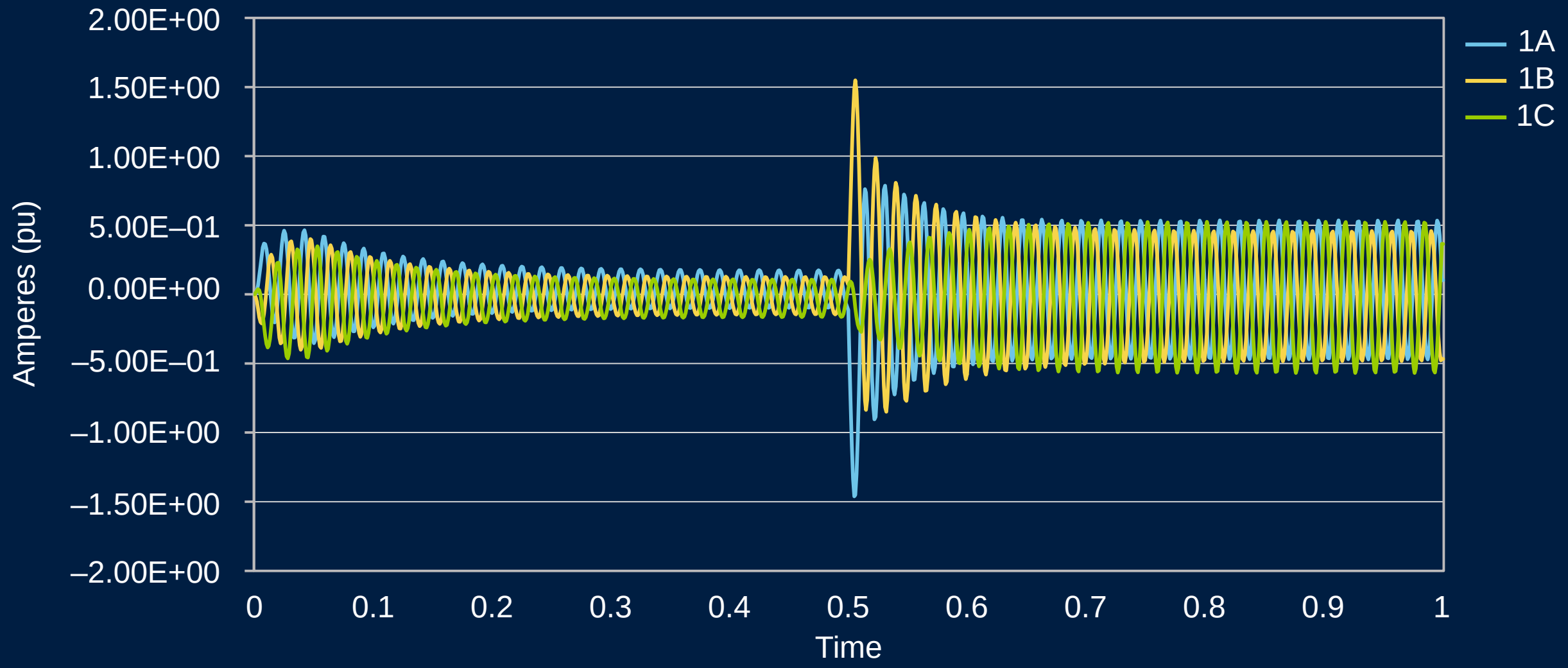
# PSCAD Simulated Waveforms

## Phase-to-Phase-to-Ground Fault



# PSCAD Simulated Waveforms

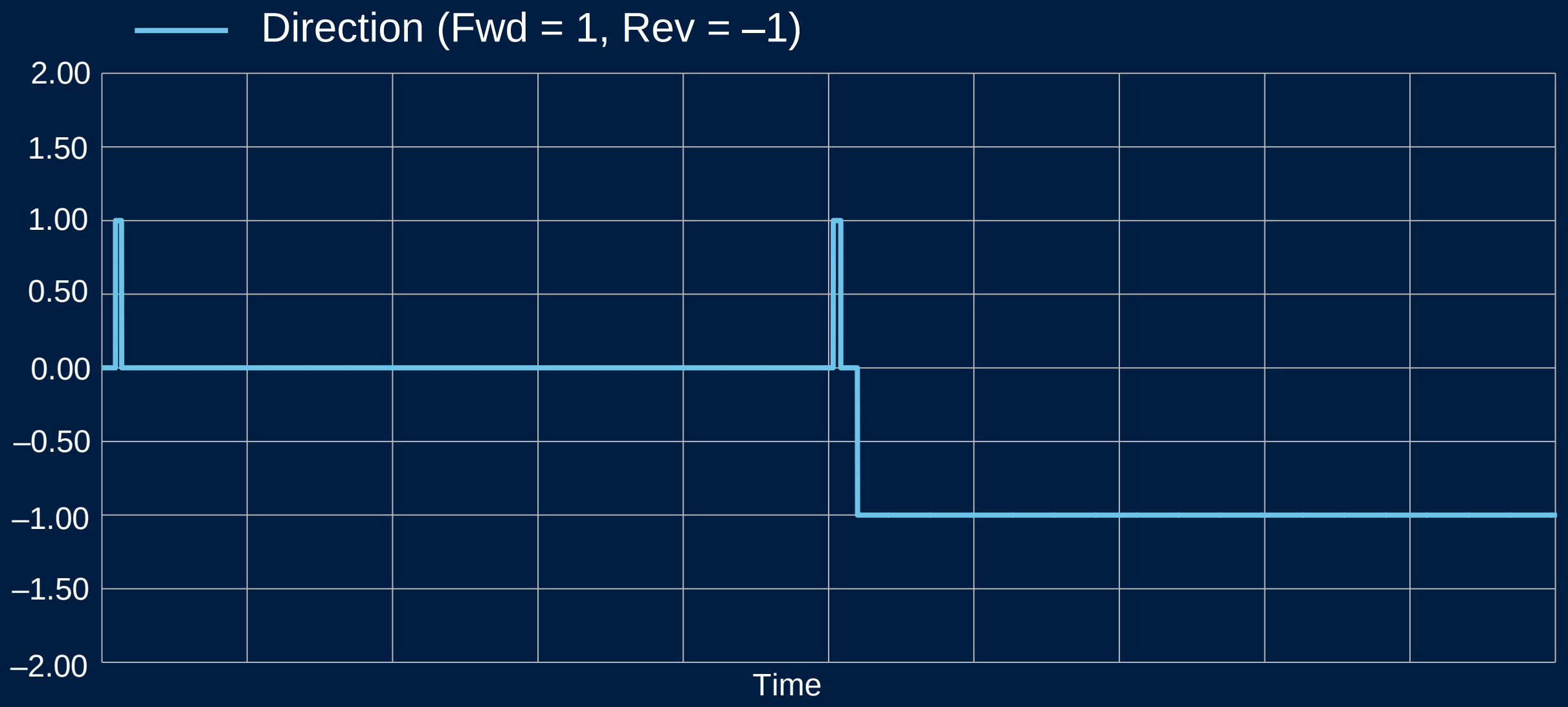
## Phase-to-Phase Fault



# Operation of Negative-Sequence Impedance Directional Element

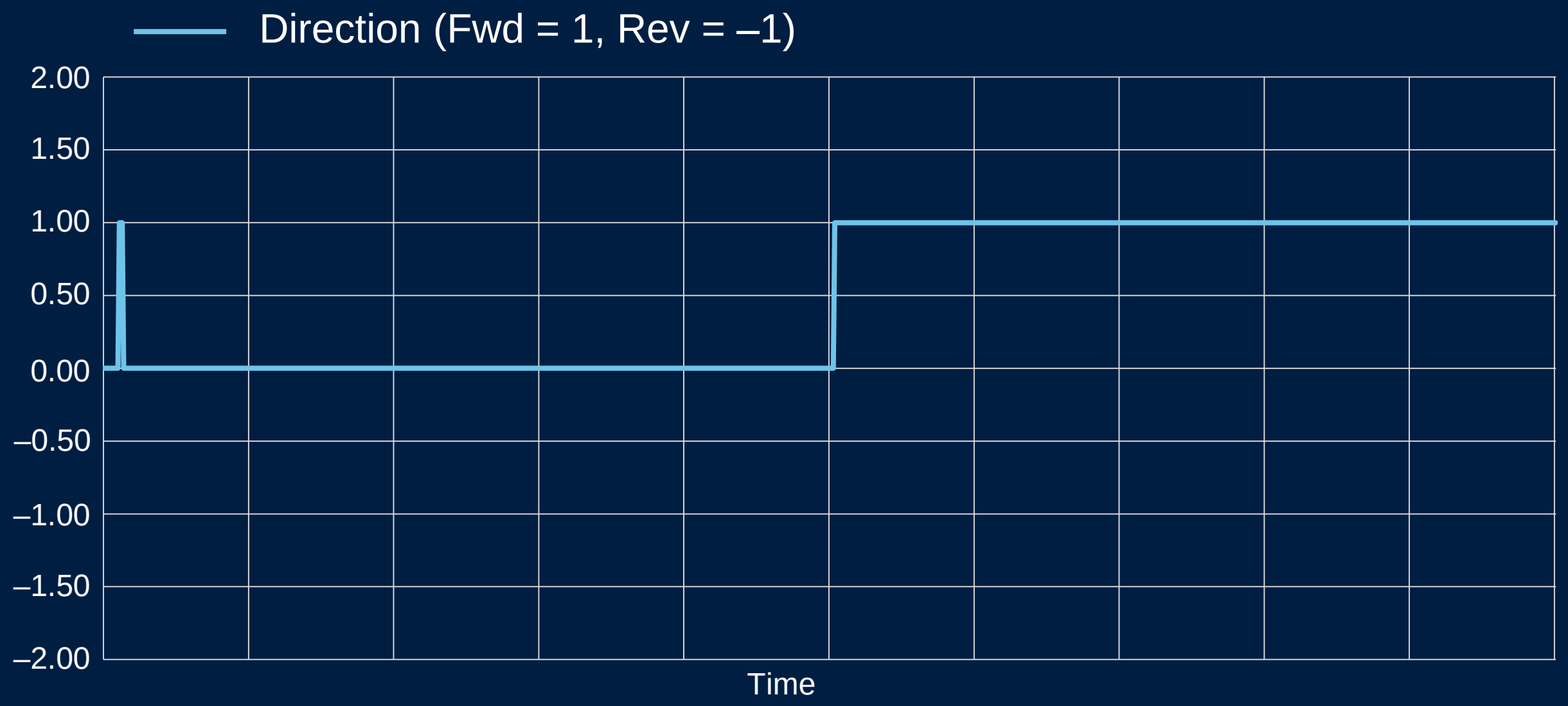
# PSCAD Simulated Waveforms

## 34.5 kV Bus Fault



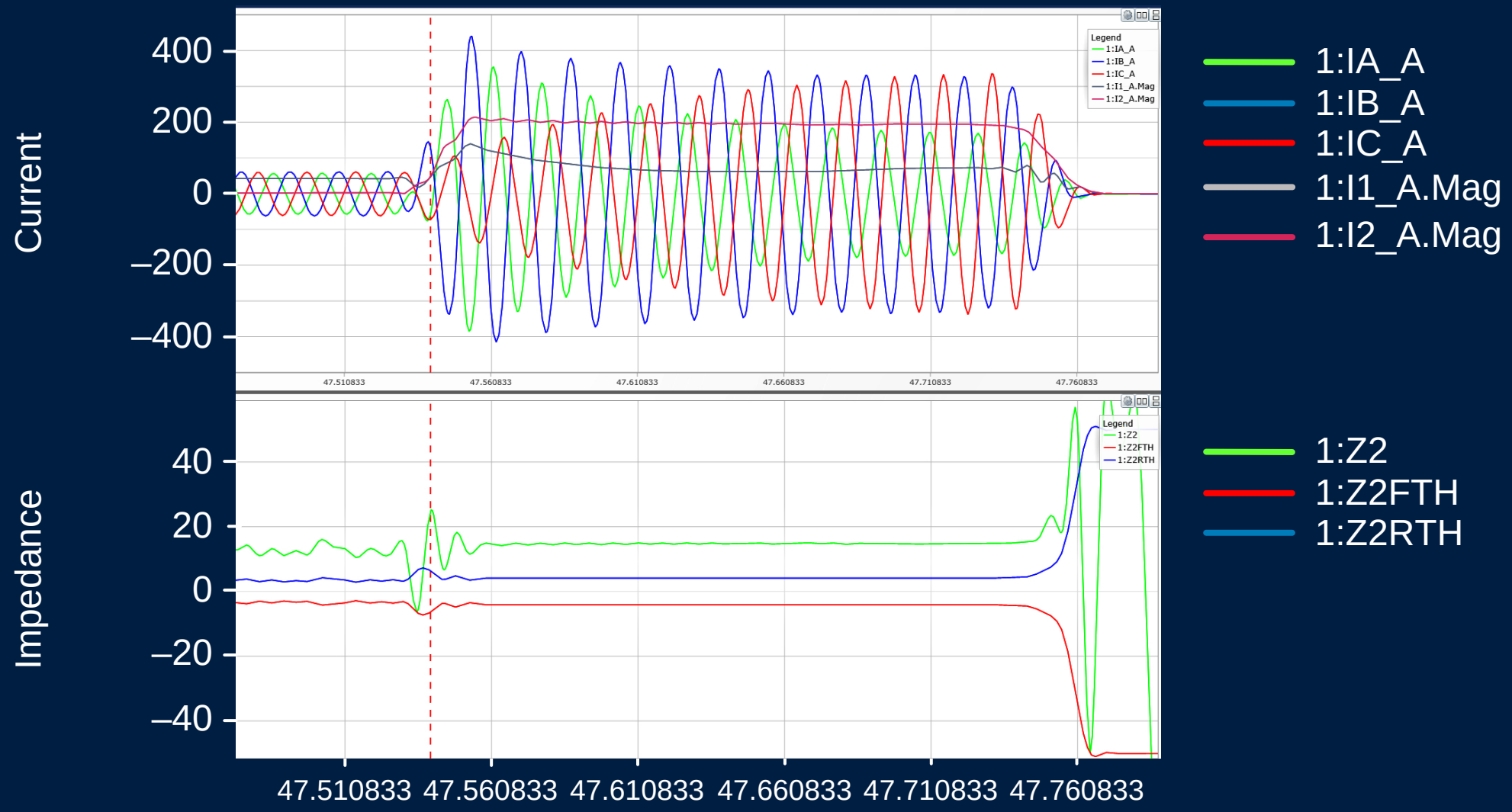
# PSCAD Simulated Waveforms

## 4.16 kV Bus Fault



# Relay 2 Waveforms

## Directional Element Operation in Relay



# Recommendations for Transformer Protection

- Inverse-time neutral overcurrent (51N)
- Restricted earth fault (REF)
- Inverse-time negative-sequence overcurrent (51Q)
  - Nondirectional
  - Directional

# Conclusion

- Consider load type for 51Q element
- Nondirectional 51Q element when set sensitively leads to out-of-zone tripping
- Use directional supervision to set element sensitively