Adaptive Protection for Meshed Secondary Networks using Network Protectors

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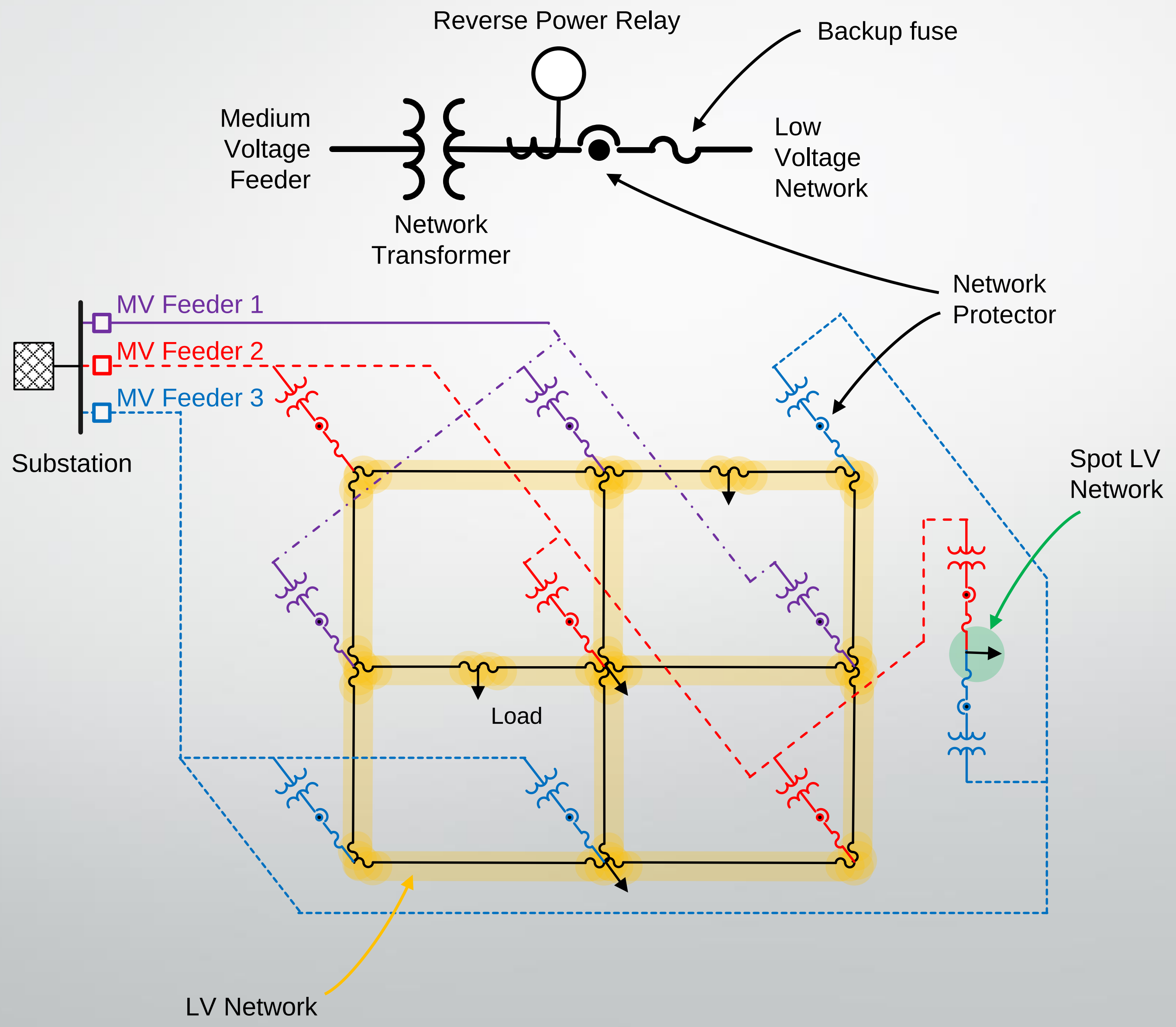
  - Electric Power Research Institute (EPRI): Aadityaa Padmanabhan, Mobolaji Bello, Sean McGuinness

Background on DOE PV-MOD Project

- Develop vendor-independent adaptive protection (AP) designs
- Demonstrate advanced application of the new models for automated assessment and design of adaptive distribution protection schemes
- Demonstrate correct operation using simulations and lab-tests of site- and hardware-specific implementations
- Deploy and test protection schemes on various types of networks

Secondary Network Overview



NWP Microprocessor Relay

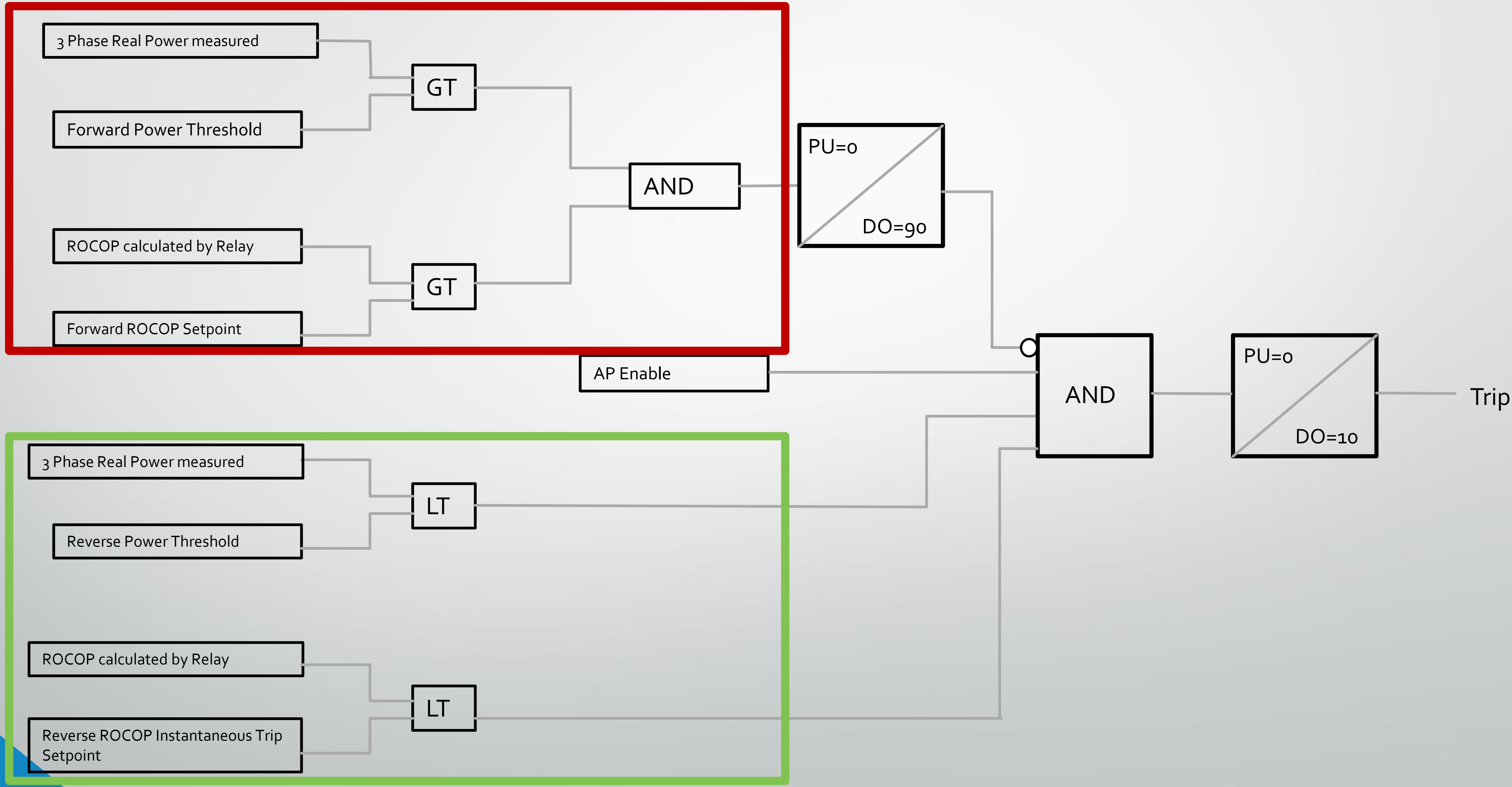
Actively monitor the system and can autonomously decide to trip or close the NWP based on existing conditions.

Secondary Network Adaptive Protection Overview

Adaptive Protection State	Reverse Flow < 50% of Rated Current	Reverse Flow > 50% of Rated Current
Disabled	Non-delayed tripping	
Enabled	Rate of Change of Power (RoCoP) Adaptive Tripping	Non-delayed tripping

- Decentralized design
- Easy to deploy
- Supplements existing protection design and logic
- Permits reverse power flow without compromising sensitivity to faults
  - Does not trip when cumulative DER causes reverse power flow through network protector
  - Trips for all credible faults on the primary feeder
  - Blocks back-feeding onto a de-energized primary feeder

AP Logic Diagram for Secondary Meshed network

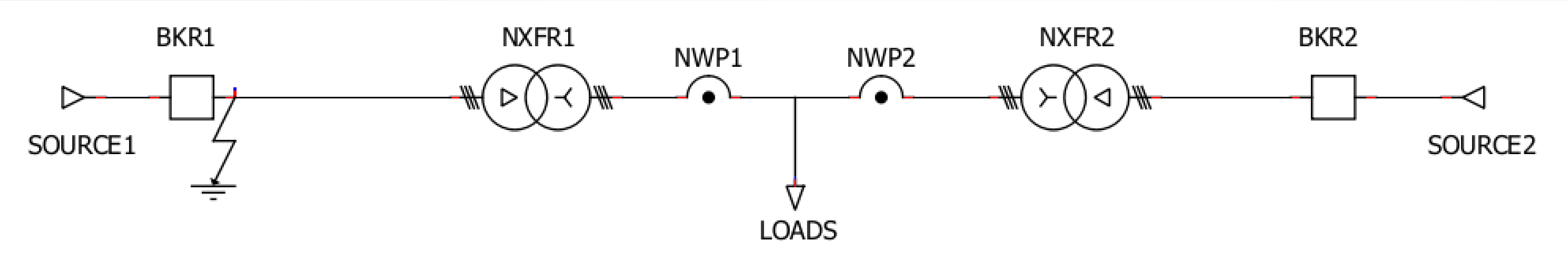


Rate of Change of Power (RoCoP) Calculation

$$RoC\ of\ Power = \frac{Power\ Flow_i\ -\ Power\ Flow_{i-1}}{Time\ Interval}$$

Power Flow_i: Most recent power flow measurement
Power Flow_i-1: Power flow measurement at previous calculation interval
Time Interval: Defined to be 100ms

Secondary Network Model for Testing

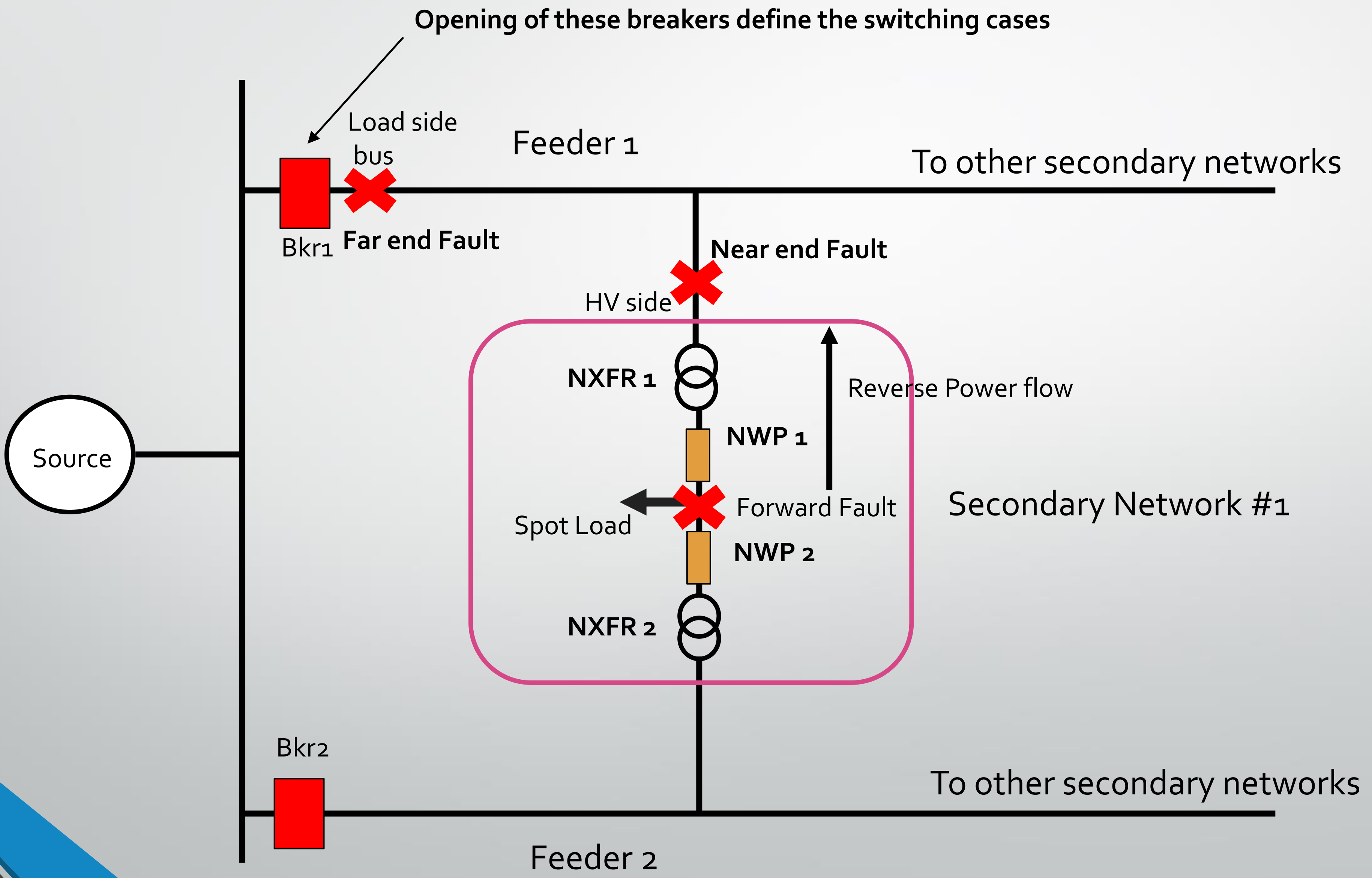


- Primary 33kV radial feeders
- Multiple 480V or 208V secondary networks supplied through delta/wye connected network transformers.
- Loads can be served by two or more network transformers
- Scenarios Considered:
  - TPH, LL, SLG faults on the primary feeder
  - Primary feeder breaker open
  - 0%, 100%, and 200% DER penetration

Phasor Domain & EMT Simulations

- **Switching cases** (which contains power flows) with primary breaker open.
- 3 major categories of fault locations were considered for these simulations.
  - Feeder head faults at the load side bus of the primary breaker (hereafter named as **Far end faults**).
  - Network transformer primary bushing faults (at the HV side bus) (hereafter named as **Near end faults**).
  - Secondary network faults at the load point inside the secondary network (hereafter named as **Forward faults**)

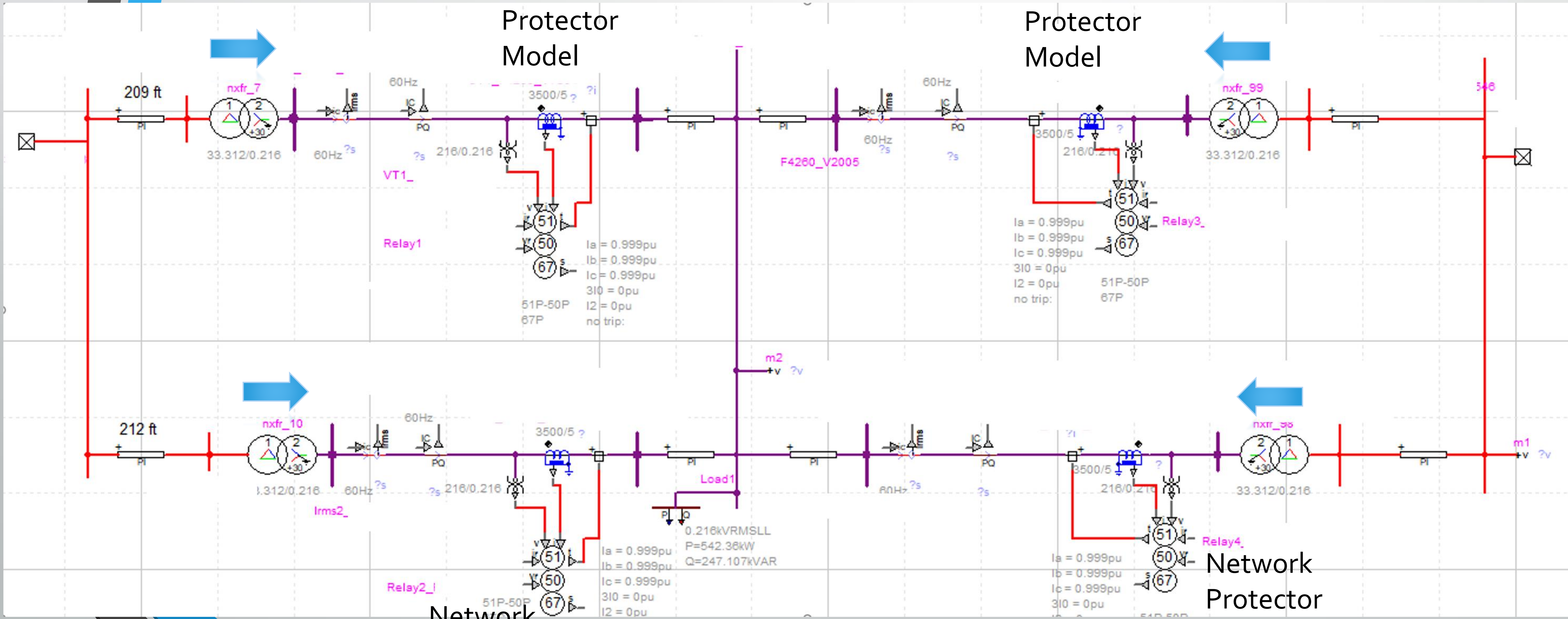
SLD view


Opening of these breakers define the switching cases
Load side bus
Feeder 1
To other secondary networks
Bkr1
Far end Fault
Near end Fault
HV side
NXFR 1
Reverse Power flow
NWP 1
Source
Spot Load
Forward Fault
Secondary Network #1
NWP 2
NXFR 2
Bkr2
To other secondary networks
Feeder 2

EMT Simulations – Secondary Network Model

Network Protector Model

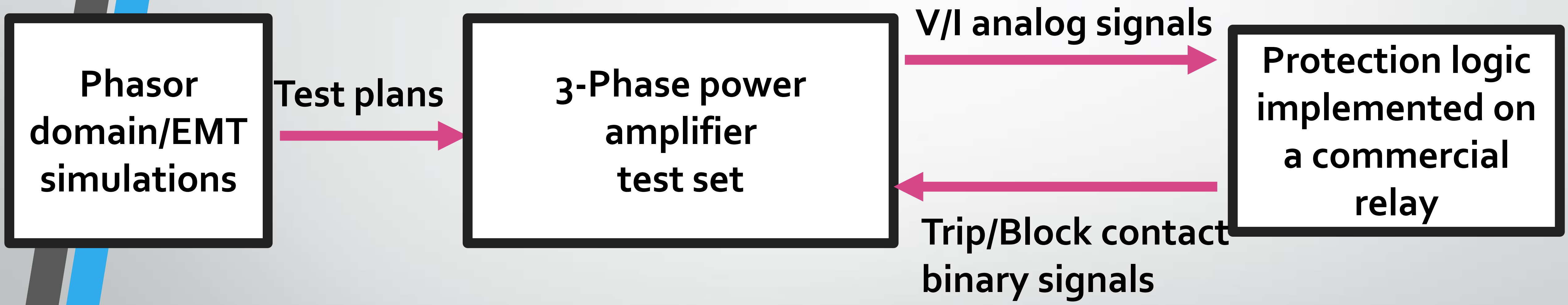
Network Protector Model



Network Protector Model

Network Protector Model

Block Diagram for Test Bench Setup



Test Plan Document Example

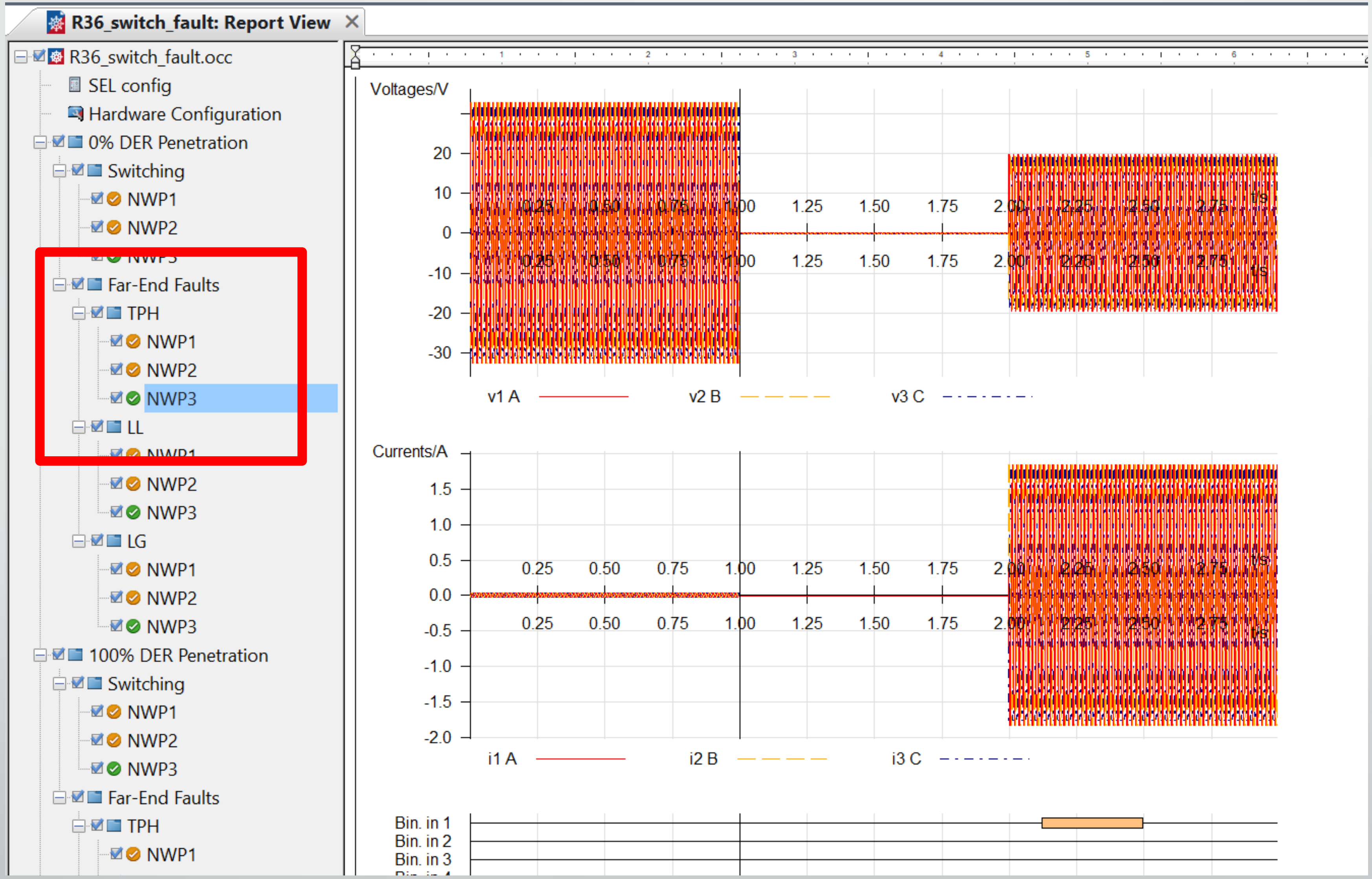


Fig: Snippet of a sample test plan document

Example Test Cases

- Near end faults/switching cases pertaining to NWP1 location with 0% and 200% DER

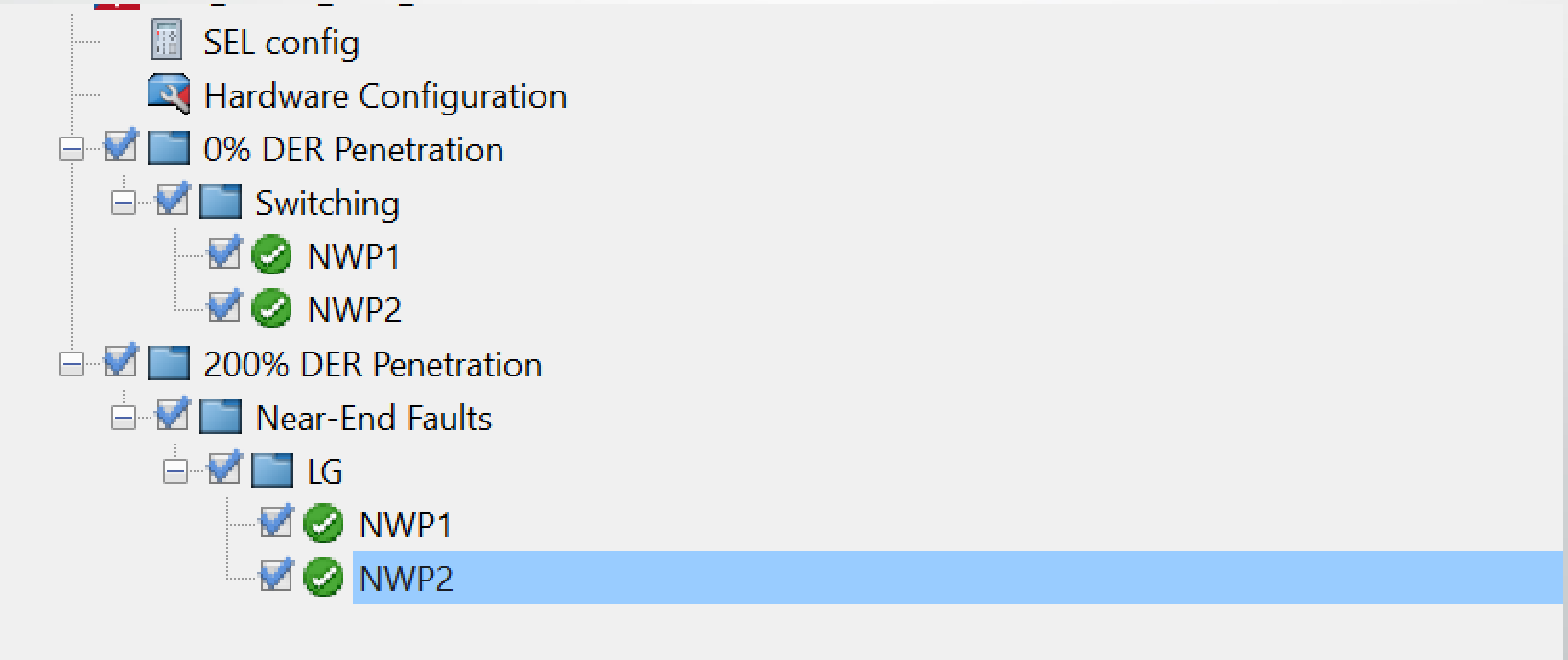
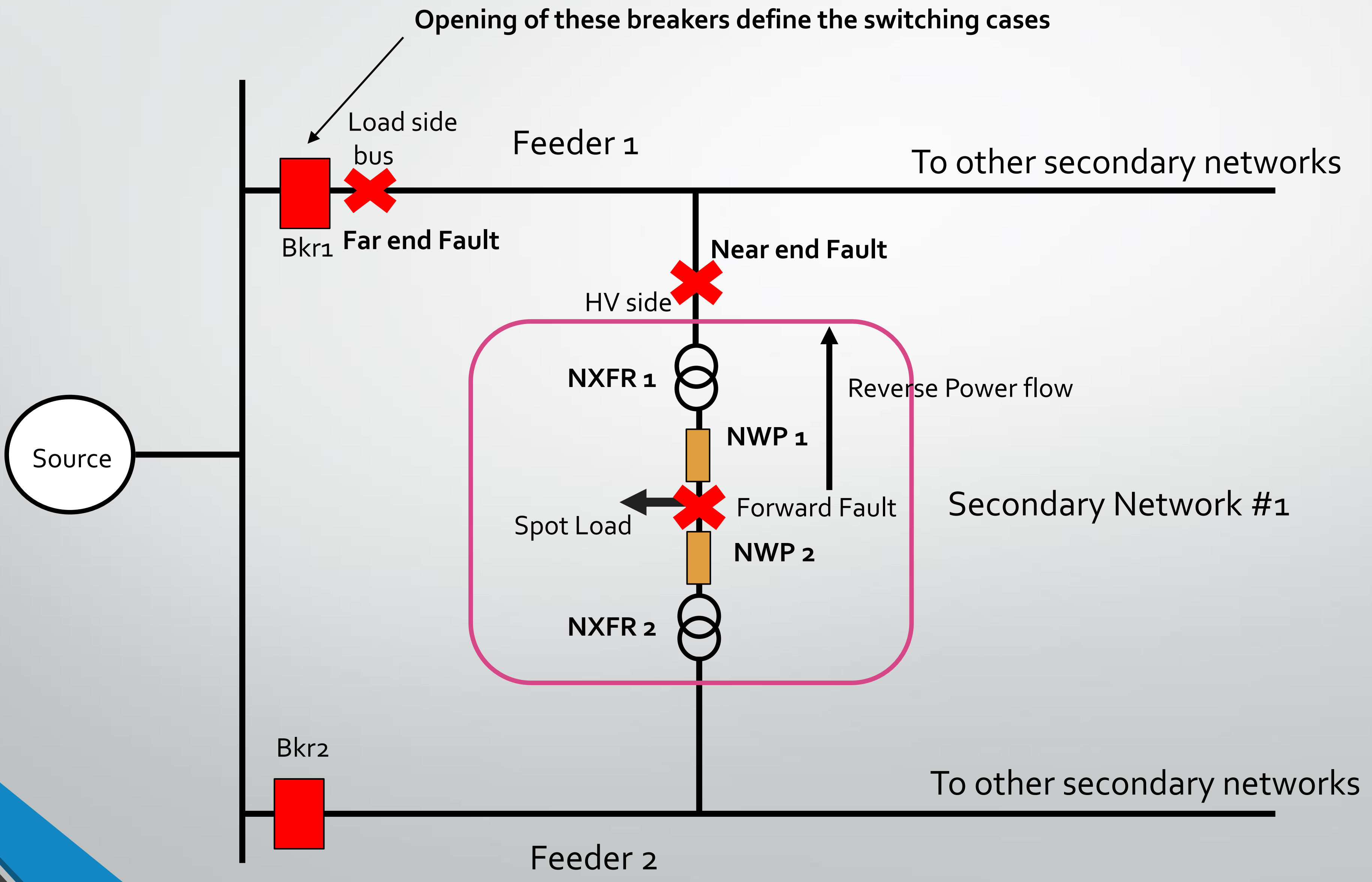


Fig: Snippet of the test plan document for NWP1 location scenarios

SLD view



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Far end Fault
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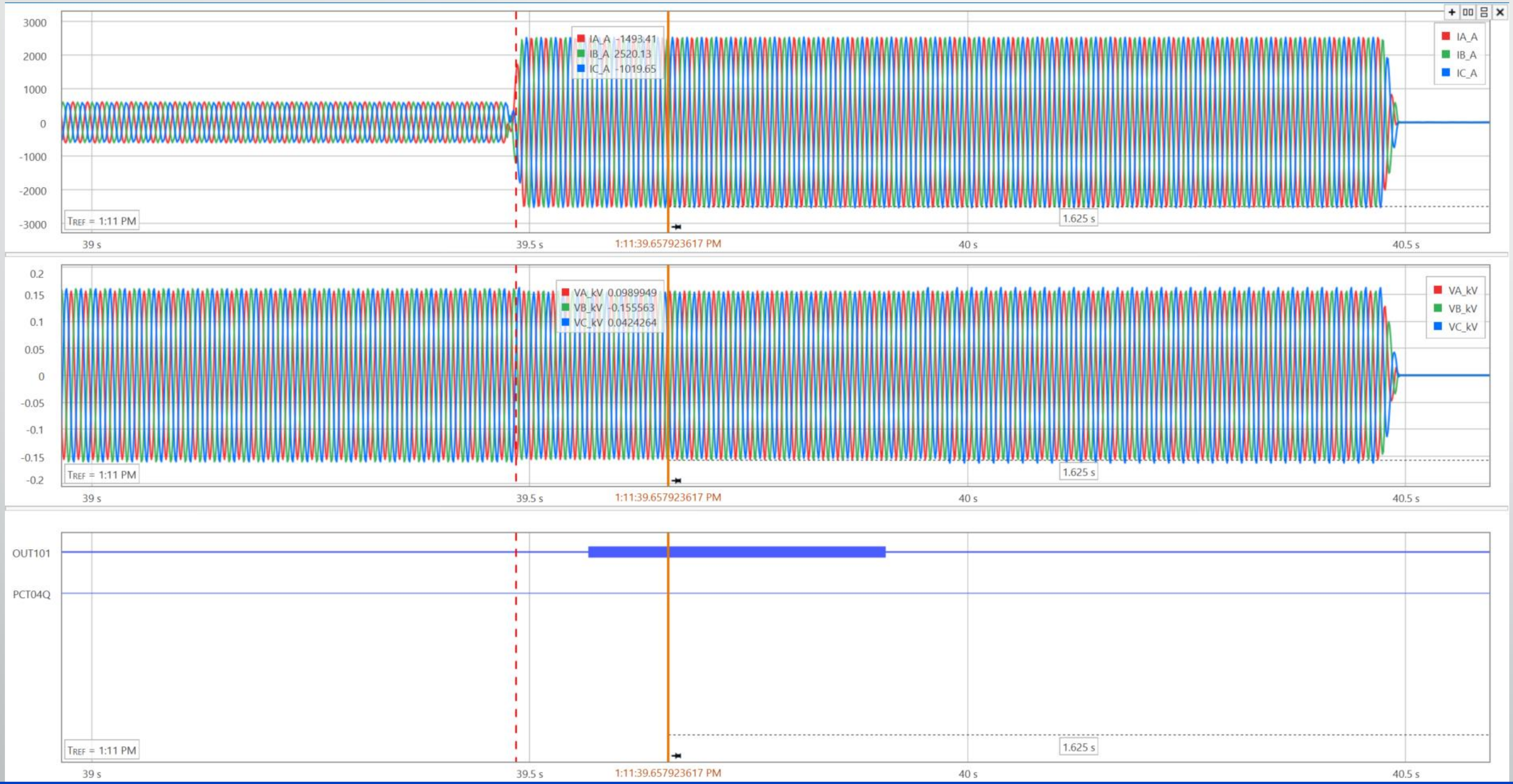
HV side
NXFR 1
Reverse Power flow
NWP 1
Source
Spot Load
Forward Fault
Secondary Network #1
NWP 2
NXFR 2
Bkr2
To other secondary networks
Feeder 2

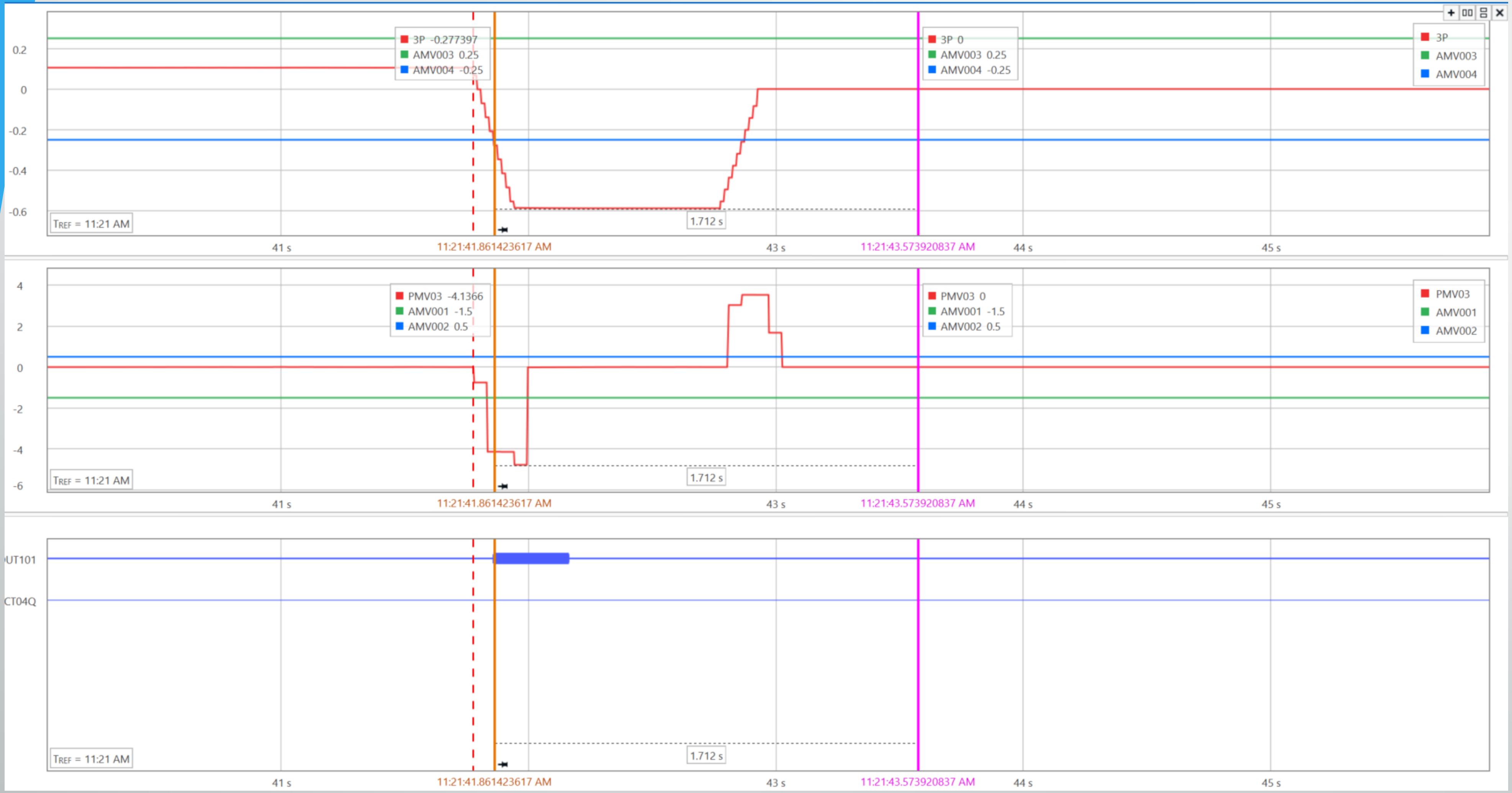
Example #1

- Switching case (NWP1 location) pertaining to NWP1 measurements with 0% DER



Successful Trip

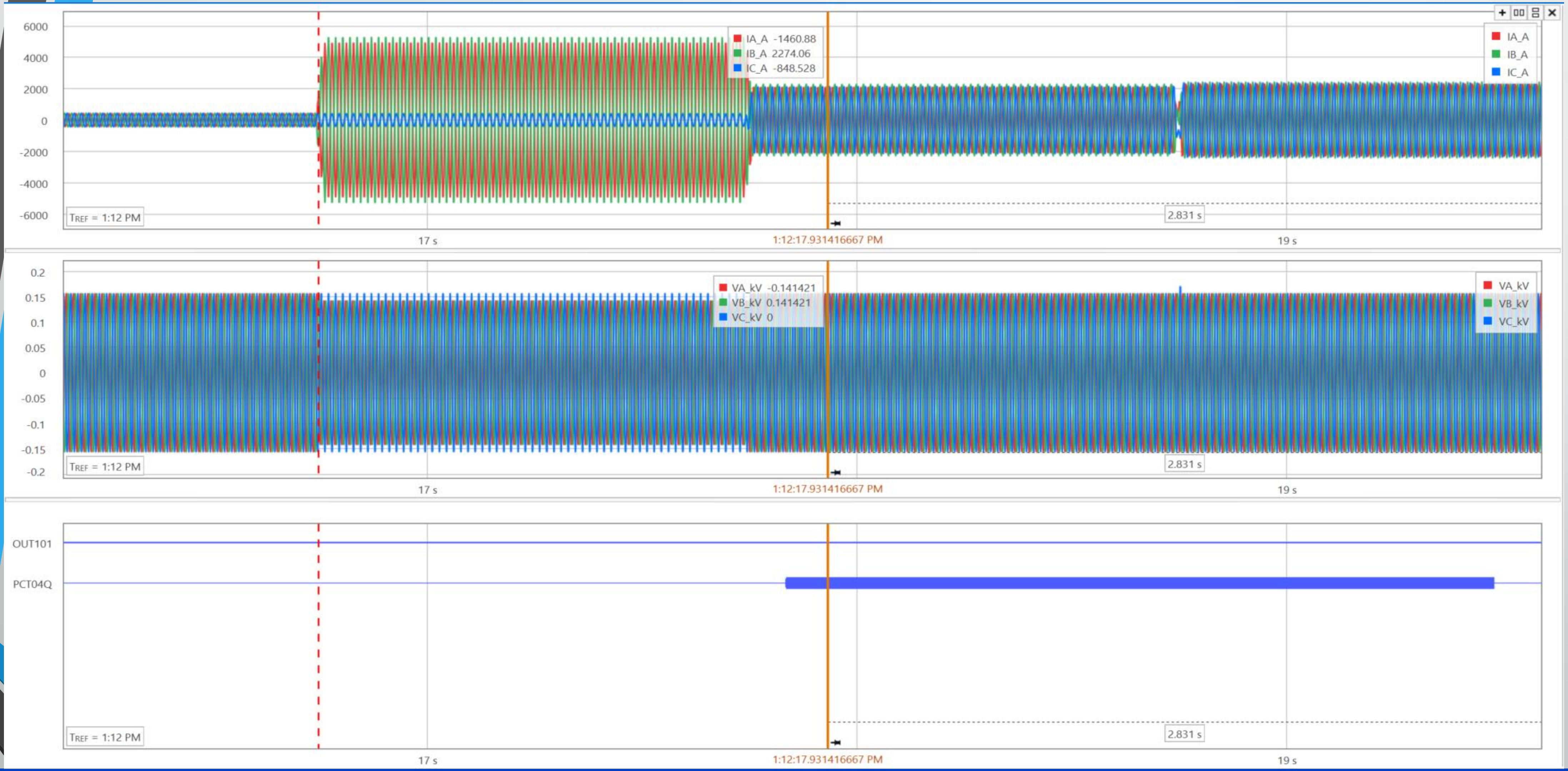
Example #1



Successful Trip

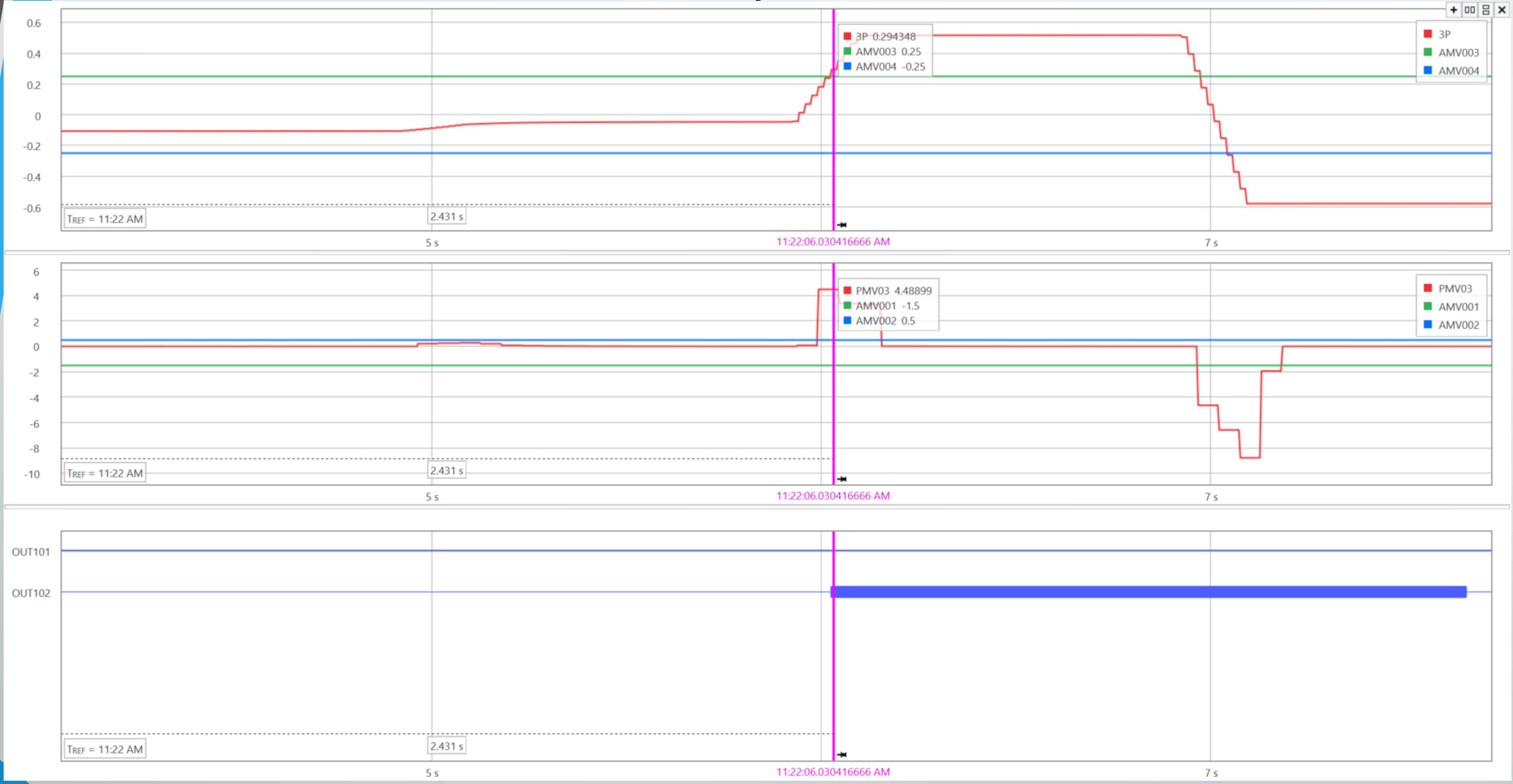
Example #2

- LG near end fault case (NWP1 location) pertaining to NWP2 measurements with 200% DER



Successful Block

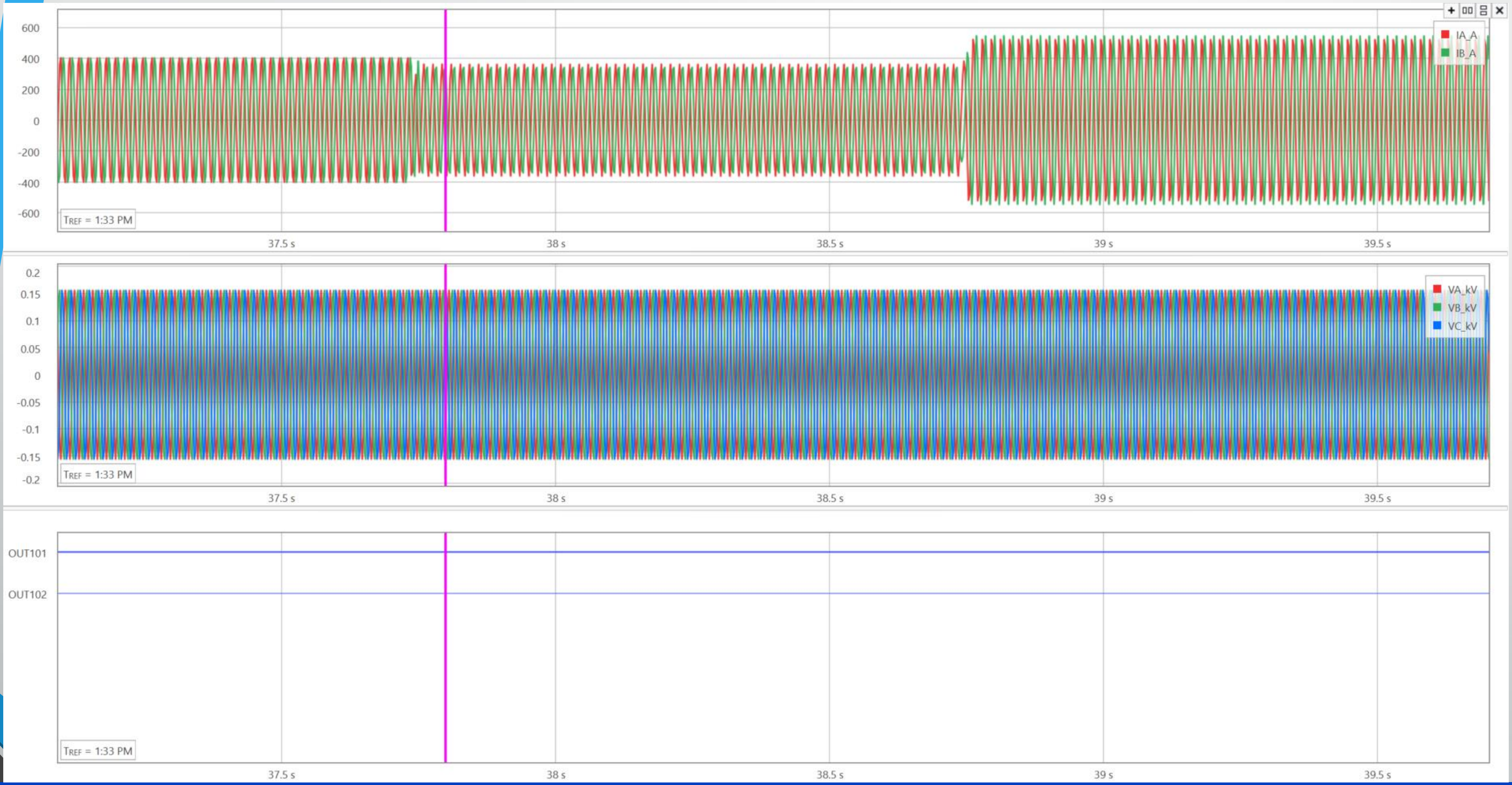
Example #2



Successful Block

Example #3

Switching case(NWP4 location) pertaining to NWP5 measurements with 200% DER



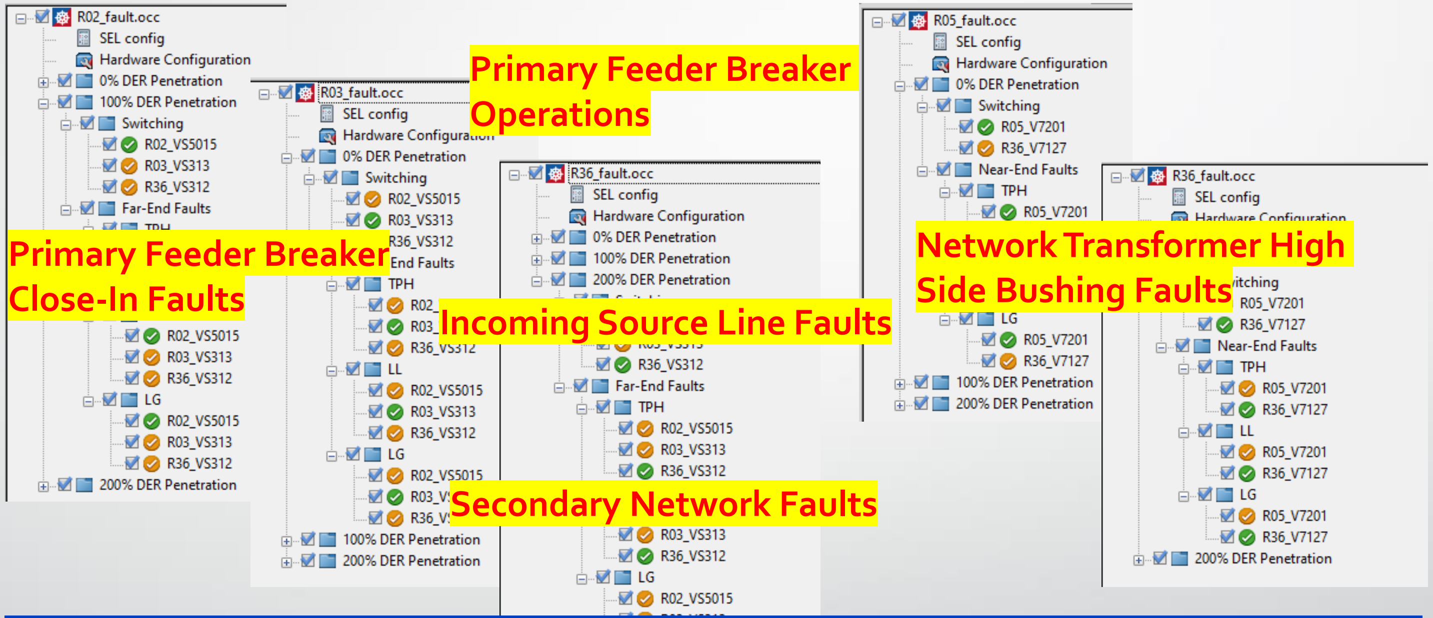
Successful operation

Example #3

Successful operation

Adaptive Protection Lab Testing

Over 100+ scenarios tested using 200+ COMTRADE files



Over 200 test cases for multiple secondary networks

Key Conclusions

- Testing shows satisfactory performance for up to 200% penetration
- Blocking and tripping schemes work in conjunction to allow steady state reverse power flow through the network protector
- Forward and reverse power thresholds should be determined based on the network transformer size and the number of network protectors that are part of the secondary network

Next Steps

- Working with network protector manufacturer to implement logic
  - Lab testing in progress
- Trial scheme with utility partner
- Other field demonstrations

Thank You

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Questions?