RTDS Tests For Utility Protection Standards Development

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RTDS Tests for Utility Protection Standards Development

- Background of the project
- Utility Protection Standards
- RTDS Test Platform
- Test Target
- Simulation Data Management and Automation
- Test Case Examples
- Project Summary
- RTDS and P&C engineering

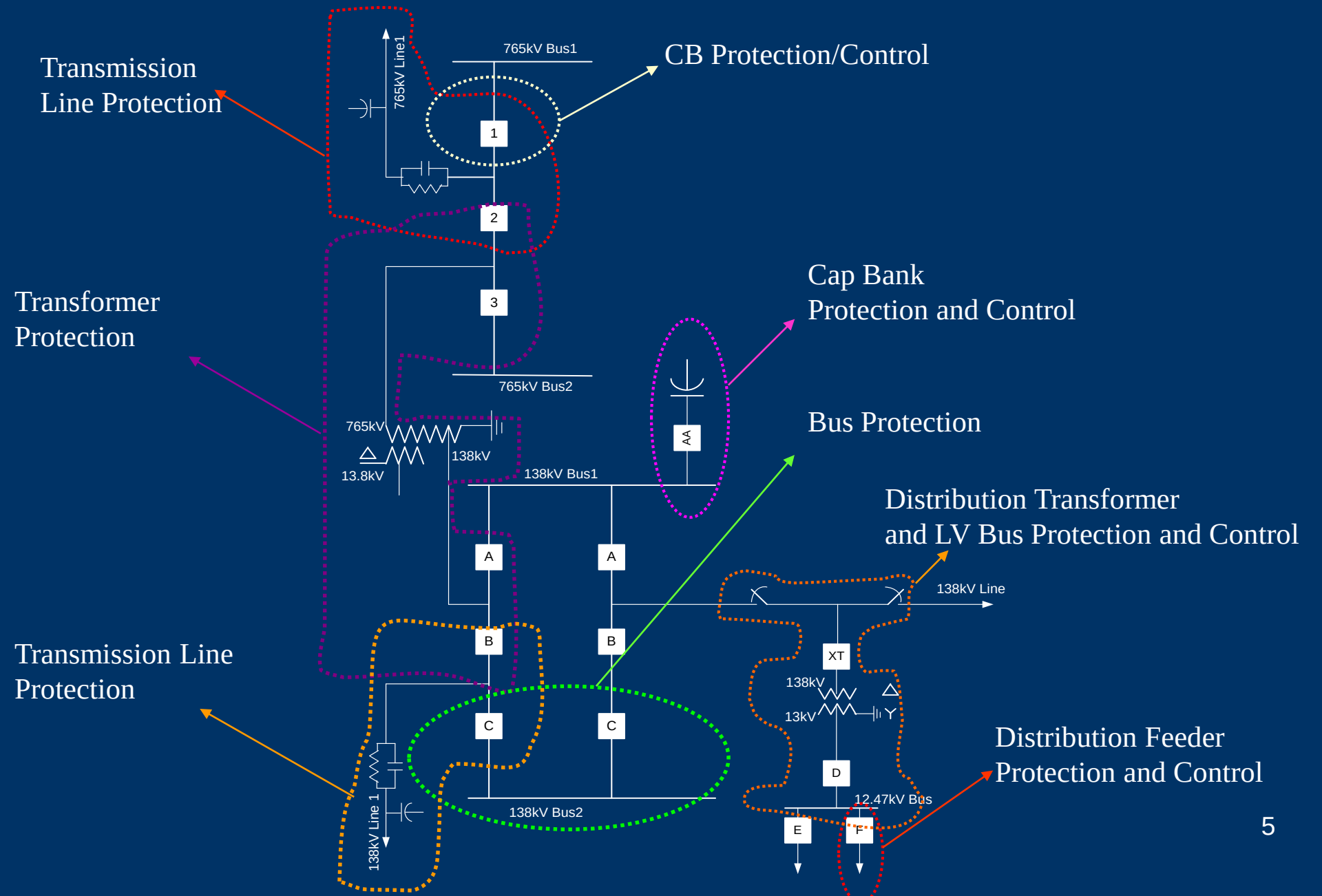
ElectraNet : Owner and Operator of South Australia High-voltage Transmission Network

Source: www.electranet.com.au

Benefit and Goal of Protection Standards

- Enhance reliability and safety
- Provide fit-for-purpose technical solutions
- Improve design efficiency and quality
- Reduce life-cycle cost
- Ensure compliance to regulations
- Provide sustainable solutions

Typical Protection Standards



Protection Standards Content

A Set of Standard Includes:

- Functional Specifications
- Drawing Templates (Front View, Schematic, Wiring, etc.)
- Relay Setting Templates
- Design Guide
- Setting Guide (includes logic diagram)
- Suite of Inspection and Test Plans (ITPs)
- Training Material

Protection Standards Development Process

Function Specifications (Preliminary Design)

Hardware Selection

Setting Templates

Validation Test

Schematics, Design Guideline Documents

Training

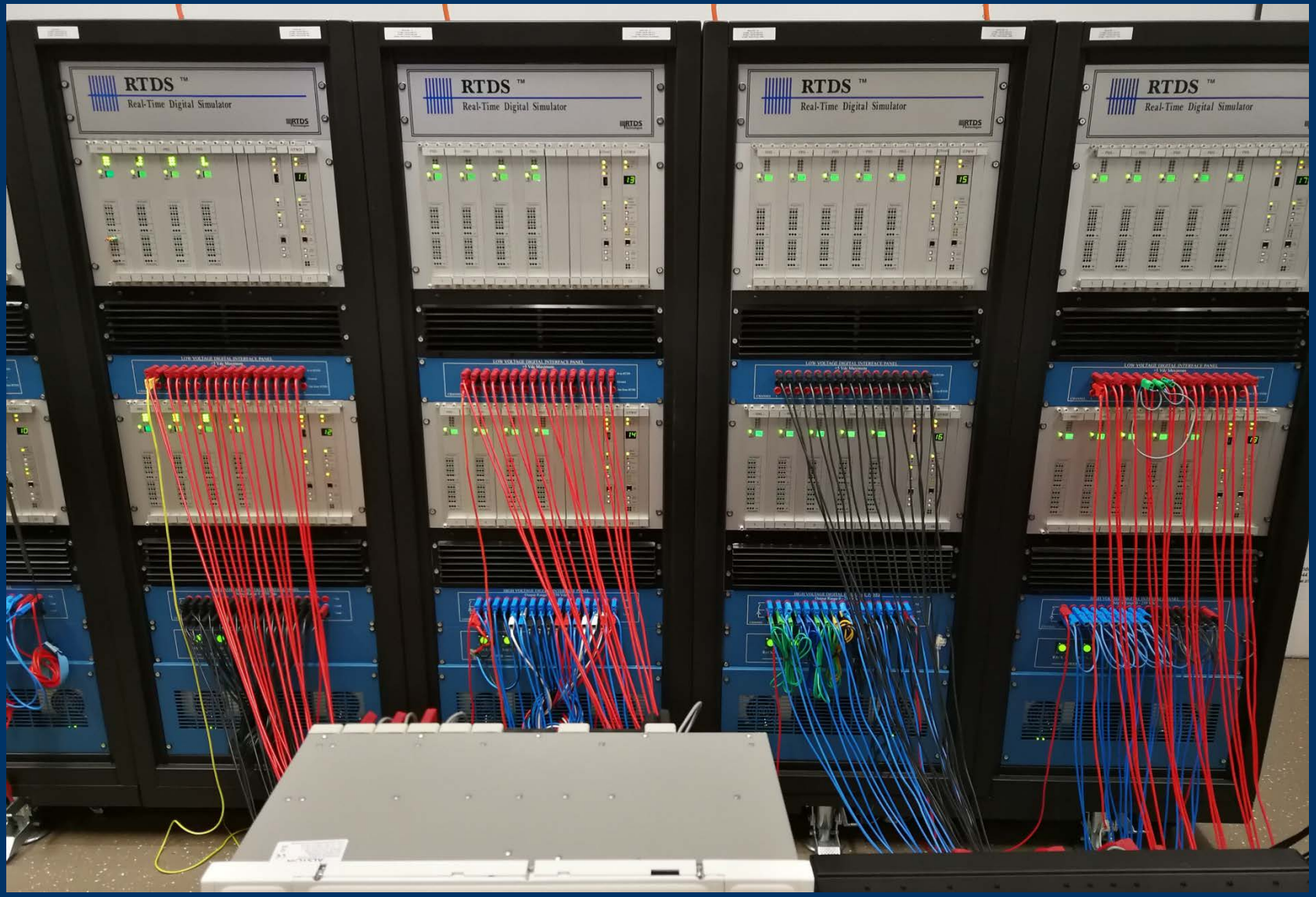
Challenges for Line Protection Standards

- Line protection exposed to more faults and has more variations
- Mis-operation can lead to significant impact to electricity network
- P&C design and settings need to consider worst scenario under different operation conditions
- Line relays include comprehensive protection and control logic
  - Relay internal protection logic
  - Customized logic
- Standard design needs to be
  - Impeccable for different applications
  - Optimized for default settings
- Provide guidance for relay engineers and technicians
- Generally, it takes many years of utility operation experience to develop fit-for-purpose line protection standards

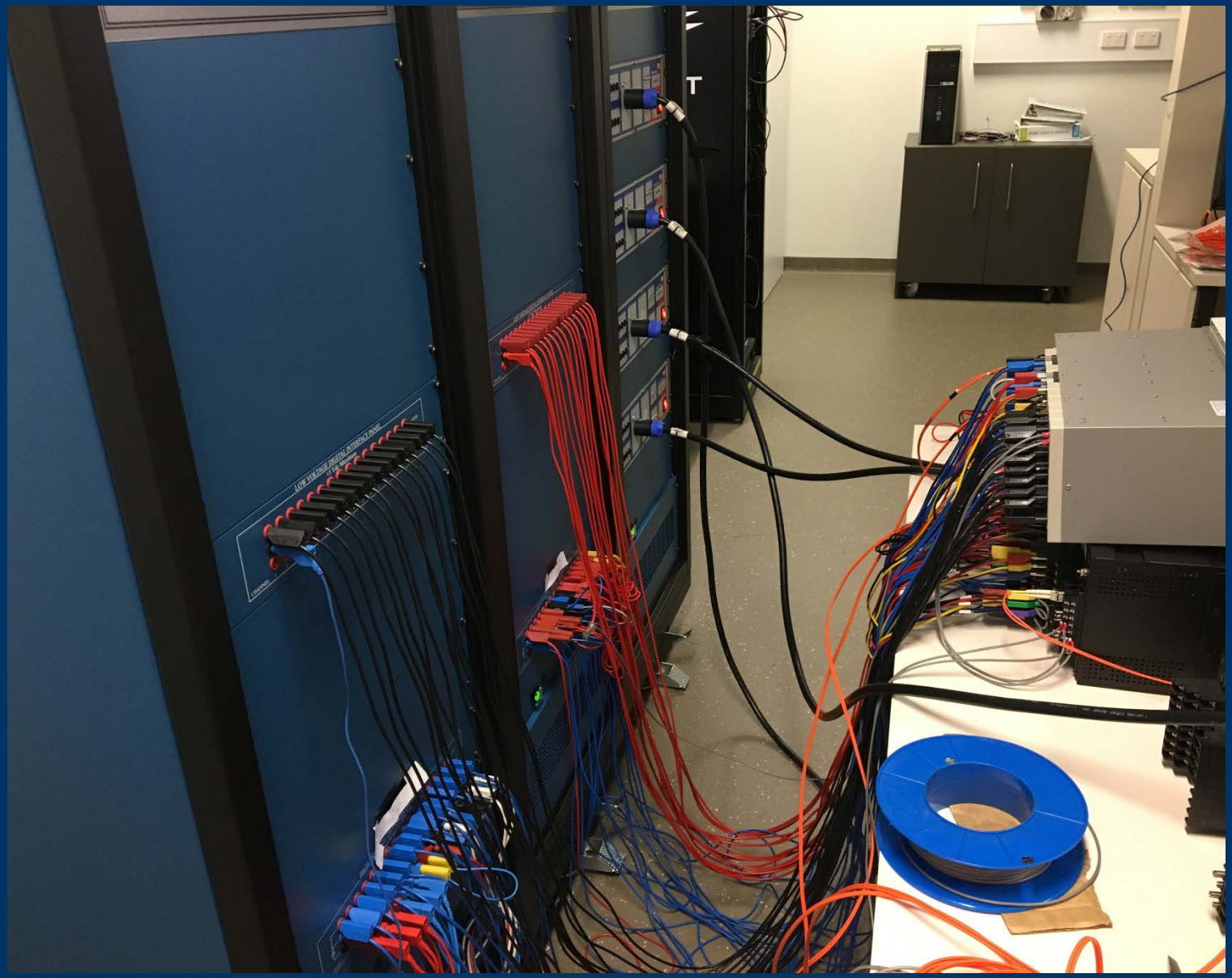
ElectraNet Line Protection Standard Specifics

- 87L or DCB
- 2-terminal lines and 3-terminal lines
- Double-circuit lines
- Weak source and fault detection
- High impedance ground faults
- 1-pole reclosing and 3-pole reclosing initiation
- 1-pole and 3-pole breaker failure
- Transfer trip and inter-tripping logic
- Trip test logic for maintenance activities
- Power swing detection and blocking
- Load encroachment
- Different setting groups

RTDS Test Platform -1

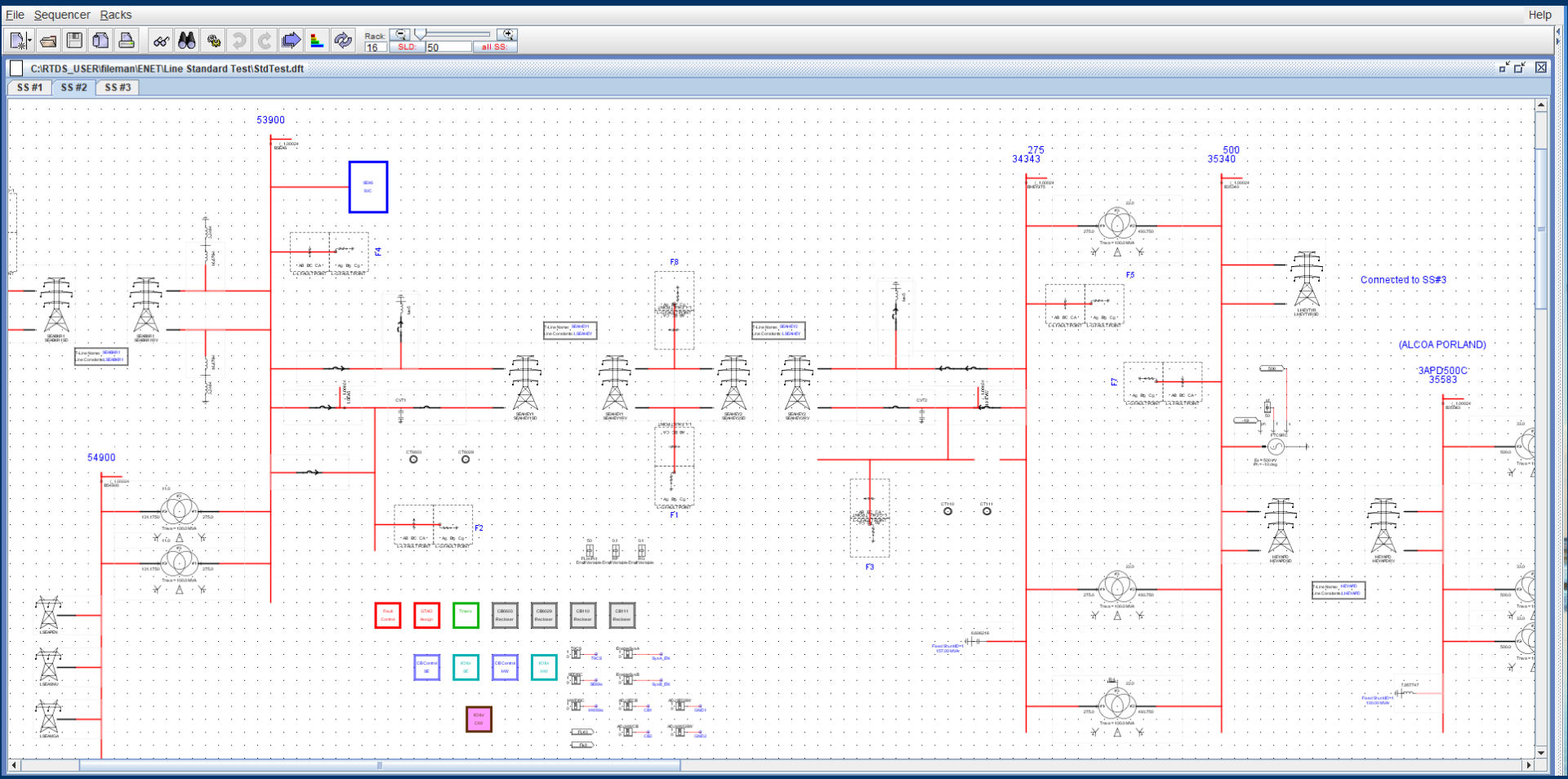


RTDS Test Platform -2



Simulated System

- Transmission system Model



Relays and Protection Functions

Relays:

- Line Protection System Set 1
- Line protection System Set 2
- Auto-reclosing and Synch-check device

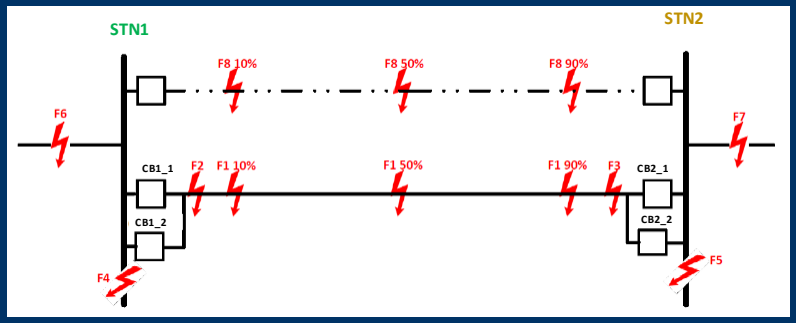
Protection and Control Functions :

- Communication-aided Schemes: 87L (2-terminal, 3-terminal), DCB (2-terminal)
- Phase Distance and Ground Distance
- Power Swing Block
- Backup Phase Overcurrent
- Backup Ground Overcurrent
- Switch-Onto-Fault
- Breaker Failure and Direct Transfer Trip
- Auto-reclosing 1-pole and 3-pole

Simulation Plan

Fault Types

- 1LG, LL, 2LG, 3LG, high impedance 1LG
- Cross country faults
- Evolving faults
- Variable fault inception angle
- Variable fault duration



System Conditions / Contingencies

- Parallel line out of service and grounded
- Weak source
- VT fuse failure
- 1-pole or 3-pole trip / auto-reclosing mode
- CB failure 1-pole or 3-pole
- Pilot scheme failure
- etc.

Simulation Data Management and Automation

- Use Excel to automate simulations and manage test results
- Use VBA to organize fault data, pass to Runtime Script
- Runtime Script perform switching and fault simulations, get relay operating timers, pass to VBA and shown on spreadsheet

- The number of simulation cases can be one or many
- Simulation cases can be added, removed, changed during the process
- Conditions and results are recorded for every case
- Save plots in COMTRADE, file name include case number

Spreadsheet for Simulation Case Management

Update Simulation Data | From 76 | To 79 | Get Timers

Case #	Fault Loc	Flt. Loc. Pe	Int or Ext	Fault Type	Fault Duration (s)	RG (Ω)	RP	(Ω)	POW (º)	RTDS	-1	-2	A-B	setting group & condit	More simlation conidtion discription	Comments on relay operation	T1-L90 -TPA (s)	TPB (s)	TPC (s)	-CB1 ARINIT(s)	-CB1 ARBLK(s)	CB1 CBFTP(s)	T2-P546 -TPA (s)	-TPB (s)	-TPC (s)	-CB1 ARINIT(s)	-CB1 ARBLK(s)	-CB1 CBFTP(s)	T2-L90 -TPA (s)	-TP (s)
76	F1	50	Internal	CG	1	180.0	0.1	0	Auto	Man	Man	3	9T	ditto		No Op	No Op	No Op	0.03375	0.15890	0.15900	0.20250	0.20150	0.20115	No Op	0.20100	No Op	No Op	No Op
77	F1	50	Internal	BG	0.3	0.1	0.1	0	Auto	Man	Man	1	12	Zone 1 Ground fault	Zone 1 disabled, No op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op
78	F1	50	Internal	BC	0.3	0.1	0.1	0	Auto	Man	Man	1	13			No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op
79	F4	50	External	BC	0.6	0.1	0.1	0	Auto	Man	Man	1	15T	87L comm off		0.43210	0.43185	0.43195	No Op	0.43190	No Op	0.42590	0.42570	0.42545	No Op	0.42590	No Op	No Op	No Op
80	F4	50	External	CG	0.6	0.1	0.1	0	Auto	Man	Man	1	14	Parallel line is in service, 87L comm off		No Op	No Op	No Op	No Op	No Op	No Op	0.46810	0.46865	0.46805	No Op	0.46880	No Op	No Op	No Op
81	F4	50	External	CG	0.6	0.1	0.1	0	Auto	Man	Man	2	14	Parallel line in service, 87L comm off	1 did not op, boundary fault due to mutual coupling														
82	F4	50	External	CG	0.6	0.1	0.1	0	Auto	Man	Man	2	14	Parallel line not in service, 87L comm off	1 C-ph op. No DIT	0.43880	0.43880	0.43875	No Op	0.43860	No Op	No Op	No Op	No Op	No Op	0.43765	No Op	No Op	No Op
83	F4	50	External	BC	0.6	0.1	0.1	0	Auto	Man	Man	1	15T	Parallel line not in service, 87L comm in	1 and 2 op ok. DIT ok														
84	F4	50	External	CG	0.6	0.1	0.1	0	Auto	Man	Man	3	14	87L comm in service, parallel line in serv	2 op ok. DIT trip SE terminal	No Op	No Op	No Op	No Op	No Op	No Op	0.46855	0.46835	0.46835	No Op	0.46875	No Op	No Op	No Op
85	F4	50	External	CG	0.6	0.1	0.1	0	Auto	Man	Man	2	14	87L comm in service, parallel line not in	1 op ok. DIT trip SE terminal	0.44065	0.44070	0.44050	No Op	0.44055	No Op	No Op	No Op	No Op	No Op	0.44160	No Op	0.45035	0.4503
86	F6	50	External	CG	1.2	0.1	0.1	0	Auto	Man	Man	2	16	87L comm in service, parallel line in	1 did not op														
87	F6	50	External	CG	1.2	0.1	0.1	0	Auto	Man	Man	2	16	87L comm in service, parallel line out	1 Z3G did not pickup?	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	1.04905	1.17225	No Op	No Op
88	F6	50	External	CG	1.2	0.1	0.1	0	Auto	Man	Man	2	16	87L comm in service, parallel line out. L90 Quad to MHO	1 Z3G did not pickup?	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	1.04950	1.17210	No Op	No Op
89	F6	50	External	CG	1.2	0.1	0.1	0	Auto	Man	Man	2	16	Ditto. 1 Quad to MHO, Force Self Polarizing	1 Z3G did not pickup?														
90	F7	50	External	CG	1.2	0.1	0.1	0	Auto	Man	Man	2	17	Test 1 Z3P. Did twice with parallel line in/out	If Parallel out, Z2G op. if parallel in, Z3G op	1.04725	1.04725	1.04715	No Op	1.04715	No Op	No Op	No Op	No Op	No Op	1.04515	No Op	1.03430	1.0345
91	F7	50	External	BC	1.2	0.1	0.1	0	Auto	Man	Man	2	17	Test 1 Z3P	1 Z3P at SE op. DIT trip HW,	1.04455	1.04445	1.04440	No Op	1.04435	No Op	No Op	No Op	No Op	No Op	1.03865	No Op	1.03180	1.0315
92	F7	50	External	CG	1.2	0.1	0.1	0	Auto	Man	Man	3	16	Test 2 Z3G	2 Z3G at SE op.	No Op	No Op	No Op	No Op	1.05095	No Op	1.04270	1.04250	1.04225	No Op	1.04310	No Op	No Op	No Op
93	F7	50	External	BC	1.2	0.1	0.1	0	Auto	Man	Man	3	17	Test 2 Z3P	2 Z3P at SE op.	No Op	No Op	No Op	No Op	1.04890	No Op	1.04115	1.04045	1.04065	No Op	1.04090	No Op	No Op	No Op
94	F7	50	External	CG	1	0.1	0.1	0	Auto	Man	Man	2	18	PT fuse failure, check backup GTOC															
95	F5	50	External	CG	1	0.1	0.1	0	Auto	Man	Man	1	18	PT fuse failure, check backup GTOC	P546 GTOC trip at SE, DIT to HW. 1 GTOC trip at SE, no DIT, change logic														
96	F5	50	External	CG	1	0.1	0.1	0	Auto	Man	Man	3	18	PT fuse failure, check backup GTOC	P546 GTOC trip at SE, DIT to HW	No Op	No Op	No Op	No Op	0.57065	No Op	0.56695	0.56685	0.56650	No Op	0.56700	No Op	No Op	No Op
97	F5	50	External	CG	1	0.1	0.1	0	Auto	Man	Man	2	18	PT fuse failure, check backup GTOC	1 GTOC trip at SE, DIT to HW														
98	F5	50	External	AB	1	0.1	0.1	0	Auto	Man	Man	2	19	PT fuse failure, check backup PTOC	1 PTOC pickup 1.0pu, op	0.58995	0.58995	0.58985	No Op	0.58985	No Op	No Op	No Op	No Op	No Op	No Op	No Op	0.57215	0.5722
99	F5	50	External	AB	1	0.1	0.1	0	Auto	Man	Man	3	19	PT fuse failure, check backup PTOC	P546 PTOC pickup 0.8pu, op														
100	F5	50	External	AB	1	0.1	0.1	0	Auto	Man	Man	1	19	PT fuse NOT failure, check backup PTOC by reducing op time to 0.1s	Trip by Z2P, not by PT fuse failure	0.45295	0.45305	0.45285	No Op	0.45265	No Op	0.43830	0.43795	0.43810	No Op	0.43790	No Op	0.43520	0.4351
101	F2	50	Internal	AG	1	0.1	0.1	0	Auto	Man	Man	1	24	SE Disconnector open, check stub protection	P546 fast trip, since it uses 87L	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op
102	F2	50	Internal	AG	1	0.1	0.1	0	Auto	Man	Man	2	24	SE Disconnector open, check stub protection	1 tripped with delay	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	0.37205	0.3723
103	F2	50	Internal	BC	1	0.1	0.1	0	Auto	Man	Man	3	24	SE Disconnector open, check stub protection	2 fast trip	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op	No Op

Case0002,171218,113445,RTDS.dat	12/18/2017 11:34 ...	dat Relay Event file	535 KB
Case0002,171218,120409,RTDS.cfg	12/18/2017 12:04 ...	cfg Relay Event file	3 KB
Case0002,171218,120409,RTDS.dat	12/18/2017 12:04 ...	dat Relay Event file	534 KB
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Case0006,171218,130351,RTDS.cfg	12/18/2017 1:03 PM	cfg Relay Event file	3 KB
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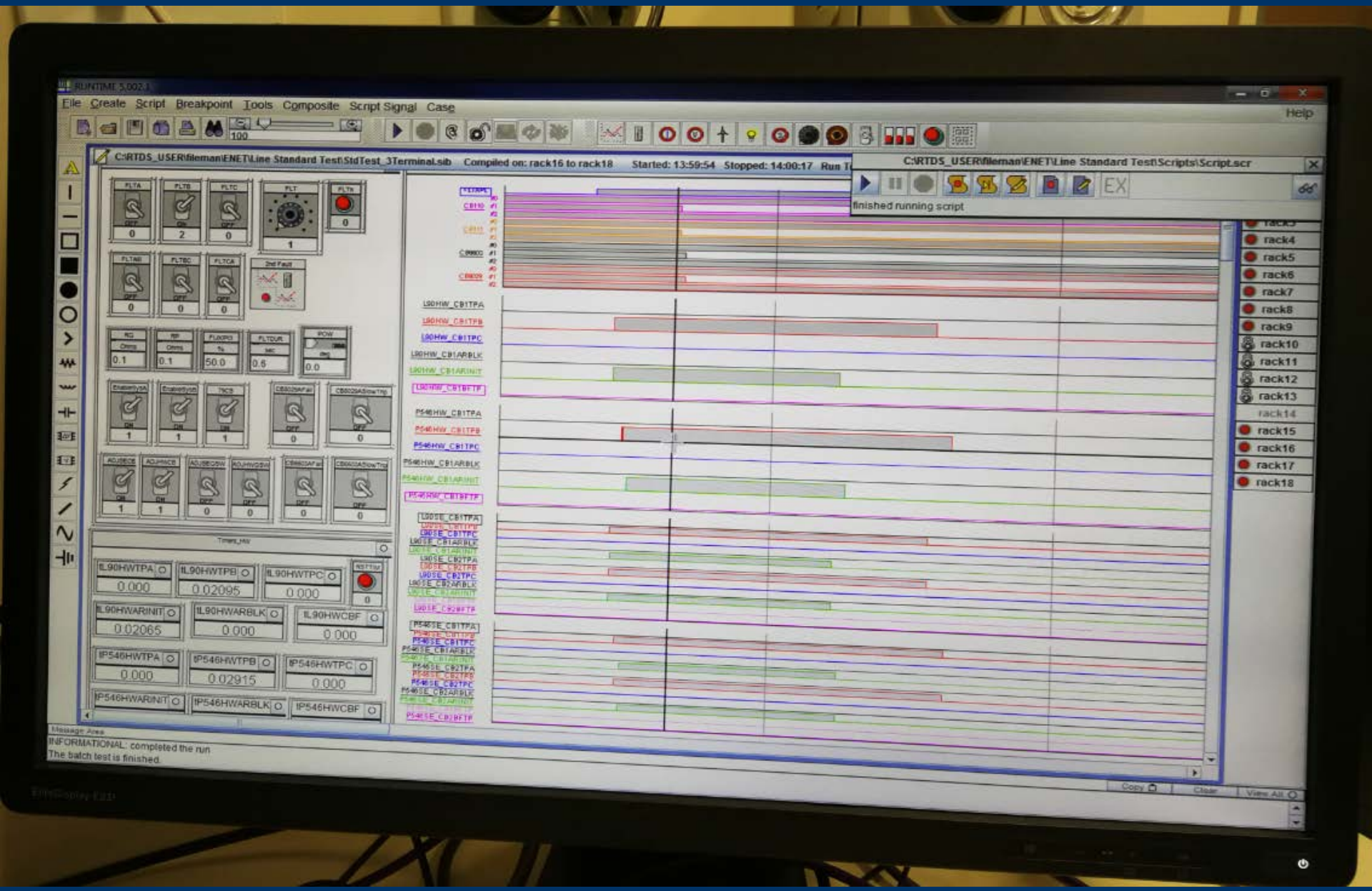
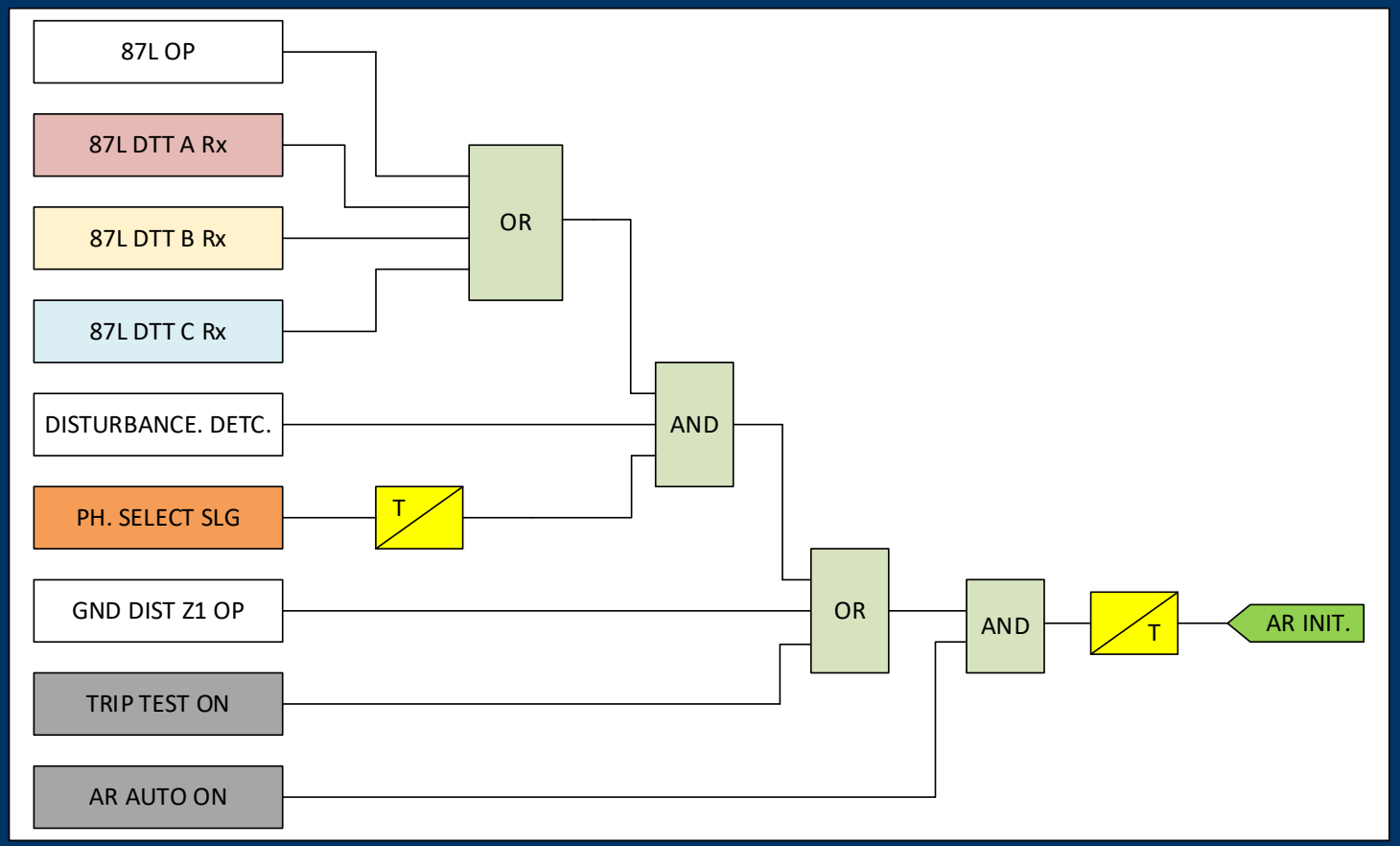
RSCAD Runtime & Script



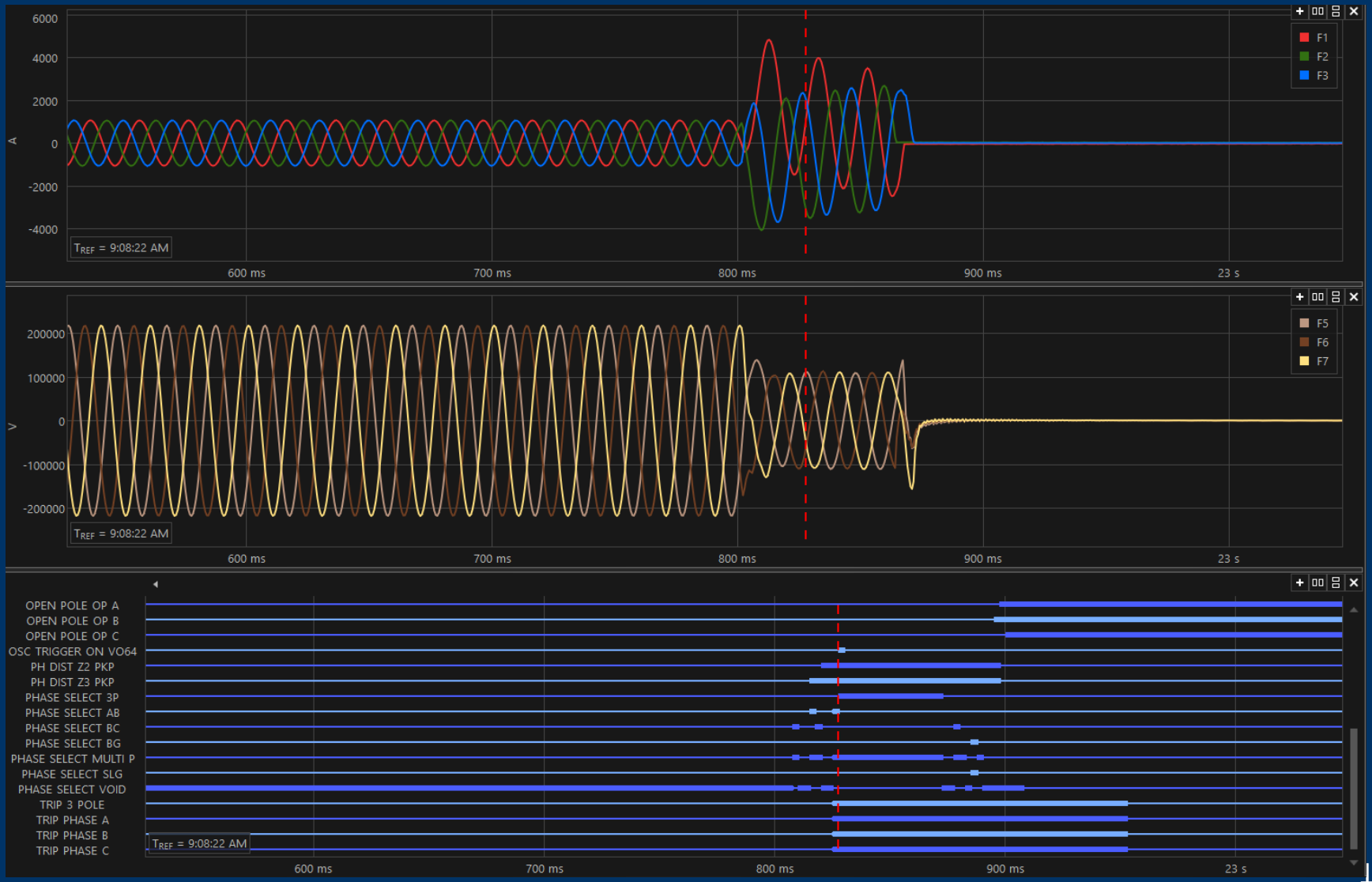
Test Case : False AutoReclosing (AR) Initiation

- Trip / AR can be “1 Pole & 3-Pole” mode or “3-Pole only”
  - 1-Pole & 3-pole Mode: Trip 1-pole for 1LG fault, one shot reclosing; Trip 3 pole for LL, 2LG, 3LG faults, no reclosing allowed.
- 1-Pole AR initiated by 87L OP, 87L DTT A Rx (or B, C), GND DIST Z1 OP
- Faulty Phase Selector is critical to 1-Pole AR



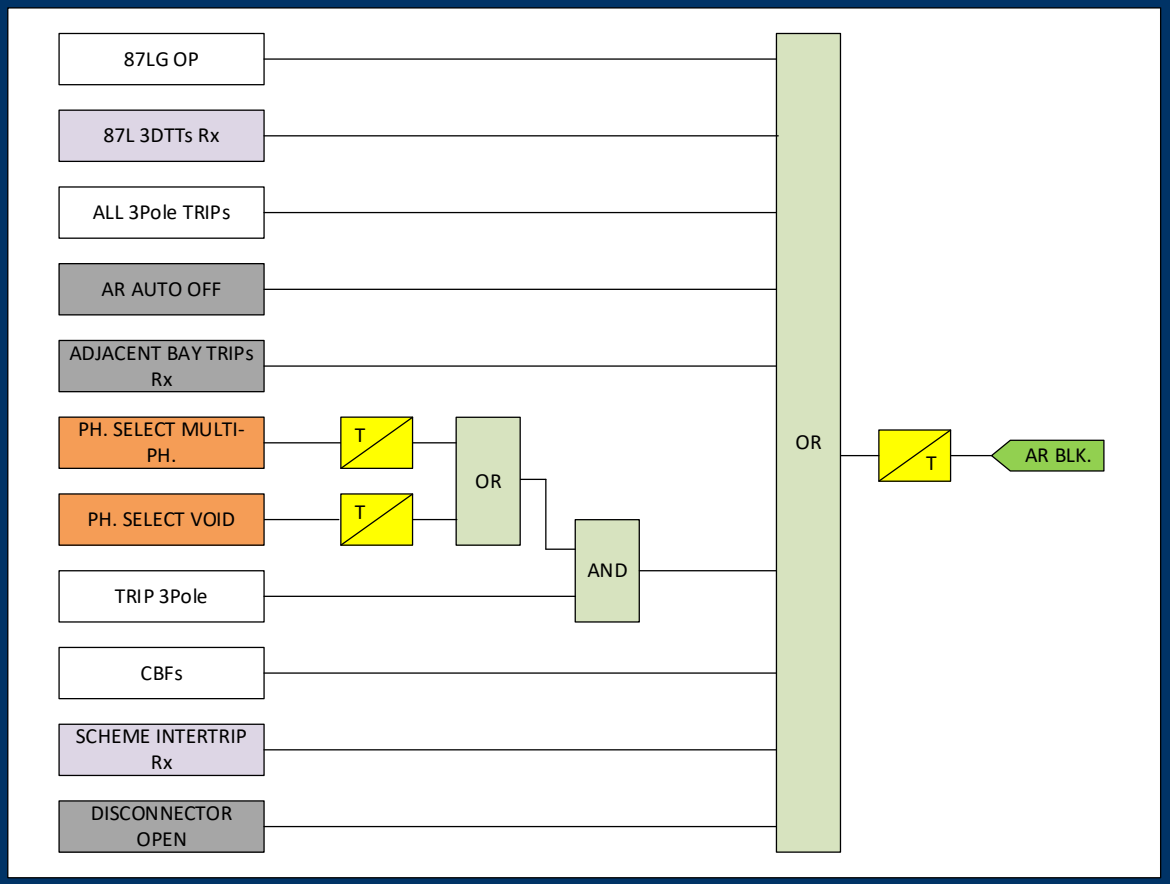
Case Study: Phase Selector Issue

PH. SELECT SLG was asserted after clearance of 3LG fault



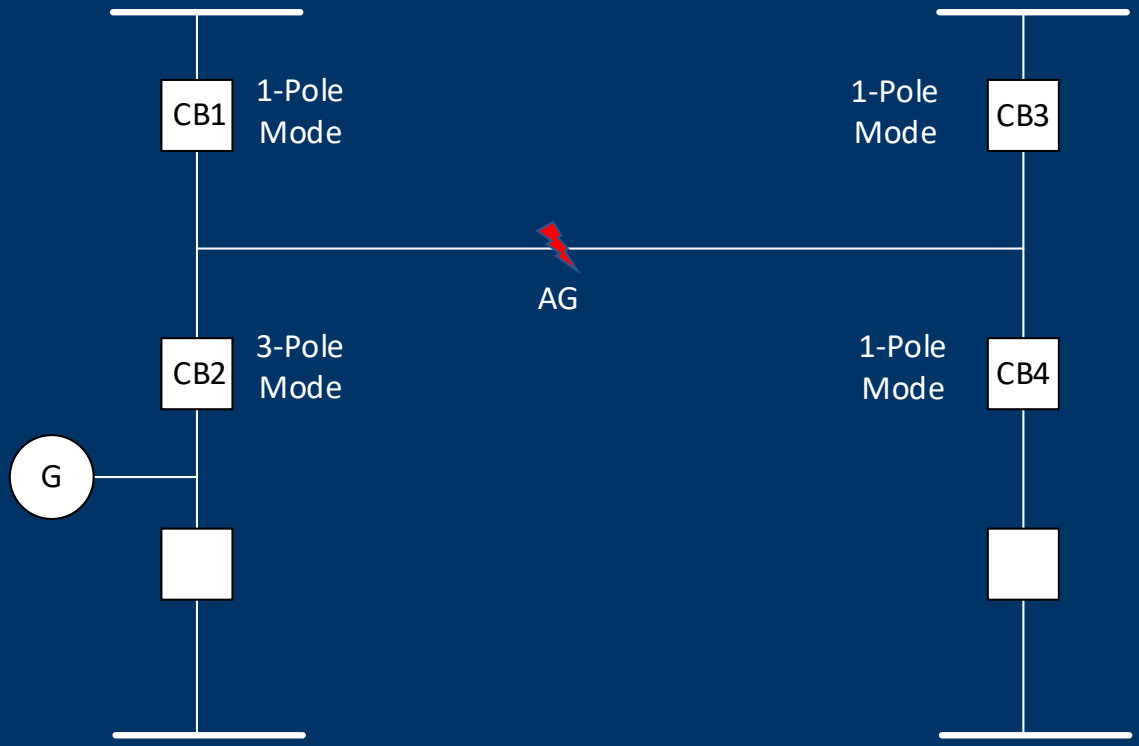
Test Case : Avoid unnecessary AR Blocking

- For “3-Pole Only” mode, tripping is 3-pole. AR should be initiated for 1LG fault and blocked for multi-phase fault
- Per RTDS simulation, Relay A may assert PH. SELECT MULTI-PH. or PH. SELECT VOID after CB is opened, due to non-simultaneous opening of the 3 poles or the three currents did not extinguish at the same time.
- Solution: Add timers for AR blocking, verify timers by RTDS simulations



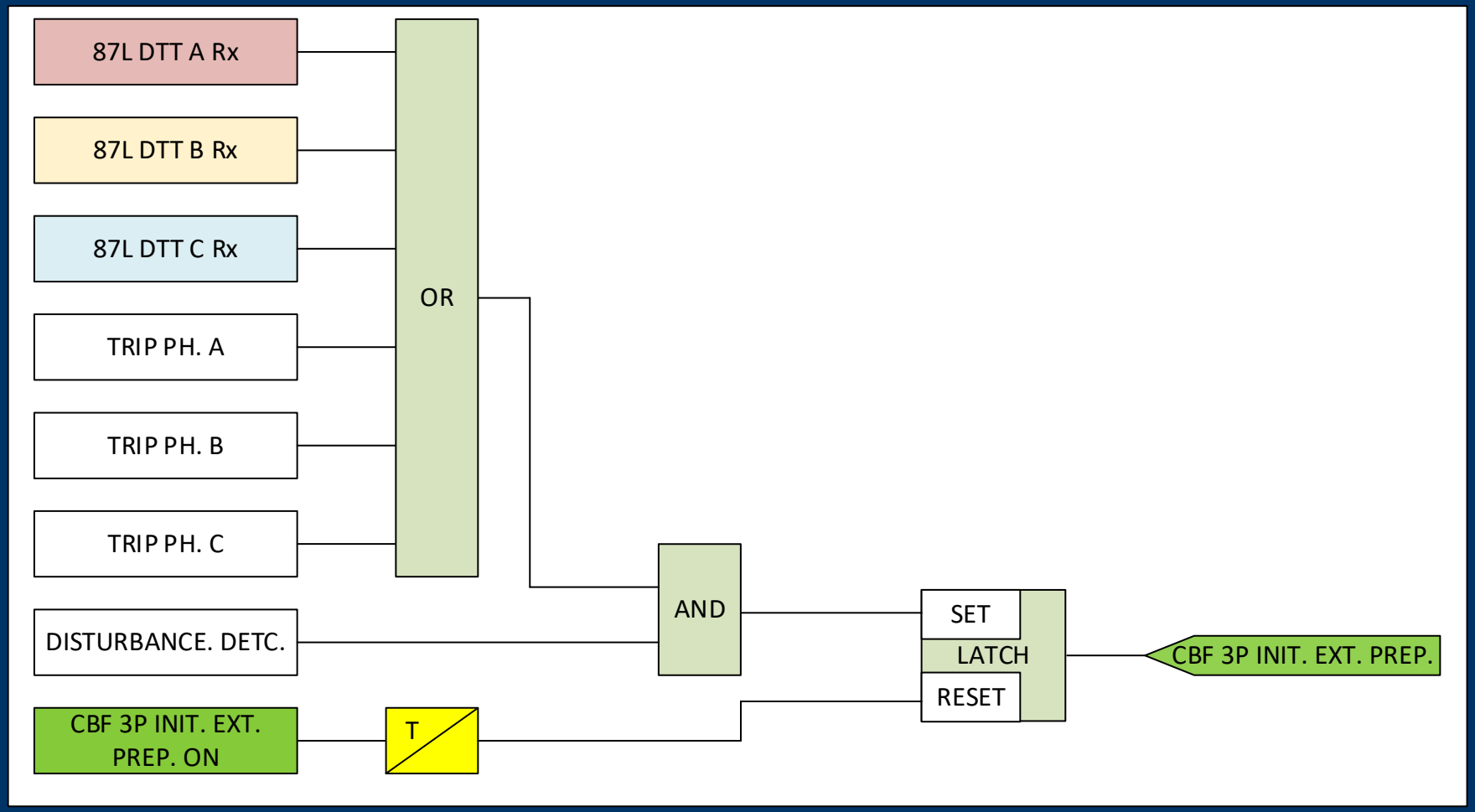
Test Case : Special Condition for Breaker Failure Protection

- Relay A has one Trip output element for two CBs. In order to trip 1-pole, the Trip Output element is set as “1-Pole & 3 Pole” mode, external jumpers is used to Trip 3-pole for CB2 when 1LG fault occurs.
- In such case, Breaker Failure Protection of CB2 may not operate if the stuck pole is not the faulty phase, because the initiation trip signal will reset under such condition.



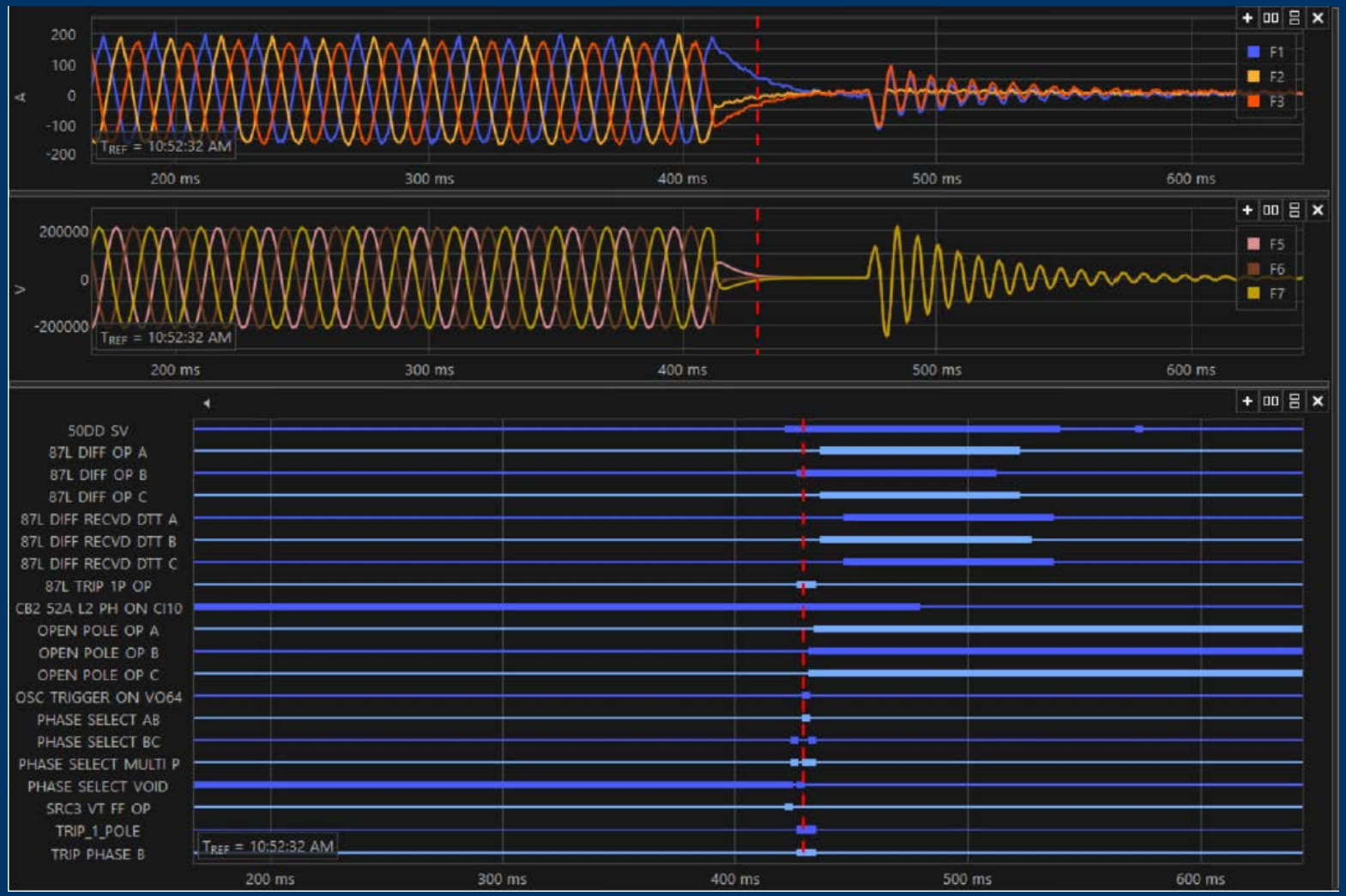
Test Case : Breaker Failure Issue for 1-Pole & 3-Pole Trip

- Solution: Extend 3-Pole Breaker Failure Initiation. Check 52a.



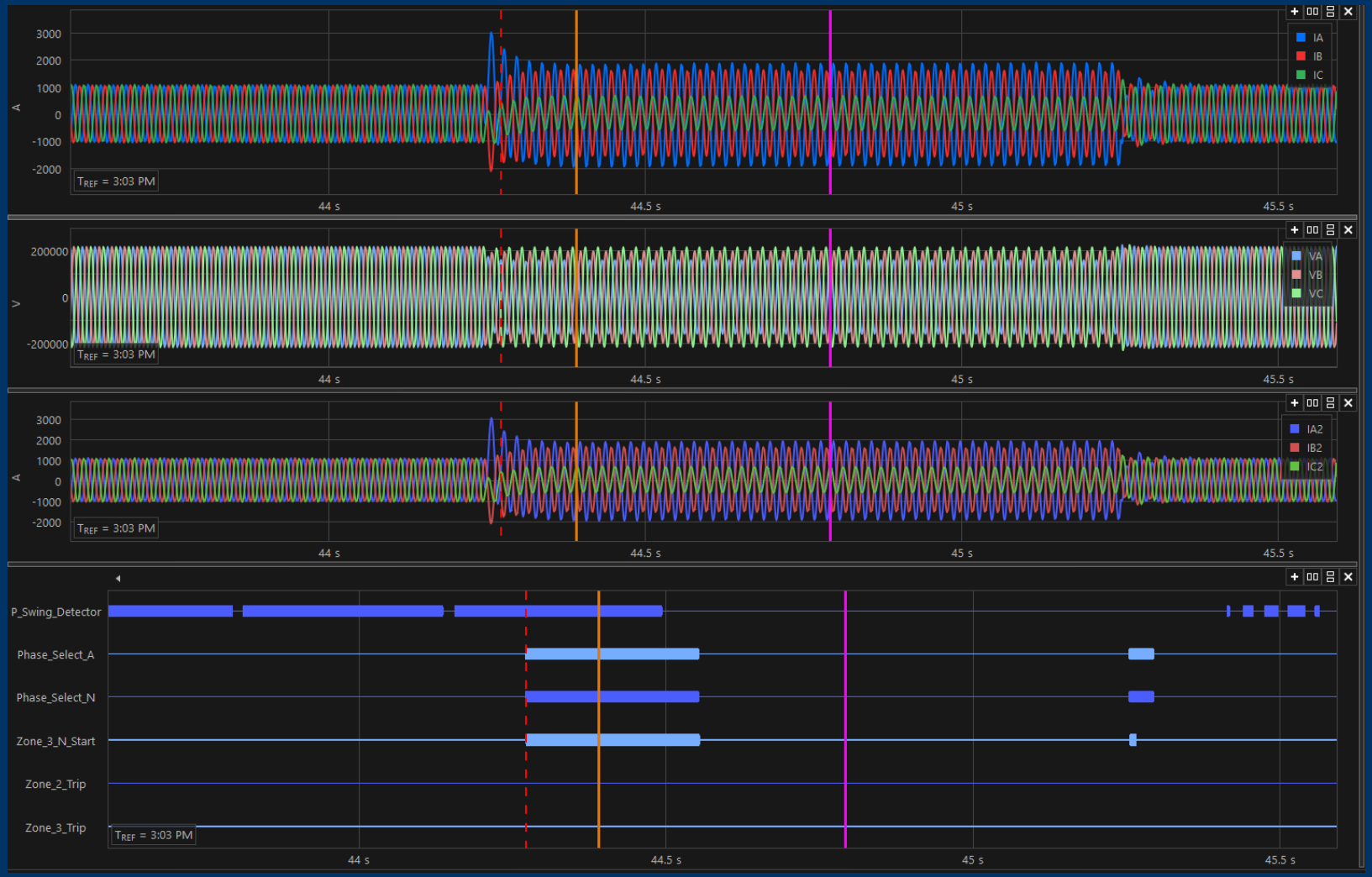
Test Case : Open Pole Assertion for High Impedance Fault

- In Relay A, pole open element may be asserted at weak terminal for high impedance fault, and it can block the 87L trip in Trip Output logic
- Solution: Use transfer trip



Test Case: Line Relay Z2P/Z2G/Z3P/Z3G Blocked

- Relay B, Z2P/Z2G/Z3P/Z3G was blocked by load blinder, which is associated with power swing detector



Summary

- Protection standards especially line protection standards could be complicated for various schemes and conditions
- By using RTDS with thorough testing, issues could be found and improvements could be made on protection standards
- RTDS Test is equivalent to many years of utility operational experience with lessons learned
- Every utility should consider such verification method to develop very robust protection standards

RTDS and P&C in General

❖ Typical RTDS tests for P&C

- Protection with new or special primary equipment
- Series Compensated Line protection
- 1-pole scheme, power swing block/trip, heavy mutual coupling
- Relay or controller verification
- Special scheme verification, etc.

❖ RTDS can be more instrumental for Utility P&C

- Awareness
- Training
- Platform improvement

Questions?