An Implementation of Multiple Setting groups based Adaptive Protection for Radial Distribution Feeder

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Acknowledgement

- Adaptive Protection to Enable Deployment of High Penetrations of Solar PV (PV-MOD) project
- Special thanks to Co-authors:
  - PPL Electric Utilities: Pei Chan
  - Electric Power Research Institute (EPRI): Aadityaa Padmanabhan, Mobolaji Bello, Sean McGuinness

Background on DOE PV-MOD Project

Develop vendor-independent adaptive protection (AP) designs

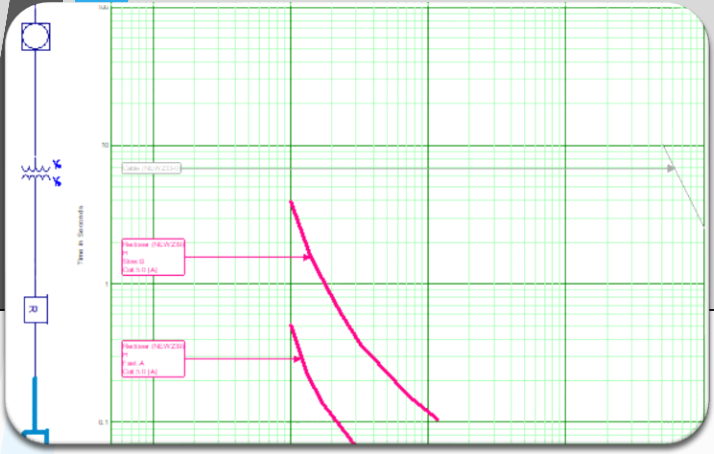
Demonstrate advanced application of the new models for automated assessment and design of adaptive distribution protection schemes

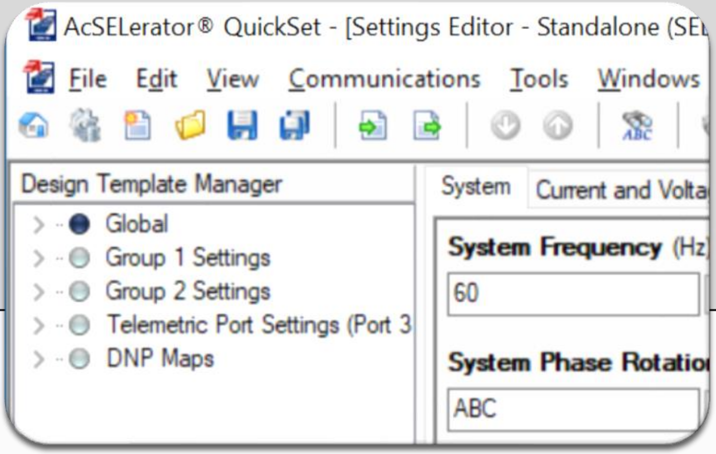
Demonstrate correct operation using simulations and lab-tests of site- and hardware-specific implementations

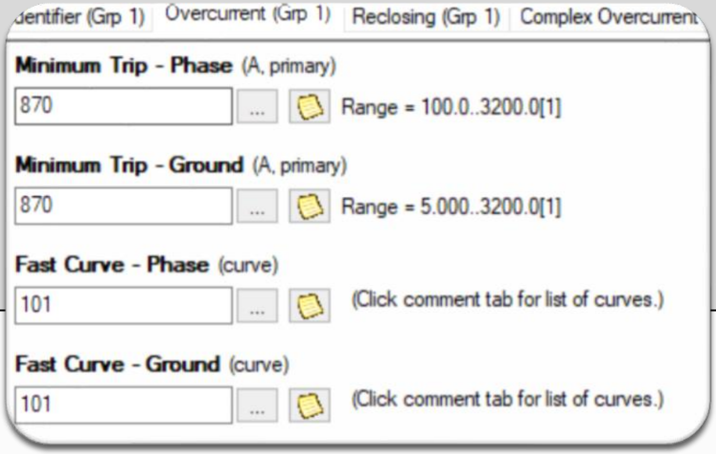
Deploy and test protection schemes on various types of networks

Adaptive Protection

Broad definition: Anything that changes how protection responds to faults







Block or release protection functions

Change settings group

Update relay settings

Triggers can be commands, time or measurements

Challenges for SG change

Understanding of minimum credible fault current magnitudes and maximum load flow essential

Knowledge of all normal and abnormal grid conditions necessary

May not be possible to adequately protect the grid for every feeder configuration

Optimal settings may need feeder specific considerations – some feeder configurations may be more frequent or important than others and the choice of settings will reflect that

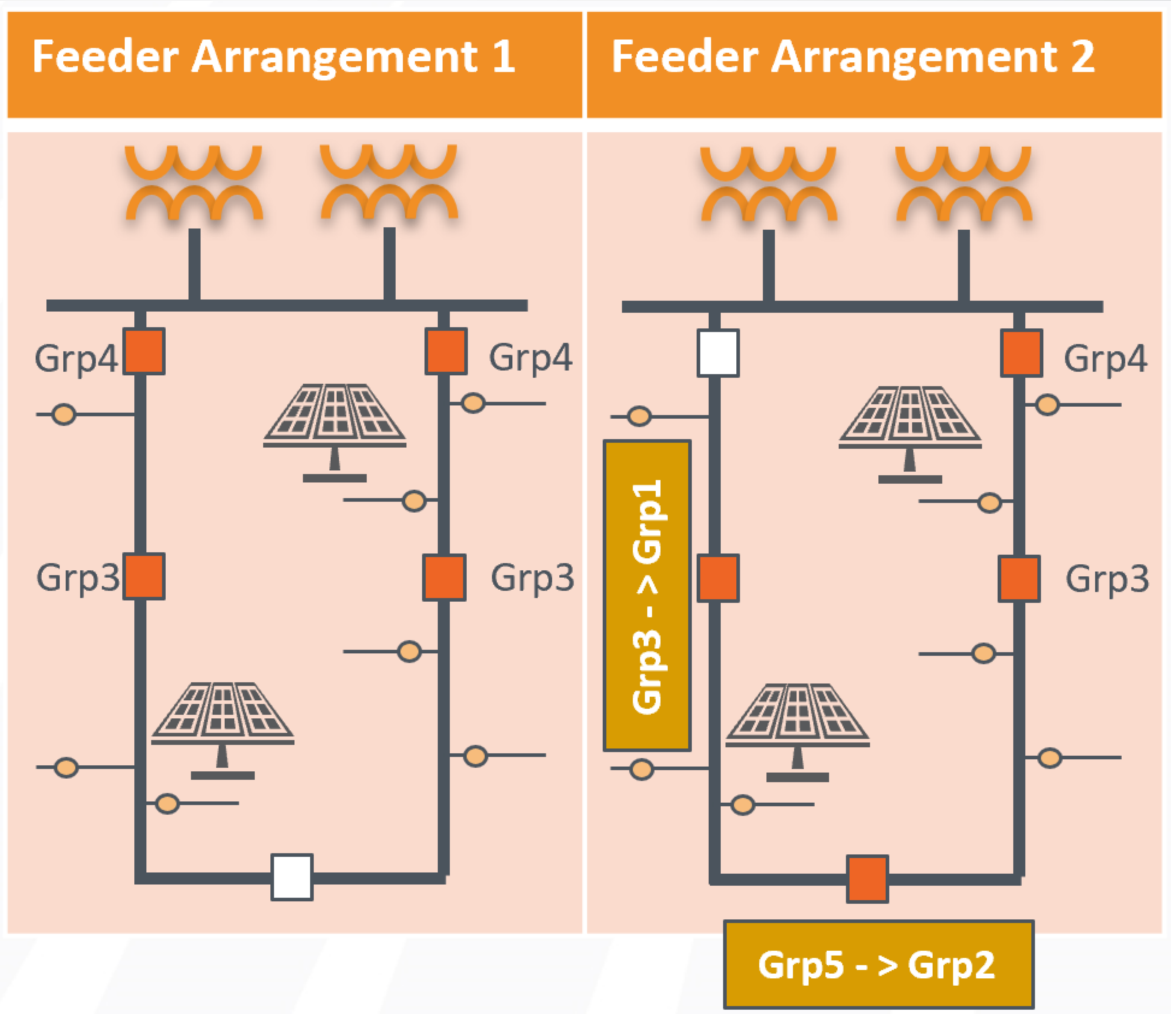
Needs appropriate system operator training and DMS design

Radial Feeder Adaptive Protection Overview

- Centralized Approach
- Consider a standard set of settings for all reclosers
- Determined based on largest downstream fuse size and minimum fault current level
- Decreases engineering effort
- Simplifies deployment strategy
- DMS determines which settings group to use based on current feeding arrangement
- Group change commands sent automatically/manually

Radial Feeder Adaptive Protection Overview

- Microprocessor relays support multiple settings groups
- Modern ADMS systems can perform coordination studies
  - Recommend appropriate settings based on system configuration
- EPRI's Distribution Protection Analysis Toolkit (DPAT) can suggest optimal settings for different system configurations
- Both these approaches involve large amounts of engineering effort



Distribution Protection Analysis Toolkit (DPAT)

Automatically analyze grids to determine optimal settings groups

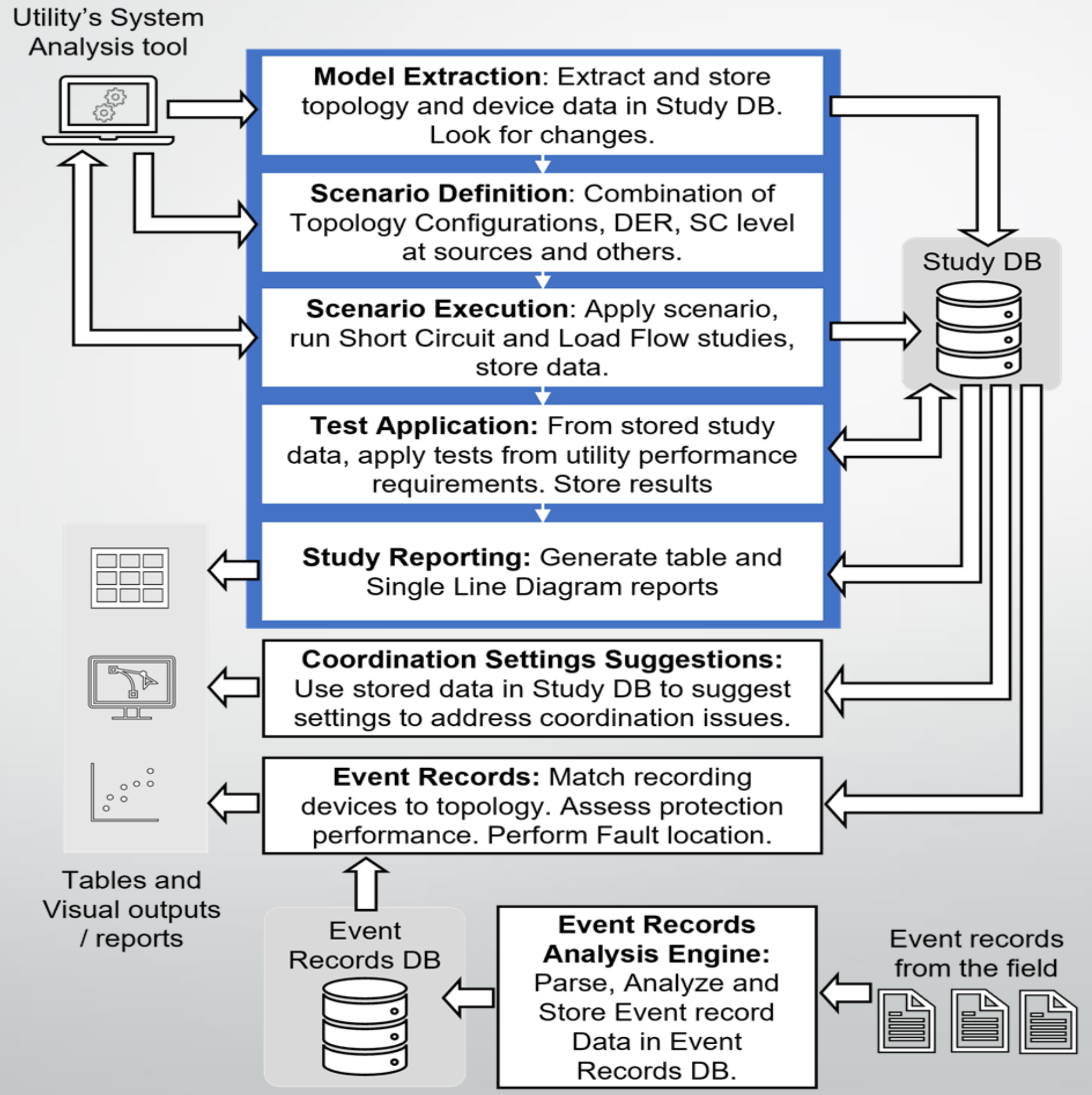
Can help in identifying mis-coordinated relays, fuses and reclosers

Under a wide range of scenarios including with/without DER, different feeding arrangements, etc.

Framework is integrated into common distribution grid Short Circuit and Power Flow Analysis tools

Makes use of available Application Programming Interfaces (APIs) to automate analyses and data extraction

Framework



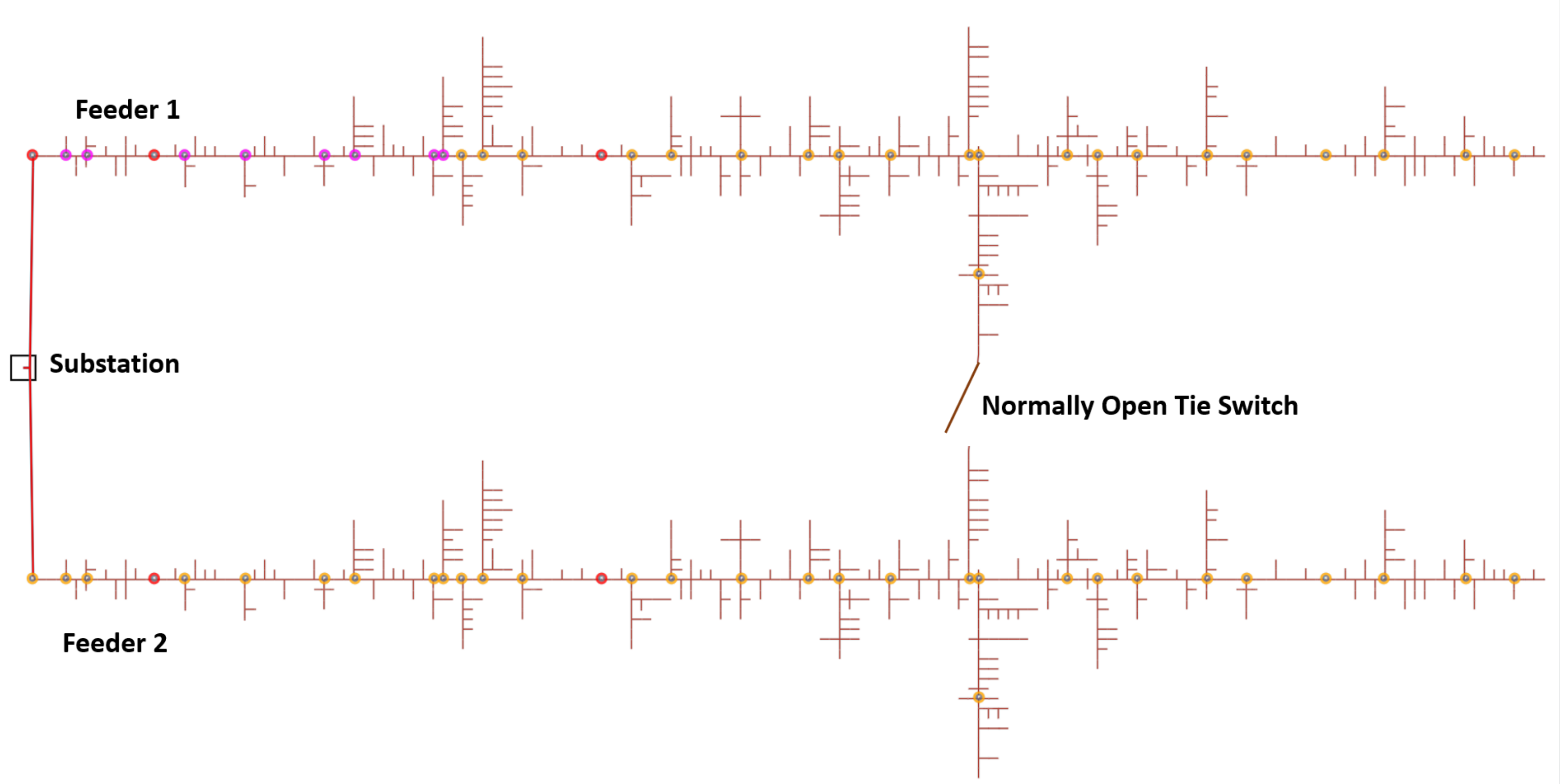
Ovalle, A.; McGuinness, S.; Padmanabhan, A.; Rocha, C.; Bannon, J.; Kistler, M.; Doodnauth, A.: 'EPRI distribution protection analysis toolkit', IET Conference Proceedings, 2023.

Key tests

- Protection device Overcurrent pickup settings are checked against
  - Upstream and downstream conductor ratings which is intended to analyze loadability limitations against protection device overcurrent pickups
  - Full Load Power Flow currents to check if devices would trip for Load current.
- Protection device observed fault currents against a percentage of the interrupting capability of devices defined by the user.
- Primary/backup protection coordination checks.
- Sequence of Operations.
- Overcurrent Pickup sensitivity: Compute ratio of minimum fault current in protection zone against overcurrent pickup.

Network Model

Description	Value
Line-Line voltage	13.2kV
PV systems/DER included	Yes
PV specs	0.38 kV, 360 kVA each
Total PV generation	10.7 MW
Total load on both feeders	2.24 MW + 0.94 MVAr



Protection analysis: Tabular Reports

Device Name	Device Type	Model	Voltage (kV)	Rated Current (A)	Interrupting Rating (A)	Test Result
02848_fuse	Fuse	Kearney T [Kearney Kearney T 65.0]	22.9 kV	65.0 A	10000.0 A	Fail Coordination Check
02848_fuse1	Fuse	Kearney T [Kearney Kearney T 65.0]	22.9 kV	65.0 A	10000.0 A	Fail Coordination Check
02895_fuse	Fuse	Kearney T [Kearney Kearney T 65.0]	22.9 kV	65.0 A	10000.0 A	Fail Coordination Check
02895_fuse1	Fuse	Kearney T [Kearney Kearney T 65.0]	22.9 kV	65.0 A	10000.0 A	Fail Coordination Check
029						Fail Coordination Check
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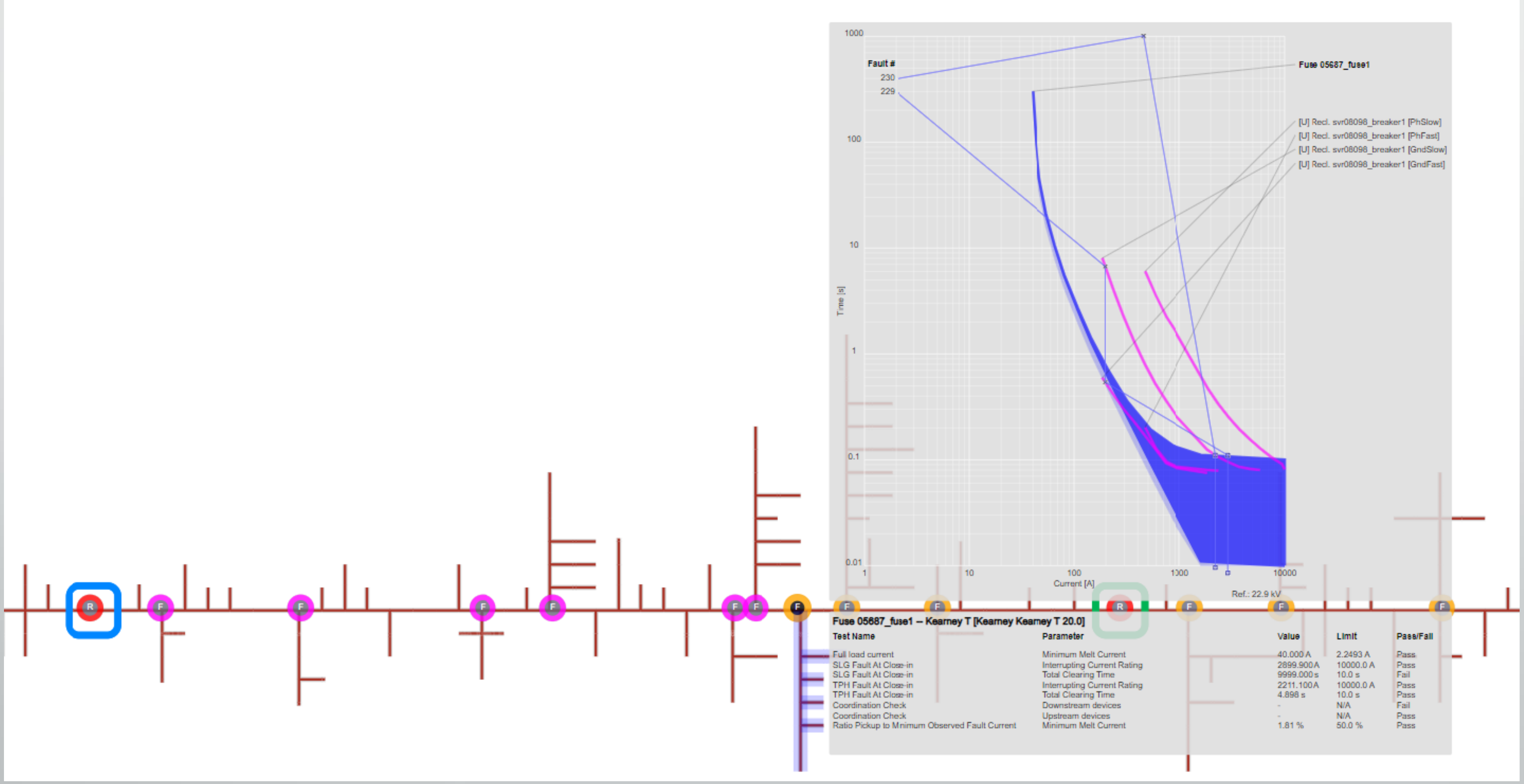
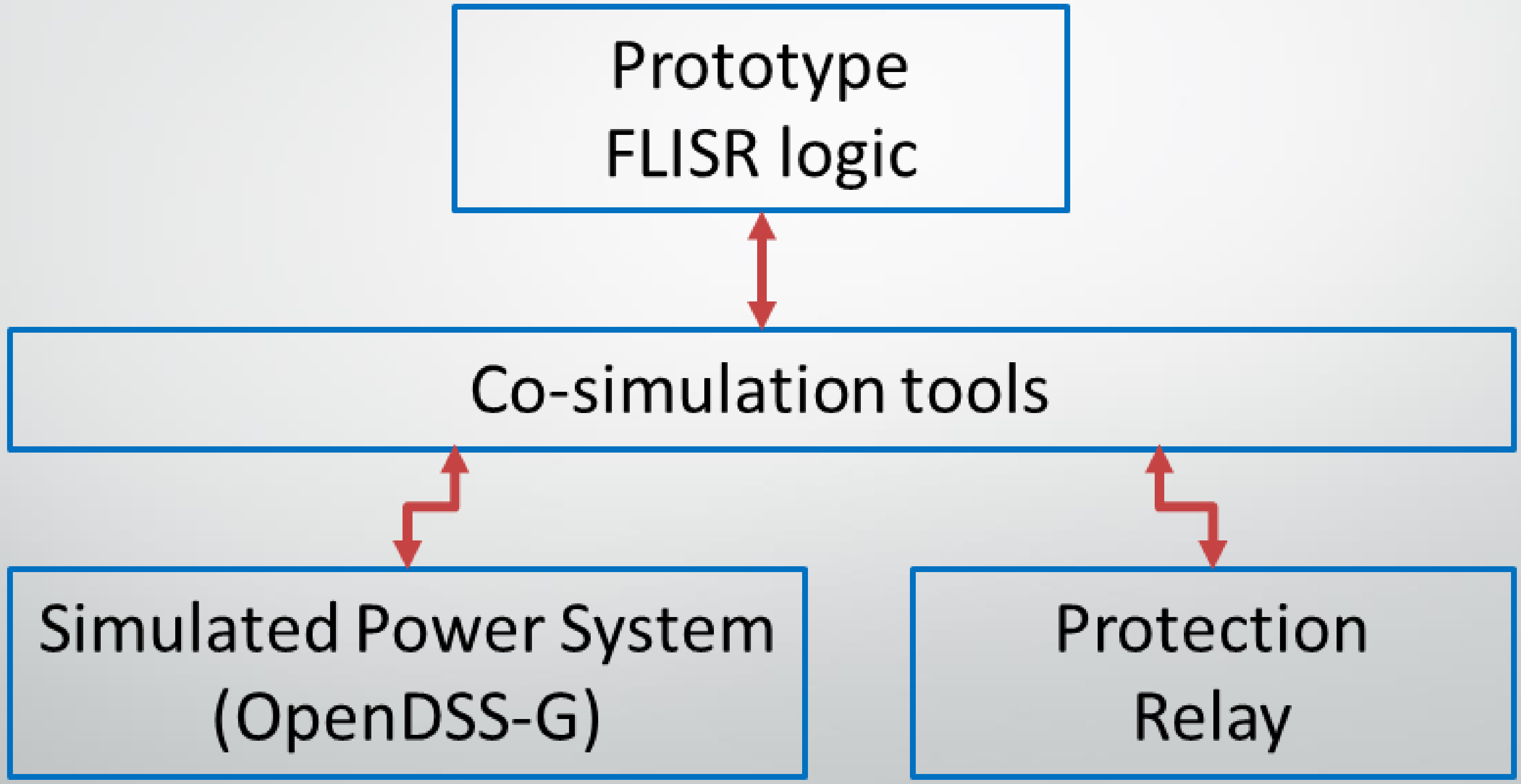
Test Name	Test Parameter	Test Value	Test Type	Test Limit	Pass/Fail	Test Result Description
Full load current	Minimum Melt Current	130.0 A	Must Be greater than	125.41 A	Pass	Fuse minimum melt current greater than full load current
SLG Fault At Close-in	Interrupting Current Rating	2351.0 A	Must be less than Rating of	10000.0 A	Pass	N/A
SLG Fault At Close-in	Total Clearing Time	9999.0 s	Must be less than	10.0 s	Fail	line.svr08097_breaker1 trips at t=9999.0 within 0.3s coordination margin
TPH Fault At Close-in	Interrupting Current Rating	2160.8 A	Must be less than Rating of	10000.0 A	Pass	N/A
TPH Fault At Close-in	Total Clearing Time	9999.0 s	Must be less than	10.0 s	Fail	line.svr08097_breaker1 trips at t=9999.0 within 0.3s coordination margin
Coordination Check	Downstream devices	-9998.902 s	Curve should coordinate with upstream and downstream devices	N/A	Fail	Miscoord. with: Recloser svr08098_breaker - fuse mmt curve / recloser slow curve
Coordination Check	Upstream devices	1.27 s	Curve should coordinate with upstream and downstream devices	N/A	Pass	Coord. with: Recloser svr08097_breaker
Ratio Pickup to Minimum Observed Fault Current	Minimum Melt Current	6.02 %	Must be less than	50.0 %	Pass	

Protection analysis: Single Line Diagram Reports

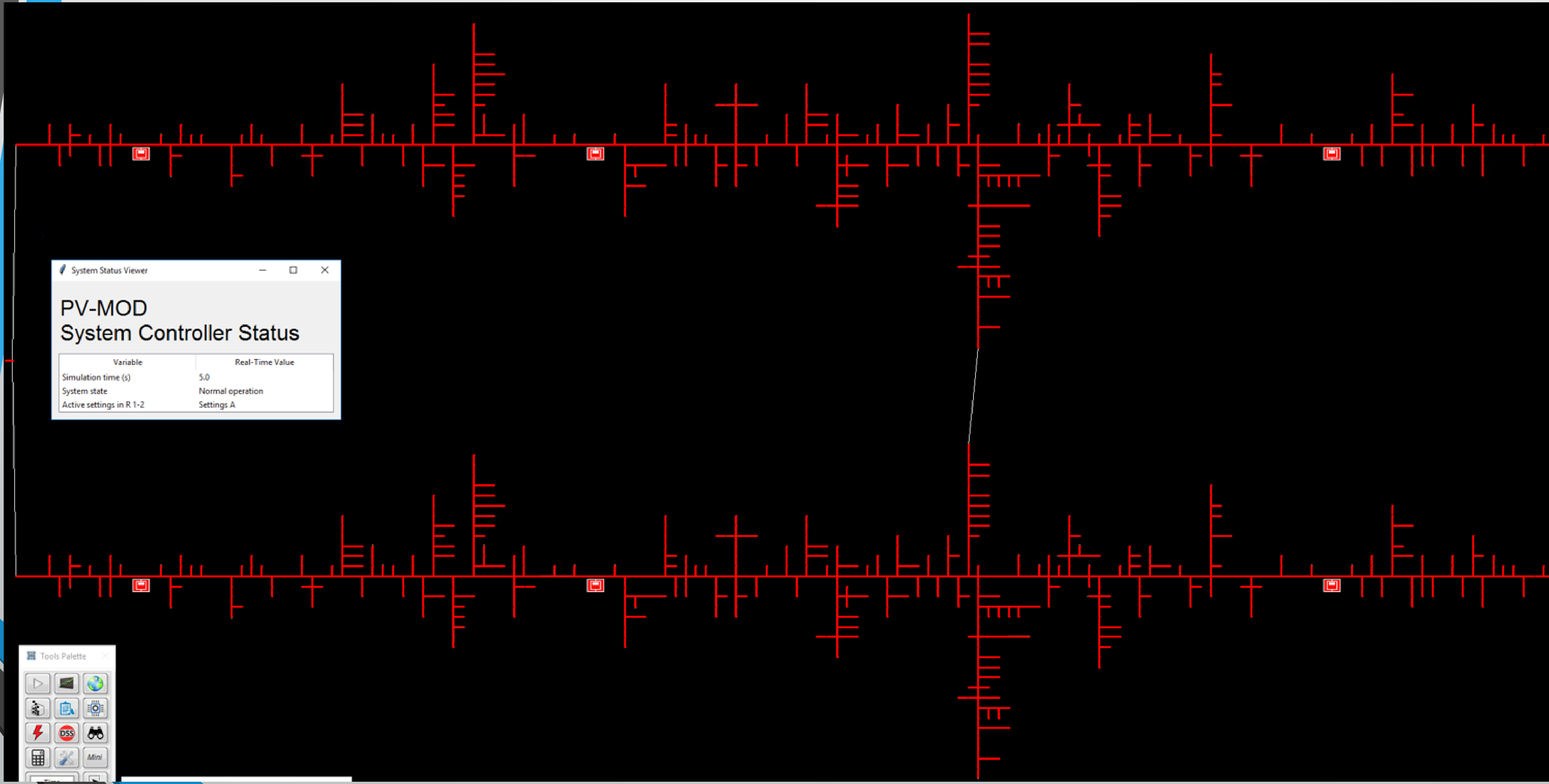


Test Name	Parameter	Value	Limit	Pass/Fail
Full load current	Minimum Melt Current	40.000 A	2.2493 A	Pass
SLG Fault At Close-in	Interrupting Current Rating	2899.900 A	10000.0 A	Pass
SLG Fault At Close-in	Total Clearing Time	9999.000 s	10.0 s	Fail
TPH Fault At Close-in	Interrupting Current Rating	2211.100 A	10000.0 A	Pass
TPH Fault At Close-in	Total Clearing Time	4.898 s	10.0 s	Pass
Coordination Check	Downstream devices	-	N/A	Fail
Coordination Check	Upstream devices	-	N/A	Pass
Ratio Pickup to Minimum Observed Fault Current	Minimum Melt Current	1.81 %	50.0 %	Pass

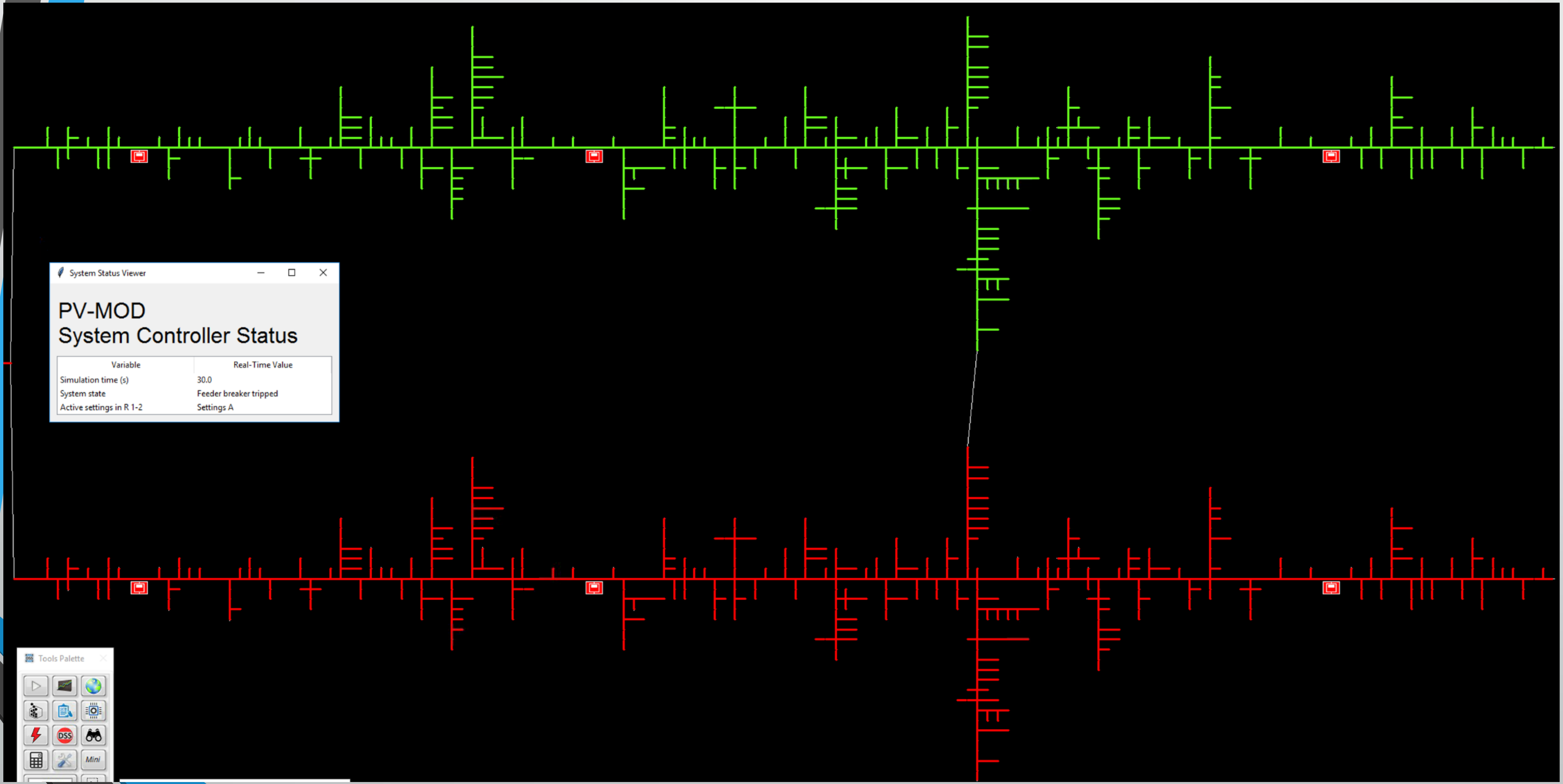
Block Diagram for Lab Test Bench Setup



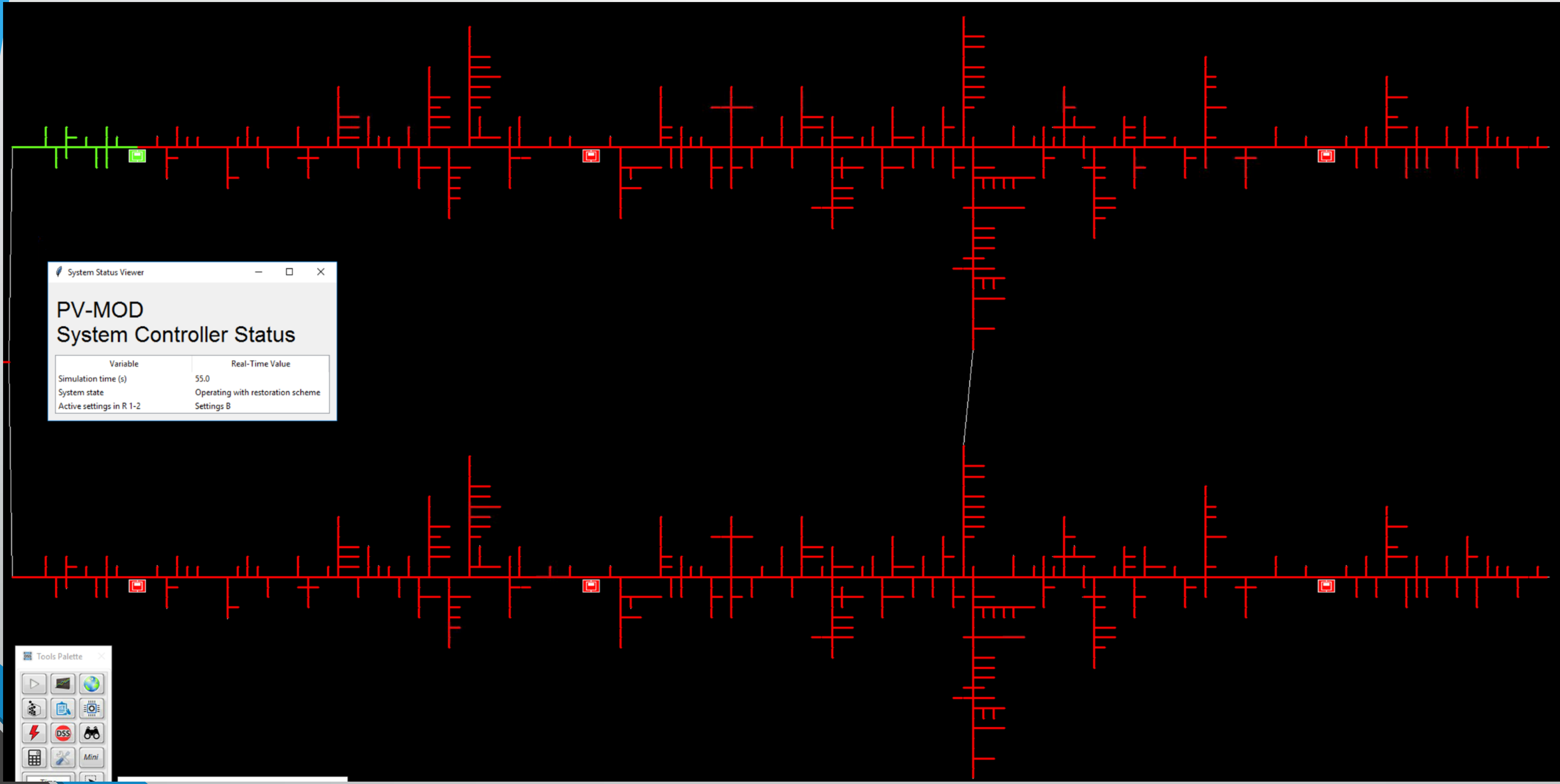
Lab Implementation (Pre-fault state)



Isolation of fault by protection device



System Reconfiguration by FLISR logic



Additional Onsite tests

- DNP3 commands over LTE network sent at utility site.
- Commands were sent to a microprocessor relay located in a laboratory a little over 2 miles away from the utility control center by an operator.
- Communication latency inherent to public LTE networks did not pose a challenge to the scheme.
- Associated costs will be lower when compared to schemes that may require optical fiber communication channels

Conclusions

- Implementation of DMS and communication interface over DNP3 tried successfully.
- A reliable communication channel is essential to deliver the commands from the control center to the individual relays and reclosers.
- Thorough analysis of the system on which this scheme is to be implemented is needed to ensure that the right set of standard settings are chosen.
- Some form of automation tools might be beneficial to perform the multitude of coordination studies needed to determine the appropriate protection settings.

Ongoing/Future work

- Research on automating the sending of the settings group change command by the DMS/SCADA system as real-time DER output changes
- Trial scheme with utility partner
- Determine the right order in which relays/reclosers are issued the settings group change command

Thank You

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Questions?