ADMS and DER coordinated capability demonstrations to assist utilities to increase resilience and reliability

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Presentation Outline

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- The proliferation of distributed energy resources (DERs) presents opportunities and challenges to distribution grid operators.
- The National Renewable Energy Laboratory (NREL) and Survalent are collaborating to demonstrate advanced distribution management system (ADMS) and DER coordinated capability to assist utilities to increase resilience and reliability.
    - ADMS and Distributed Energy Resource Management System (DERMS) Coordination for Peak Load Management (PLM)
    - Fault Location, Isolation, and Service Restoration (FLISR) in the Presence of DERs
    - Grid-Edge Intelligent Distribution Automation System for Self-Healing Distribution Grids.
- These laboratory demonstrations use NREL's ADMS Test Bed.

ADMS Test Bed

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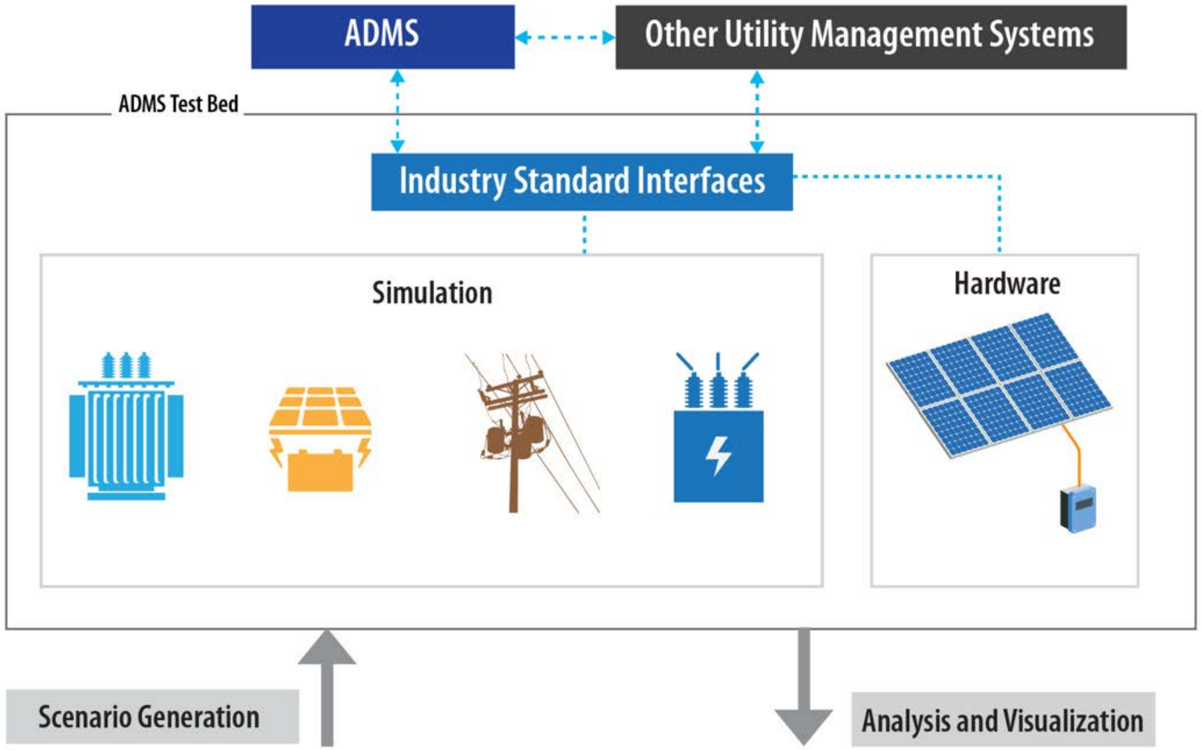
Goal: Accelerate industry adoption of ADMS to:

- Improve normal operations with high levels of DERs.
- Improve resilience and reliability.

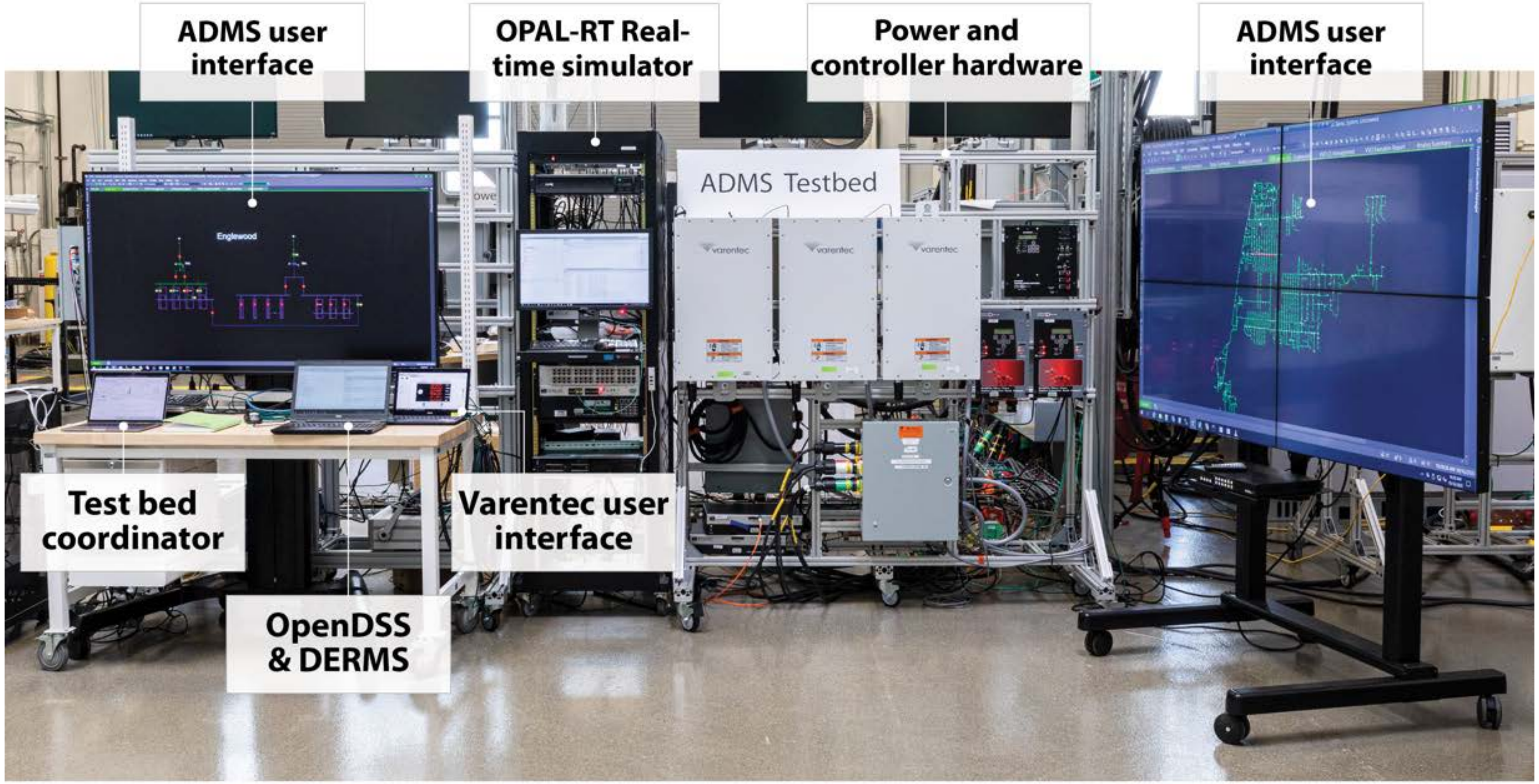
Approach: Partner with utilities and vendors to evaluate specific use cases and applications to:

- Set up a realistic laboratory environment.
- Simulate real distribution systems.
- Integrate distribution system hardware.
- Use industry-standard communications.
- Create advanced visualization capability.



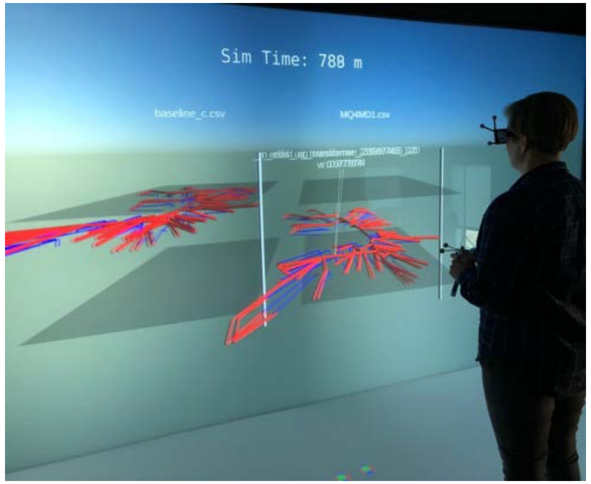
https://www.nrel.gov/grid/advanced-distribution-management.html

ADMS Test Bed



Photos by NREL

2D real-time visualization



3D visualization

Developed with support from the U.S. Department of Energy, Office of Electricity, Advanced Distribution System Management System Program

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ADMS and DERMS Coordination for Peak Load Management

ADMS-DERMS Coordinated PLM

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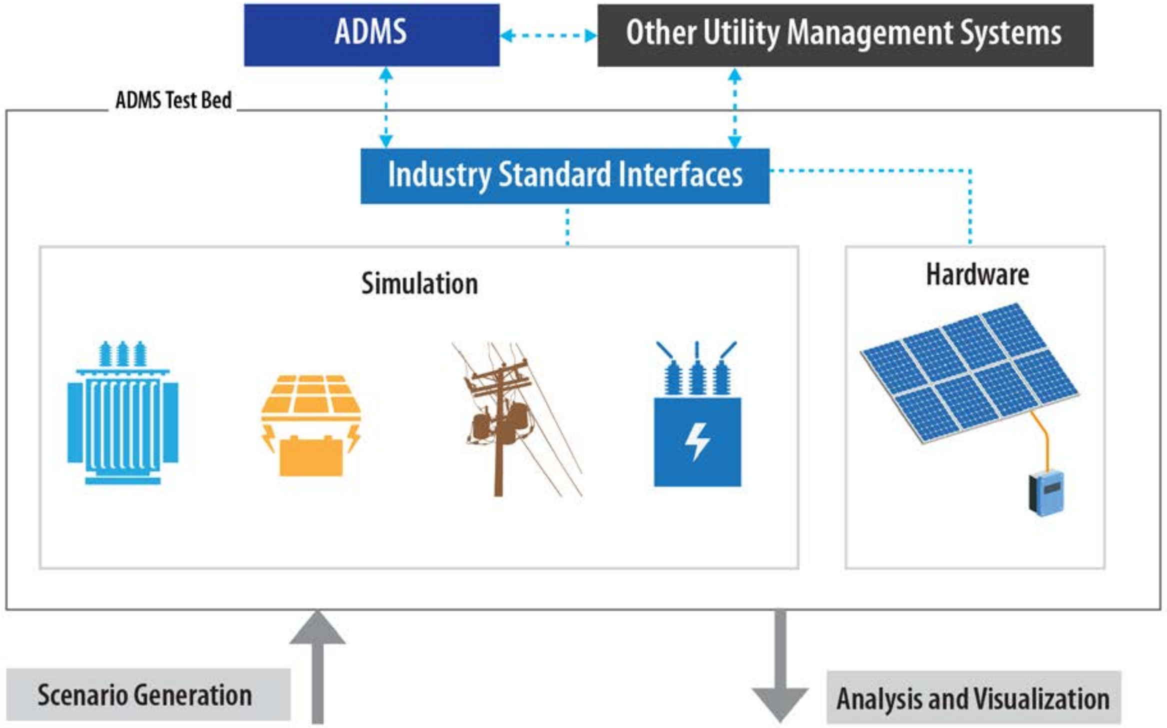
Objective: Evaluate the performance of PLM coordinated across ADMS and DERMS.

- Effectiveness of DERMS in complementing ADMS operations
- Communications interface between ADMS and DERMS
- Focus on municipal and cooperative utilities.



Evaluation Feeder

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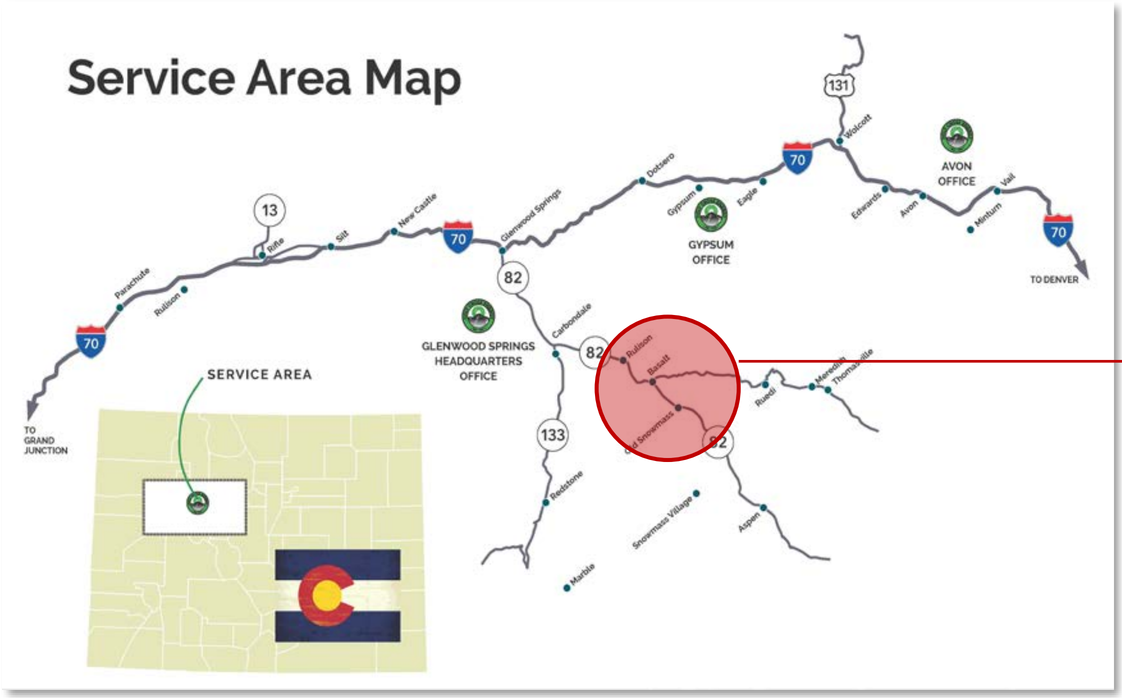

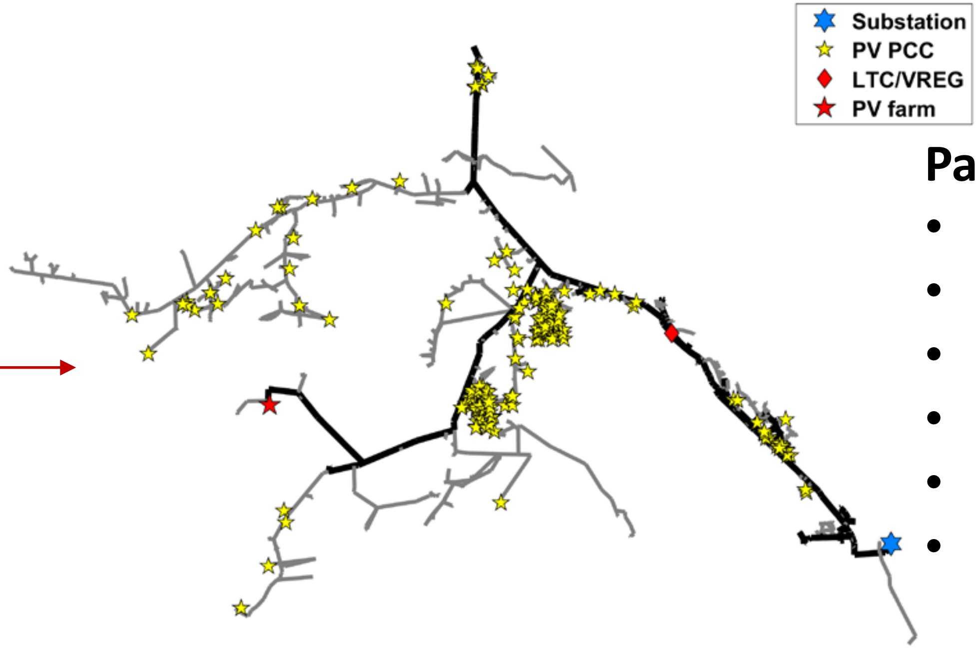

Partners:

- Holy Cross Energy
- Survalent
- NRECA
- EPRI
- Opal-RT
- PNNL

- **14.4-kV system with an approximate peak load of 11 MW**
  - **1,100 loads, including 163 all-electric residential loads**
  - **Load tap changer (LTC) at substation, band center 121 V**
  - **Ganged voltage regulator (VREG), band center 123 V.**

Evaluation Configuration

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Used historical data from December 30, 2019, 4:30 to 7:30 p.m.

- **All-electric homes equipped with simulated photovoltaics (PV) and battery energy storage system (BESS)**
- **ADMS controlled legacy devices**
  - LTC and VR band centers set by dynamic voltage regulation (DVR) application
- **Prototype DERMS (developed at NREL) controlled PV and BESS**
  - Simulated control managed 1.635 MW of residential PV and an approx. 1-MW/2.7-MWh BESS.

Dynamic Voltage Regulation-Only Scenario

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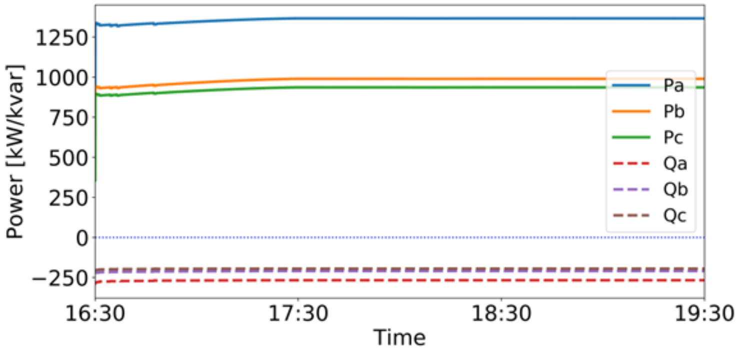
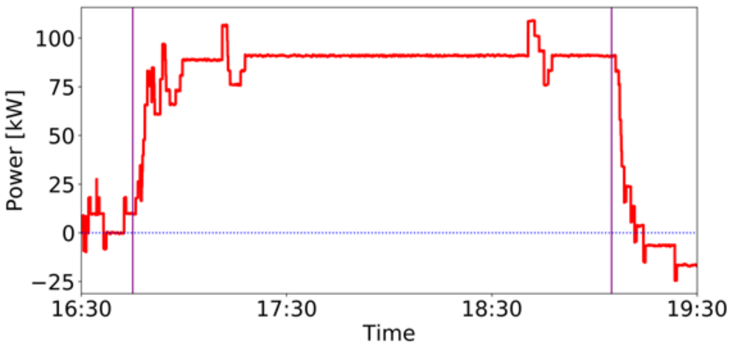
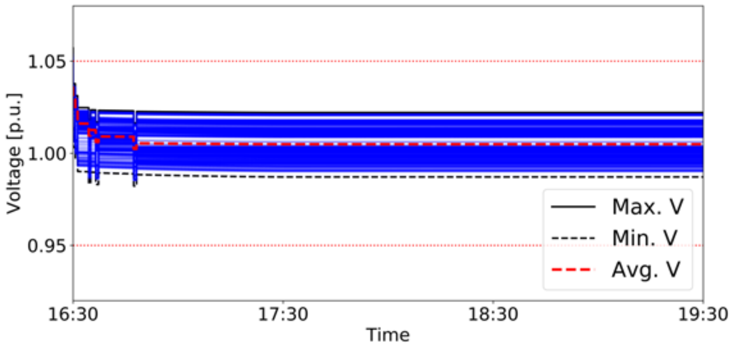


Feeder Head Power (Baseline)

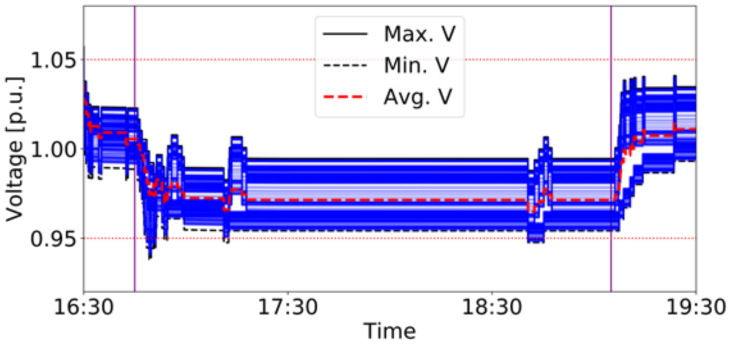


DVR Feeder Head Power Reduction

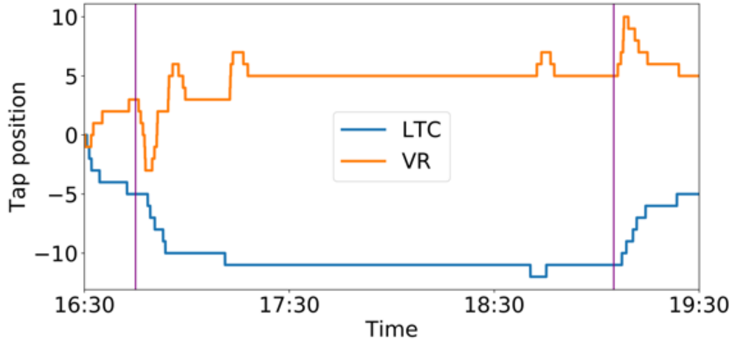
DVR is enabled at 16:45 and disabled at 19:15.



Feeder Voltage (Baseline)



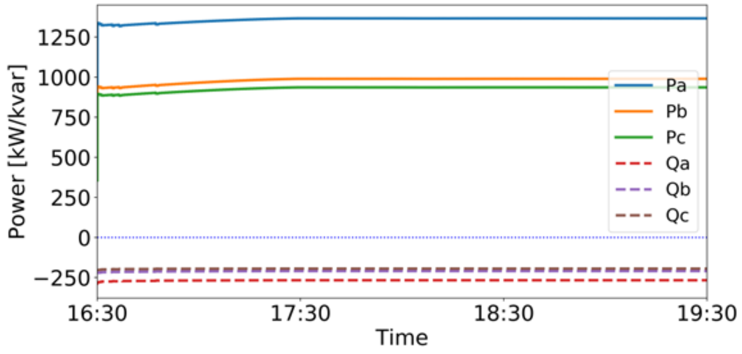
Feeder Voltage (DVR)



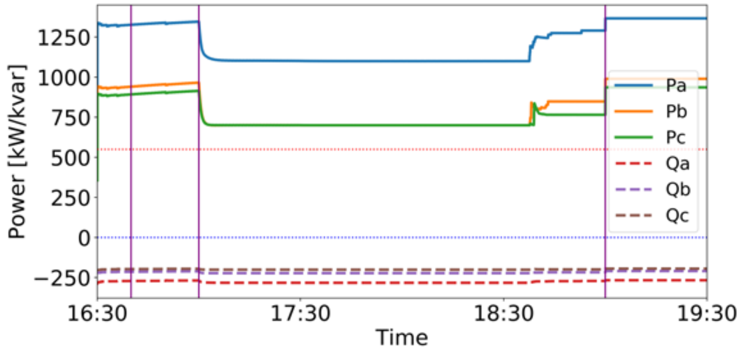
DVR LTC & VR Activity

DERMS-Only Scenario

Survalent.



Feeder Head Power (Baseline)



DERMS Feeder Head Power Reduction

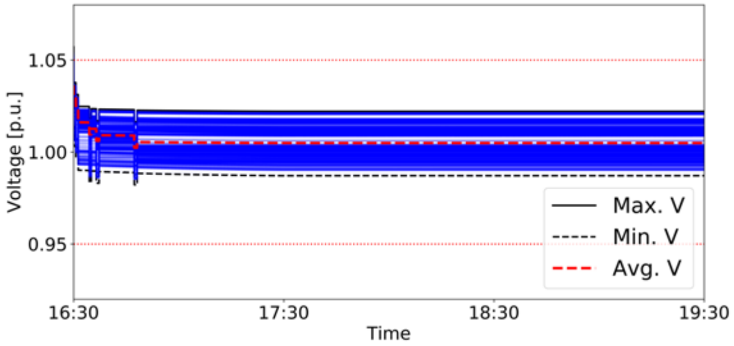
PLM is enabled at 17:00 and disabled at 19:00.

Set points:

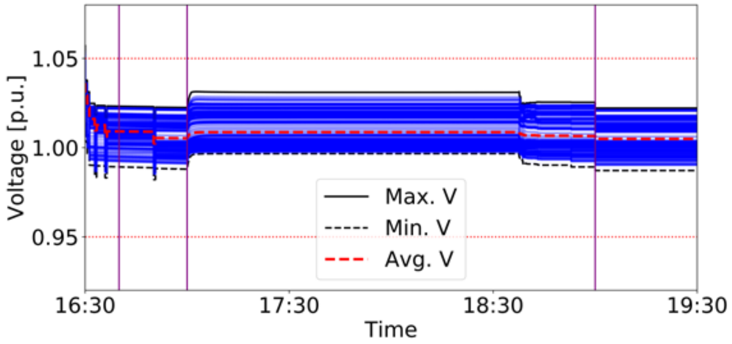
Phase A – 1,100 kW

Phase B – 700 kW

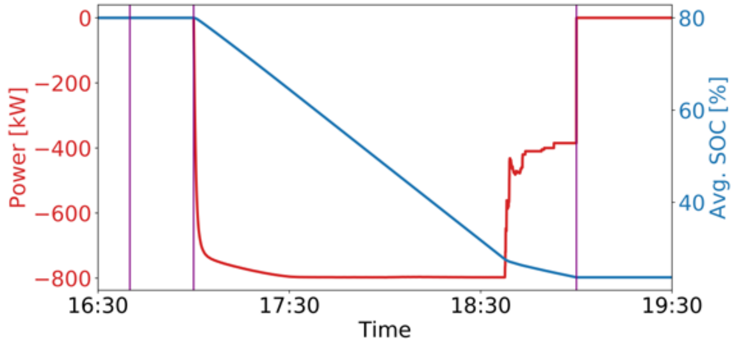
Phase C – 700 kW



Feeder Voltage (Baseline)



Feeder Voltage (DERMS)



BESS Dispatch

DERMS + DVR Scenario

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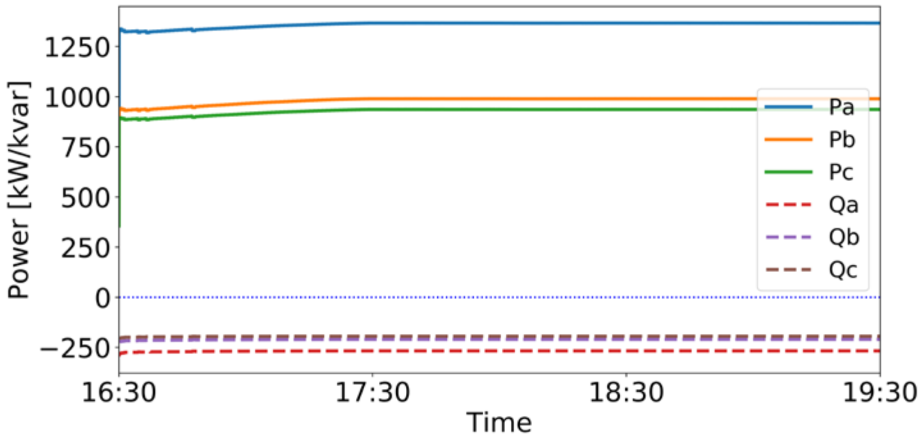
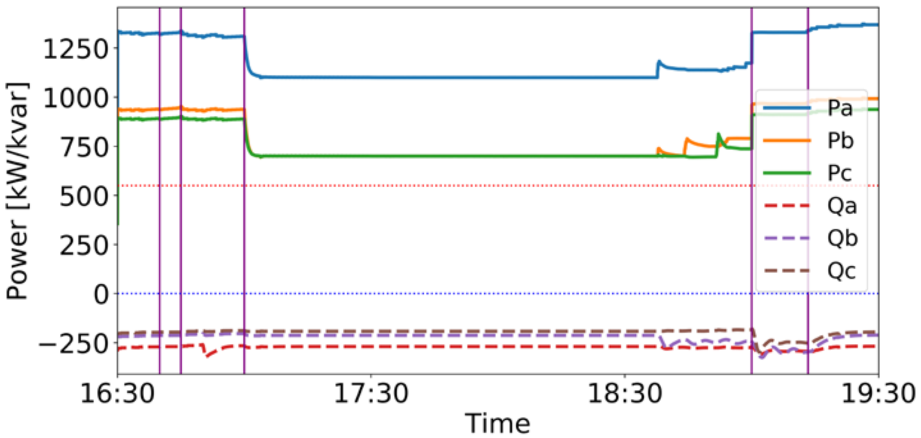


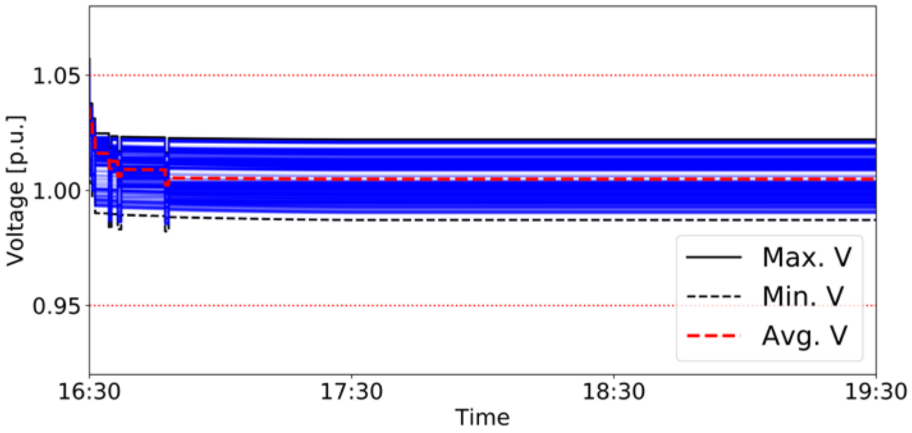
Feeder Head Power (Baseline)



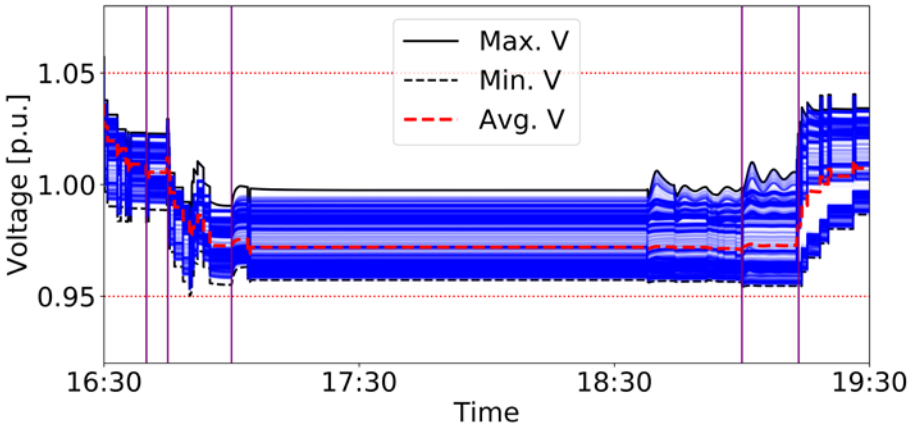
DERMS + DVR Feeder Head Power Reduction

DVR is enabled at 16:45 and disabled at 19:15.

PLM is enabled at 17:00 and disabled at 19:00.



Feeder Voltage (Baseline)



Feeder Voltage (DERMS + DVR)

FLISR in the Presence of DERs

FLISR in the Presence of DERs

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<u>Objective:</u> Evaluate the performance of a commercially available ADMS FLISR application in the presence of DERs.

Partners:

– Utility: Central Georgia EMC

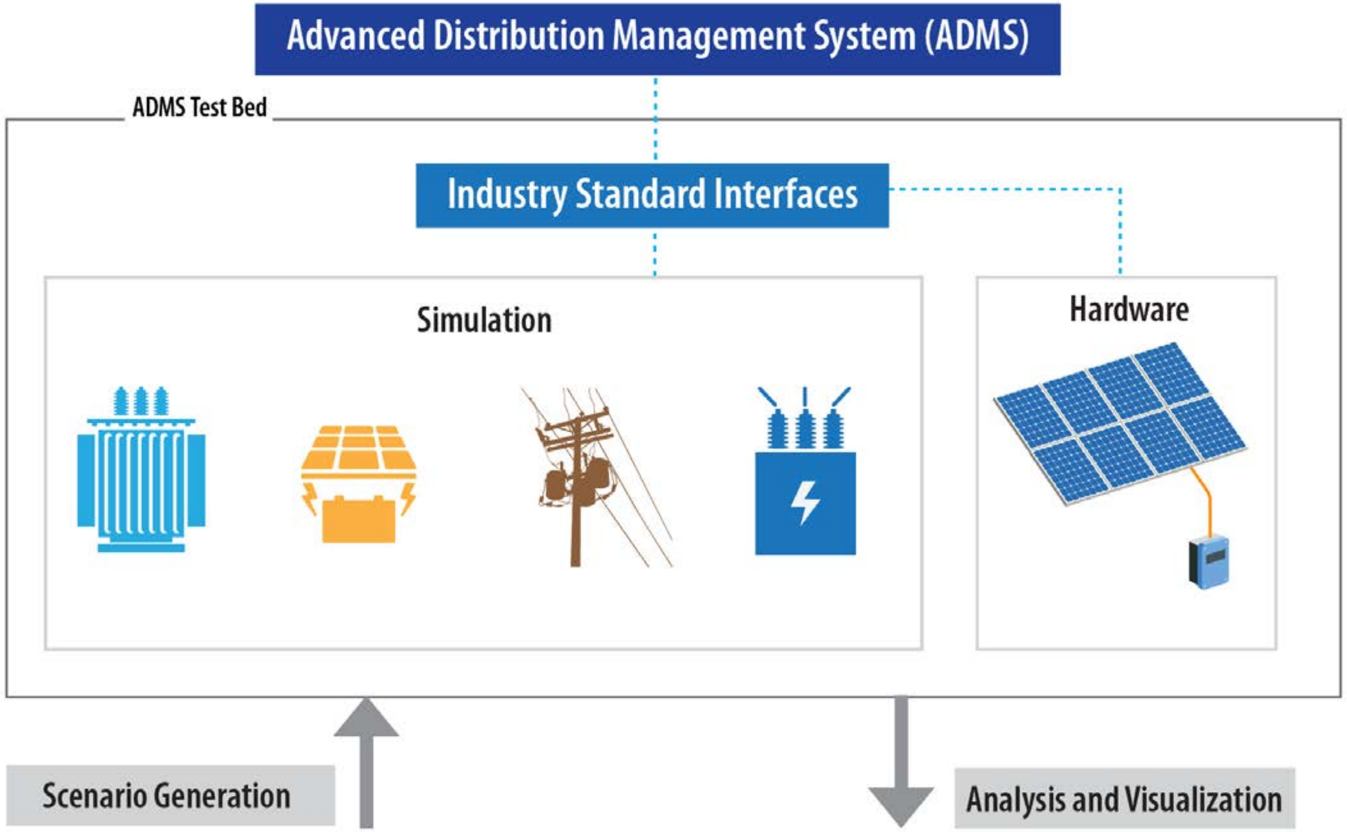
– ADMS: Survalent.

Evaluate the impact of:

– DER locations

– Fault locations

– DER trip settings.



FLISR Flowchart

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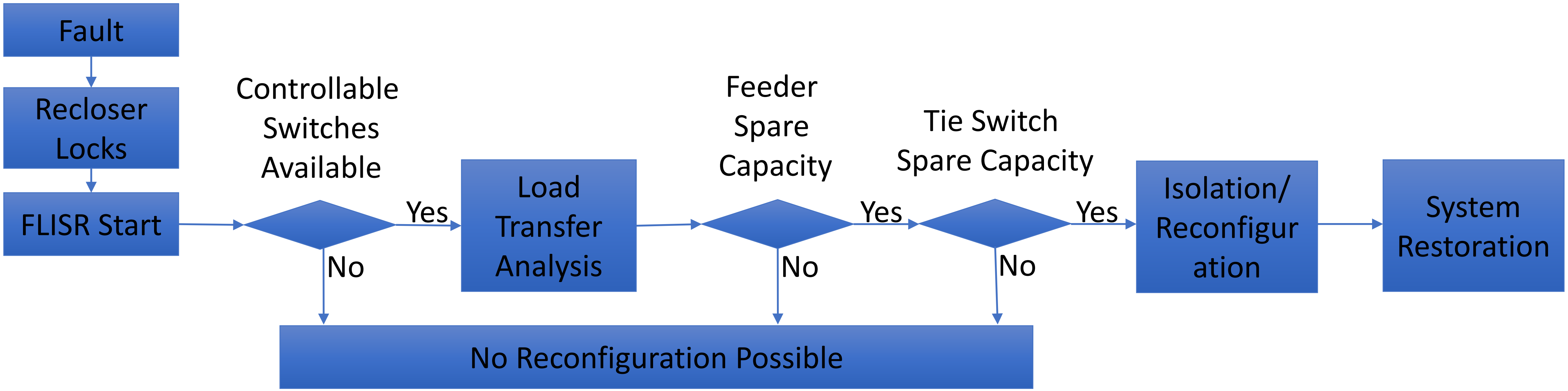

Simplified, not showing all possible iterations

Scenario Overview

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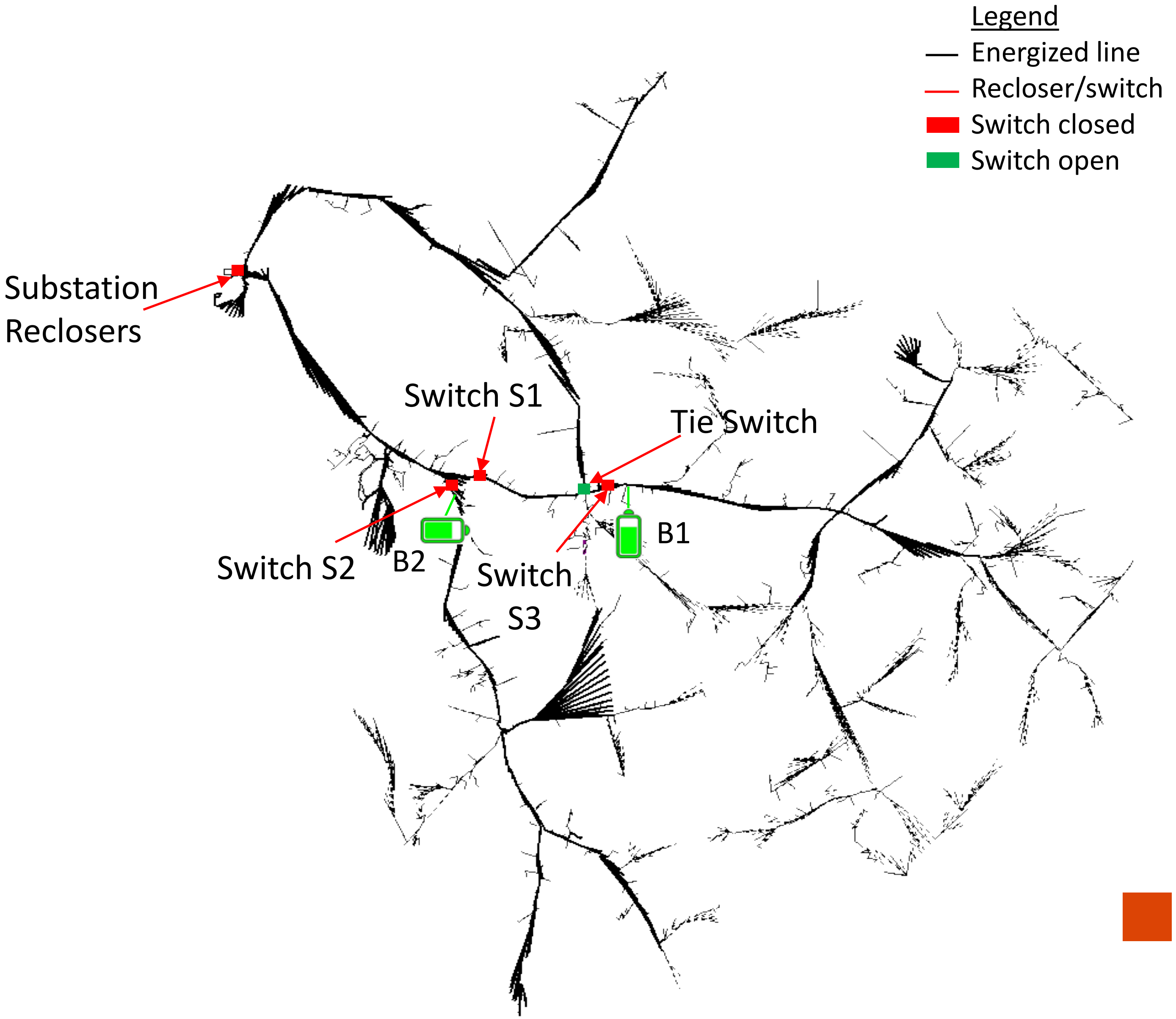
Rural feeders with tie switch

Central Georgia EMC is evaluating BESS.

- Form microgrids for improved resilience
- Requires grid-forming (GFM) inverters
- Two potential locations.

Substation details:

- 9.2 MW total active power
- 1,018 loads with 10% small commercial
- 4,045 nodes
- 2,760 lines.



Historical FLISR Evaluation

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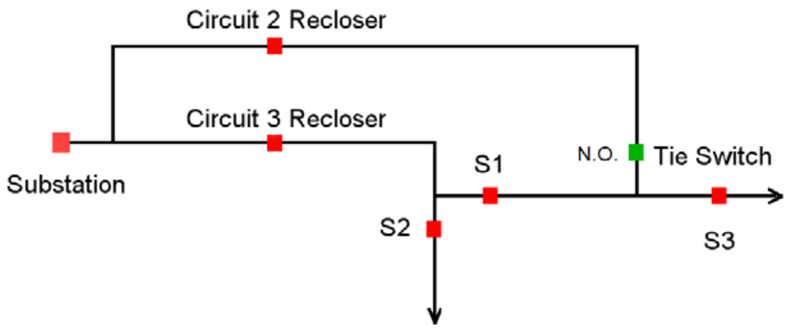

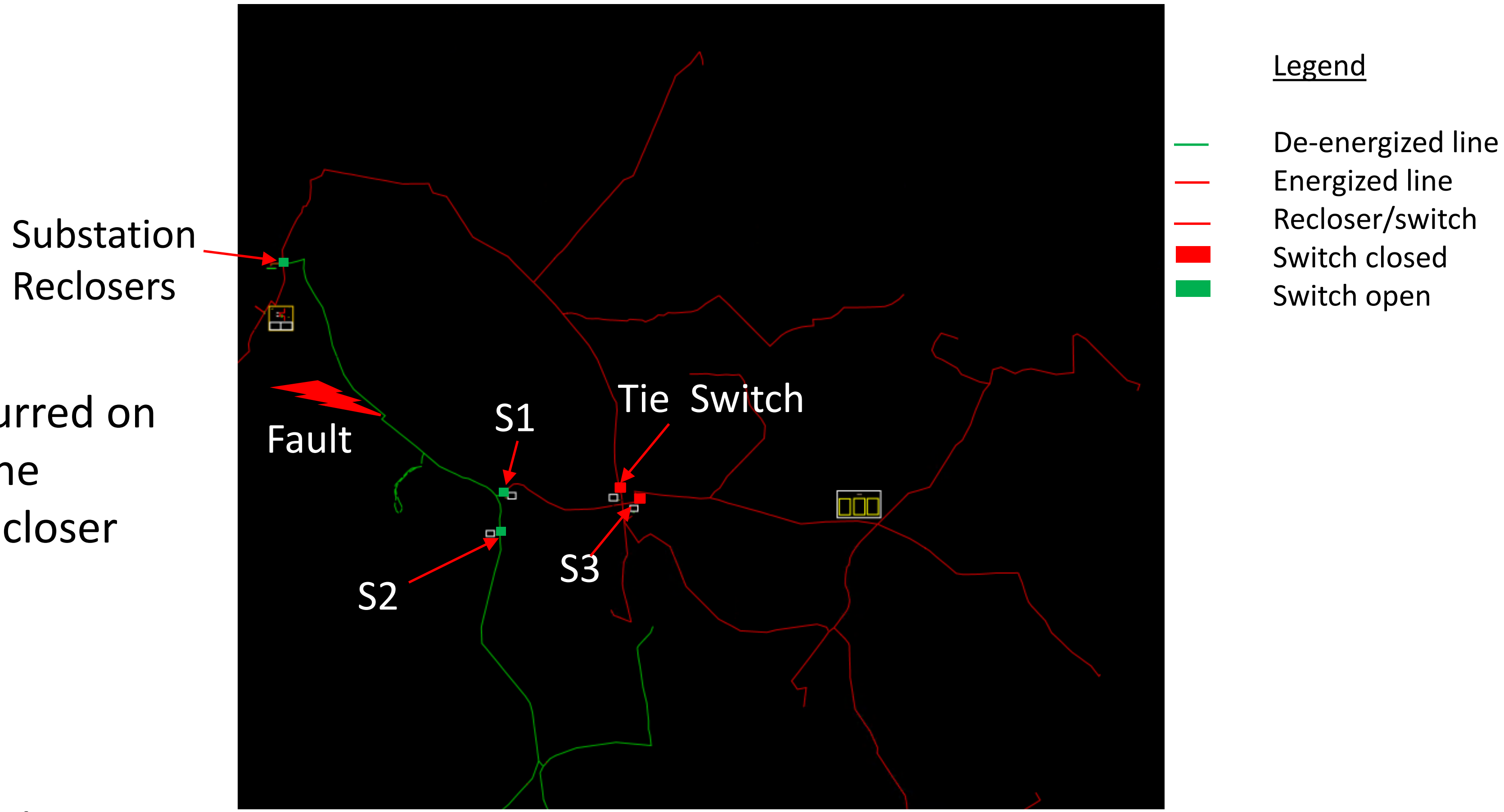

A three-phase fault in Circuit 3 occurred on August 9, 2020, at 9:36 p.m. near the substation between the Circuit 3 recloser and Switch S1.

Post-fault sequence of events:

- Circuit 3 recloser opens and locks out.
- FLISR opens Switch S1 and Switch S2.
- FLISR closes the tie switch (reenergizes part of the feeder).

Baseline Load Transfer Operation

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- Table 1 shows the ADMS FLISR snapshot load transfer analysis portion behind Switch S1.
  - Based on calculated kVA scaled by feeder injection and measured values.

Table 1. Load Transfer Calculations		
	Total	Units
Circuit 2 total capacity	13,500	kVA
Circuit 2 current load	725.88	kVA
Circuit 2 spare capacity	12,774.12	kVA
Load behind Switch S1	2,253.23	kVA
Tie switch capacity	600	AMPS
Tie switch capacity	9,000	kVA

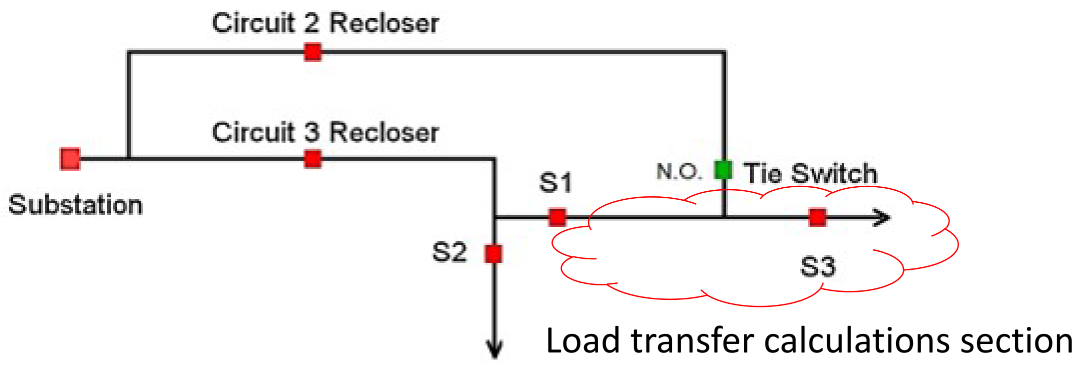

Table 2. Load Transfer Simulation Measurements		
	Total	Units
Circuit 2 measured power before the fault	0.685	MW
Circuit 2 measured power after the fault	2.896	MW
Circuit 3 measured power before the fault	5.272	MW
Tie switch measured power after the fault	2.168	MW

- Table 2 shows the simulation load transfer measurements.

Evaluation Points

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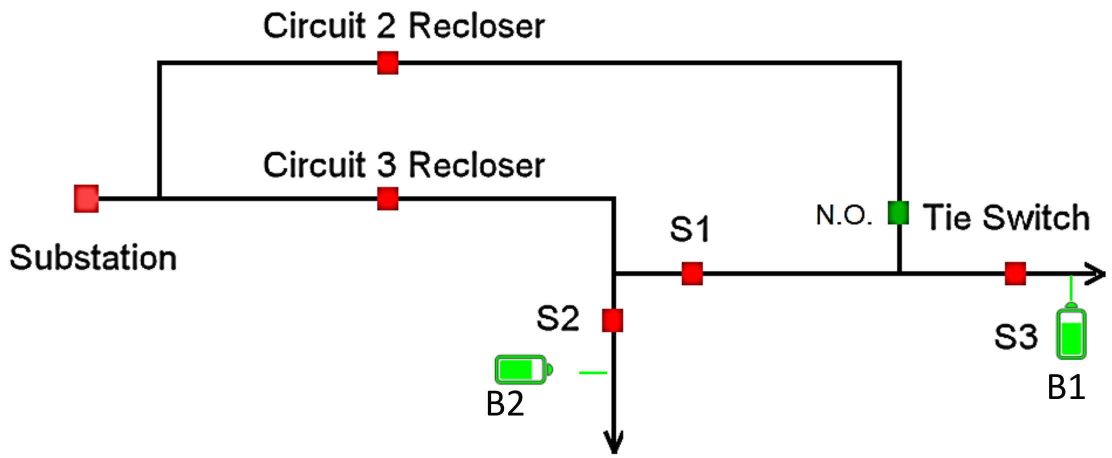
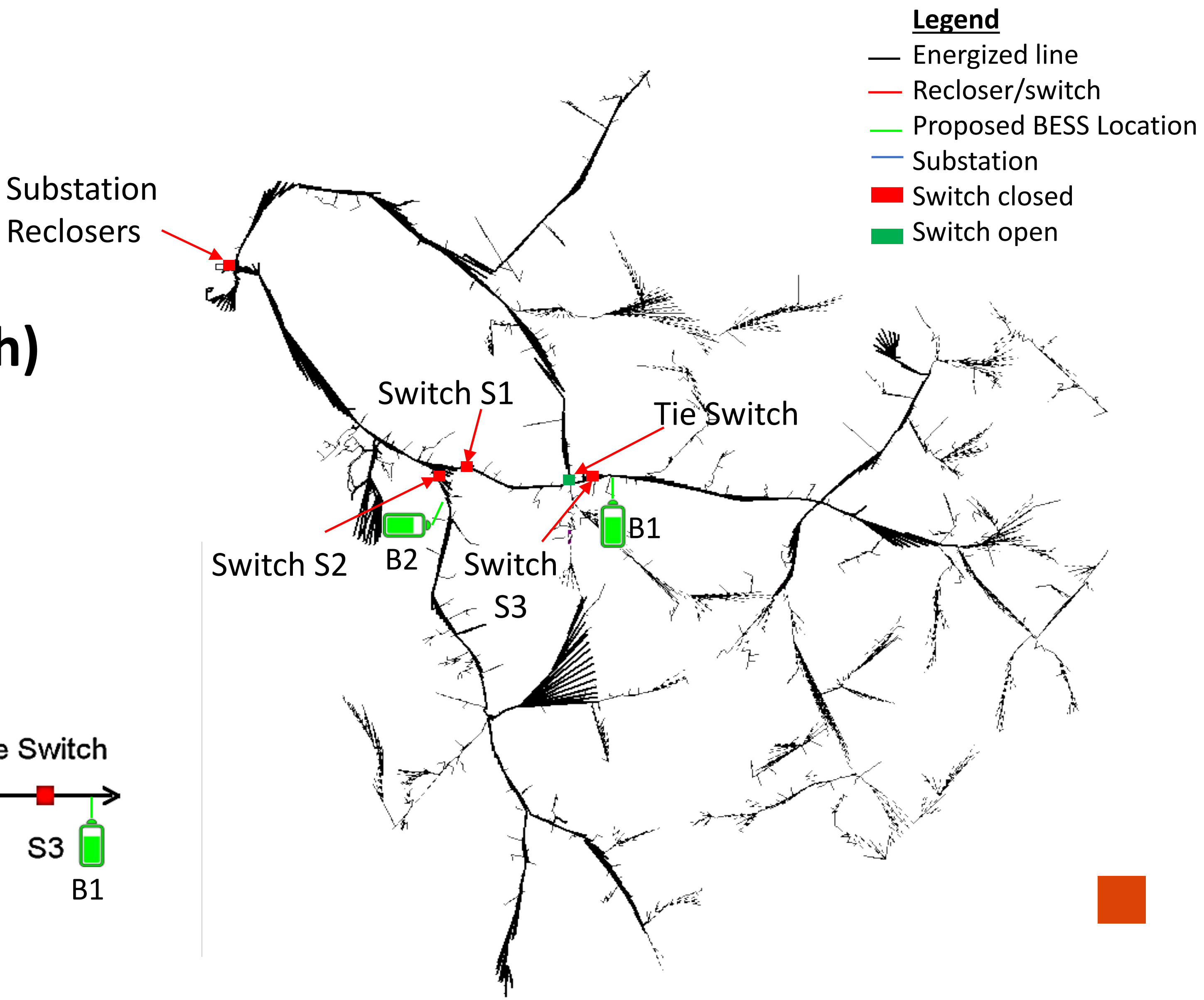
Consider two BESS locations:

- **Impact on feeders downstream of BESS**
- **Impact on load transfer (backup feeder and tie switch)**
- **FLISR opportunities.**





BESS Partial Load Support—First Location

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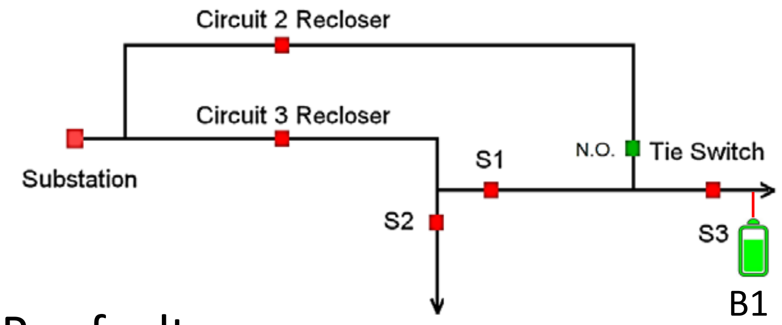
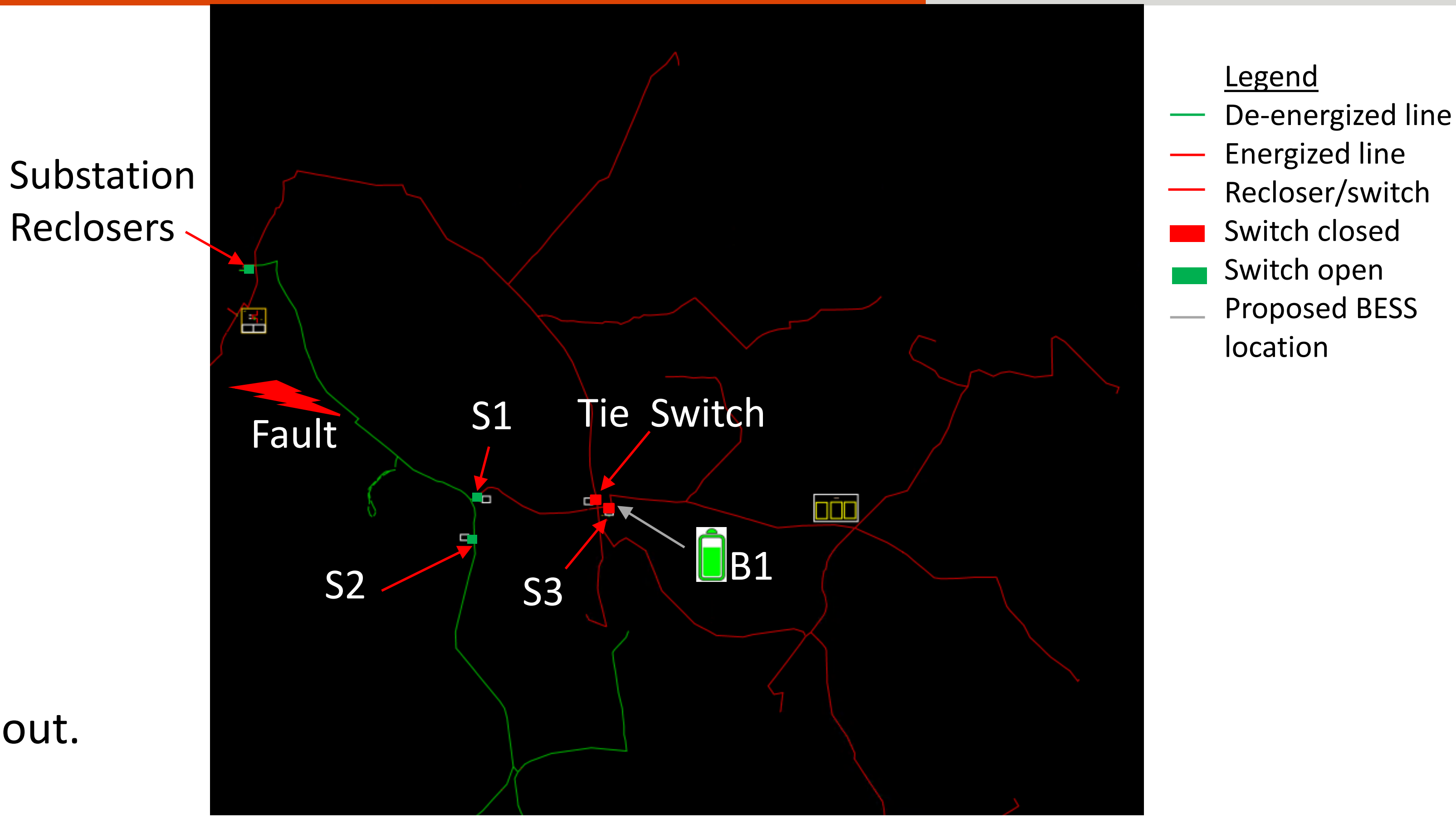


Pre-fault:

- B1 injects ~750 kW
  - 25% of 3.0-MVA rating
- B1 in grid-following (GFL) mode.



Post-fault sequence of events:

- Circuit 3 recloser opens and locks out.
- B1 opens S3 to form microgrid.
- B1 changes mode to GFM and picks up portion of the feeder during the transition.
- FLISR opens Switch S1 and Switch S2.
- FLISR closes tie switch.
- B1 closes S3 and changes to GFL mode.

Load Transfer Operation With B1

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- Table 3 shows the ADMS FLISR snapshot load transfer analysis in the presence of a single BESS for partial load support.
- Table 4 shows the simulation load transfer measurements.
- B1 operation assists by:
  - Reducing the load transfer compared to the baseline by ~1 MW
  - Avoiding partial cold-start load pickup of Circuit 2.

Table 3. Load Transfer Calculations

	Total	Units
Circuit 2 total capacity	13,500	kVA
Circuit 2 current load	708.34	kVA
Circuit 2 spare capacity	12,791.66	kVA
Load behind Switch S1	1,174.79	kVA
Tie switch capacity	600	AMPS
Tie switch capacity	9,000	kVA

Table 4. Load Transfer Simulation Measurements

	Total	Units
Circuit 2 measured power before the fault	0.685	MW
Circuit 2 measured power after the fault	1.752	MW
Circuit 3 measured power before the fault	3.884	MW
Tie switch measured power after the fault	1.056	MW

FLISR Opportunities

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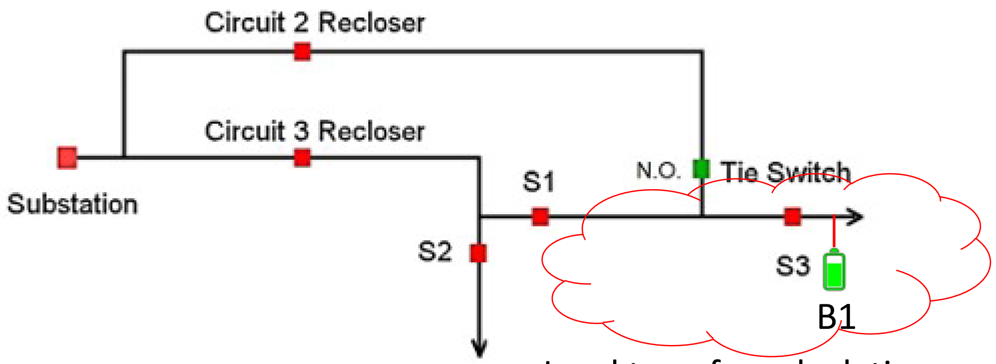
- What if the feeder capacity or the tie switch capacity were reduced to less than the transfer load of ~2.2 MW?
  - – No restoration is possible.
- What if FLISR could dispatch the DERs to reduce the transfer load?
  - – Provides a pathway to restoration.

Table 1. Load Transfer Calculations		
	Total	Units
Circuit 2 total capacity	13,500	kVA
Circuit 2 current load	725.88	kVA
Circuit 2 spare capacity	12,774.12	kVA
Load behind S1	2,253.23	kVA
Tie switch capacity	600	AMPS
Tie switch capacity	9,000	kVA



Load transfer calculations section

FLISR Flowchart With DER Dispatch

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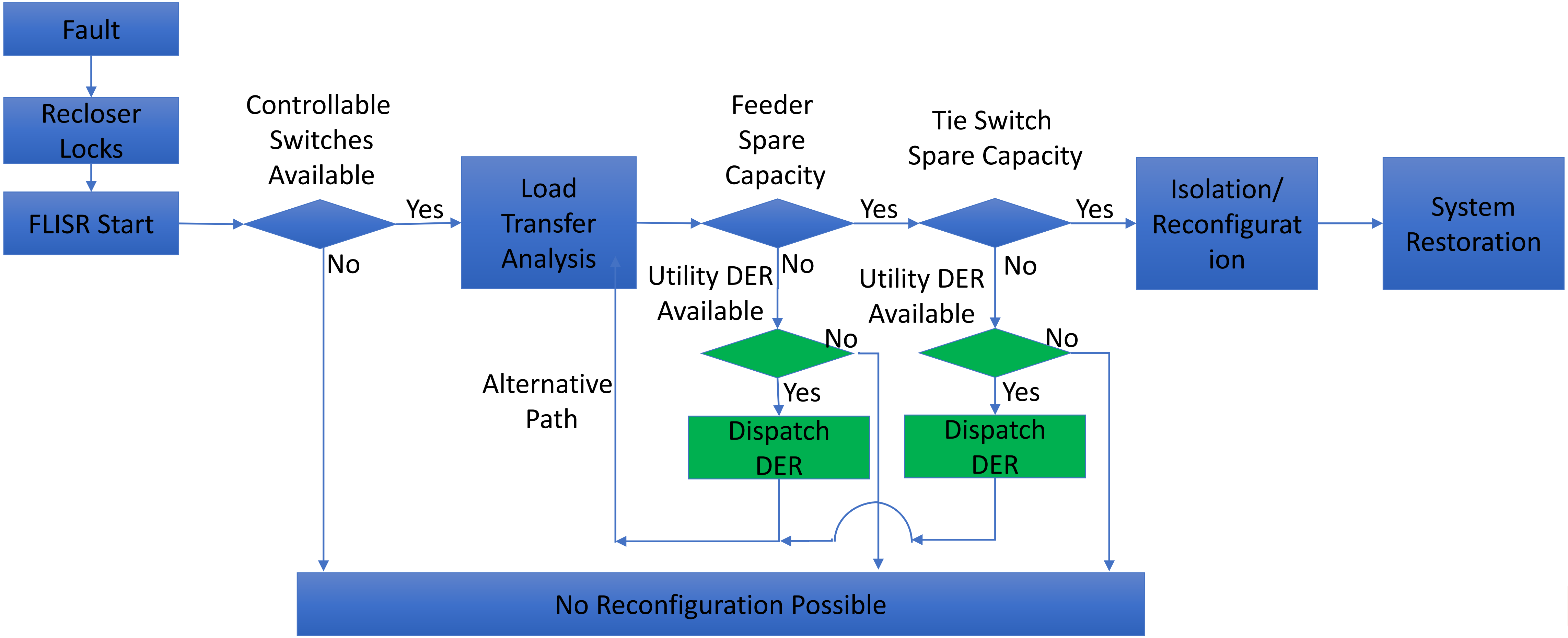
What if FLISR could dispatch DERs?



Simplified, not showing all possible iterations

Load Transfer Operation With B1 Opportunity

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- Example: Reduce load transfer by increasing the B1 output to 50% (1.5 MW) before closing the tie switch.

Table 5. Load Transfer Calculations

	Total	Units
Circuit 2 total capacity	13,500	kVA
Circuit 2 current load	710.03	kVA
Circuit 2 spare capacity	12,789.97	kVA
Load behind Switch S1	341.92	kVA
Tie switch capacity	600	AMPS
Tie switch capacity	9,000	kVA
BESS 50% discharge transfer load reduction (vs. baseline)	1,911.31	KVA
BESS at 25% discharge transfer load reduction (vs. baseline)	1,078.44	KVA

Table 6. Load Transfer Simulation Measurements

	Total	Units
Baseline load transfer	2.168	MW
25% BESS discharge	1.056	MW
50% BESS discharge	0.237	MW

- B1 operating at 50% discharge assists by reducing the load transfer compared to the baseline by ~2 MW and lightening the demand of Circuit 2.

Two BESS Partial Load Support

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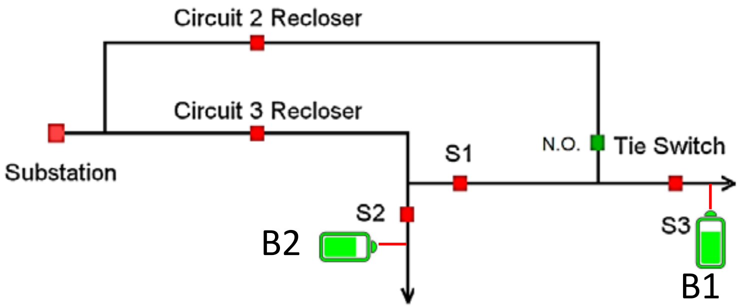
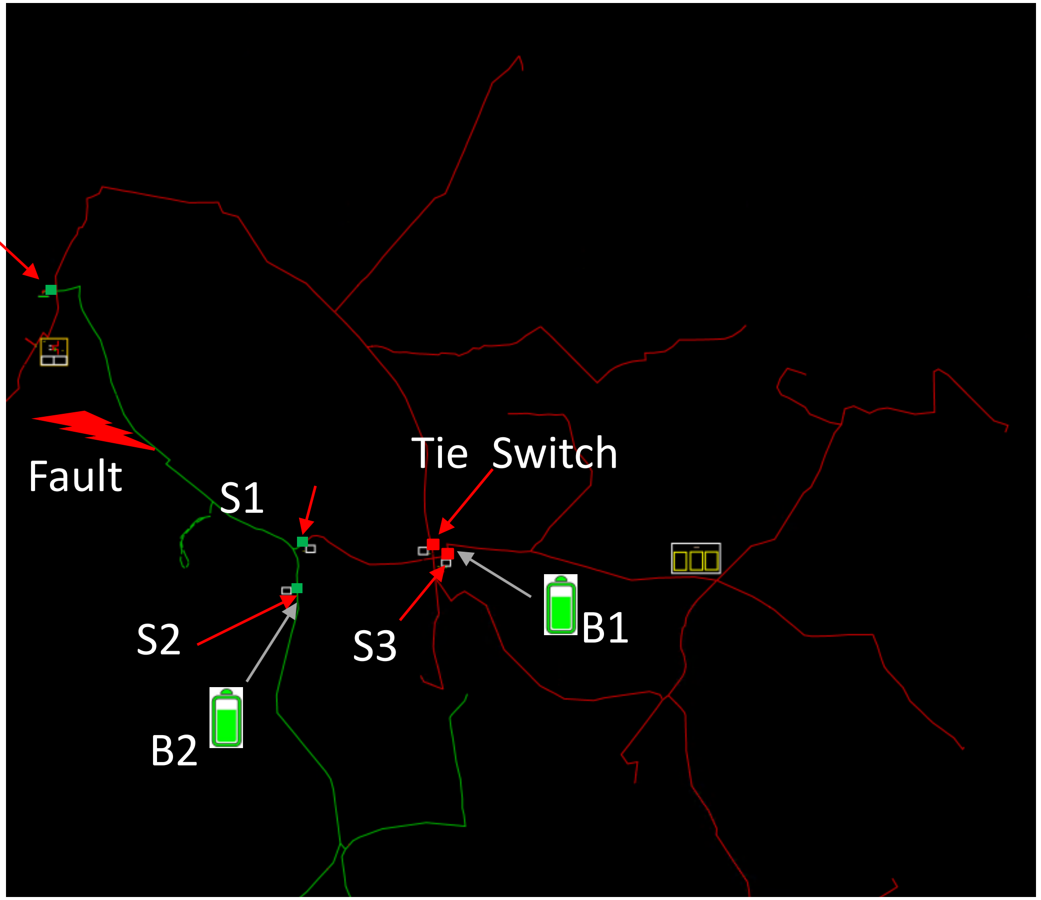


Pre-fault:

- B1 and B2 in GFL mode
- B1 and B2 each inject ~1.5 MW (50%).

Post-fault sequence of events:

- Circuit 3 recloser opens and locks out.
- B1 opens S3 to form microgrid.
- B1 changes mode to GFM and picks up a portion of the feeder during the transition.
- B2 opens S2 to form microgrid.
- B2 changes mode to GFM and picks up a portion of the isolated feeder.
- FLISR opens Switch S1 and Switch S2.
- FLISR closes the tie switch.
- B1 closes S3 and changes to GFL mode.
- B2 remains in GFM mode.



Grid-Edge Intelligent Distribution Automation System for Self-Healing Distribution Grids

Grid-Edge Intelligent Distribution Automation System for Self-Healing Distribution Grids

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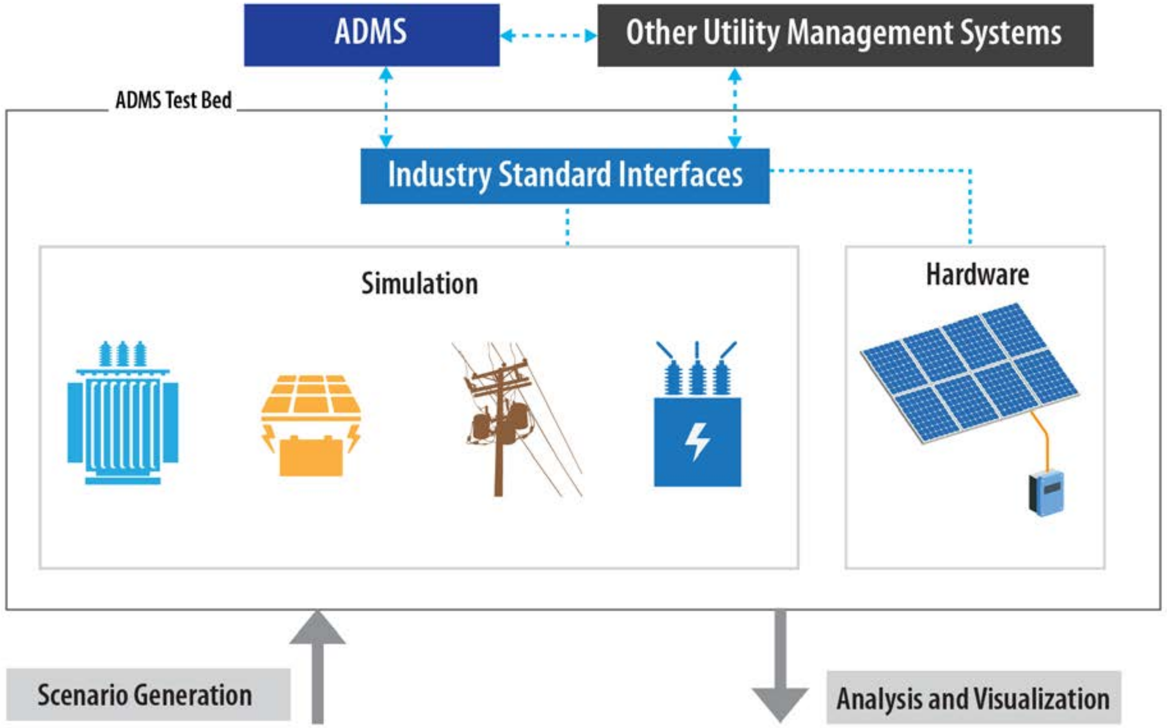
Objective: Develop and validate a model-based, DER-cognizant, hierarchical ADMS platform to achieve self-healing, reliable, and resilient distribution grids.

- **Evaluate the effectiveness of DER integration for a DER-cognizant ADMS FLISR application.**
- **Evaluate the coordinated operation with grid-edge resources to achieve dynamic reconfiguration.**



Platform Development

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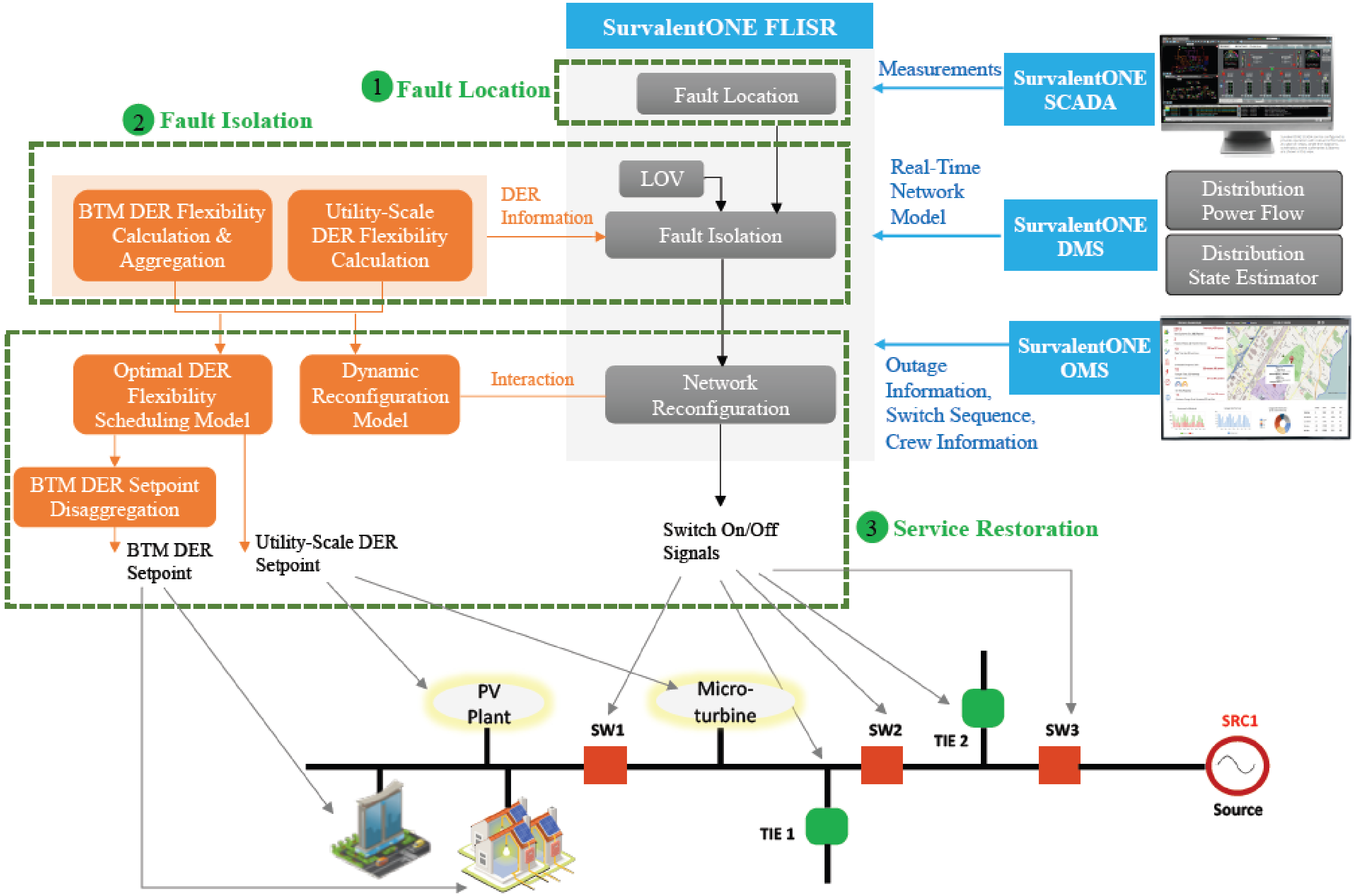
Integrate NREL's grid-edge flexibility quantification and optimization algorithm with multiple solutions provided by SurvalentONE ADMS to develop a model-based, DER-cognizant, hierarchical FLISR application.



Central Georgia EMC Test Case Setup

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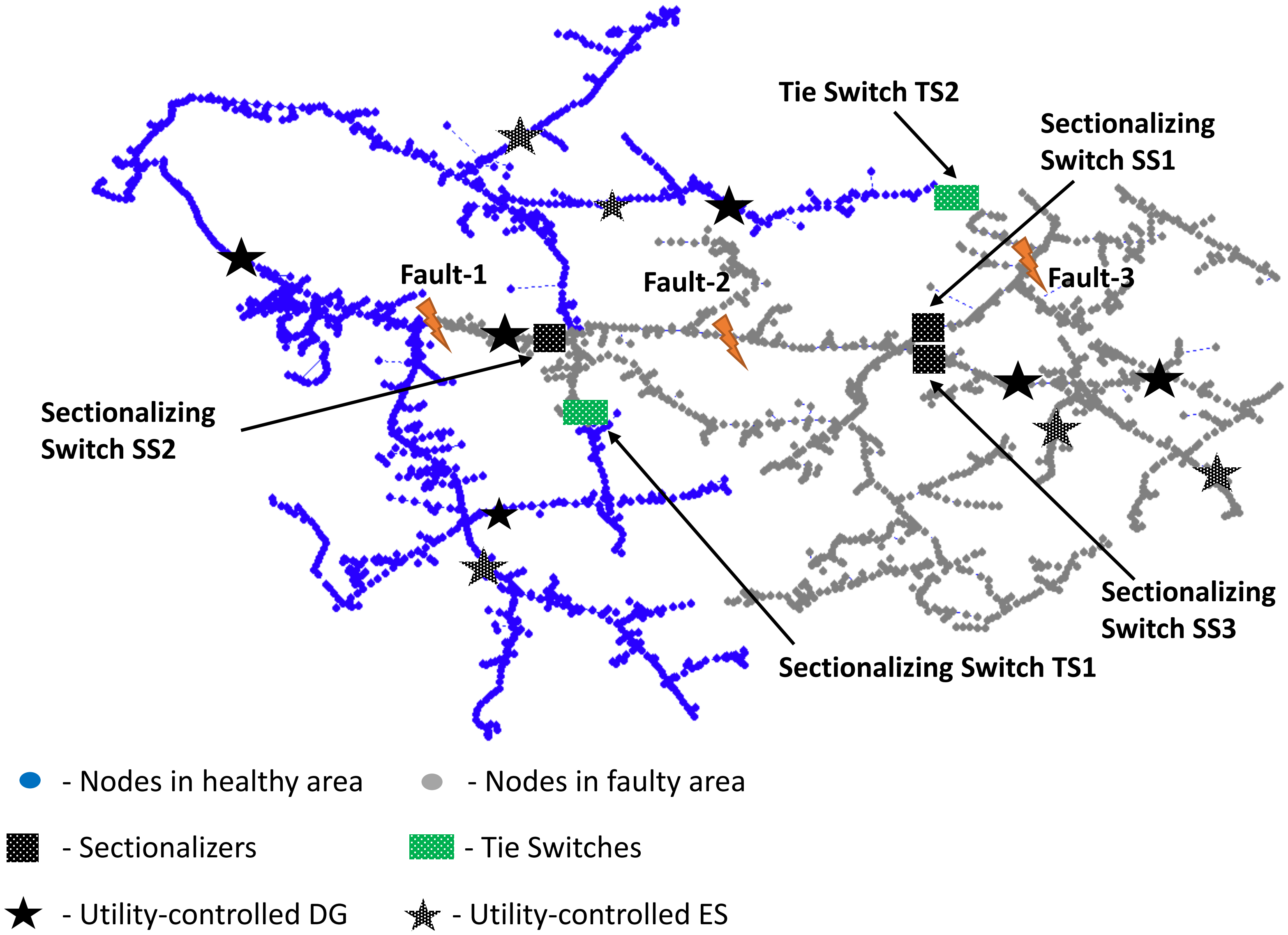

- Three faults are considered at different time intervals.
- Two healthy feeder connections can be used to supply power to the faulty areas, via TS1 and TS2.
- There are three sectionalizing switches (SS1, SS2, and SS3) in the faulty areas.
- Utility-controlled/BTM DERs exist in the faulty areas.

Comparison Overview of the Scenarios

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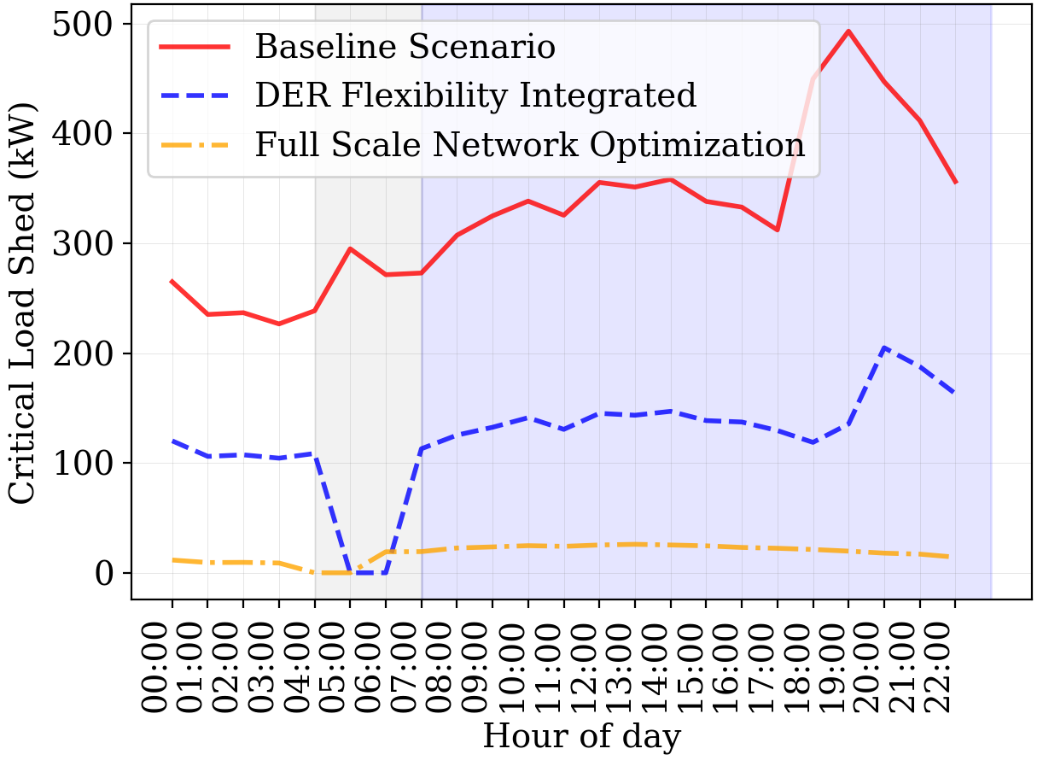

Scenario	Daily Critical Load Shed (kWh)	Median Indoor Temp. (°F)	Median Water Heater Temp. (°F)
Baseline scenario	7837	50.79	105.42
DER flexibility integrated	2973	52.73	107.96
Full-scale network optimization	421	55.47	110.46

- Scenario 2 with DER flexibility integrated has a smaller amount of critical load shed than the baseline scenario.
- Scenario 3 with full-scale network optimization has a significantly smaller critical load shed than the other scenarios.
- Median indoor and water heater temperatures are the highest for Scenario 3 with full-scale network optimization, indicating improved comfort for customers.

Upcoming Events

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ADMS Test Bed Workshop

Planned for in person at NREL, Golden, CO, Nov. 7–8, 2022

https://www.nrel.gov/grid/2022-adms-test-bed-workshop.html

If you are interested in learning how you can work with NREL and use our capabilities for your project, contact me.

Questions?

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Thank you

NREL/PR-5D00-84112

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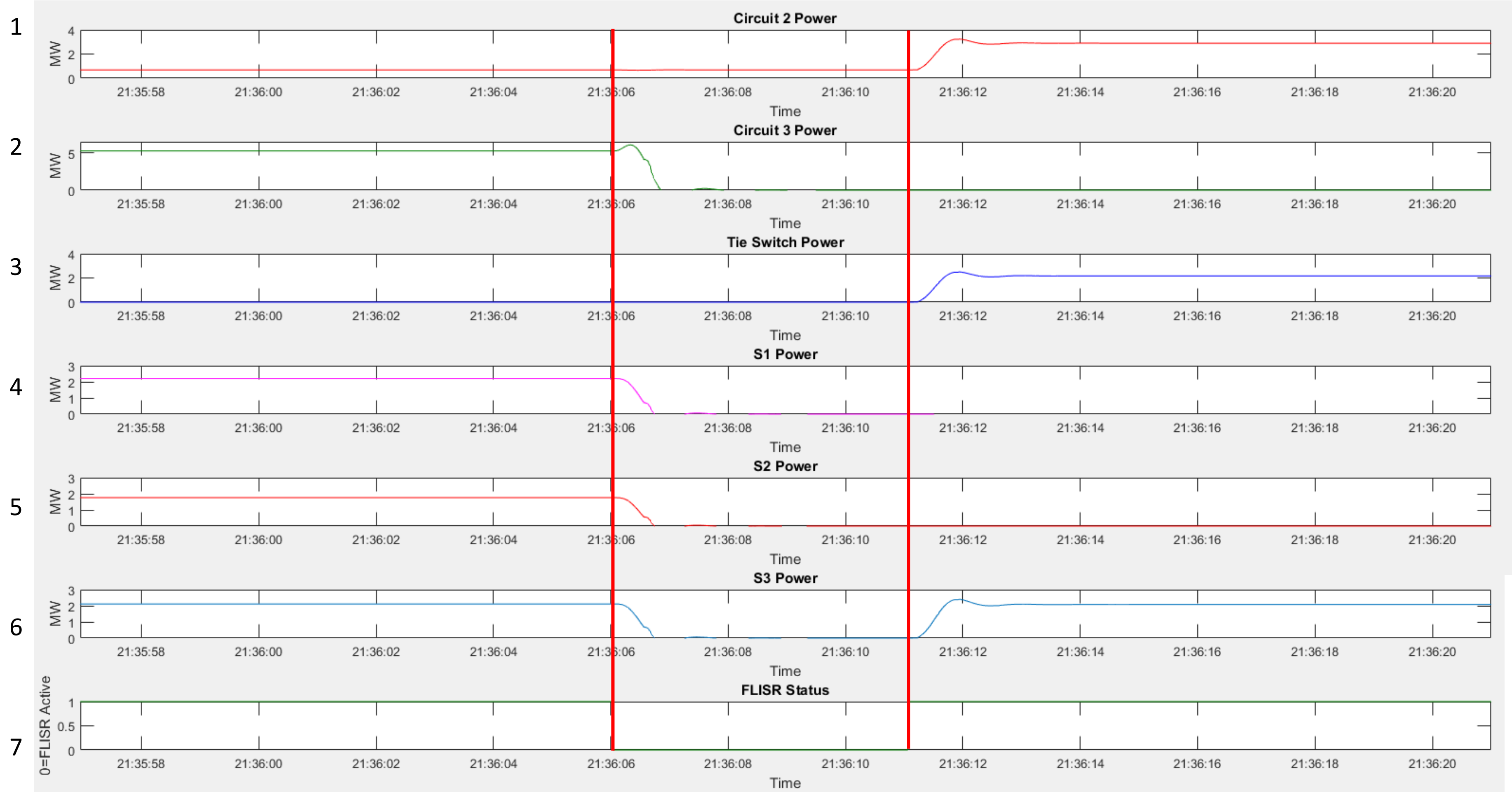
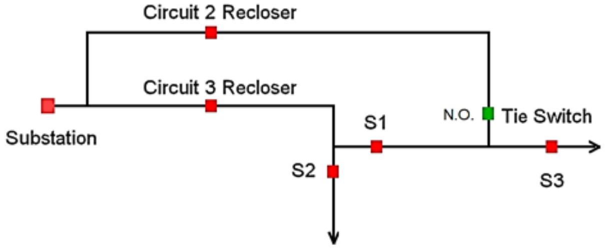
Backup slides

Baseline Power Measurements (No BESS)

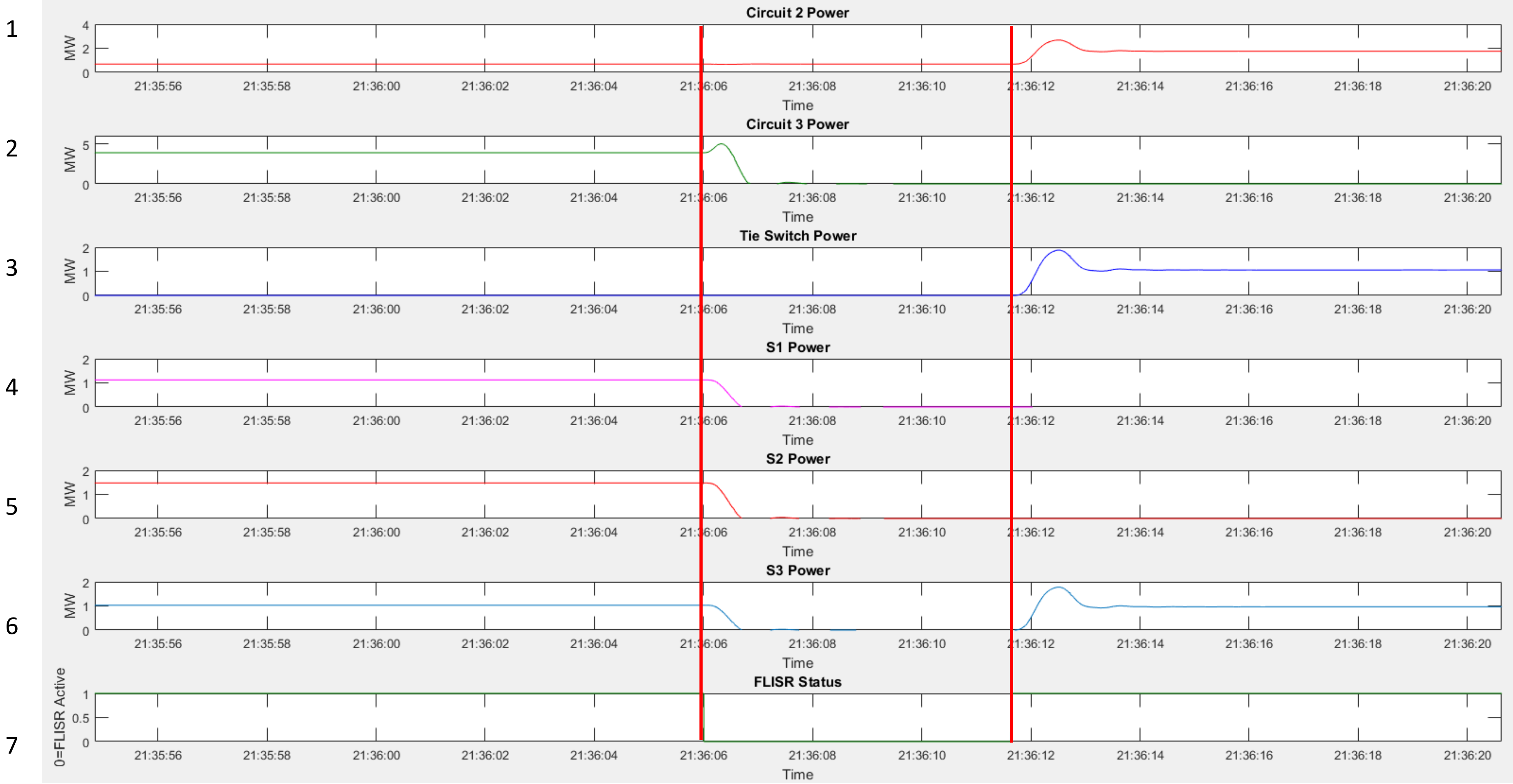


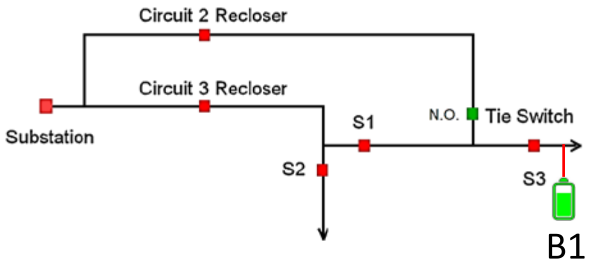


t=21:36:06: Fault occurs, de-energizing Circuit 3

t=21:36:11: ADMS issues the tie switch to close, reenergizing a portion of Circuit 3

Power Measurements With B1 (GFM BESS)



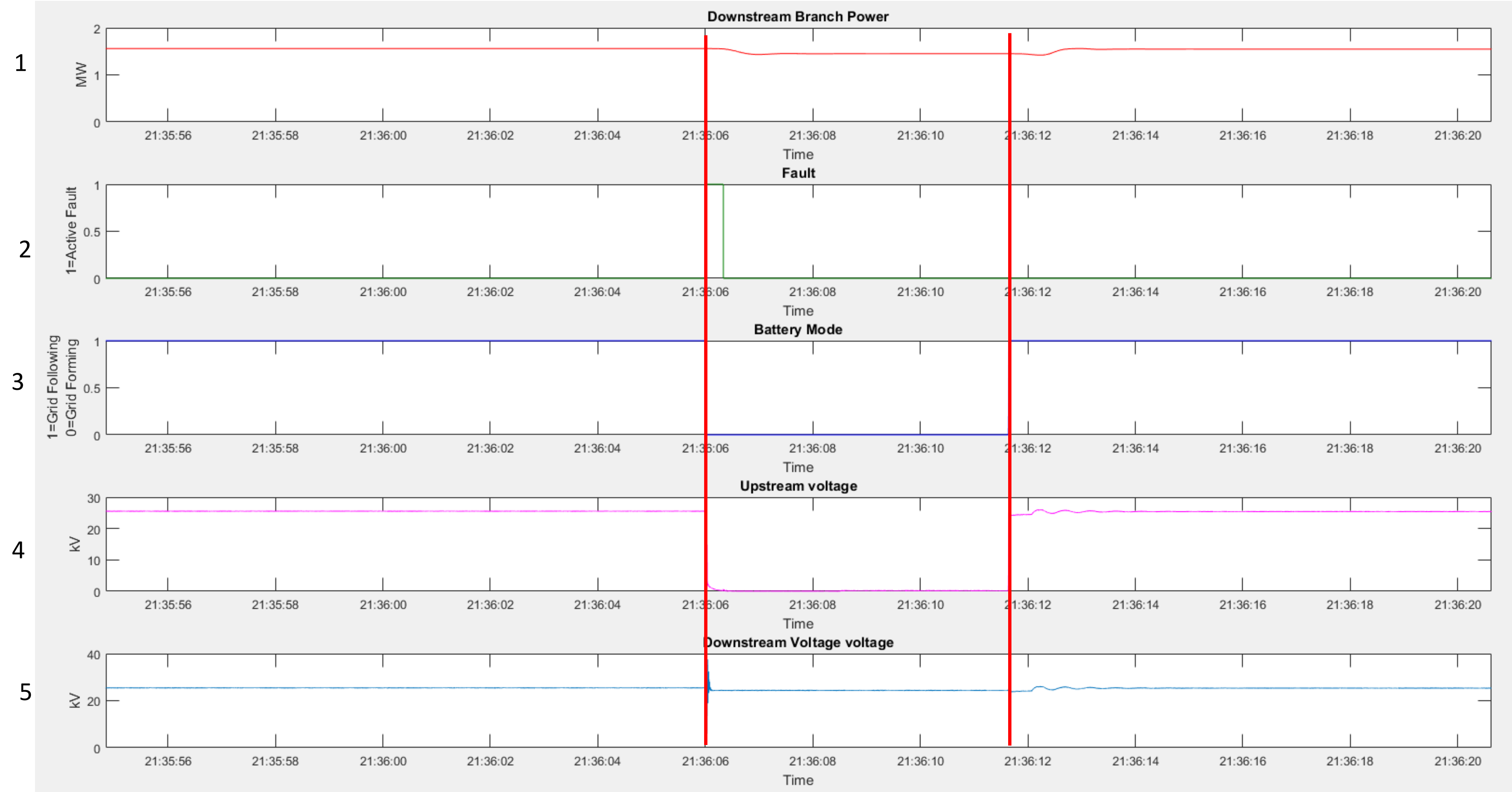


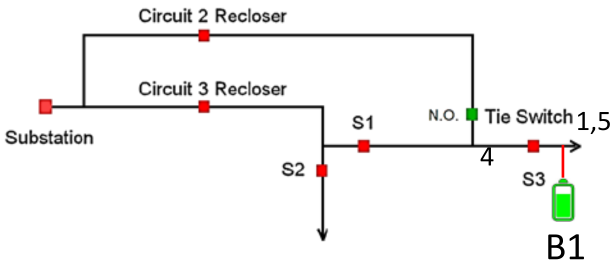
t=21:36:06: Fault occurs, de-energizing Circuit 3

t=21:36:11.6: ADMS issues the tie switch to close, reenergizing a portion of Circuit 3

Single BESS Measurements

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

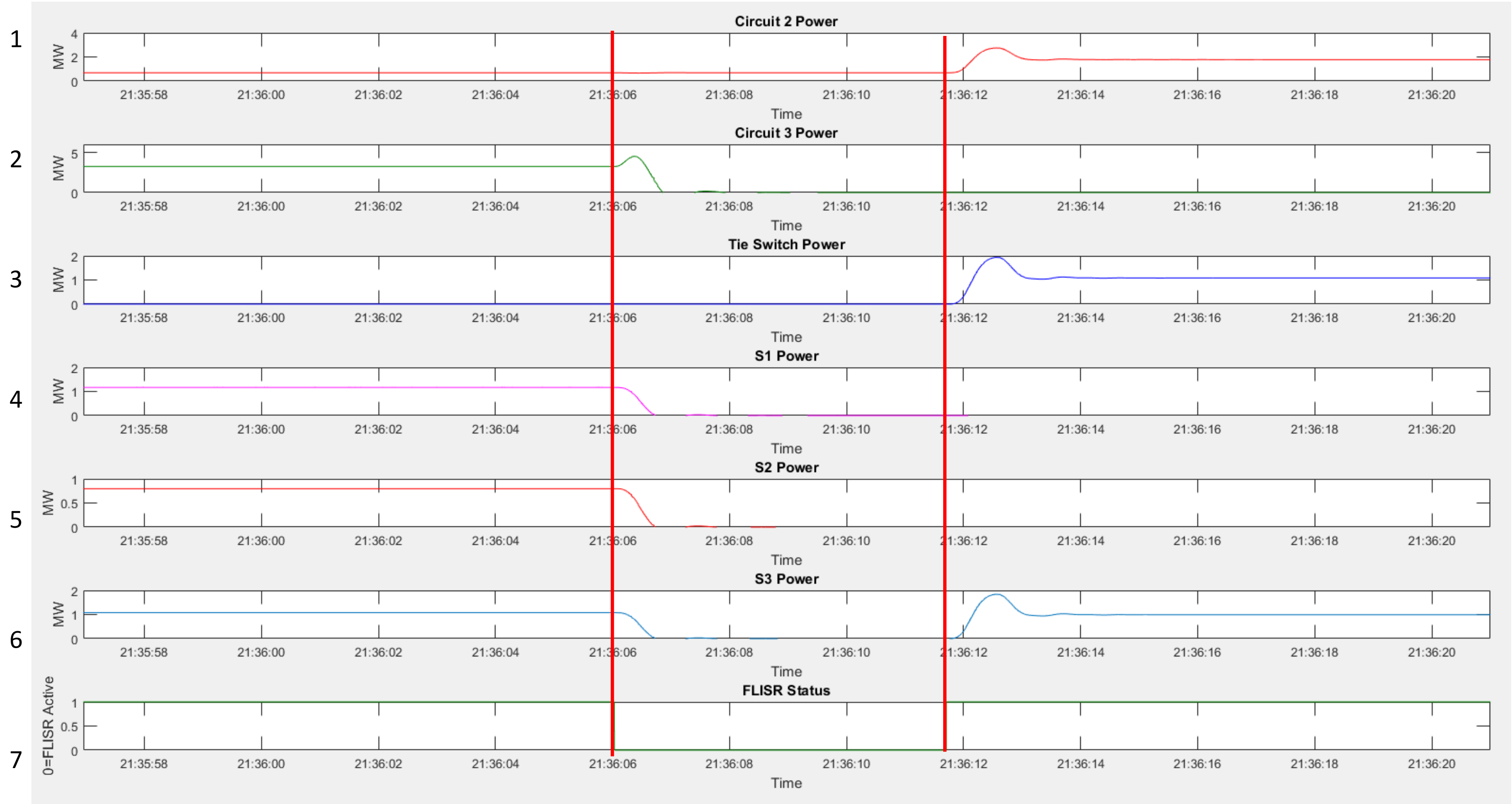


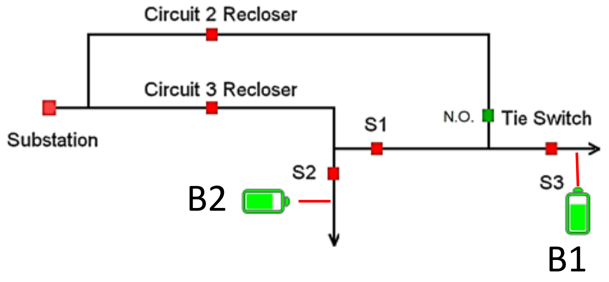


t=21:36:06: Fault occurs, de-energizing Circuit 3; BESS 1 switches to GFM mode to pick up load during the transition

t=21:36:11.6: ADMS issues the tie switch to close, reenergizing a portion of Circuit 3; BESS changes back to GFL mode

Power Measurements With B1 & B2 (GFM BESS)



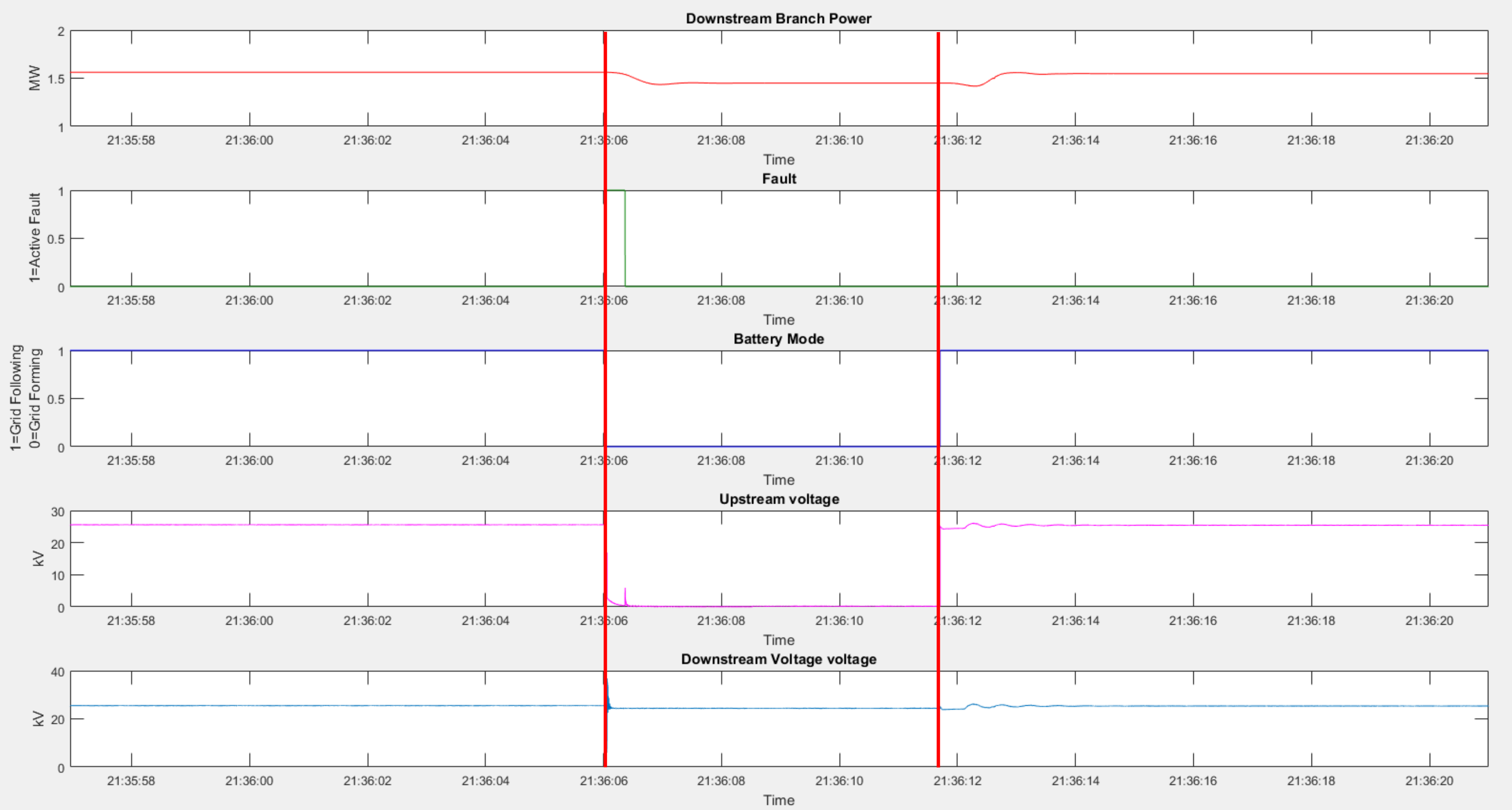


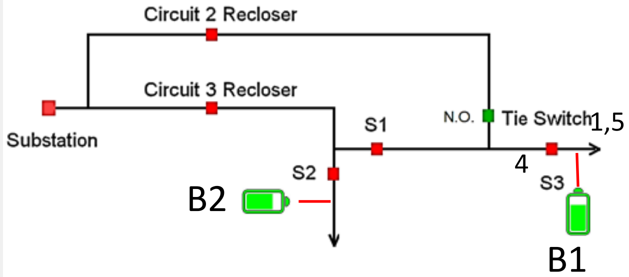
t=21:36:06: Fault occurs, de-energizing Circuit 3; both BESS switch to GFM mode to pick up load during the transition

t=21:36:11.6: ADMS issues the tie switch to close, reenergizing a portion of Circuit 3; BESS 1 switches to GFL

B1 Measurements

1
2
3
4
5

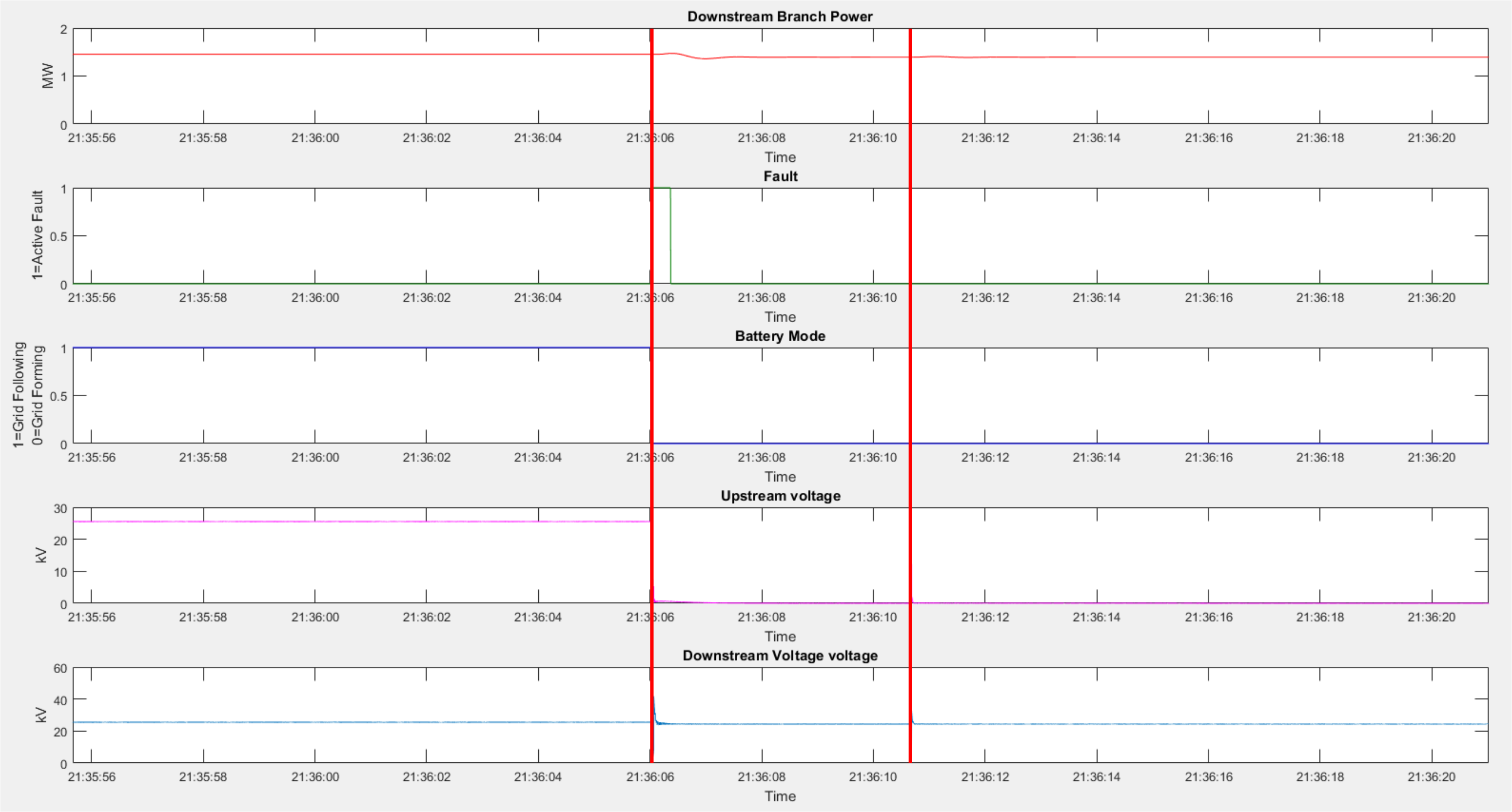


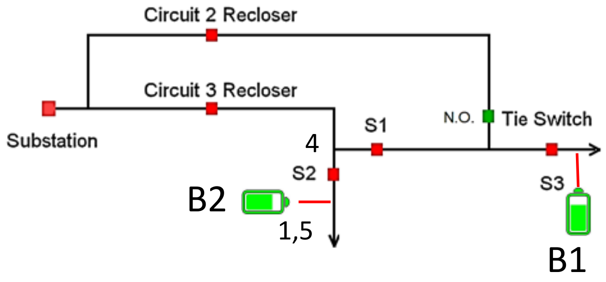


t=21:36:06: Fault occurs, de-energizing Circuit 3; B1 switches to GFM mode to pick up load during the transition
t=21:36:10.6: ADMS issues the tie switch to close, reenergizing a portion of Circuit 3; B1 switches to GFL mode

B2 Measurements

1
2
3
4
5





t=21:36:06: Fault occurs, de-energizing Circuit 3; B2 switches to GFM mode to pick up load during the extended transition
t=21:36:11.6: ADMS issues the tie switch to close, reenergizing a portion of Circuit 3; B2 stays in GFM mode, supporting a portion of the feeder

Load Transfer Operation With Two BESS

- Table 9 indicates the ADMS FLISR snapshot load transfer analysis in the presence of two BESS for partial load support.
- Table 10 shows the simulation load transfer measurements.
- The load transfer operation calculation impact is similar to the previous measurements of B1 because B2 is outside the load transfer calculations after Switch S1.

Table 9. Load Transfer Calculations

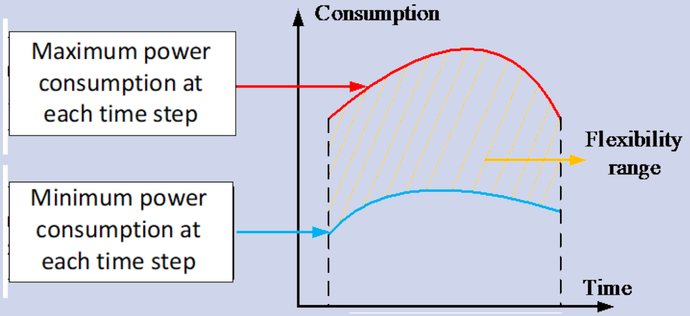
	Total	Units
Circuit 2 total capacity	13,500	kVA
Circuit 2 current load	710.03	kVA
Circuit 2 spare capacity	12,789.97	kVA
Load behind Switch S1	341.92	kVA
Tie switch capacity	600	AMPS
Tie switch capacity	9,000	kVA

Table 10. Load Transfer Simulation Measurements

	Total	Units
Circuit 2 measured power before the fault	0.685	MW
Circuit 2 measured power after the fault	1.779	MW
Circuit 3 measured power before the fault	3.250	MW
Tie switch measured power after the fault	1.080	MW

Evaluated Scenarios

Survalent.

Scenario 1: Baseline Scenario (Survalent FLISR)	Scenario 2: Integrate DER Flexibility	Scenario 3: Full-Scale Network Optimization
• Check whether healthy feeders are available. • Select one healthy feeder each time to restore loads in the faulty area. • If no segmentation is available, the healthy feeder is only connected when it can restore all loads; otherwise, no restoration can be performed. • If the healthy feeder can restore parts of loads via segmentation, then open the sectionalizing switch to enable such segmentation. • The capability of the heathy feeder and loads to restore are both evaluated using kVA capacity. • Assume all utility-owned DERs are not used and are offline.	• We apply the same rules as Scenario 1, but when evaluating the loads that should be restored, we use load flexibility.  • For the area that cannot be reconnected to the healthy feeder, use local GFM resource to form an islanded microgrid, and dispatch GFL DERs to maximize load restoration.	• Determine the optimal statuses of all available tie switches connecting to healthy feeders and all sectionalizing switches that can make segmentations to maximize restored loads in the entire faulty section while maintaining radiality. • Unlike other scenarios, in this scenario, the tie switches with healthy feeders can be closed, even if the healthy feeders can only partially meet the load requirement of the area(s), by allowing to shed loads in faulty areas and dispatching DERs. • For all isolated areas, use local GFM resource to form an islanded microgrid, and dispatch GFL DERs to maximize load restoration.