GRID MODERNIZATION INITIATIVE PEER REVIEW

1.3.10 Vermont Regional Partnership: Facilitating the Effective Expansion of Distributed Energy Resources

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April 18-20, 2017

Sheraton Pentagon City – Arlington, VA

1.3.10 Vermont FEEDER project

High Level Summary

Project Description

Develop an optimal and replicable approach to DER integration at the distribution level to meet the state's goal of 90% renewable energy penetration by 2050.

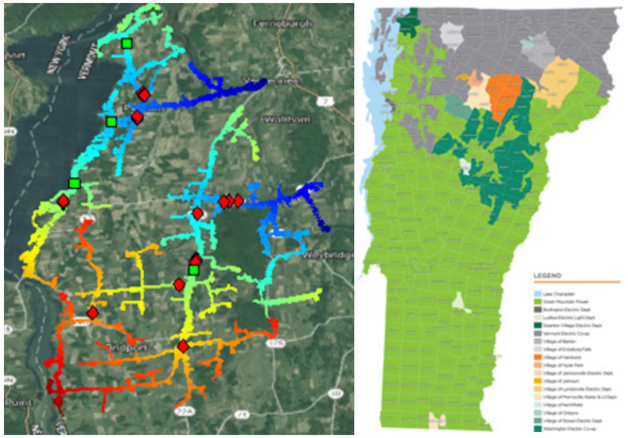
Value Proposition:

- ➢ *The VT FEEDER team—in partnership with VT's electric utilities—is developing an innovative and replicable approach to distribution-level DER integration.*
- ➢ *This multi-pronged approach combines optimal placement of DER within a distribution network with advanced control systems and high-resolution weather forecasting to enable the efficient harnessing of intermittent generation.*

Project Objectives

- ✓ Facilitate and optimize the integration of DER
  - ✓ New and optimized integration methods
  - ✓ Effective controls
  - ✓ Forecast evaluation
- ✓ Partner with multiple institutions in VT, a state ahead of the curve on grid-modernization

DER Integration in Vermont



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Project Team

Partners and Roles

Sandia National Laboratories	**Lead and PI for Tasks 1-3**
NREL NATIONAL RENEWABLE ENERGY LABORATORY	CO PI on Tasks 2 & 3
The University of Vermont; Georgia Tech	Modeling and optimizing DER integration (Task 1)
Green Mountain Power; Vermont Electric Co-op Inc; Vermont Electric Power Company VELCO	Utility Partners: data & DER challenges

Utility partners GMP, VEC, VELCO have provided <u>massive amount of data</u> and have provided direct feedback to guide our research.

PROJECT FUNDING		
Lab	FY16	FY17
SNL	$250K	$500K
NREL	$85K	$165K

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Relationship to Grid Modernization MYPP

This project's aligns with the Grid Modernization Multi-Year Program Plan (MYPP) to achieve an outcome of a "50% cut in the costs of wind and solar and other distributed generation (DG) integration" and to achieve "resilient distribution feeders with high percentages of low-carbon distributed energy resources."

Devices and Integrated Systems Testing

- Activity: Energy Storage Systems
- Task 2.1.3

System Operations and Power Flow

- MYPP Activity 1&2
- Task 4.3.1

Design and Planning Tools

- Activity 2: Developing and Adapting Tools for Improving Reliability and Resilience
- Task 5.2.6

Devices and Integrated Systems (MYPP Activity 1) – Our work will demonstrate the ability of ES to improve system reliability and provide improved benefit-cost ratio through valuable grid services, thus enabling higher penetration of other DER.

System Operations and Power Flow (MYPP Activity 1&2 and MYPP Task 4.3.1) – Develop and demonstrate advanced control-technologies for load management and ES systems in order to support high DER penetration.

Analysis and validation of high-resolution solar forecasting will enable predictive generation control and reduce the uncertainty associated with controlling for intermittent resources.

Design and Planning Tools (MYPP Task 5.2.6) –Develop algorithms and public-domain tools using big data (AMI) for model development and validation.

We will develop modeling tools for improving feeder performance and reliability when siting high DER penetrations.

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Approach

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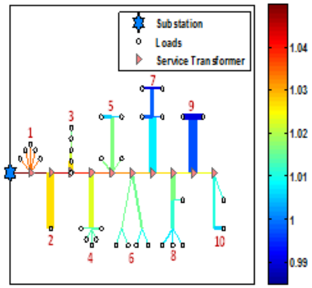
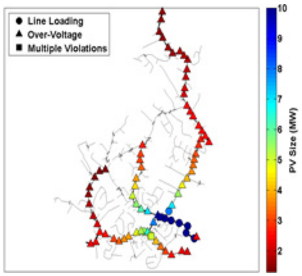
The overall objective of the FEEDER project is to develop an optimal and replicable approach to DER integration at the distribution level, utilizing the state of Vermont as a testbed.
In partnership with Vermont's largest distribution utilities, we have identified three task areas to promote a renewables-intensive 21st century grid:





DER Integration Modeling and optimizing:

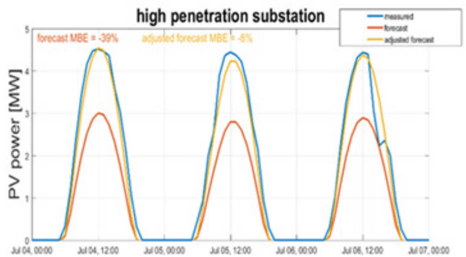
I. Create new accurate secondary system distribution models with AMI data and new, <u>innovative</u> parameter estimation methods that are not used today by utilities.
II. Determine the optimal amount and placement of DER (PV and storage) on distribution feeder using a <u>unique</u> advanced location specific hosting capacity analysis.
III. Determine the best energy storage amount and placement on the distribution system using <u>new</u> optimization methods.

DER Control Modeling and optimizing:

- Develop and validate new control strategies for managing DR rebound effects.

DER Forecasting:

- Improve the forecasting of solar and wind to enable more accurate and higher resolution generation prediction to reduce the uncertainty associated with controlling for intermittent resources.



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Key Project Milestones

Milestone Name/Description	Status	Due Date
Task 1 – DER integration Put in place all agreements needed to receive feeder data, AMI data and controller data from partners **Task 2– DER control** Complete the design of communications interfaces to ES and PV systems in the Spirae Wave™ controller for DR rebound effects. **Task 3– Validation and Improvement of Forecasting Engine.** Assemble and qualify existing data for comparison with weather, power and load forecasts. Quantify forecast performance using operationally relevant metrics and identify where additional data can significantly enhance forecast evaluation.	Complete. Complete. Complete.	**Sept 30, 2016**
Task 1 – DER integration Received at least two feeder models, AMI data and controller data. Begin conversion and data cleaning. Data integrated into models for running analysis and visualization **Task 2– DER control** Formulate network model and develop preliminary optimization algorithms. Grid LAB-D models, populated with residential ES system models, running in IESM. Update algorithms after analysis and simulation. Ability to control residential ES systems from aggregator module within IESM demonstrated.	Complete. Complete.	**March 30, 2017**

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Key Project Milestones

Milestone Name/Description	Status	Due Date
Task 1 – DER integration Detailed results and graphics of locational impacts and benefits of ES and PV. The locational PV hosting capacity analysis will be done on 7 feeders, parameter and topology estimation on 2 feeders, and optimal ES siting on 3 feeders **Task 2– DER control** Demonstrate algorithms on the Vermont system Update algorithms based on test results Scenarios selected and simulation of scenarios completed. Deliver report on simulation results **Task 3– DER forecast** Provide at least 3 areas for potential improvement of the VTWAC forecasts.	**In Process**	**Sept 30, 2017**

Other Key activities and industry involvement:

- Mid-Project status meeting with all Vermont partners on March 8th and March 9th, 2017
- Project kick off meeting with all Vermont partners on April 28th, 2016
- Bi-weekly coordination calls with stakeholder VELCO and monthly calls with GMP and VEC
- Upcoming papers and presentations at Photovoltaics Specialist Conference in June 2017:
  - ***"Targeted Evaluation of Utility-Scale and Distributed Solar Forecasting"***
  - ***"Full-Scale Demonstration of Distribution System Parameter Estimation to Improve Low-Voltage Circuit Models"***
  - ***"Demand Response of Electric Hot Water Heaters for Increased Integration of Solar PV"***

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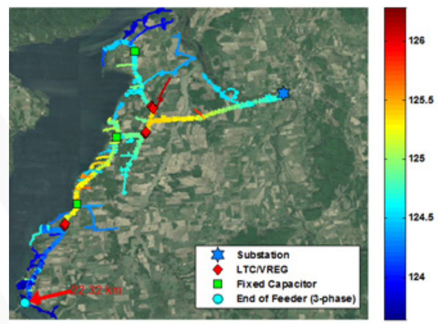
Accomplishments to Date

Task 1: DER Integration

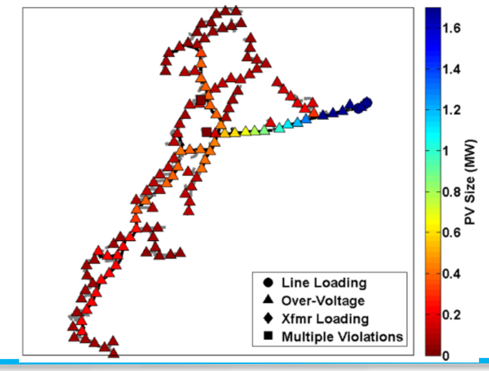
- ✓ 3 GMP feeders and 7 VEC distribution feeders have been received. GMP models have been converted and validated in OpenDSS using integrated data, and detailed location specific hosting capacity analysis has begun.

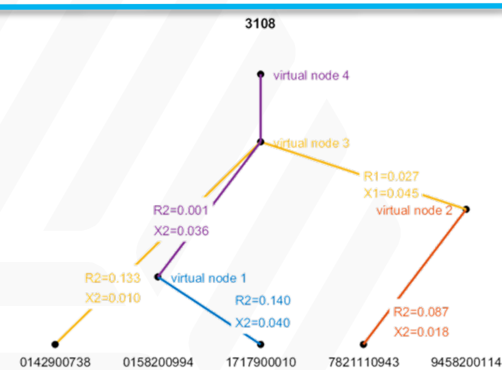
- ✓ Parameter estimation on GMP feeder Panton – 9G2. Initial results at two transformers along Jersey Street show excellent estimation of the secondary system impedance which shows great promise to dramatically improve the accuracy of feeder models.

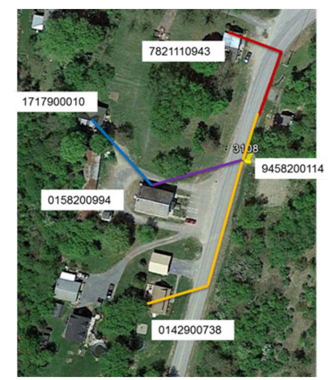
- ✓ Developed circuit reduction methods for energy storage optimization methodology to determine the optimal amounts and locations for new storage installations.



Feeder-9G2



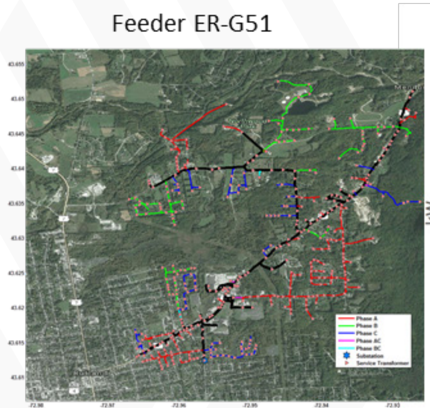


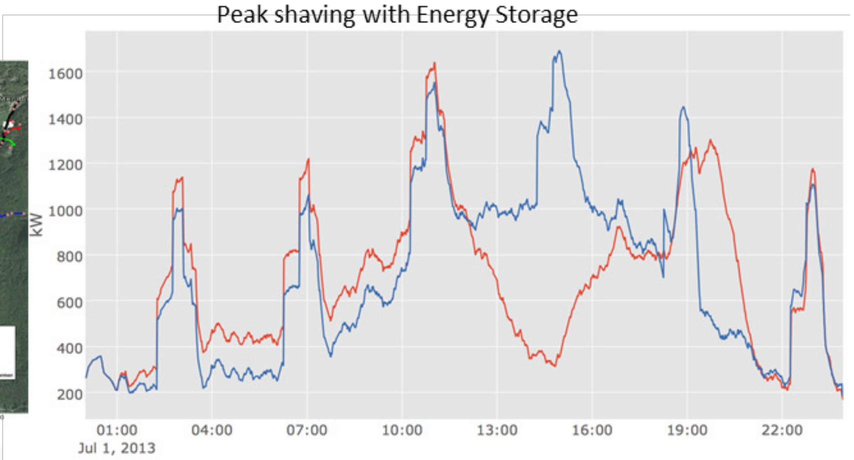


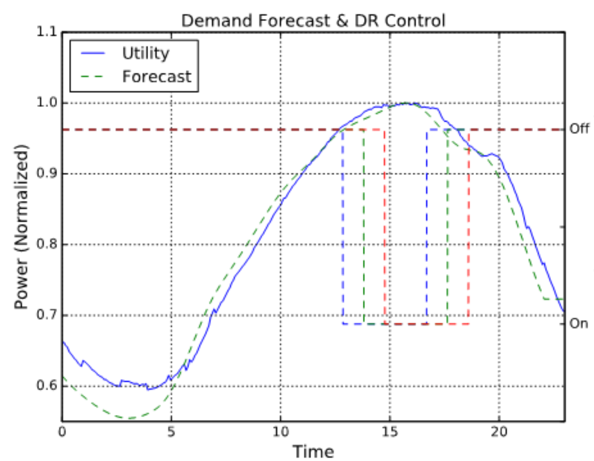
Circuit reduction results showing a reduced feeder model with ~10 representative nodes. Performed K-means clustering using electrical distances in combination with voltage data from QSTS model

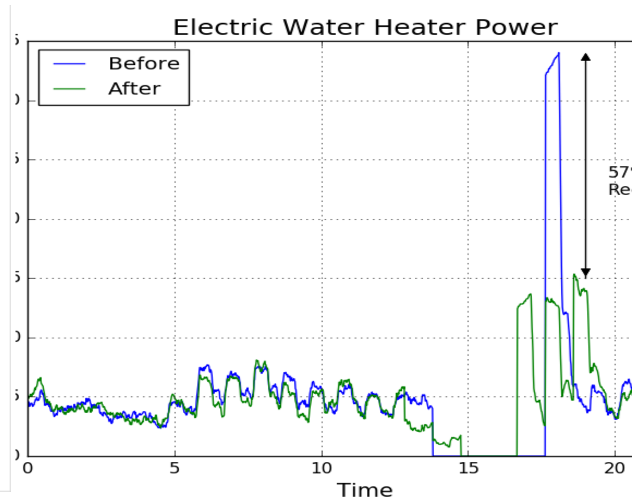
Task 2: DER control

- ✓ Converted Green Mountain Power feeder ER-G51 to GridLAB-D, populated with house models, and performed initial simulation runs with simple control strategies
- ✓ Grid LAB-D models, populated with residential ES system models, running in IESM.
- ✓ Developed multiple bin control approach that shaves water heater peak load while minimizing rebound
- ✓ This strategy was able to provide peak shaving at the time of the ISO peak and reduce the rebound by about 57% as shown









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Accomplishments to Date

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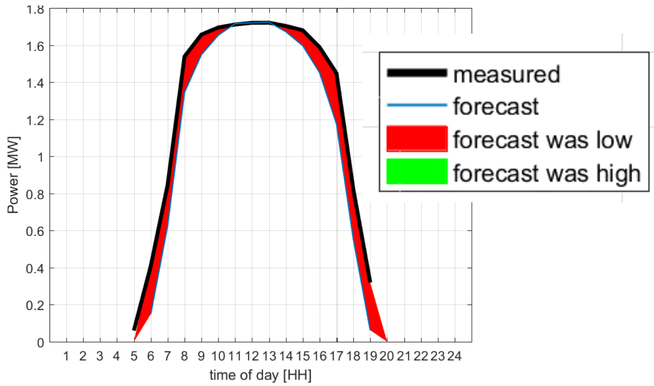
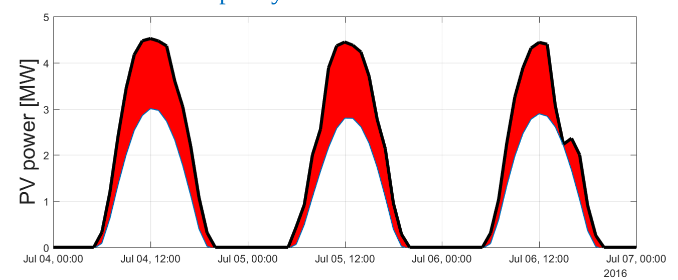
Task 3: Forecast Evaluation

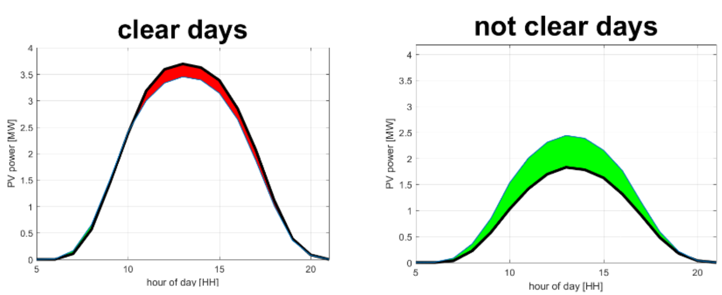
- Evaluated forecast data from:
  - 21 PV farms ~2MW each
  - 4 substation aggregates of distributed PV and load
  - Distributed PV for entire state of VT
  - 4 wind farms
- Directly presented results to VECLO, forecast provider, and distribution utilities
  - Feedback on important use cases has directed targeted evaluation
  - Suggested improvements to forecast methods directly conveyed to forecast provider
    - Account for azimuth of PV modules
    - Faster adjustments to changes in distributed PV capacity
    - Separate forecast training on clear vs. cloudy days

dual axis tracking not fully captured at PV farm



Added PV capacity makes substation forecast low





Forecast low on clear days, high on cloudy days

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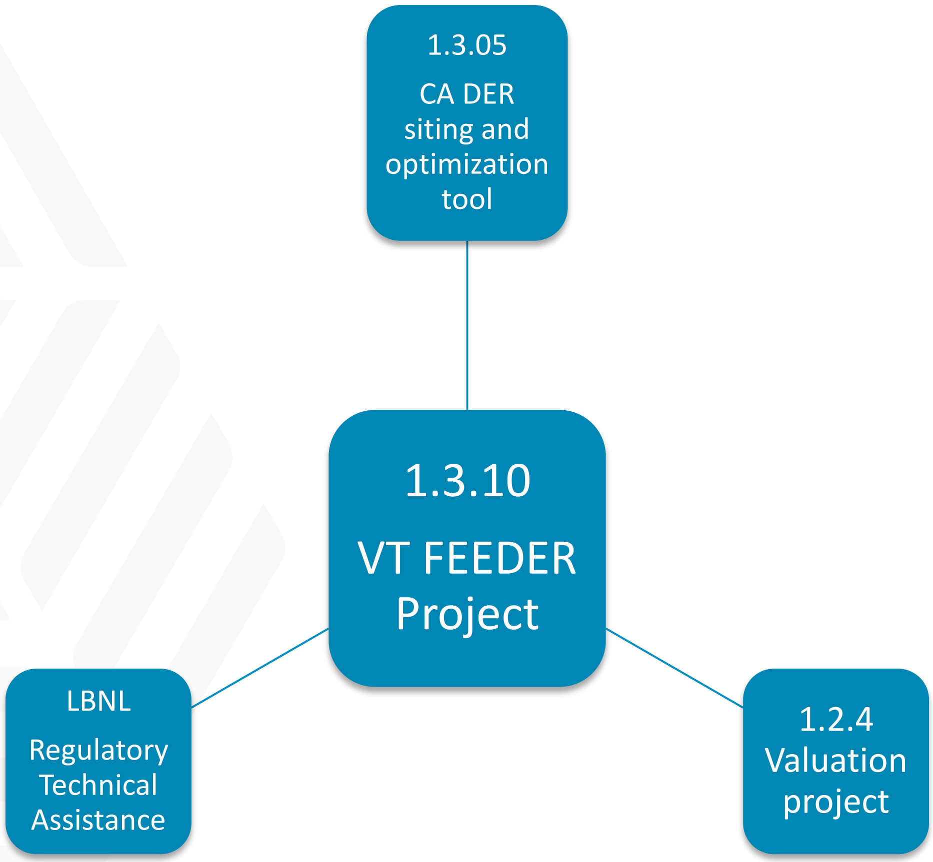
Response to December 2016 Program Review

Recommendation	Response
While the optimization goals may be different, please work closely with the CA DER Regional Partnership (1.3.5) to make sure the approaches are similar where they need to be.	We are coordinating with John Grosh (LLNL) and Goncalo Cardoso (LBNL) focusing on areas where each project can complement the other for optimal integration and siting of DER on distribution feeders in their respective states.
Please coordinate with the valuation project as well 1.2.4.	Coordination is ongoing with Bobby Jeffers (SNL) and Mark Ruth (NREL) on the valuation project focused on energy storage.
Please coordinate with LBNL as they provide regulatory technical assistance to stakeholders in VT. Regulators should understand the implications of your work.	Coordination is ongoing with LBNL and key regulatory stakeholders in Vermont including the Vermont Energy Investment Corporation (VEIC).

- Both the VT and CA Regional Partnership projects complement each other by investigating the optimal integration and siting of DER on distribution feeders in their respective states. We are coordinating with John Grosh (LLNL) and Goncalo Cardoso (LBNL) focusing on comparing analysis methods and thresholds for impacts to determine optimal methods for different use cases.
- Coordination is ongoing with Bobby Jeffers (SNL) and Mark Ruth (NREL) on the valuation project to determine how the Energy storage installations in Vermont can be test cases for evaluating the methodologies.



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Next Steps and Future Plans

Next Steps:

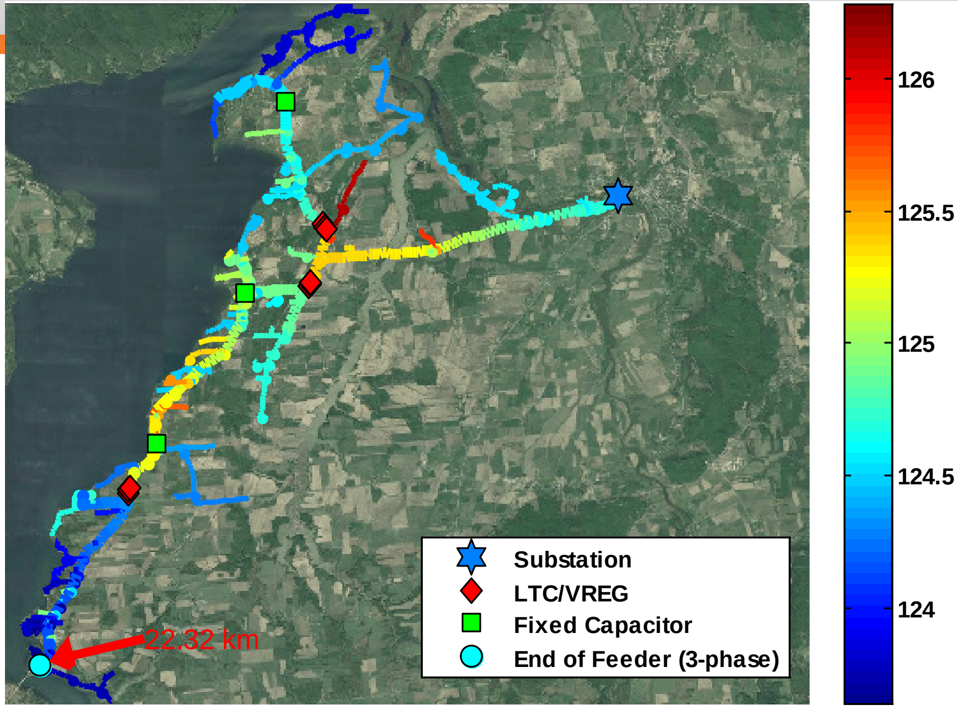
1) Detailed results and feeder map graphics of locational impacts and benefits of ES and PV.
2) Demonstrate DR control algorithms across a variety of simulation scenarios.
3) Provide at least 3 areas for potential improvement of the VTWAC forecasts

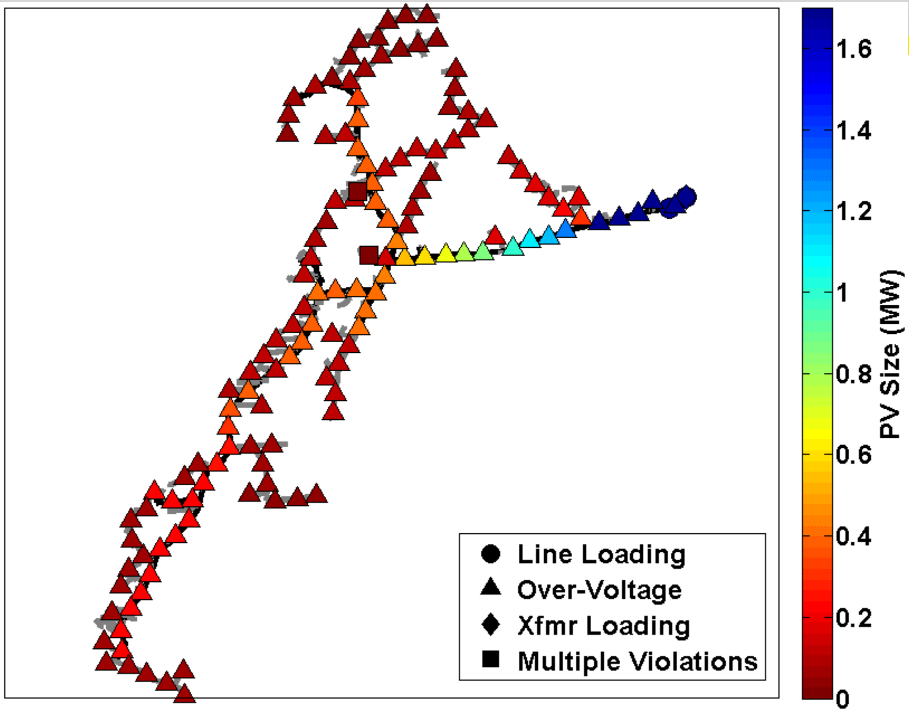
This project's key outcomes will be 1) to achieve resilient distribution feeders and the use of energy storage for high penetration of renewable energy generation without causing negative impacts to the distribution system. 2) develop a replicable approach and road map for DER integration at the distribution level in each of the three task areas and 3) Disseminate the results of this project to VT stakeholders and the Vermont Department of Public Service and to other utilities and stakeholders across US via conference presentations and publications.

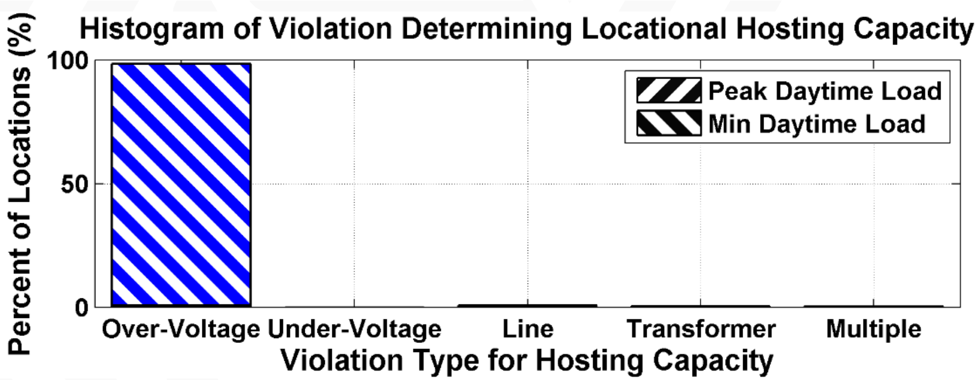
Future Plans with additional funding to expand project to achieve MYPP goals:

- ❑ Expand to include other New England utilities and COOPs
- ❑ Apply methodology for resilient distribution feeders for high penetration of DER to different utility service territories.
- ❑ Apply DER control and optimization in other regulatory frameworks and with different aggregators.
- ❑ Apply forecast improvements evaluation to other forecasting tools in other states.

Hosting Capacity Results (9G2)

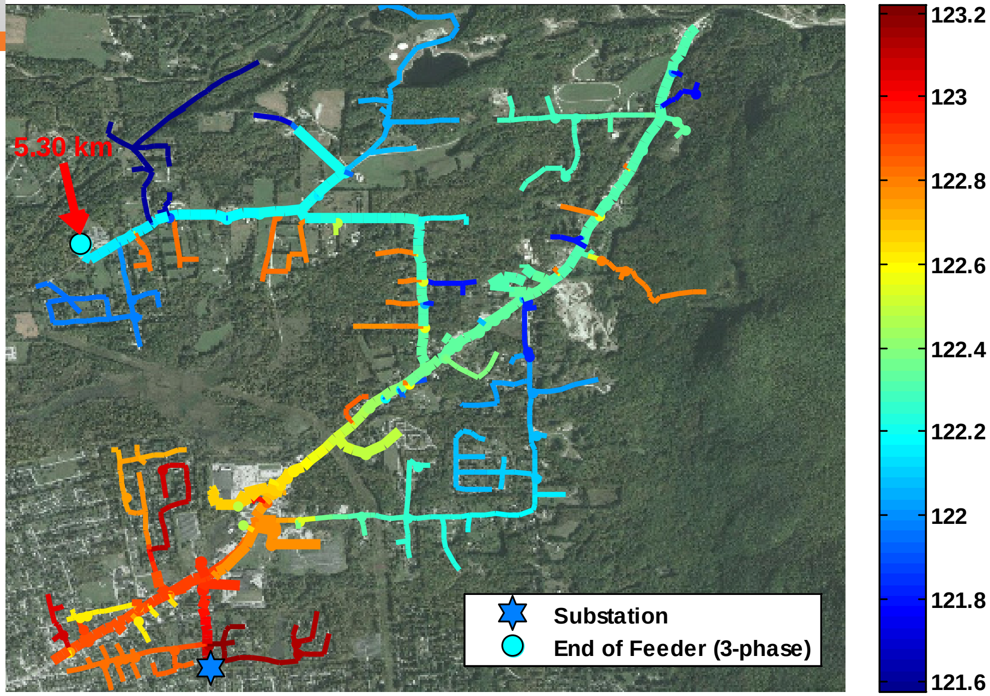


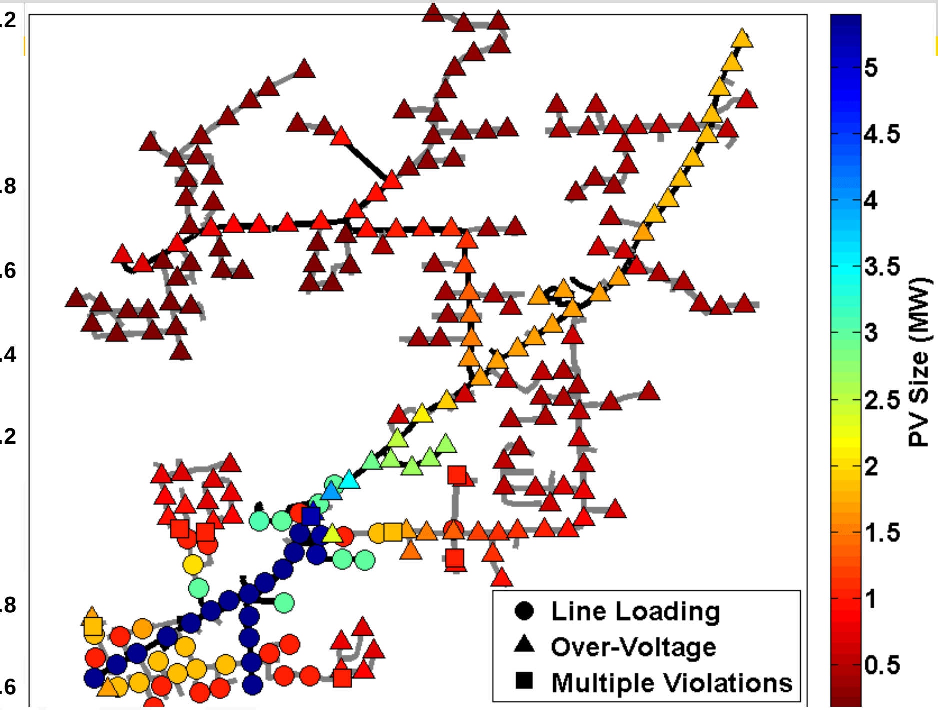


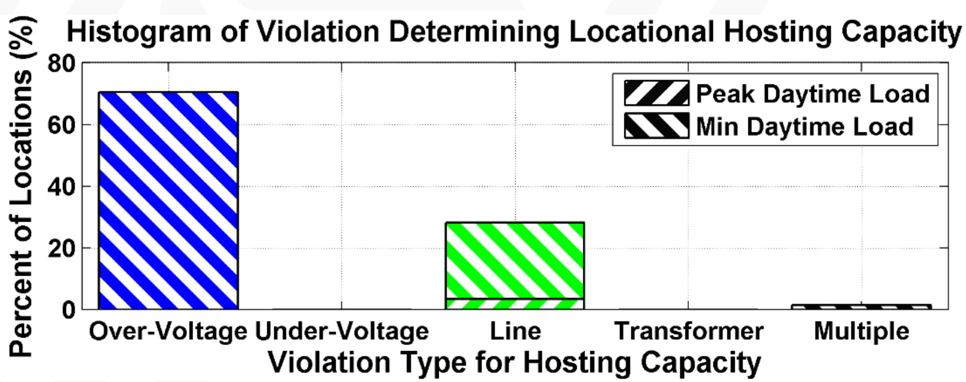


These are preliminary as we calibrate the distribution system models and define the thresholds and metrics

Hosting Capacity Results (ER-G51)

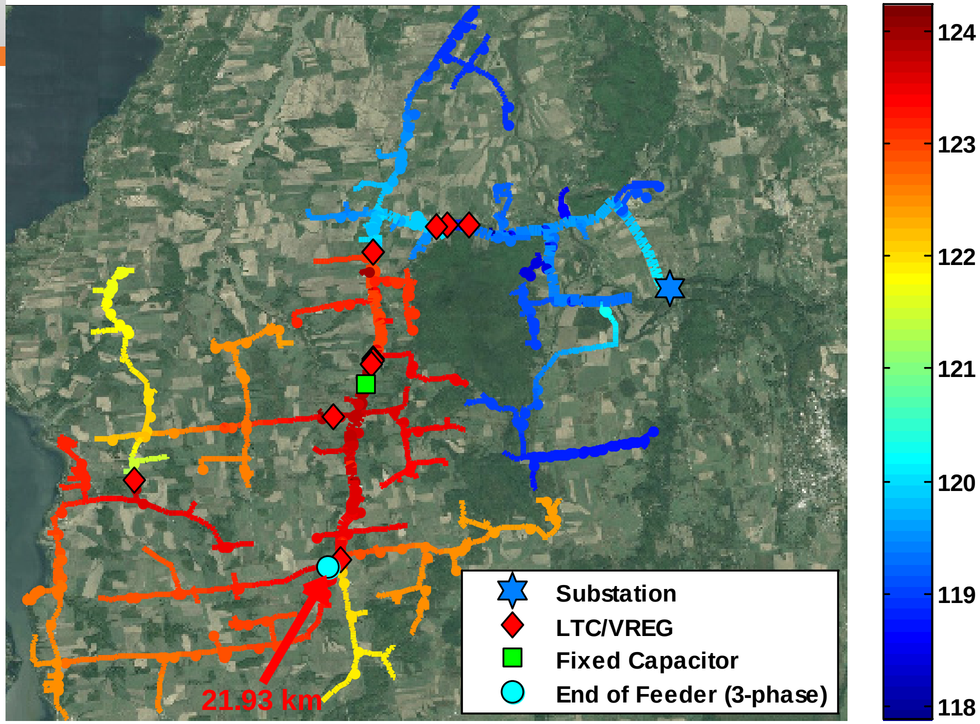


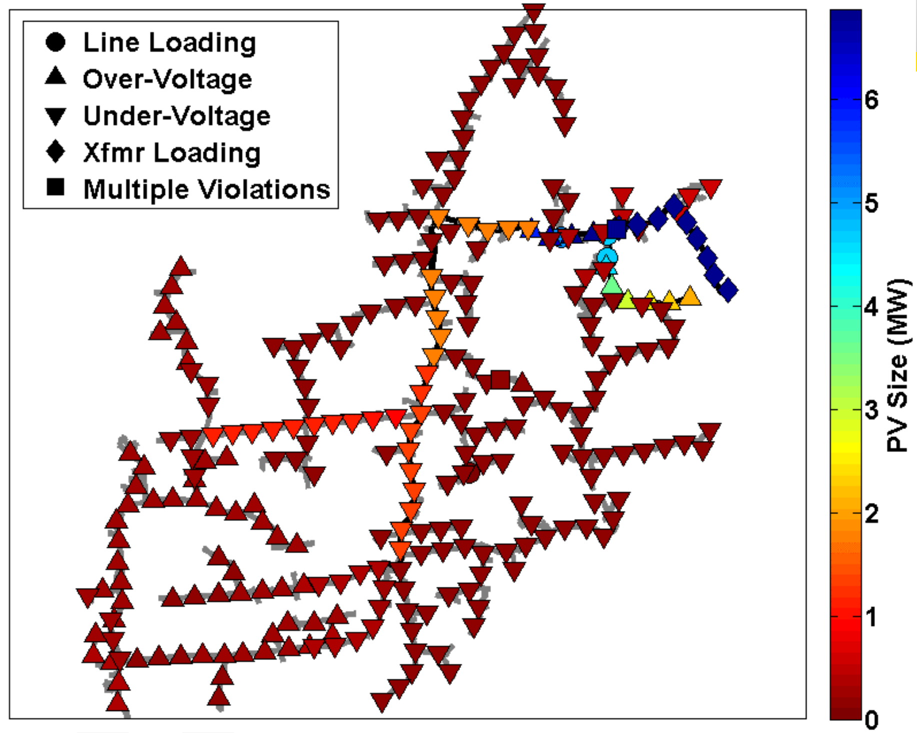


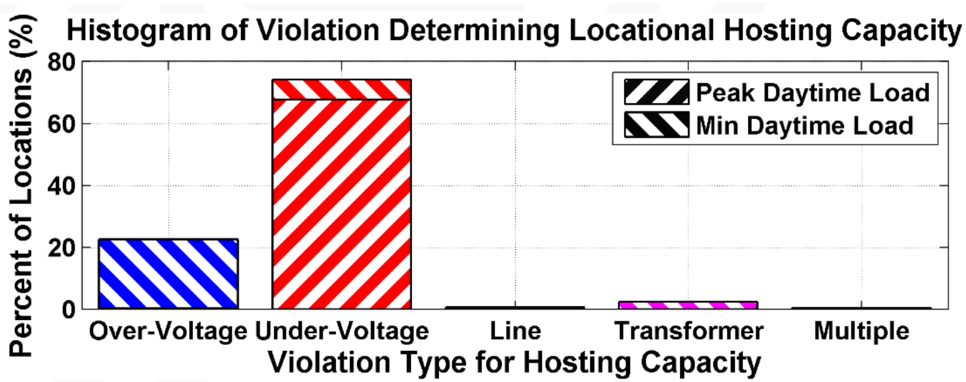


These are preliminary as we calibrate the distribution system models and define the thresholds and metrics

Hosting Capacity Results (WY-G81)







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