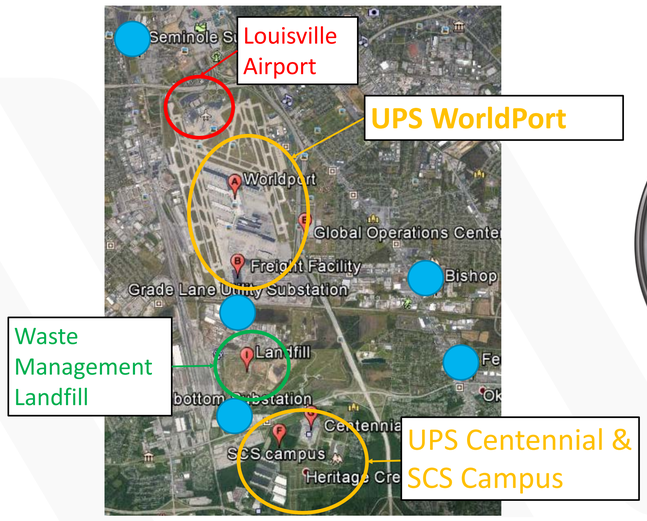
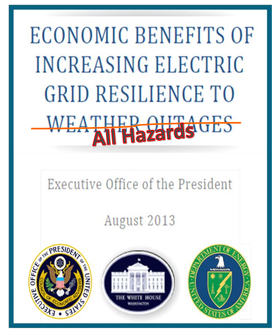
GMLC 1.3.4 – Industrial Microgrid Design and Analysis for Energy Security and Resiliency

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

ORNL and SNL will design and perform cost/benefit analysis of an industrial-scale microgrid with the goal of sharing lessons learned and best practices with other industries and utilities. The analysis will be performed on the UPS Worldport facility in Louisville, Kentucky.





Expected Outcomes

- All-hazards risk analysis of facilities
- Cost/benefit analysis of industrial-scale microgrids
- Potential for grid services provision
- Roadmap to industrial microgrid deployments & lessons learned
- Aim to deliver the results to the hands of industrial consumers and utilities interested in microgrids to stimulate conversation on grid modernization.
- Expect results can be used as lessons learned for other grid modernization projects

Option	Facility A	Facility B	Tie	Cost ($K)	Overall Availability (Ci)	Post-Startup Availability (Ci)	Post Startup Occurrences with Load Loss (Ci)	Overall Diesel Efficiency
Baseline	550 kW	550 kW	No	$740,000	97.909024%	97.914717%	4.67%	24.03%
Baseline with Tie	550 kW	550 kW	Yes	$1,255,000	99.989214%	99.995262%	4.55%	25.91%
Baseline with Additional Facility A Gen	550 kW (x2)	550 kW	No	$1,509,500	98.879204%	98.88567%	2.91%	24%
Baseline with Additional Facility B Gen	550 kW	550 kW (x2)	No	$1,509,500	98.222782%	98.228565%	3.18%	23.7%
Baseline with Additional A & B Gen	550 kW (x2)	550 kW (x2)	No	$2,279,000	99.939886%	99.945881%	1.02%	23.96%
Facility A Microgrid	550 kW (x2)	550 kW	Yes	$2,024,500	99.993829%	99.999745%	2.59%	25.82%
Facility B Microgrid	550 kW	550 kW (x2)	Yes	$2,024,500	99.994035%	99.999988%	0.15%	25.72%
Facility A-B Microgrid	550 kW (x2)	550 kW (x2)	Yes	$2,794,000	99.993963%	99.999995%	0.2%	25.69%

Significant Milestones	Date
Initial Microgrid Design	10/1/16
Risk Analysis Completed	4/1/17
Energy Efficiency and Ancillary Service Analysis	10/1/17
Cost/Benefit Modelling and Analysis	10/1/17

Progress to Date

- Analysis utilizes open-source software
- Two site visits to UPS Worldport to tour facilities and infrastructure
- Met with utility and industry stakeholders to discuss rate programs and partnerships
- Identified critical industrial and electrical infrastructure
- Performed microgrid analysis on a critical industrial facility
- Data collection underway for two more microgrid sites
- Modelling and simulation have resulted in upgrades to existing DOE tools

Grid Analysis and Design for Energy and Infrastructure Resilience in New Orleans, LA

PIs: Robert Jeffers (Sandia), Mary Ewers (LANL)
Project Team: Mike Hightower, Nancy Brodsky, Sarah Walsh, Amanda Wachtel, Mike Baca (Sandia)
Mary Ewers, Donatella Pasqualini, John Ambrosiano (LANL)

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

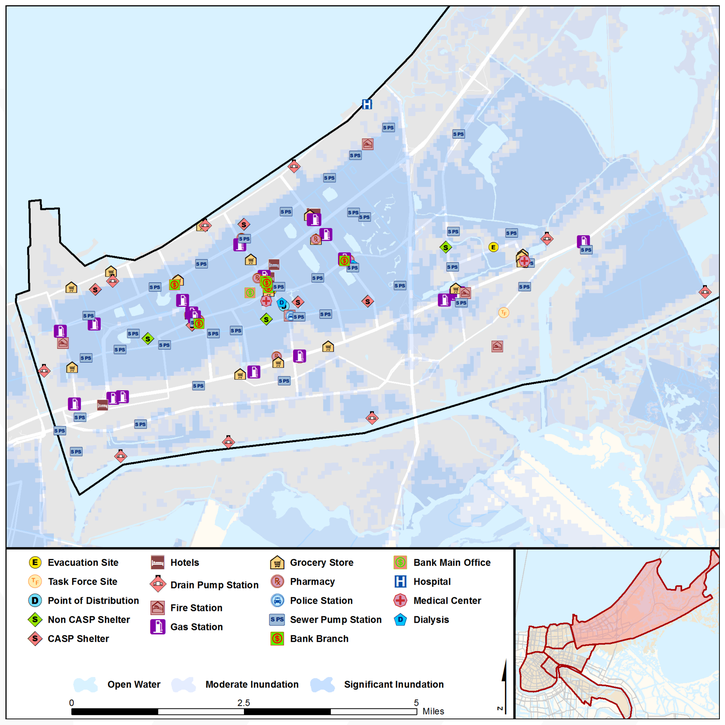
Grid resilience investments often do not fully account for their impacts to **community-level resilience metrics**. This project is using a community-level resilience analysis to aid the City of New Orleans in **identifying and prioritizing grid modernization options**. The focus is on understanding where collections of critical infrastructure services can be cost-effectively supported by grid investments.

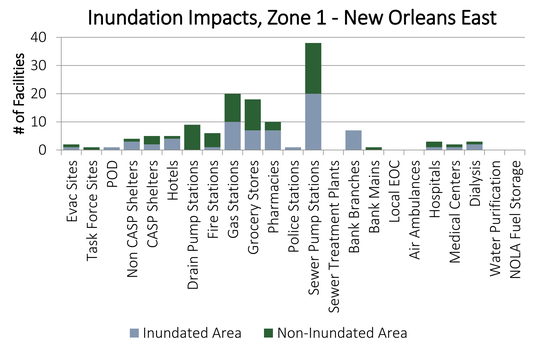
Expected Outcomes

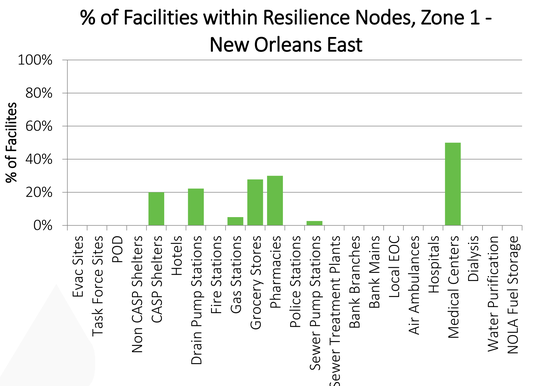
- Aid the City of New Orleans in identifying and prioritizing areas where grid modernization options can cost-effectively improve community resilience
- Identify potential implementation paths, working in conjunction with Entergy New Orleans and community stakeholders

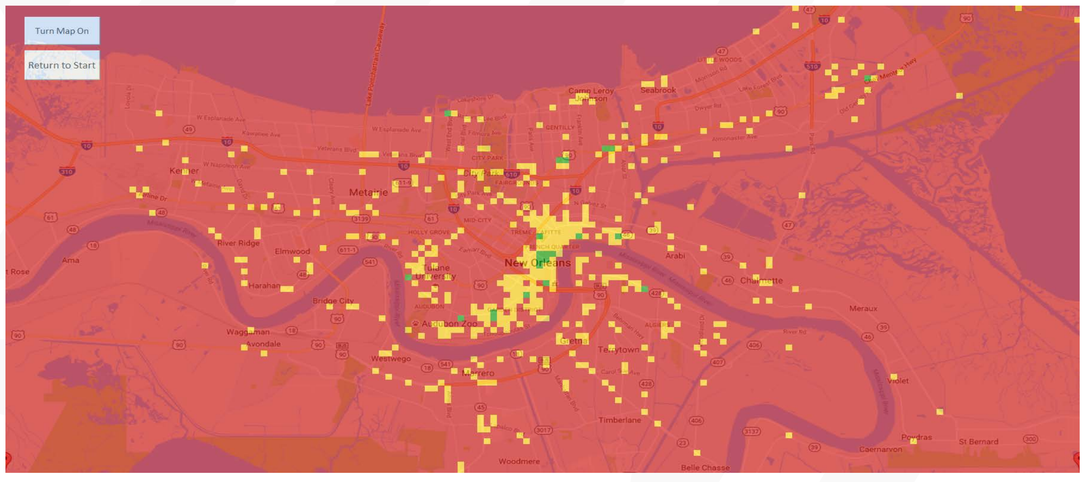
Progress to Date

- Provided baseline urban infrastructure resilience analysis to New Orleans
- Assisted the City of New Orleans in generating alternative portfolios of microgrid options with associated resilience benefits
- Identified a path toward prioritization of options and ultimate implementation









*Investing in grid modernization to minimize consequence to communities involves understanding which lifeline services receive greatest benefit from improved power resilience (**top**). Subsequently, areas are identified where clusters of high-impact infrastructure assets can be served by advanced microgrids (**bottom**).*

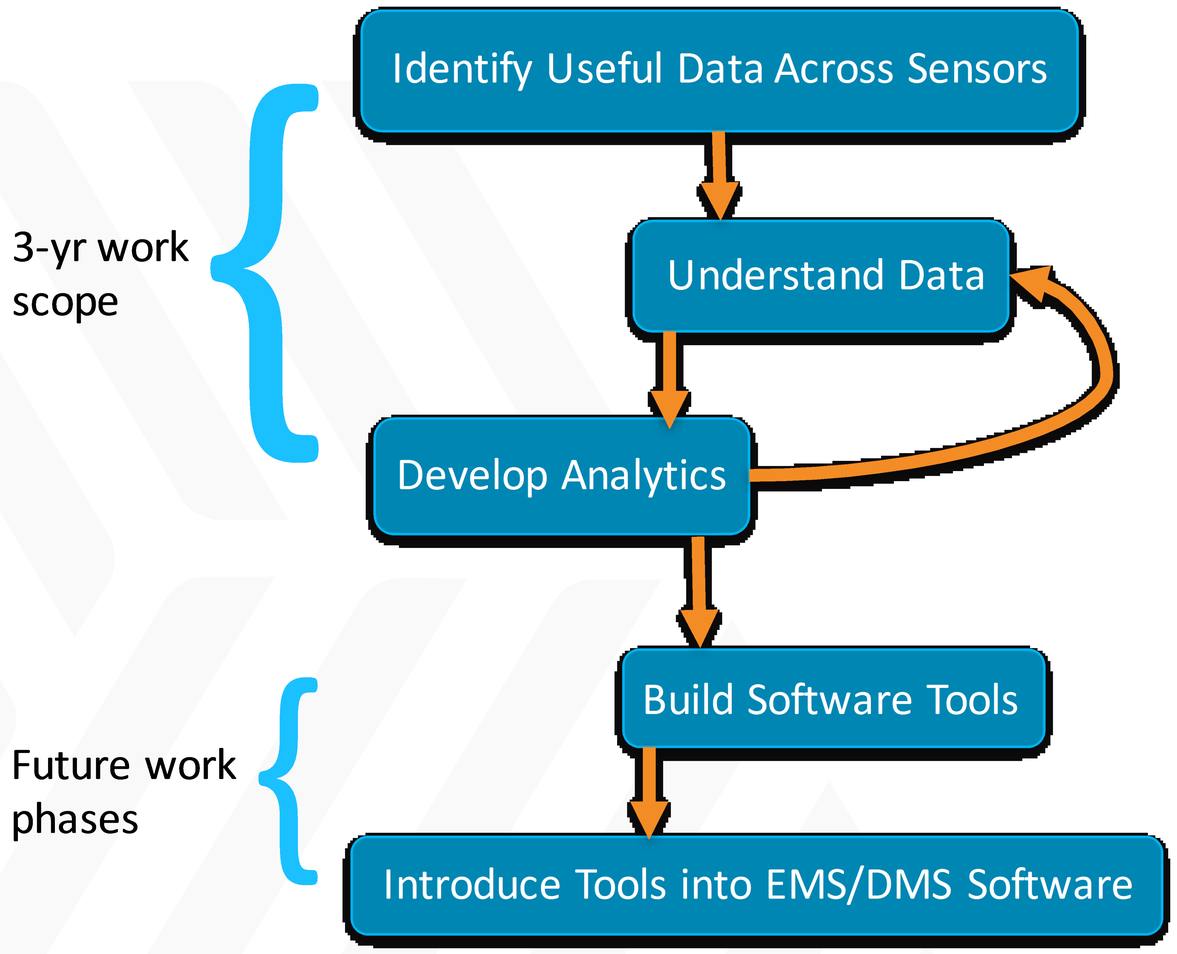
Significant Milestones	Date
Multi-infrastructure community resilience analysis based on Urban Resilience Analysis Process	Aug 2016
Analysis of transactive controls feasibility for resilience in NOLA	Dec 2016
Initial grid modernization recommendations	Jan 2017
Final report including costs and benefits	Mar 2017

Threat Detection and Response with Data Analytics

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

- Develop advanced analytics on operational technology (OT) cyber data in order to detect complex cyber threats. Differentiate between cyber and non-cyber-caused incidents using available cyber data.



Expected Outcomes

- Analytics being developed will assist asset owners in triaging grid incidents
- Identifying incidents in a timely manner reduces outages and associated costs

Significant Milestones	Date
Establish MOU with industry collaborator (EPB) and identify sample data sets (related to NESCOR, EPB Smart Grid operations, etc.) for analysis. (ORNL)	10/1/16
Establish use case for evaluation of case studies. (INL)	4/1/17
Integrate SEL-3620 into selected NESCOR scenario. Identify physical and cyber events (features) in SEL-3620 available for monitoring. (SNL)	4/1/17
Organize subset of public outage data for specific distribution outages and transmission circuits for analysis. (ORNL)	4/1/17
Identify simulator requirements to perform attack-defense-mitigation study on PNNL testbed. (PNNL)	4/1/17

Progress to Date

- Preparing submittal to Resilience Week 2017
- Presented project to DARPA, EPSA, DHS, WAPA and CAISO
- Seeking further industry partners for data sharing, demonstration, and commercialization

MultiSpeak® Secure Protocol Enterprise Access Kit (MS-SPEAK)

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

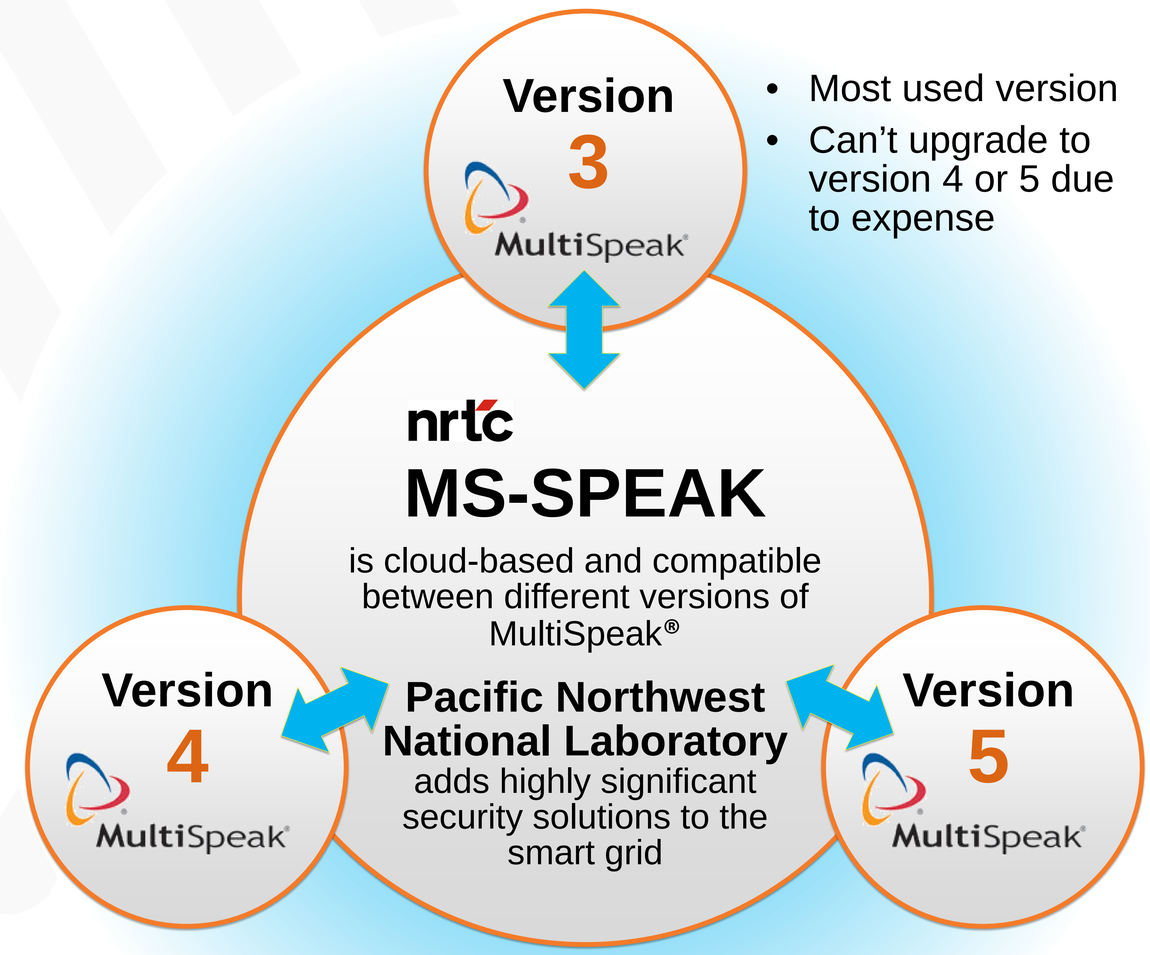
Project Description

MS-SPEAK fills a gap and makes the grid "smarter" (i.e. more intelligent and resilient) through the creation of an innovative ESB+ (enterprise service bus) for MultiSpeak. The ESB+ will support increased interoperability and security of the MultiSpeak standard and reduce costs in utilities that depend on MultiSpeak.

Expected Outcomes

- Automated translation between multiple MultiSpeak Standards (v3.0, v4.x, and v5)
- Validation, translation, operations, and forwarding of existing MultiSpeak messages
- Increased standards compliance
- Improved interoperability between devices, applications, and utilities

Significant Milestones	Date
Technical Requirements	6/15/2016
Industry Advisory Board Acceptance (NRTC, NRECA)	7/15/2016
Protocol Handler Prototype	9/15/2016
End-to-End Workflow Deployed	12/15/2016
MS-SPEAK Tested with NRECA's *Essence*	+3-6 Months
Field Testing with Selected Utilities	+3-6 Months
Final Technical Report	+6-9 Months
Phase 2: API Framework and Extensions	+12 Months
Phase 3: Applied R&D Solution for Industry	+24 Months



- Most used version
- Can't upgrade to version 4 or 5 due to expense

- Few users
- Adds encryption
- Not compatible with version 3

- No users
- Great improvements
- Not compatible with version 3 or 4

Progress to Date

- Summary report of technical achievements and explanation of potential utilization of other protocols (e.g., DNP3 and Modbus)
- End-to-end prototype deployed

Cybersecurity for Renewables, Distributed Energy Resources, and Smart Inverters

Presenter: Junjian Qi, Ph.D.
Project Team: Argonne National Laboratory, Washington State University, EPRI

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Objective: Develop a holistic attack-resilient architecture and layered cyber-physical solution portfolio to protect the critical power grid infrastructure and the integrated distributed energy resources (DER) from malicious cyber attacks

Expected Outcomes

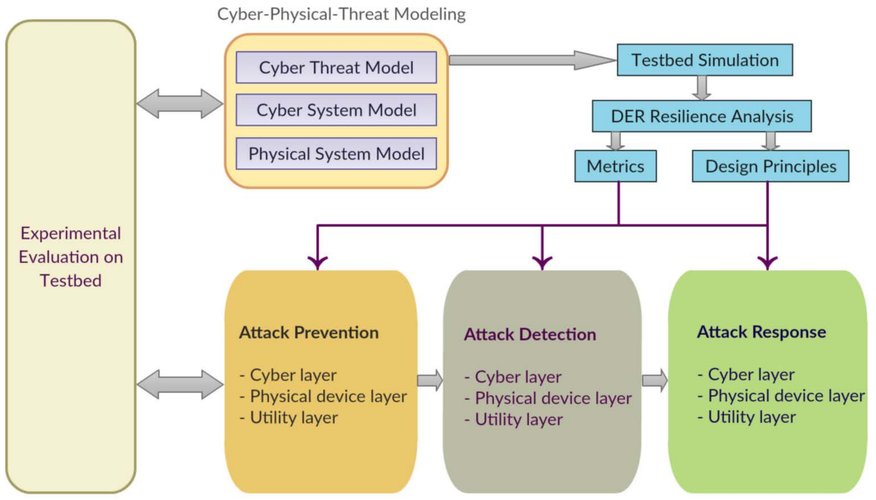
Deliverables:

- A DER cybersecurity research framework
- DER cyber threat modeling and resilience metrics
- DER cyber attack prevention, detection, and response strategies across cyber, physical device, and utility layers of the system
- Demonstration on Washington State University's Smart City Testbed

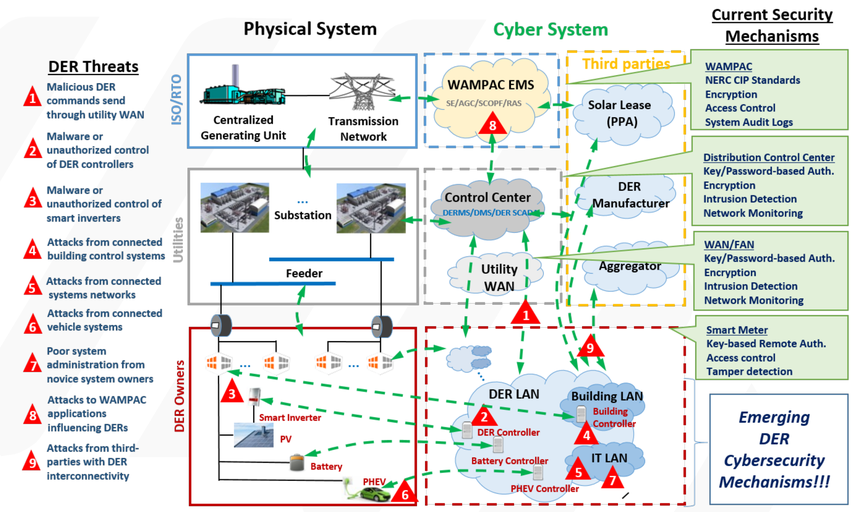
Impacts and Benefits:

- Utilities can use the resilience analysis methodology to evaluate their system and identify vulnerabilities
- Utilities and DER third parties can use the attack prevention, detection, and response strategies to harden their system, rapidly detect cyber attacks, and effectively mitigate attacks
- Smart inverter vendors can improve the cybersecurity of smart inverters using the developed cyber attack detection and mitigation measures and by the developed energy buffer
- Customers and utilities will benefit from the reduced economic cost of power outages with the enhanced security of the distribution grid against outages caused by cyber attacks on DER
- Decrease in net integration cost of DER from the enhanced resilience of the power system against cyber attacks on DER

Significant Milestones	Date
Development of DER cybersecurity framework	Oct. 1, 2016
Design of DER cyber threat modeling and resilience metrics	Apr. 1, 2017
Design of DER attack prevention and detection strategies at cyber, physical device, and utility layers	Apr. 1, 2018
Design of DER attack response strategies and completion of experimental evaluation	Apr. 1, 2019



Attack-resilient framework for DER cybersecurity



Emerging DER architecture and cyber attacks

Progress to Date

Peer-reviewed journal articles and technical reports:

1. J. Qi, A. Hahn, X. Lu, J. Wang, and C. C .Liu, "Cybersecurity for Distributed Energy Resources and Smart Inverters," *IET Cyber-Physical Systems: Theory & Applications*, vol. 1, no. 1, pp. 28-39, Dec. 2016.
2. Cybersecurity for Renewables, Distributed Energy Resources, and Smart Inverters Research Framework, Technical Report, Oct. 2016.
3. DER Cyber Thereat Modeling and Resilience Metrics, Technical Report, Apr. 2017.

Workshop and conference:

1. NREL workshop on Security & Resilience of Grid Integration with Distributed Energy Resources on 07/13/2016
2. Resilience Week conference on 08/18/2016
3. DOE-OE CEDS Program Peer Review Meeting on 12/07/2016

Improved Forecasts of Electric Outages from Tropical Cyclones

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Modify existing *HEADOUT* tool to:

- improve forecasts of electric outages from tropical cyclones; and
- identify infrastructure at-risk for tropical cyclone events affecting U.S. territory in the Caribbean, Atlantic seaboard, and Gulf of Mexico regions.

Improved tool would be used by DOE (and others) in preparation and response to tropical cyclone events.

Major tasks include:

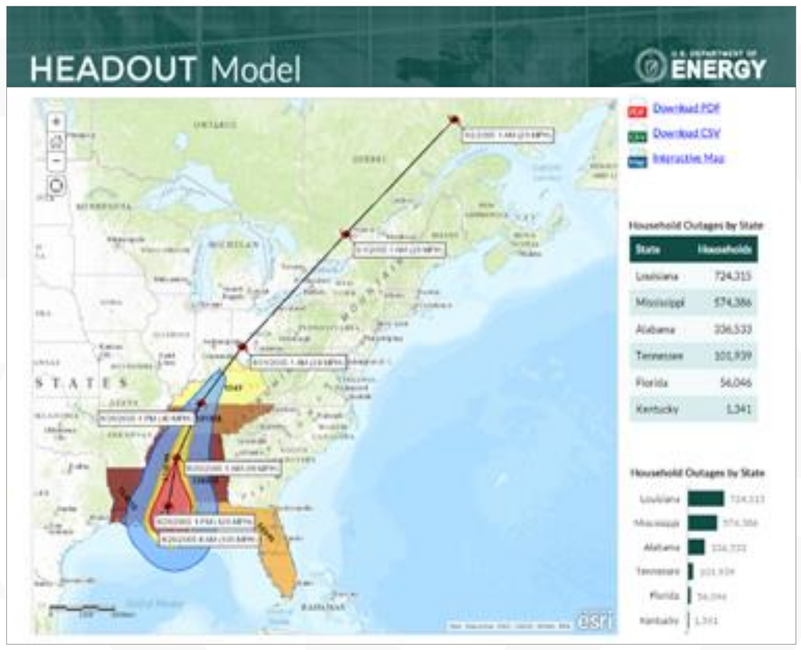
- Enhance high-resolution spatial distribution of U.S. population and households to county-block level.
- Apply downscaling algorithm for hurricane-induced storm surge combined with high-resolution topography.
- Develop universal fragility curves (percent damage versus wind speed, rainfall, etc.).
- Modify algorithm with NOAA's NDFD forecast data.

Expected Outcomes and Deliverables

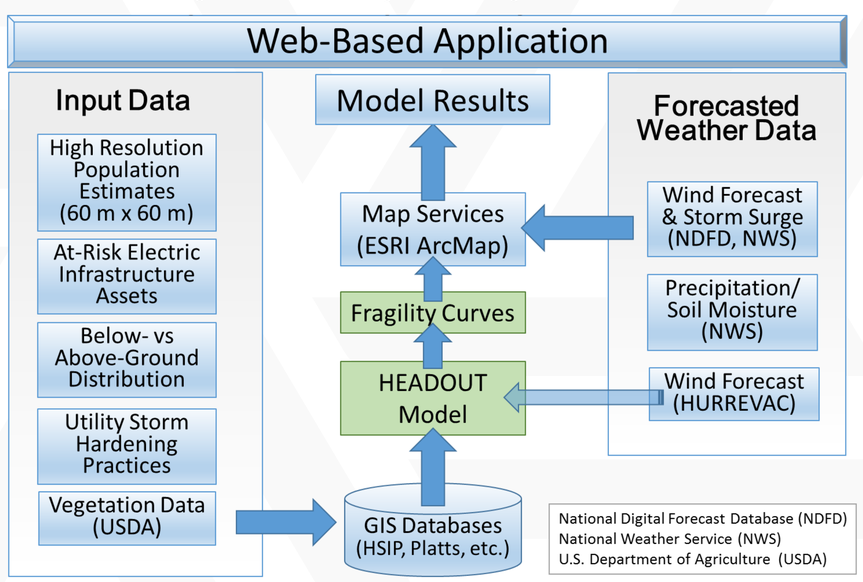
- A web-based model will be developed that will estimate electric outages at a county block level—roughly 250 meters by 250 meters.
- Electric utilities, ISO/RTOs and regulatory agencies will have a quantitative method to evaluate damage and coordinate response and recovery.

Significant Upcoming Milestones	Date
Complete development of population data at the county block level (60 meters by 60 meters)	May 2017
Enhance precision in SLOSH output for coastal flooding	June 2017
Finish development of universal fragility curves for the Gulf and Atlantic Coasts	June 2017
Modify existing HEADOUT Model to incorporate NOAA weather feeds	Aug. 2017

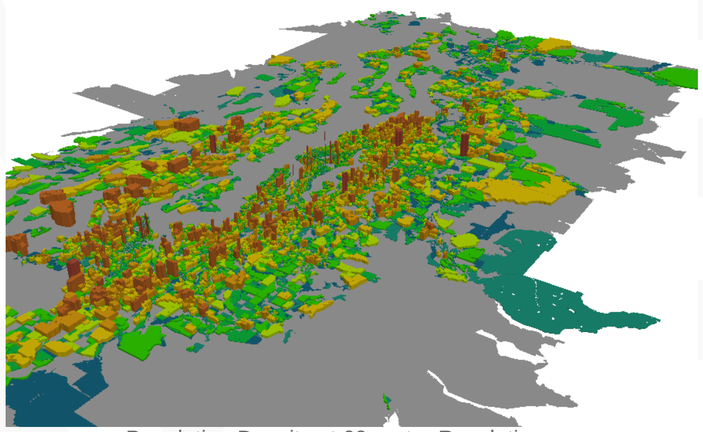
Existing HEADOUT Tool Web Interface



Proposed Tropical Cyclone Tool



Example Enhanced Population Data

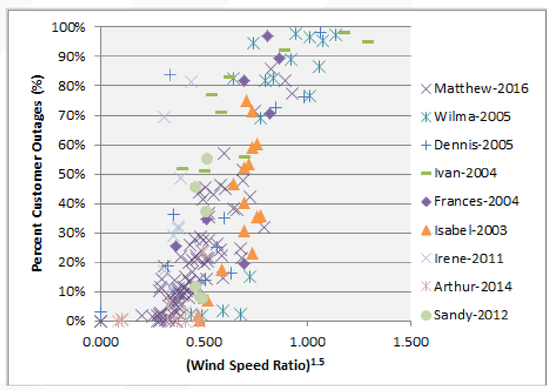


Population Density at 60-meter Resolution

Progress to Date

- Current version of *HEADOUT* tool being incorporated into DOE-OE EAGLE-I automated system for real-time situational awareness.
- Proposed tool development discussed and validated with Gulf Coast electric utilities.
- Utility-specific electric outage data being pursued → *data protection and NDA issue.*
- Enhanced population dataset developed for Gulf and East Coast→ *verification and validation of distributions to be completed*.
- Preliminary fragility curve developed based on historical data → *to be compared with utility-specific outage data*.
- Preliminary incorporation of enhanced storm surge approach using NHC P-Surge.

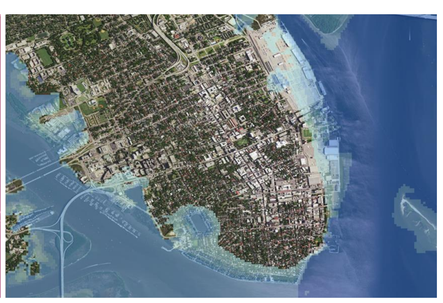
Preliminary Fragility Curve of Percent Damage Versus Wind Speed Ratio



Wind Speed Ratio = Maximum Sustained Wind Speed / ASCE-7 Basic Wind Speed

Example Enhanced Storm Surge Results, Hurricane Matthew

P-Surge, 10% Exceedance



Enhanced P-Surge, 10% Exceedance

U.S. DEPARTMENT OF ENERGY

Stephen Folga and Leah Talaber, Argonne National Laboratory
Alan Bercheid and David Judi, Pacific Northwest National Laboratory

April 18, 2017

A Closed-Loop Distribution System Restoration Tool for Natural Disaster Recovery

Presenter: Jianhui Wang, Ph.D.
Project Team: Argonne National Laboratory, Brookhaven National Laboratory, Iowa State University

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Objective: Design a closed-loop distribution system restoration decision support tool to assist distribution utility operators in making optimal and effective decisions during distribution system restoration under extreme weather events. This is a synergistic collaborative project among national labs, university, utilities, and vendors.

Expected Outcomes

Deliverables:

- A probabilistic data fusion framework to improve situational awareness of distribution grids after extreme weather hazards integrating multiple sources of information, including weather, measurements from field devices, and data from customers' end.
- Repair crew dispatch and resource allocation optimization models and solutions
- Optimal grid reconfiguration and load pick-up methodologies to reduce outage sizes and durations to facilitate supply continuity.
- Development of user-defined multi-objective optimization models with efficient closed-loop feedback scheme

Impacts and Benefits

- Utilities can use the tool to expedite the restoration process and facilitate supply continuity
- Consumers will benefit from the reduced sizes and durations of power outages
- ISO/RTOs will be able to use the methodologies to coordinate transmission-level restoration processes with distribution-level utilities to improve the overall system restoration
- Regulatory agencies will have a quantitative method to evaluate the resilience enhancement of distribution systems.
- Vendors may be able to use the tool to specify the requirements for development of devices and outage management systems

Significant Milestones	Date
An integrated framework development for the distribution system restoration decision support tool under natural disasters	09/01/2016
An alpha version of the restoration tool with functionalities of major modules completed	06/01/2017
A beta version of the restoration tool with enhanced modules and interfaces for all major extreme weather events completed	06/01/2018
Validation, testing, and demonstration for the tool on test cases and possible real distribution systems with utility partners	06/01/2019

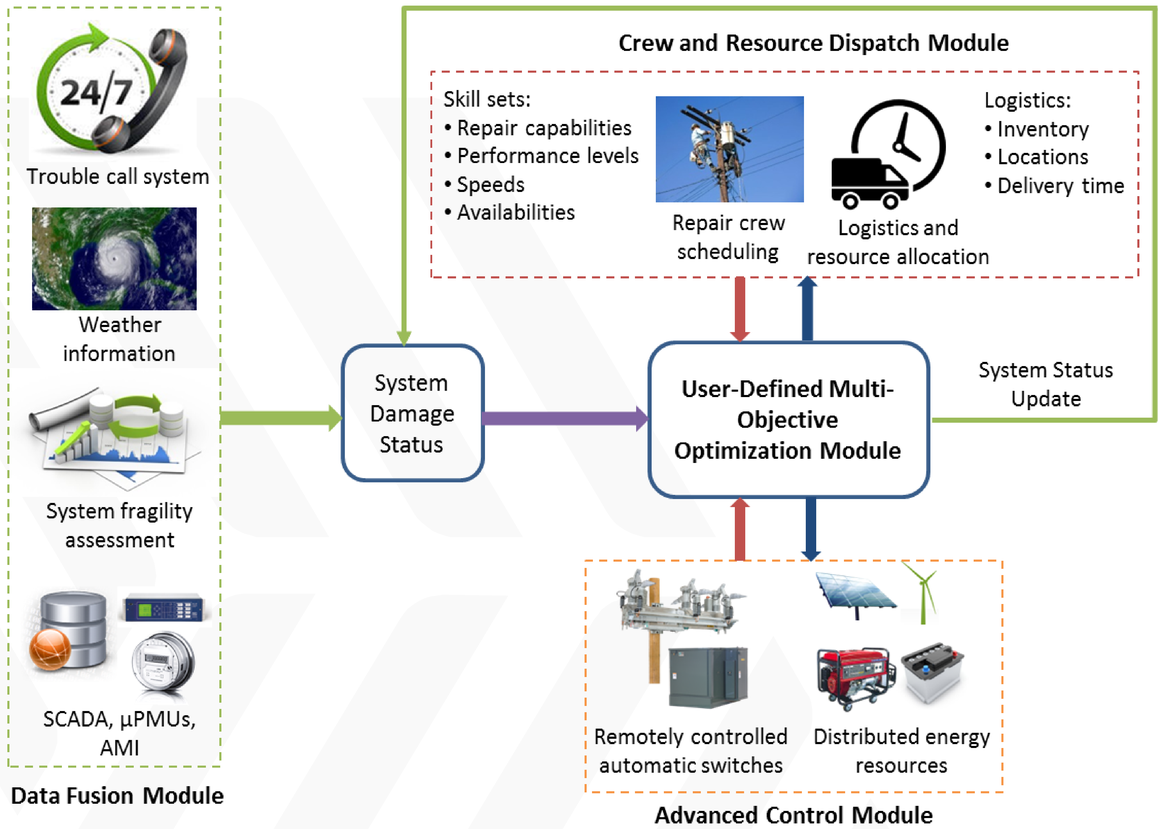


Figure 1: Framework of the Integrated Distribution System Restoration Decision Support Tool with Four Modules

Progress to Date

Peer-reviewed journal articles:

1. C. Chen, J. Wang, D. Ton, "Modernizing Distribution System Restoration to Achieve Grid Resiliency Against Extreme Weather Events: An Integrated Solution", *Proceedings of the IEEE*, in press.
2. B. Chen, C. Chen, J. Wang, K. Butler-Purry, "Multi-Time Step Service Restoration for Advanced Distribution Systems and Microgrids", *IEEE Transactions on Smart Grid*, under review.
3. B. Chen, C. Chen, J. Wang, K. Butler-Purry, "Sequential Service Restoration for Unbalanced Distribution Systems and Microgrids", *IEEE Transactions on Power Systems*, under review.
4. A. Arif, Z. Wang, J. Wang, C. Chen, "Power Distribution System Outage Management with Co-Optimization of Repairs, Reconfiguration, and DG Dispatch", *IEEE Transactions on Smart G*rid, in press.
5. Z. Wang, J. Wang, C. Chen, "A Three-Phase Microgrid Restoration Model Considering Unbalanced Operation of Distributed Generation", *IEEE Transactions on Smart Grid*, in press.

Workshop and conference:

1. DOE-OE MYPP Workshop on Resilient Electric Distribution Grid on 07/12/2016.
2. 2016 Smart Grid R&D Program Peer Review Meeting on 08/16/2016.
3. Eversource Energy Center and EPRI workshop on predictive analytics and storm situational awareness for grid resilience on 01/19/2017.

Diagnostic Security Modules for Vehicle to Building Integration

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

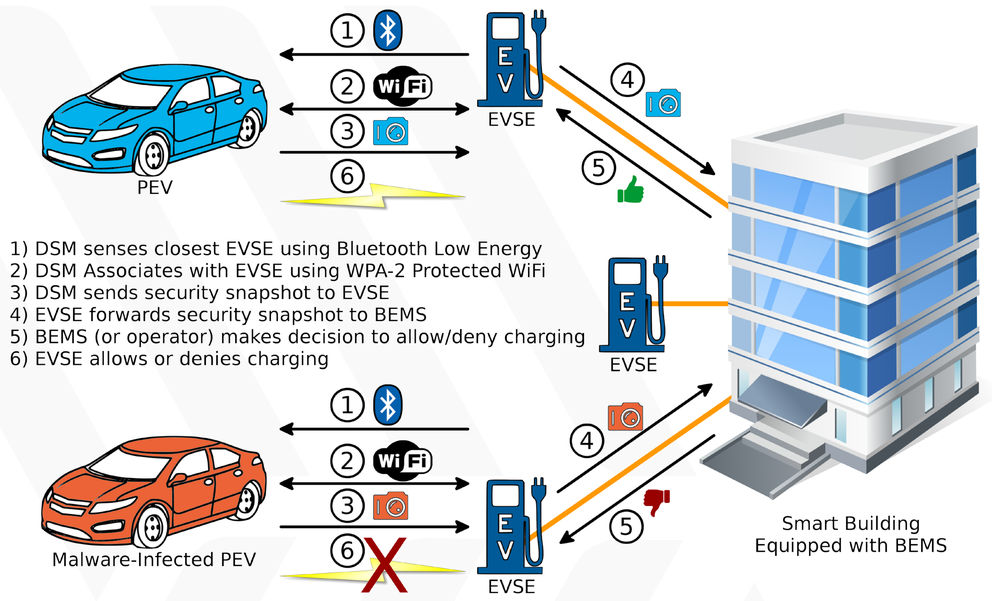
Project Description

Securing the integration of Plugin-Electric Vehicle (PEV) charging infrastructure with Smart Grid enabled buildings.

Expected Outcomes

- Create a Diagnostic Security Module (DSM) framework for secure end-to-end integration of Plug-in Electric Vehicles
- Establish a demonstration laboratory with multiple DSM enabled vehicles and charging stations connected to a Building Energy Management System (BEMS).
- Support adoption of emerging standards such as SAE J2931/7 and Smart Energy Profile (SEP) 2.0

Significant Milestones	Date
Procurement of Two Commercial AC Level-2 EVSE	Oct 2016
EVSE Cyber Assessments Complete and Reports Sent to Vendors	Jun 2017
Prototype DSM Lab Established	Oct 2017



DSM Communications Overview

Progress to Date

- All project equipment procured and setup in laboratory
- DSM nodes and framework undergoing Alpha testing
- One PEV and one Electric Vehicle Supply Equipment (EVSE) station shipped to the University of Louisiana-Lafayette test facility
- Cybersecurity assessments of the EVSE are 50% complete

INL/MIS-17-41464

Strategic Transformer Reserve Study

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

If a serious event – natural or man-made – destroyed part of the United States' electric grid, are there enough spare large power transformers (LPTs) to restore the grid and get the lights back on? This project identified spare LPTs needed throughout the nation - crucial elements to restoring electric power quickly - and the extent to which these spare LPTs existed.

Expected Outcomes

Technical team identified:

- Number and technical characteristics of needed spare large power transformers;
- Possible spare LPTs already on hand at electric utility companies;
- Operational transformers that could be used on a provisional basis.

Results informed a report to Congress about the potential to establish a strategic reserve of LPTs for restoring service in the event of a large-scale natural or man-made power outage, thereby increasing reliability and security of the U.S. electric grid.

*Partners: University of Tennessee, Electric Power Research Institute, Sandia National Laboratories, Southern Company, Dominion Virginia Power, and Western Area Power Administration.

Significant Milestones	Date
Technical Report submitted to the Department of Energy's Office of Electricity Delivery and Energy Reliability to inform Congress.	12/01/2016

In our interconnected electrical grid, LPTs, as seen left, perform the function of connecting the various voltage levels to one another. Losing an LPT removes the connection between voltage levels, causing disruptions in the flow of power.

Progress to Date

- Submitted Technical Report to the Department of Energy's Office of Electricity Delivery and Energy Reliability.
- Identified crucial substations operating at the highest voltages in each inter-connection as well as large power transformers located in those substations.
- Determined extent spare LPTs were already available, usually in storage locations owned by electric utilities, for each of the transformers in crucial substations.

**The report is not publicly available.*

ORNL 2017-G00475/lmh

Web Tool for Improved Electric Outage Forecasting for Response to Tropical Cyclone Events

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Develop a cloud based software tool for DOE Emergency Operations Center (EOC) analysts to make predictions of electrical outages caused by imminent or synthetic tropical cyclones with quantified uncertainty.

The tool will identify critical infrastructure at risk from direct cyclone impacts and secondary impacts from electric power outages to provide DOE decision-makers with defensible, actionable analytic results for use by Federal, State, and local government agencies and industry partners.

Challenges

- Increase spatial resolution of forecasted outages to 250m X 250m spatial scale and runtimes per forecast of less than 30 minutes
- Acquire proprietary electric distribution utility network and outage data over periods with tropical cyclone events
- Integrate disparate codes, algorithms and datasets in maintainable and extensible architecture with scalable capacity

Expected Outcomes

- Cloud-deployed, demonstrable software tool that uses weather forecast feeds to automatically predict electrical outages at 250m resolution from tropical cyclones and identify at-risk infrastructure
- Improve DOE outage prediction capability for emergency response, planning and coordination with government and industry
- Outage forecast method built on 10 years of peer-reviewed state-of-the-art outage model research with computation and display of outage predictions in under 30 minutes

Significant Milestones	Date
Initial training of statistical outage model using environmental parameters and storm-specific utility outage data	Mar 2017
Collect and process static and dynamic environmental datasets for outage model development	Feb 2017
Acquire and process utility distribution network and outage data for input to outage model development	Feb 2017
Leverage and expand cloud based architecture of compute resources and services as deployment platform	Jan 2017
NOTE: The Period of Performance end date for this project is August 31, 2017	

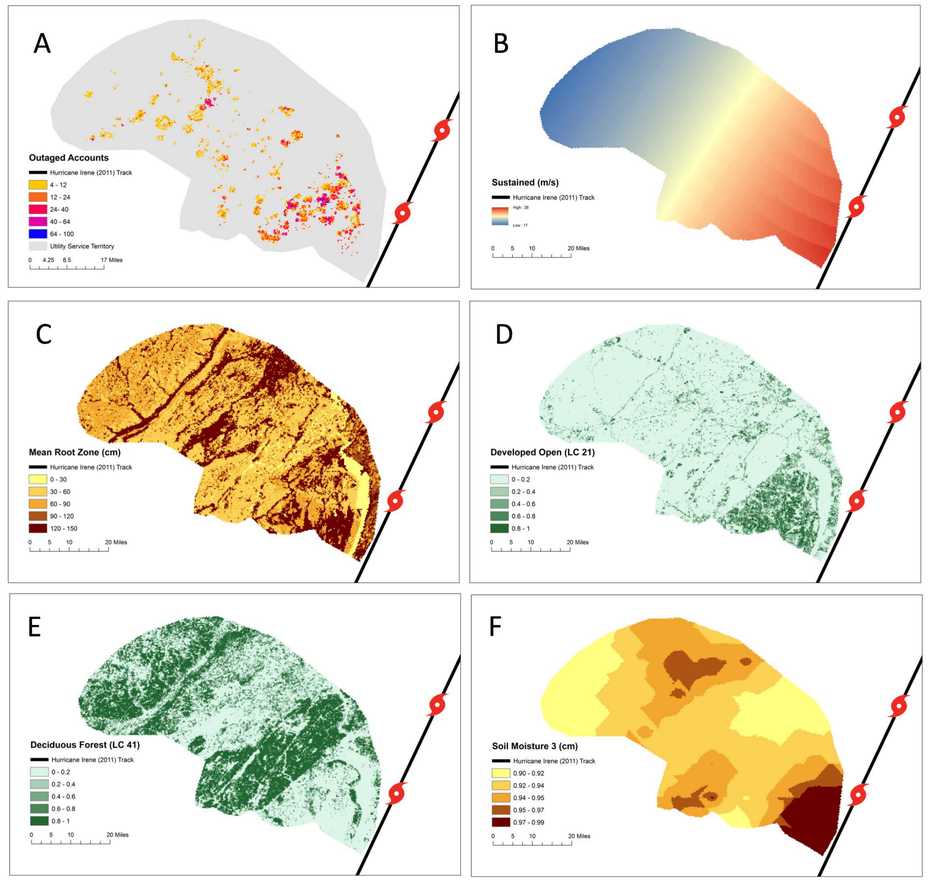


Figure 1. Hurricane Irene impacts on a utility service territory and selected variables used in the outage model: (a) observed customer outages, (b) maximum sustained winds (m/s), (c) mean root zone depth (cm), (d) fractional area of developed open space, (e) fractional area of deciduous forest, (f) soil moisture percentiles (40 to 100 cm layer)

Progress to Date

- Developed a national database of soil, vegetation, elevation and other environmental conditions at 250 m resolution
- Developed an initial power outage model at 250 m resolution, allowing the team to iteratively improve the variable selection and modeling process
- Developed an improved hurricane wind field model and created an open-source R package for distribution of the model
- Created initial geospatial outage inputs for outage model development from distribution network and outage records over tropical cyclone events

Secure, Scalable Control and Communications for Distributed PV

PI: Jay Johnson (SNL)
Project Team: Raymond Byrne, Jimmy Quiroz, Felipe Wilches Bernal, Jordan Henry, Derek Hart, Ricky Concepcion, Patricia Cordeiro, Cedric Carter, Ifeoma Onunkwo, Trevor Hutchins, Matt Reno, Eric Vugrin, Nick Jacobs, Christine Lai

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

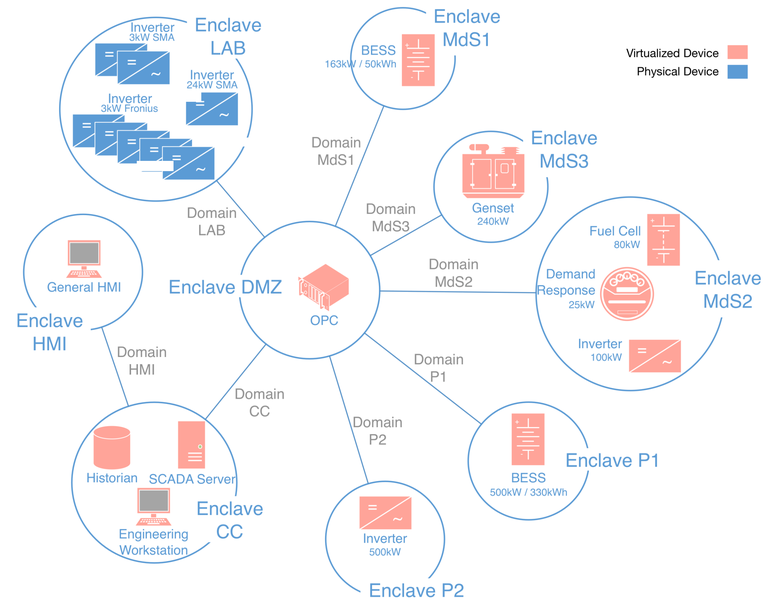
Project Description

We are developing communication and cybersecurity requirements for a range of grid services provided by distributed energy resource (DER) control networks. These requirements will guide the design of appropriate cybersecurity architectures to provide grid services while maximizing control network security. We will leverage existing requirements for specific latency, network dropout tolerance, and communication to provide effective grid services (e.g., voltage regulation, frequency reserves, protection, etc.) using DER devices.

Expected Outcomes

- Networking requirements and optimal cyber-secure control architectures will be determined for multiple grid services, including:
  - Distribution circuit voltage protection
  - Synthetic inertia to support the bulk power system
- Cyber security network penetration tests will be conducted on a emulated communication and power co-simulation to indicate methods to improve the U.S. power system cyber security posture.
- This work will inform utilities, grid operators, DER vendors, and DER aggregators of recommended cyber-secure reference architectures to provide secure grid-support services.

Significant Milestones	Date
Determine grid service performance when varying the SunShot communication metrics: • Scalability: up to 5,000,000 nodes • Availability: > 99.999% • Response time: < 1 second • Interoperability: compliance with open standards	11/30/16 (Complete)
Development of cyber security reference architecture	11/30/18
Quantify increased latency from various cyber security schemes	11/30/18
Comparison of control/communications complexity for different approaches	11/30/18



Example Cyber Reference Architecture which enclaves DER devices to minimize common-mode vulnerabilities. In this configuration, if an adversary gains access to one of the enclaves, they cannot control the utility/aggregator power devices in the other enclaves—reducing the risk of widespread grid failures.

Progress to Date

- Determined communication requirements for multiple distribution and transmission grid services.
- Completed installation of communication network emulation and power co-simulation capability at Distributed Energy Technologies Laboratory (DETL) at Sandia National Labs.
- Conducted cyber security assessments of multiple DER devices.
- Created new synthetic inertia concept called “Communication Enabled Fast Acting Imbalance Reserve (CE-FAIR)” and began the patenting process.
- Disseminated results through the following publications and presentations:

1. R. Byrne, R. Elliott, F. Wilches-Bernal, R. Concepcion, J. Neely, O. Lavrova, and J. Quiroz, “**Small signal stability of the western North American power grid with high penetrations of renewable generation**,” 43rd IEEE Photovoltaic Specialists Conference, Portland, OR, June 2016.
2. M. Reno, J. Quiroz, O. Lavrova, and R. Byrne, ”**Evaluation of Communication Requirements for Voltage Regulation Control with Advanced Inverters**,” IEEE North American Power Symposium 2016, Denver, CO, September 2016.
3. F. Wilches-Bernal, R. Concepcion, J. Neely, R. Byrne, and A. Ellis, “**Communication Enabled Fast Acting Imbalance Reserve (CE-FAIR)**,” submitted to the IEEE Power Engineering Letters.
4. J. Quiroz, M. Reno, O. Lavrova, R. Byrne, “**Communication Requirements for Hierarchical Control of Volt-VAr Function for Steady-State Voltage**,” IEEE ISGT 2017, Arlington, VA, April 23-26, 2017.
5. R. Concepcion, F. Wilches-Bernal, R. Byrne, “**Effects of Communication Latency and Availability on Synthetic Inertia**,” IEEE ISGT 2017, Arlington, VA, April 23-26, 2017.
6. O. Lavrova, “**Communication Enabled Fast Acting Imbalance Reserve**,” SunSpec Alliance Industry Meeting, Las Vegas, NV, September 13, 2016.
7. R. Byrne, “**Secure, Scalable Control and Communications for Distributed PV**,” WECC Renewable Energy Modelling Task Force (REMTF), Los Angeles, CA, November 16, 2016.
8. F. Wilches-Bernal, “**Secure, Scalable Control and Communications for Distributed PV**,” WECC Modelling & Validation Working Group (MVWG), Los Angeles, CA, November 17, 2016.