Microgrid R&D Program at the U.S. DOE

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### Advanced Grid R&D within OE

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**Advanced Grid R&D Research**

**U.S. DEPARTMENT OF ENERGY**
A **microgrid** is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to enable it to operate in grid-connected or island-mode.
The Need for Microgrids

The current grid needs more redundancy to protect critical infrastructure and open new value streams.

Critical infrastructure is vulnerable to major disruptions.

Intentional physical attacks could cause major damage.

Grid infrastructure should be neutral to generation sources while maintaining transmission reliability.

Customers are seeking new opportunities to provide grid services to operators and tenants.
General Features of a Microgrid

• **Point of Common Coupling**
  A single interconnection point to the larger main grid

• **Energy Storage System**
  Both short-term and long-term capacity to “ride through” load transients and shift load peaks

• **DERs**
  Generation sources, both fossil and renewables

• **Primary Controls**
  Systems located locally at the DER to respond immediately to changes in microgrid frequency and voltage

• **Secondary Control**
  Supervisory level system that optimizes microgrid performance based on its operating objectives

• **System Protection**
  Specific protection systems to support island operation
Operational Modes of a Microgrid

**Grid Connected**
- Main grid provides primary control for frequency.
- Microgrid primary control is available to control voltage.
- Microgrid secondary control used for optimization of microgrid DERs.

**Island Operation**
- Microgrid provides primary control for both frequency and voltage since the main grid is not connected.
- Microgrid secondary control used for optimization of microgrid DERs.
Microgrids can serve crucial recovery centers during major weather or man-made disruptions that mitigate damage from storms and minimize impact from bad actors targeting the grid. Going forward, microgrids will seamlessly communicate with each other and/or the macrogrid to provide valuable services to grid operators to improve the cost-benefit of microgrid installations and provide low-cost solutions for grid management and damage mitigation.
Microgrid Program Areas

- Remote, Off-grid Microgrids
- Grid-connected Microgrids
- Networked Microgrids
- Resiliency Tools
- Standards and Testing
Meet community-specific goals. In Alaska, the goal is to achieve a reduction in total imported fuel usage by 50%, while lowering system life-cycle cost and improving reliability and resiliency.

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<th>Performing Entity</th>
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<td>LBNL</td>
<td>ROMDST: Remote Off-grid Microgrids Design Support Tool</td>
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<td>GMLC</td>
<td>Resilient Alaskan Distribution System Improvements Using Automation, Network Analysis, Control, and Energy Storage (RADIANCE)</td>
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<td>SNL</td>
<td>Grid-bridging Inverter Application at St. Mary’s/ Mountain Village Microgrid Systems</td>
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<td>GMLC</td>
<td>Alaska Microgrid Partnership</td>
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Leverage DER-CAM to deliver an optimization-based design support tool for remote, resilient, and reliable microgrids.

**Phase I**
- Focus on formulation and implementation
- Introduced new features, including multi-node, power flow, contingencies

**Phase II**
- Further development, validation testing, and transition to end-users, all completed in May 2018
- Published user manual; held training classes

**Active Partners**
- LBNL, LANL, ANL, BNL
- Alaska Center for Energy and Power, General Electric, Burns Engineering
Industry Needs/Challenges Addressed

- Multi-node modeling (community microgrids)
- Optimal DER placement
- AC & DC microgrids
- Security constraints (lines and generators)
- Topology design
- Uncertainty
- GIS integration

Expected Impact

- Optimum off-grid microgrid designs, replacing existing back-of-the-envelope and non-optimal calculations
- Reduction in capital costs and risk of microgrid deployment
- Removing barriers to microgrid assessments by lowering microgrid soft costs, as the tool is freely usable
- Reliable and resilient microgrid designs that reduce the cost of critical load shedding due to component outages
DER-CAM: State of the Microgrid Design Tool

In FY18, DER-CAM was made easier to use by:
- Releasing the stand-alone desktop interface
- Releasing incremental improved versions
- Automating user registration
- Standardizing user-support ticket submissions via dercam@lbl.gov

- Total user-base: > 1,800 users across versions
- > 37,000 runs executed via desktop application
- User-base grew by 6% in past 30 days
- User-support activity ~1 request per workday

![2018 DER-CAM Jobs Completed](chart)

*include jobs completed through desktop UI only

![User-Support Activities - Sept 2018](chart)

estimated from support tickets submitted to dercam@lbl.gov
The tool has four versions for different expertise and complexity levels:

- Basic
- Intermediate
- Advanced
- Full

Field validation of resilience-based design and operation leveraging resources from multiple networked microgrids.

Scope

- Resilience Metrics Framework for Design and Operation – Develop and demonstrate practical use of resilience metrics for coordinated operation, design to minimize outages and financial losses
- Multiple Networked Microgrids in Distribution System – Leverage rotational and virtual inertia of microgrids assets including hydro, diesel, energy storage, and micro PMU-based sensing to enhance resilience of the overall regional distribution network
- Cyber-security Architecture and Rapid Prototyping of Controls – Rapid prototyping of controllers as HIL and cyber-vulnerability testing in a real-time cyber-secure environment
- Field Validation of Resiliency Enhancement Methods – Field validation of increasing resiliency of overall distribution system by leveraging resources from multiple networked microgrids
Significance and Impact

Industry need/challenge being addressed by the project

- Microgrids (loosely- and tightly-networked, standalone) as a resiliency resource.
- Adoption of early-stage grid technologies such as distribution PMUs.
- Integration of energy storage, fast-sensing and control requirements, and smart-grid technologies into existing grid control systems.
- De-risked, scalable deployment through cyber-secure unit and functional testing, progressive upscaling and iterative testing incorporating knowledge from partial field tests toward full-scale field validation.

Specific improvements/advancements targeted by the project with respect to reliability, resiliency, affordability, flexibility, security, and/or sustainability of electricity delivery

- Develop resiliency framework from multi-dimensional perspective including physical and cyber aspects.
- Deploy methodologies for tightly-, loosely-networked microgrid architectures as resiliency resource.
Resilience can be Enabled through Data-Driven Distribution Automation Technologies

- Spanning-tree & Critical-First Restoration Algorithm
- Deployment of advanced sensors and micro-PMUs
- Smart Switch and recloser placement to minimize outages
- Proactive Reconfiguration
- Big Data and Machine Learning
- Outage management optimization
City of Cordova
Demonstration site; engineering support and regional expertise for field validation/deployment.

Cordova Electric Cooperative
Engineering support and regional expertise for field validation and full-scale deployment; approval on the networked microgrid design based on cyber-resilience framework.

Alaska Village Electric Cooperative
Local project coordination; information provider about remote sites and 58 dispersed villages in Alaska for feasibility of loosely-networked microgrids and operation with larger utility grids.

National Rural Electric Corporation of America
Regulatory structure for generalized knowledge assimilation and information dissemination from this project.

Siemens Corporation corporate Technology
Design and optimization of energy storage system with associated lower- and higher-level controls.
Energy Resilience Challenge:

- Both villages are rural microgrids supplied by diesel gensets
- Diesel fuel shipped up Yukon River, impassable August-April
- Life threatening issues if diesel runs out during winter
- High energy cost, >25% of average household income
Three-stage plan to lower costs and increase reliability and resilience

1. Wind turbine-generator to reduce fuel use (DOE/IA)
2. Storage-based grid bridge system (GBS) for spinning reserve (DOE/OE + DOD/ONR)
3. Network St. Mary’s MG with Mountain Village MG via 12.47 kV tie-line

Eventual goal to run in diesels-off mode
Sandia National Labs Alaska, Village Electric Coop (AVEC), and Alaska Center for Energy and Power (ACEP), partnering to study and demonstrate advanced renewable-based microgrids

Planned outcomes:

1. Open-source GBS optimal sizing tool
   - Incorporates LCOE and performance models for a wide variety of storage technologies
2. Validated open-source models for RE-based networked MG, including grid-forming inverters
3. Demonstration of replicable and sustainable energy resilience solution for AK & beyond
   - 6 potential AK locations identified
4. Identification of technology, standards, and workforce gaps relevant to the deployment of islanded and grid-connected networked microgrids

Simulated St Mary’s MG voltage and frequency dynamic behavior

GBS sizing tool optimizes GBS for size, cost and performance
Alaska Microgrid Partnership

Reduce cost of energy for isolated communities by establishing information sharing resources for replacing imported fuels with local energy resources, energy efficiency, and optimized energy usage.

Outcomes

- Transitioned processes and methods for sharing and archiving lessons learned and design information to the Alaskan Energy Authority and the University of Alaska.
- Built Alaska Energy Data Gateway (website/repository) to allow stakeholders to collect and store information needed to implement innovative power systems.
- Led technical and economic analyses for the communities of Chefornak and Shungnak as examples of the pathway for assessing system feasibility.
- Developed numerous support documents and technical assessments to help communities implement their own development pathway.

Labs

LBNL, NREL, PNNL, SNL

Partners

Where We Are – Where We Are Going

**PAST**
- Campuses and Military Bases
- Single Owners
- Microgrid Design Tools

**PRESENT**
- Commercial Applications
- Grid-connected and Off-grid Applications
- Local, State, Multi-state and Regional Partnerships

**FUTURE**
- Networked Microgrids
- Multiple Value Streams
- New Ownership Models