Cordova, AK, a coastal city and microgrid that delivers power to 2,700 residents. *Photo from iStock, 1282751408*

RADIANCE
Executive Summary

Micrograms are gaining attention from organizations and cities because of their potential reliability and resilience benefits, especially in remote geographic areas: Microgrids can provide local power during emergencies, and they can reduce the costs of imported fuel by reducing overall fuel use. But the complexities and novelties of microgrid technologies are often barriers to deployment that require testing and validation to overcome.

This report describes the testing, validation, and deployment of microgrid technologies in Cordova, Alaska, completed through the U.S. Department of Energy (DOE) Grid Modernization Laboratory Consortium (GMLC) project Resilient Alaskan Distribution system Improvements using Automation, Network analysis, Control, and Energy storage (RADIANCE).

RADIANCE was the largest GMLC grant to date, with $6.2 million from DOE. It involved four national laboratories—Idaho National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, and the project lead, the National Renewable Energy Laboratory (NREL)—two universities, four technology vendors, the Cordova Electric Cooperative (CEC), the Alaska Village Electric Cooperative (AVEC), and the Alaska Center for Energy and Power (ACEP). Organizations supporting rural cooperatives and Alaskan communities also provided input and received project results throughout RADIANCE, including the National Rural Electric Cooperative Association (NRECA).

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Modernizing the nation's power grid to accommodate more clean energy resources while being resilient, reliable, and secure in the face of increasing extreme events and man-made threats is critical to our national security and economic prosperity. The Grid Modernization Laboratory Consortium (GMLC) coordinates and executes research and development in support of the Department of Energy's Grid Modernization Initiative.

RADIANCE improved the microgrid in Cordova, a coastal city with a population of 2,700 that regularly experiences strong winter storms and avalanches and less frequently experiences volcanos, earthquakes, and tsunamis. It is a remote city, effectively an island, that relies on either hydropower or diesel for electrical generation. Apart from emergency resilience, Cordova's microgrid faces widely varying loads due to being a hub for both tourism and seafood processing, which cause dynamic summer seasonal load peaks and switching. For these reasons, the CEC sought microgrid improvements that allow for finer sensing and control to manage loads and to remain aware of power conditions.

Beginning in 2017, as Cordova procured new microgrid technologies, NREL began designing a digital twin of the Cordova system with the Advanced Research on Integrated Energy Systems (ARIES) platform. This allowed lab research teams to precisely model microgrid controls and operations so that CEC could deploy a microgrid with limited risks. Once the technologies and digital twin were in place, the labs and Cordova created a "superlab" validation environment, with data sharing and coordinated simulations.

Hence, RADIANCE had two parallel developments: a resilient and smart microgrid for a remote city and advanced research capabilities for system emulation. One is a model and case study for integrating microgrid technologies, and the other is a resource for future technology deployments. Together, they fulfill the stated goal of RADIANCE, which was to enhance resilience methods for distribution grids under harsh weather, cyber threats, and dynamic grid conditions using multiple early-stage technologies. The project also supported the GMLC objectives of modernizing the power grid through regional perspectives, enhanced coordination with labs and stakeholders, and the integration of multi-technology systems.

Discussion of Importance

The biggest beneficiary of RADIANCE is Cordova, whose microgrid is undeniably more resilient and effective. The CEC can now establish zonal microgrids to prioritize loads, better track electricity usage, and identify cyber and physical anomalies on its distribution system, and the CEC's BESS can balance load swings and emergency supply needs.

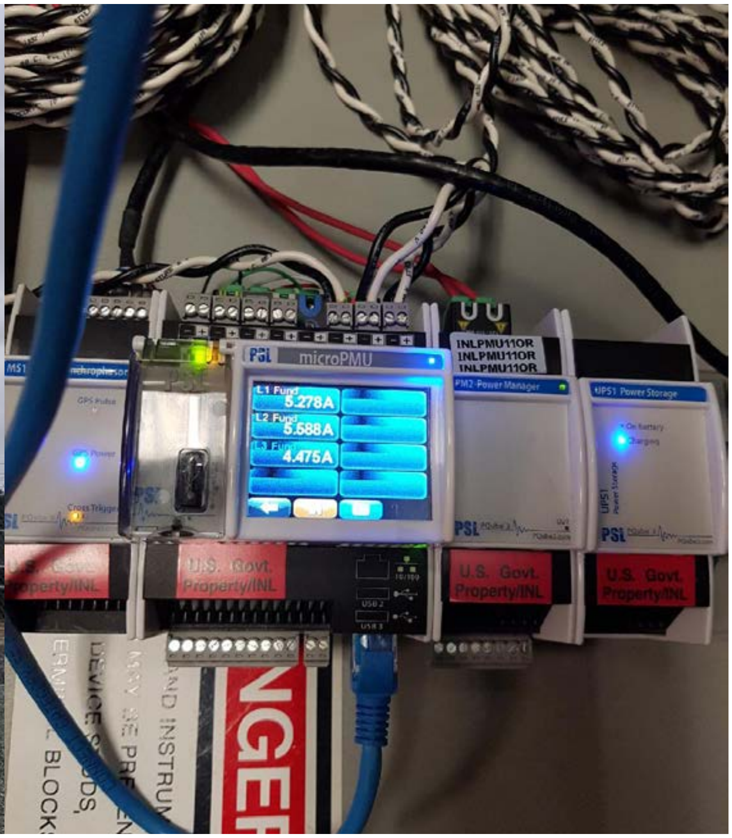
Cordova's upgraded microgrid was purposefully designed to use technologies and controls that are available to other cities. Advanced metering infrastructure is not particularly new, and the microgrid technologies have been commercially available for years. In theory, other remote cities could acquire much of the same hardware and configure their own resilient, smart microgrids—and now they also have a technical roadmap and controls template to do so.

The national lab complex also significantly benefitted from RADIANCE. The project served as a first run for many new ARIES assets, including CHIL and digital twin capabilities. It also validated an improvement to the inter-lab connection over the Energy Sciences Network (ESnet) that reduced communication latency. These lab advancements are pivotal for future experiments—they signify the start of full-replica microgrid research and open the door to cross-lab experiments that combine the full stock of DOE capabilities.

Key Accomplishments

The RADIANCE project resulted in several major accomplishments:

- **Deployed modern** and **smart microgrid sensing** and controls in Cordova, Alaska, an economically important city that requires a high level of resilience
- Performed a **field validation** of commercially available microgrid technology, including **metering networks**, a battery energy storage system (BESS), micro-phasor measurement unit sensing, and distribution system controls
- Published a **CEC-specific and generic guide** for deploying and operating the microgrid controls for circulation with cooperative utilities in coordination with NRECA
- Developed a **surgical load management strategy** using advanced metering infrastructure in which operators can prioritize higher-importance loads, such as a community shelter during an emergency, and automatically create zonal microgrids
- Demonstrated a **digital twin constructed with field data**, identical hardware, and an emulated Cordova network
- Proved a **"superlab" concept** using multiple lab capabilities connected with high-speed data to perform remote and enhanced experiments
- Created a controller-hardware-in-the-loop (CHIL) testing environment with **NREL's ARIES platform**. Controllers such as Cordova's hydropower and diesel plant controllers can be evaluated in-the-loop with simulated power systems.
- Leveraged past GMLC and DOE investments across offices to design microgrid controls and monitoring and BESS controls
- Created a **robust cyber/physical security plan** using resilience-by-design for remote microgrids.



Photos by Mayank Panwar, NREL

Project Findings and Future Directions

RADIANCE achieved what the project team sought to accomplish and what the GMLC represents, with results that span nearly all GMLC technical pillars. From its inception, RADIANCE was a standout project for its scope of advanced microgrid design, its relevance to remote communities and villages in Alaska, and its scale of collaboration. Now that RADIANCE is complete, we can look back on what the team learned and look ahead to the implications for future DOE and GMLC projects.

One major realization and reminder is that microgrid operation is at least as important as integration. Cities can make major investments in resilient technologies, but configuring the technologies, choosing the right controls, and operating and optimizing the microgrid for the desired applications require additional levels of expertise. Microgrid operation was intentionally baked into the RADIANCE project—assisted through the digital twin—with the labs providing strong technical support to Cordova. Configuring and transferring the controls to Cordova was a major undertaking of RADIANCE, and without that effort, the city would not have quickly and optimally advanced their operations. The same lesson applies across Alaska, where most villages will have even less familiarity with operating new microgrid technologies.

Cordova is a relatively prosperous remote city. It has received numerous grants from DOE, the state of Alaska, the U.S. Department of Agriculture, and the Denali Commission to modernize its energy system, and it has a high percentage of relatively affluent ratepayers. This does not negate the relevance of Cordova's technical achievements to other cities, but it does put into perspective the feasibility of energy transitions: If Cordova requires this level of investment and attention to upgrade and operate its microgrid, what about the hundreds of other remote cities throughout Alaska that also need to improve their resilience? More reproducible and cost-effective strategies should be developed.

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