Micro grid power systems

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A microgrid is a group of interconnected loads and distributed energy resources that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to operate in grid-connected or island mode. Microgrids can improve customer reliability and resilience to grid disturbances.

Advanced microgrids enable local power generation assets--including traditional generators, renewables, and storage--to keep the local grid running even when the larger grid experiences interruptions or, for remote areas, where there is no connection to the larger grid addition, advanced microgrids allow local assets to work together to save costs, extend duration of energy supplies, and produce revenue via market participation.

Caterpillar is deploying a 750-kW microgrid on the island of Guam--a challenging deployment environment because of the island power grid and extreme weather phenomena. To address these challenges, the microgrid will include a rapid solid-state switch to protect the microgrid from grid disturbances.

NREL collaborated with Caterpillar to test a prototype utility-scale energy storage inverter and microgrid controller. Microgrid operation was validated in a power hardware-in-the-loop experiment using a programmable DC power supply to emulate the battery and a grid simulator to emulate the Guam grid-tie point. The validation scenarios included grid disturbances approaching 1 MW.

NREL developed a PV-battery-diesel hybrid power system for the U.S. Army Rapid Equipping Force and the Expeditionary Energy and Sustainment Systems to provide power to forward operating bases. The cornerstone of the hybrid power system is the Consolidated Utility Base Energy (CUBE) system. The CUBE provides the power conversion, distribution, and protection necessary to integrate various power sources and was built from the ground up to provide a flexible platform that can be modified to meet specific needs.

The CUBE was tested to demonstrate fuel savings as well as power quality relative to a baseline diesel-generator-only system. Additional tests were performed to demonstrate CUBE power quality during load steps, mode transitions, and a black start. Results demonstrated the ability of the CUBE to provide comparable load step response as a diesel generator, to maintain high power quality during transitions from diesel generator as a grid-forming unit to CUBE as a grid-forming unit and vice versa, and to provide high power quality during a black start onto a load.

NREL has developed a cyber-physical test bed to investigate the complex interactions among emerging microgrid technologies such as grid-interactive power sources, control systems, and communication platforms and bandwidths. The cyber-physical testbed consists of three major components for testing and validation:

On this platform, several load profiles and microgrid configurations were tested to examine effects on system

performance with increasing channel delays and router processing delays. Testing demonstrated that the controller"s ability to maintain a target grid import power band was severely diminished with increasing network delays and laid the foundation for future testing of more complex cyber-physical systems.

NREL supported Raytheon on a Department of Defense Environmental Security Technology Certification Program microgrid demonstration at Marine Corps Air Station Miramar. The project included integration of a central controller with PV inverters, a zinc bromide flow battery energy storage system, utility service entrance equipment, metering, and building electrical loads. The goals were to demonstrate energy security, provide islanding capability, and reduce energy costs.

Microgrid functionality was initially tested at NREL"s Energy Systems Integration Facility in 2014 using a Parker battery inverter, AE PV inverters, and programmable DC power supplies to emulate the battery and PV arrays and a programmable AC power supply to emulate the grid-tie. Grid-tied and islanded operation of the fully installed, high-penetration system at Miramar was demonstrated in December 2015 and again in June 2016. As a result, the project team received the 2016 Environmental Security Technology Certification Program Project of the Year Award for Energy and Water.

NREL is running this model on a combination of local real-time digital simulators and real-time digital simulators at San Diego Gas & Electric"s Integrated Test Facility, with the simulators connected remotely. This will allow San Diego Gas & Electric to use NREL"s power hardware capabilities remotely.

NREL and San Diego Gas & Electric are also working to understand the use of grid-forming inverter functionalities in a microgrid setting. NREL will install grid-forming inverters in its Energy Systems Integration Facility and performpower hardware-in-the-loopexperiments to understand the support these inverters provide to the microgrid.