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Scientists develop tech to manage two-way power flow to commercial buildings

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From left, Michael Starke, Steven Campbell and Madhu Chinthavali of ORNL discuss the configuration of the power electronics hub demonstrated with hardware in the low-voltage lab at GRID-C. Credit: Carlos Jones/ORNL, U.S. Dept. of Energy

Researchers at Oak Ridge National Laboratory recently demonstrated a new technology to better control how power flows to and from commercial buildings equipped with solar, wind or other renewable energy generation.

"We are creating an electric grid of the future that allows renewable energy to be deployed in the most effective way," said ORNL's Madhu Chinthavali, who leads the research. "With this new grid interface architecture, operators can control energy flows much more meaningfully, even when power generation is decentralized."

Renewable energy is key to helping the U.S. electricity sector achieve national decarbonization goals. But they also add uncertainty to the electrical grid because they are unevenly available across the country and generate electricity intermittently. Developing and coordinating power electronic systems to incorporate these resources more easily is vital to creating a more resilient grid for reliable electricity.

Chinthavali's research team designed a hybrid AC/DC power electronics hub to act as a gatekeeper between the larger grid and subsystems including renewables, generators and battery storage. The technology was developed and tested in the Department of Energy's Grid Research Integration and Deployment Center, or GRID-C, at ORNL.

GRID-C offers a unique platform for building power electronics systems, starting with the smallest component, then testing and demonstrating full systems that incorporate both hardware and simulation. In the low-voltage lab, rows of metal containers house ORNL-developed power electronic converters, trailing cords thicker than a wrist and ending in plugs as wide as a plate. These converters provide different levels of power to electrical feeds based on different scenarios. They are paired with equally large power emulators that can mimic energy delivered by a solar array or a battery system. Huge touchscreens allow engineers to rearrange the system and tweak its operation.

ORNL engineers designed the power electronics hub to control how the converters interact with each other and the grid. Emulators are set up to mimic the electrical draw and generation of a solar array, a storage battery, an emergency generator and a critical data center with high electrical demand. The power electronics hub was programmed to autonomously manage the power flow of all these electrical loads, helping prevent fluctuations in supply and demand on the wider electrical grid.

The power electronics hub plays the role of a middle manager between the larger electric grid and the local power electronics. "Instead of the utility talking to, say, a million resources, this technology reduces that number by a factor of 10," said ORNL's Michael Starke, lead software architect for the project. "From a utility's point of view, all the equipment managed by the power electronics hub functions as a single system."

This is an advantage for power companies faced with incorporating distributed and intermittent energy from solar, wind, geothermal and other renewable sources into a century-old grid that was designed to push steady flows of energy out from centralized power plants.

Similar concepts have been tested by some utilities, but these approaches use a single vendor's proprietary products in a prescribed way, Starke said. Because ORNL constructed the power electronic converters and many of the components, the resulting technology is openly available and can be customized to achieve specific goals.

For example, experiments by Chinthavali's team have shown the power electronics hub can prioritize providing the most cost savings to customer-owned systems or providing a consistent supply of power for utility systems. ORNL researchers demonstrated that these objectives can be integrated directly into the hardware and software, and they have also developed the supporting communication and control infrastructure.

"It starts with pretesting and pre-automating systems that can be easily scaled up and deployed quickly," said Chinthavali, adding that the project has led to three patent applications. "We're trying to standardize systems so they are interoperable." Moving beyond modeling to demonstrating the technology in wired hardware was a milestone that was only possible because of ORNL's capabilities in GRID-C. "This is the only place where we could develop both the software and hardware to fully prepare to deploy this technology to industry," Chinthavali said.

Several industries could see significant benefits. The technology could be used by a builder or building owner to save money and energy, or it could be installed by a utility for enhanced power control and reliability. The team is moving to the next step in the research: substituting higher-power, commercial converters secured directly from industry. This will demonstrate that the power electronics hub can manage the megawatts of power handled by electric utilities using components from commercial suppliers.

The ORNL team that developed the power electronics hub includes Steven Campbell, lead architect for systems integration; Ben Dean, communication interface developer; Jonathan Harter, hardware systems specialist; and Rafal Wojda, magnetic systems specialist.

"We're now working on how to extend these power electronics hubs from small scale to thousands working together, coordinating to deliver energy as needed from all sorts of different angles and different sources," Starke said. "We're trying to show that the power electronics hub can act like a battery almost, pushing power in and out under our control. That provides all kinds of flexibility to the grid that wasn't there before."

The power electronics hub is an example of the type of technology developed in GRID-C that could be deployed with a potential consortium of partners. ORNL held an interest meeting today with stakeholders from industry, utilities and research institutions to discuss power electronics challenges and strategies. Participants discussed a possible framework for an organization to accelerate development and deployment of power electronics systems for managing the electric grid of the future.

Provided by Oak Ridge National Laboratory

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