



Demonstrating the Grid Benefits of Connected Devices

The Electric Power Research Institute (EPRI), the University of Delaware, and a team of device manufacturer partners have developed and validated a means by which smart, connected consumer devices can act to enable the use of more clean energy technologies on the electric power grid. Project partners worked at the Energy Systems Integration Facility (ESIF) at the National Renewable Energy Laboratory (NREL) to demonstrate a diverse set of products working together to mitigate common constraints that limit the level of renewable energy resources that the grid can support.

Technology improvements are resulting in more and more “smart” devices with built-in communication capability, including energy sources like the inverters for solar power systems, as well as loads such as dishwashers and dryers, and controls such as thermostats. The projects with EPRI and the University of Delaware explored the potential of these devices to better serve the function of the grid as a whole.

The EPRI project employed open-standard communications protocols at the device level to allow the devices to be integrated and work collectively at multiple levels. This kind of open flexibility results in a platform on which a wide range of communications and control strategies may be developed and deployed. The project examined the grid-support capabilities of electric vehicle supply equipment, as well as smart thermostats, pool pumps, resistive and heat-pump water heaters, solar inverters, and battery energy storage devices.

The study found that common connected devices have the potential to provide a wide range of grid services, including specific actions that enable more renewable energy. The potential is great, because modern products of all types are increasingly microprocessor-based, and available open communication standards were found to be sufficient to allow connected devices to be monitored and managed effectively. The responses provided by the connected devices were “smart” in that they could act intelligently to provide the maximum level and duration of grid service, while minimizing consumer inconvenience and

guaranteeing that their core purpose (e.g. daily swimming pool filtration) was satisfied.

With real-time status monitoring of the connected devices, a management system could be built to aggregate the information from the devices to indicate how much power they can supply to the grid, if needed, and how much power they can absorb from the grid. In addition, the connected devices could report the levels of energy that they could produce or absorb so that grid operators could know how long a given level of response can be sustained.

Further expanding the potential of grid-connected devices is vehicle-to-grid (V2G) technology, which enables electric vehicles to not only charge from the grid, but also to discharge to the grid, providing grid services. The University of Delaware project examined the V2G characteristics of electric vehicles, including a TransPower school bus and BMW MiniE, as well as two V2G charging stations and an aggregator, demonstrated at the ESIF. The aggregator technology communicates to EVs and charging stations via an open-source protocol that manages a large fleet of EVs and a distributed group of V2G-enabled charging stations and tracks trips and required energy for the EV fleet, as well as the grid-connection status for the charging stations.



Using the ESIF Energy Storage Lab, researchers further explore the potential of vehicle-to-grid technology on electric school buses. NREL 38471



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The ESIF provides a unique, integrated energy systems platform on which our academic, industry, or laboratory partners can work with a team of specialized scientists and engineers to identify and resolve the technical, operational, and financial risks of integrating emerging energy technologies into today's energy environment. Bring us your biggest energy system challenges, and let's solve them together.

Contact the ESIF User Program at 303-275-3027 or userprogram.esif@nrel.gov to discuss opportunities.

Learn more about the ESIF and see a list of current partners at

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For complete details on the ESIF's capabilities, tools, research focus areas, and user facility opportunities, please visit www.nrel.gov/esif.

The ESIF research examined the basic electrical characteristics of the V2G vehicles, such as the:

- Round-trip efficiency of providing grid services
- Robustness during voltage transients and electrical faults
- Latency between sending a control signal to the vehicles and seeing a response in power output
- Maximum rate of increase in power output
- Maximum and minimum up time for the vehicles, and
- Any impacts on power quality as the battery discharges.

The research also quantified the vehicles' response to simulated utility control signals and demonstrated autonomous operation for grid support based on local frequency and voltage measurements, using a grid simulator in the ESIF.

In two additional use cases, the vehicles were paired with home-sized photovoltaic systems. The solar-EV test was used first to minimize power injected into the grid—minimizing customer bill impact—and second to store peak solar generation and discharge at a time of minimum solar generation—helping to better match the solar generation to the load.

The projects are two of five partnerships NREL is managing under the Integrated Network Testbed for Energy Grid Research and Technology Experimentation (INTEGRATE) project, which aims to enable the nation's electric grid to handle increasing amounts of renewable energy. INTEGRATE is a \$6.5-million, cost-shared project between the U.S. Department of Energy and industry partners that aims to allow renewable energy systems and other clean energy technologies to be connected to a smart power grid in a “plug-and-play” manner, similar to how computers automatically connect to new devices plugged in by the users. INTEGRATE is part of the U.S. Department of Energy's Grid Modernization Initiative.



With renewable energy expanding at all scales, new tools and technologies are needed to enable the grid to handle high penetrations of these renewable energy systems, particularly the smaller systems installed on utility distribution feeders as distributed energy resources. To address this need, NREL is managing five partnerships under the Integrated Network Testbed for Energy Grid Research and Technology Experimentation (INTEGRATE) project. See the NREL news release on INTEGRATE at: <http://www.nrel.gov/news/press/2015/18515>. Photo from istock 514327842

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