Plug and Play Solar Power: Simplifying the Integration of Solar Energy in Hybrid Applications

Cooperative Research and Development Final Report

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In accordance with Requirements set forth in Article XI. Reports and Abstracts A.(3), of the CRADA agreement, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Commonwealth Scientific and Industrial Research Organization

CRADA number: CRD-13-523

CRADA Title: Plug and Play Solar Power: Simplifying the Integration of Solar Energy in Hybrid Applications

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1	$ 100,000.00
Year 2 or Modification #	$ 200,000.00
Year 3 or Modification #	$ 100,000.00
Year 4 or Modification #1	$ 44,200.00
TOTALS	$ 444,200.00

Abstract of CRADA Work:

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's national science agency. CSIRO received funding from the Australian Solar Institute (ASI) for the United States-Australia Solar Energy Collaboration (USASEC) project 1-USO032 Plug and Play Solar Power: Simplifying the Integration of Solar Energy in Hybrid Applications (Broader Project). The Australian Solar Institute (ASI) operated from August 2009 to December 2012 before being merged into the Australian Renewable Energy Agency (ARENA). The Broader Project sought to simplify the integration, accelerate the deployment, and lower the cost of solar energy in hybrid distributed generation applications by creating 'plug and play' solar technology. CSIRO worked with the National Renewable Energy Laboratory (NREL) as set out in a Joint Work Statement to review communications protocols relevant to plug-and-play technology and perform prototype testing in its Energy System Integration Facility (ESIF). For the avoidance of doubt, this CRADA did not cover the whole of the Broader Project and only related to the work described in the Joint Work Statement, which was carried out by NREL.

Summary of Research Results:

This project reviewed communications protocols relevant to plug and play (PnP) technology and performed validation of a microgrid control system using a 250 kVA-scale microgrid configuration at NREL's ESIF.

In total, nineteen communication protocols were examined in the context of their ability to support and/or integrate in a PnP context. In the utility space, the IEC 61850 protocol has strong support for PnP functionality within substations. The protocol implements key features such as a robust object model and hardware abstraction, integration with enterprise IT systems, device discovery and automatic configuration, and guaranteed data delivery times. The protocol is standards-based and has been adopted by major equipment vendors. Gateways and protocol converters are available for connecting with legacy systems. On the customer side of the meter, OpenADR specifies secure Automated Demand Response (ADR) messaging between the utility and client applications, and can integrate with building automation systems using LonWorks, BACnet, SEP2.0, etc. allowing true ADR applications in the commercial and residential spaces. The device language model specification (DLMS) for advanced metering applications can be integrated with these networks, allowing flexibility in ADR implementation with legacy building automation system (BAS) networks. Many protocols have been developed for the residential sector, with ZigBee and Z-wave taking dominant roles. Both support mesh networking for home area networks. Key alliances between ZigBee, HomePlug, OpenADR and other key protocol alliances put ZigBee in a good position to become a dominant protocol in the residential ADR space.

CSIRO teamed with an industrial partner to develop a microgrid control system capable of monitoring and controlling a variety of generation and load assets according to advanced dispatch algorithms. This novel microgrid control system enables simplified integration and increased penetration of renewable generation (i.e., solar) into traditional hybrid distributed generation systems using a system of distributed controllers (one controller per device) and solar forecasting and demand response capabilities. CSIRO successfully demonstrated the basic functionalities of this microgrid control system using a low power (~30 kVA) microgrid test bed at its Renewable Energy Integration Facility (REIF) in Newcastle, NSW, Australia. CSIRO then partnered with NREL to provide additional validation of this microgrid control system using a 250 kVA-scale microgrid consisting of a grid simulator, diesel generator, photovoltaic (PV) inverter with PV simulator input, and a load bank at the ESIF. The microgrid control system was evaluated using a sequence of test scenarios that used common solar irradiance and system load profiles, but systematically added controller functionality so as to evaluate each function independently. Each test scenario was evaluated using key metrics of PV energy penetration achieved, maximum ramp rate of the grid-forming unit, and number of ramp rate excursions beyond a defined threshold. Key outcomes from those investigations include:

- Experimental validation at NREL demonstrated that the PV, generator, and load control functionalities of the microgrid control system could enable greater PV energy penetration and reduce ramping of traditional generation assets as compared to the uncontrolled base case

- All methods of PV-only control investigated, including with and without different solar forecasting methods, resulted in less severe and less overall incidents of traditional generator ramping as compared to the base case with no control

- Solar forecasting adds very tangible benefit to base PV-only control by further reducing the severity and overall number of traditional generator ramp rates beyond the PV-only control base case. Two primary solar forecasting methods were investigated. The more conservative method demonstrated similar PV energy penetration as the PV-only control case, but with significantly less severe maximum ramp rate and less overall ramping events for traditional generation. The second, less conservative, method provided even further reductions in maximum ramp rate and ramping events for only a 5% decrease in total PV energy penetration.

- The load control functionality does promise the ability to increase PV energy penetration and reduce generator ramp rates and the number of ramping events, however, with automated load control functionality still being under development, only limited testing was possible. Using a rudimentary method of manual load control that mimicked one possible automatic control implementation, greater PV energy penetration and a reduction of max traditional generator ramp rate was achieved, but at the cost of slightly more ramping events. The implementation of automatic load control that fully employs the various demand response modes available is likely to fix this shortcoming.

Subject Inventions Listing:

None

Report Date:

5 July 2017

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