A BATTERY STORAGE SYSTEM FOR DISTRIBUTED DEMAND RESPONSE IN RURAL ENVIRONMENTS

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This paper presents the results of deploying four sets of 75-kWh battery distributed energy storage (BDES) systems developed by LGW Incorporated at residences located in Binger, Oklahoma, and Fayetteville, Arkansas. In addition, two commercial facility installations have been brought online. Each of the sites includes renewable energy generation consisting either of (1) solar photovoltaic: 450 watts at residential sites and 10 kilowatts (kW) at commercial sites, or (2) wind generation peak of 65 kW for a commercial facility. The BDES system was developed by LGW in collaboration with the University of Arkansas and deployed with assistance from Caddo Electric Cooperative (Oklahoma) and Ozarks Electric Cooperative (Arkansas). The motivation for this research is to investigate the potential benefits of implementing a distributed demand response (DDR) system that is configured for the circumstances encountered in rural environments. The objectives are to quantify the benefits of BDES systems in terms of

- Peak load management,
- Electric service reliability,
- Renewable integration,
- Voltage regulation/Reactive power support, and
- Financial and economic incentives.

Challenges for rural electric power systems include recurring outages due to storm damage, difficulty in voltage regulation, and large load fluctuations associated with agricultural equipment and irrigation systems over low-density networks covering large geographical areas. There has been considerable research in the integration of electric utility communication protocols with customers in real time to coordinate loads for peak shaving and load leveling [1]. The adoption of distributed energy sources has further encouraged the investigation of advanced demand response (DR) systems [2]. Much of the published work in this area has been with respect to analysis of historical usage profiles [3]. The contribution of this pilot study is the development of a DDR system where an electric utility has the ability to schedule in 15-minute intervals the maximum load level for a particular customer. The BDES system is implemented with an IEEE 1547 compliant grid-tie power electronic inverter [4-5] and a 75-kWh lead-acid battery storage system that can meet customer demand for loads that exceed the utility DDR set point. Commands and feedback between the utility and the BDES system is over a Cooper-Cannon PowerLine communication link. Included in the BEM functionality is coordination with the utility service provider to signal preferred times for recharging the battery bank during off-peak times [6]. In this pilot, the four installation sites generally were operated with 12-kW discharge during the peak daily load times of 2:00 to 8:00 p.m. Battery charging occurred during off-peak time when marginal electricity rates are lowered. Operational data collected remotely from the LGW installation in Binger, Oklahoma, can be viewed at http://www.lgwenergynow.com/MSLineGraph.aspx on line with real-time updates.

A critical element to the success of the pilot study of the BDES systems is the battery technology. Lead-acid batteries were selected due to low cost and robustness to environmental conditions. By properly accounting for conditions at the site location, the battery configuration can be optimized to provide sufficient reserve capacity for the anticipated temperature and humidity variations. A novel battery formulation has been developed by the authors that increases the porosity of Pb/PbO_2 plates beyond that achieved with conventional tribasic and tetrabasic lead oxides. Lead normally grows in needle-shaped crystals with secondary and tertiary branches. Novel curing and soaking processes have been found to produce octahedral and dodecahedron crystals that have both improved electrochemical porosity with high anode/cathode plate densities. This processing technology achieves approximately 16% increased reserve capacity for a given battery mass/volume metric. Lead-acid battery technologies are attractive economically because of the nature of lead mining production and processing. In particular, purified lead (Pb) ore is the principal capital investment in lead-acid battery systems. Given that reprocessing recovers over 98% of the Pb/PbO_2 material, the capital investment in a lead-acid battery installation is a one-time expense that depending on commodity prices may in some cases become an investment for the battery diesel generator (DG) system. Consequently, the financing of lead(II) sulfate ($PbSO_4$) batteries can be achieving in various means. One option would be for the DG system vendor to retain ownership of the Pb/PbO_2 with lease options made to the utility company for use of the inverter and other related components. Alternatively, the utility may exercise an option to own the Pb/PbO_2 material and provide the DG as part of a service contract. This arrangement overcomes one of the principal challenges in deploying DG systems in terms of the cost implications for utility and end users/customers wishing to employ energy storage systems.

In conclusion, it has been demonstrated that BDES systems are effective in providing improved reliability and load management capability in meeting utility DDR objectives. In addition, BDES systems confirm the capability for financial planning [7] by the associated electric utility company for postponing the need for adding generation capacity and therefore avoiding large capital expenditures.

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BIOGRAPHICAL NOTES

Conference presenter: Roy McCann received a B.S. in Electrical Engineering from the University of Illinois at Urbana-Champaign in 1990 and an M.S. in Electrical Engineering for the University of Illinois at Urbana-Champaign in 1991. After completing the MSEE degree, he was employed by General Motors Corporation in Dayton, Ohio, working towards the development of advanced electronically controlled engine, braking, and steering systems. He began a Ph.D. program at the University of Dayton in 1995 related to electric power systems research. With funding by Delphi Corporation and the Dayton Area Graduate Studies Institute, he was awarded the Ph.D. in Electrical Engineering in 2001 from the University of Dayton. During this time, Dr. McCann was the engineering supervisor for the Electrical Systems Group at Delphi-Saginaw Steering, where the first large-scale fully electric and electronically controlled power steering system was designed and produced for the North American passenger vehicle market. Dr. McCann has received 19 U.S. patents related to his work in automotive electronic systems and authored numerous papers for the Society of Automotive Engineers (SAE) and the IEEE. In August 2003, Dr. McCann accepted an appointment as an Associate Professor of Electrical Engineering at the University of Arkansas–Fayetteville. In August 2009, Dr. McCann was promoted to the rank of Professor. He teaches and conducts research in control systems with particular emphasis on energy conversion related applications. He is the director of the Control Systems laboratory at the University of Arkansas and also an associate director for the National Center for Reliable Electric Power Transmission (NCREPT), also located at the University of Arkansas.

Robert Winkelman has served as Chief Executive Officer of LGWI since the company was formed in 2009. He earned an LLB degree from the University of Texas. He was a trial lawyer for Baker, Botts, Andrews & Shepherd in Houston until joining one of his principal clients, Electric Storage Battery Company (ESP). ESP later became Exide, the world's largest battery manufacturer with 26 factories worldwide. He worked with research and development at Exide developing an electric car that was successfully marketed in the United States under the name Sebring City Car. He subsequently earned national awards for his work with Sears on the development of the Diehard battery. He left Exide to form Winkelman Battery Company, which became the largest American importer of Global Y batteries from South Korea. He also worked with a leading Chinese battery manufacturing company named Palma to develop an advanced version of an absorbed glass mat (AGM) battery. Finally, he was a principal and early contributor to Good Earth Energy Conservation, Inc., an electric vehicle manufacturer, before forming LGWI. His reputation as a leader in battery technology, energy management, and electric vehicle development has resulted in a number of international consulting assignments, including projects in China, Russia, Bulgaria, Hungary, Zanzibar, and South Africa.

David Moody joined the company in February 2011 and currently serves as President of LGWI. He has degrees in Public Administration from the University of Central Arkansas (Honors) and the University of Houston. He joined the federal service through the Presidential Management Internship Program and worked for the National Aeronautics and Space Administration and in the aerospace industry for 14 years. During that time he served as a program analyst, manager, and consultant for the shuttle, space lab, and space station programs. Since leaving the aerospace industry, Mr. Moody has owned and operated several businesses in the fields of risk management, retail, and business consulting. As a business consultant focused on startup and technology businesses, he has worked with a variety companies to commercialize products and services in the areas of nanotechnology, biotechnology, medical devices, computer science, and energy technology. Before joining LGWI, Mr. Moody served as the Deputy Director of the Arkansas Energy Office. As Deputy Director he was responsible for developing the staff and organization to administer $52M in federal grants that funded 13 major programs and dozens of individual projects across Arkansas.