Southern Research Energy Storage Research Center

B. Taube*, E. Ringler*, and T. Hansen*

*Southern Research Institute, Energy & Environment
2000 9th Avenue South, Birmingham, AL 35205, United States, btaube@southernresearch.org

ABSTRACT

Southern Research, with support from the Electric Power Research Institute (EPRI), Oakridge National Laboratory (ORNL), the State of Alabama, and Southeast (SE) regional electric utilities, is developing a new Energy Storage Research and Test Center (ESRC) focused on grid-scale energy storage (ES) applications in combination with renewables in the Southeastern US. The purpose of the ESRC is to provide independent, third party, research and testing as well as engineering and economic assessment for ES technologies and use cases important for and unique to the Southeast. Technologies and applications relevant at utility scale are the primary focus. Southern Research has initiated work to identify ES testing capabilities and needs nationwide, as well as defining technology specific use cases and risks relevant to Southeastern utility service areas. This effort will inform identification of regionally prioritized ES target attributes and corresponding test and verification strategies. The results will serve as the basis for the ESRC facility infrastructure requirements and test protocols, with the goal of developing consensus test protocols that address all stakeholder information needs and priorities. This paper will present results of this effort at Southern Research to date and provide a platform to engage with conference attendees to obtain feedback on how the ESRC might be best shaped to meet user needs.

Keywords: Energy storage technologies, gap analysis, test protocols, grid-scale testing and verification, ESRC design

1 INTRODUCTION

Without the ability to store electricity, generation must equal consumption. With the development and deployment of Energy Storage Systems (ESS), energy generated at one time can be used at another. Recent technology advancements in energy storage have increased the potential of ESS to serve a variety of service scenarios in electric power management. The ESS will ideally support multiple applications or “stacked benefits” in a single installation in order to achieve a competitive return on investment.

Not every type of energy storage technology is suitable for every application, which may result in a portfolio approach. ESS have yet to achieve broad deployment in the utility sector. Limiting factors for wider ESS deployment include costs, validated performance, reliability, safety, and lack of industry experience and acceptance. Widespread use of energy storage will require improved grid integration tools which allow predicting how ESS can be sited, deployed and used to achieve maximum value. A ccordinated effort between utilities, academia, technology developers, and government is needed to ensure ESS are designed and evaluated to adequately address limiting factors.

Key objective of this collaboration is to establish the technical capabilities (approaches, protocols, personnel and infrastructure) required for the ESRC to enhance knowledge and understanding of integration, performance, and use of grid-ready energy storage technologies in a grid deployed environment. The ESRC is expected to serve as an industry-wide resource for conducting evaluations of new storage technologies and approaches to cost-effectively inform end-users, vendors, utilities and regulators about the availability and efficacy of new technology. The ESRC will also support the completion of research defined through industry-wide organizations such as DoE and EPRI, which is necessary for the broader deployment and subsequent cost reduction of energy storage systems. In addition to the key collaborators, the ESRC will prove to be a long-term regional asset, providing continued economic growth development for the Southeast in the emerging energy storage market.

2 ENERGY STORAGE TECHNOLOGIES

Recent years have seen significant improvements in existing and development of new energy storage technologies. In addition to changes in technologies, costs of existing ESS have dropped precipitously. The level of technical maturity of a range of technologies is displayed in figure 1.

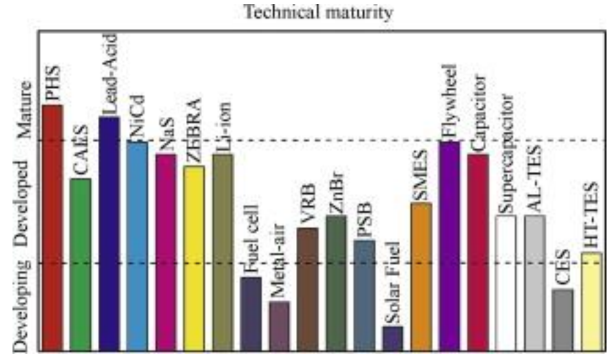

Figure 1: Maturity of Energy Storage Technologies [1]

More mature energy storage technologies include pumped hydro storage (PHS), lead-acid and nickel-cadmium batteries, or flywheels overall while lithium-ion and NaS batteries or capacitor based energy storage technologies can be classified as well developed. Except from automotive battery technologies, however, a lack of standards for utility-scale ESS must be noted which will be addressed by the ESRC as one of its focus areas.

The newest (and least developed) technologies include fuel cells, metal air batteries, solar fuel, and cryogenic energy storage (CES). These technologies are reviewed in further detail by Chen et al (Chen et al. 2009). In addition to the developing technologies highlighted here, some relatively mature technologies have been improved such that they are now able to provide a much wider range of services. Large-scale flywheels are a good example.

As illustrated in figure 2, the adoption of energy storage technologies varies significantly. With almost 200 installations, the Lithium-Ion battery technology represents the mostly adopted followed by more than 100 installations using Ice-Thermal energy storage technology. More significant ESS technology adoption rates also include lead-acid batteries, pumped hydro, sodium-based and flow batteries and flywheels.

As shown in figure 3, the adoption of ESS technologies in the Southeastern U.S. is by-in-large driven by pumped hydro storage with some scattered deployments of electromechanical (flywheels) and electrochemical (battery) energy storage systems. At utility-scale, the only known flywheel deployment in the Southeast can be found at Beacon Power.

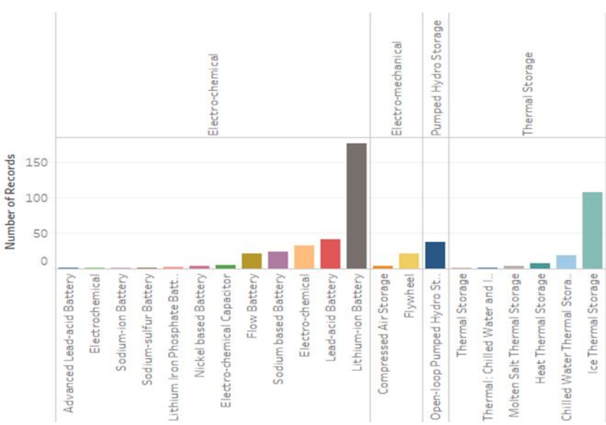

Figure 2: Number of ESS Installations by Technology [2]

The energy storage options studied at the ESRC may include a range of storage technologies such as battery, thermal, pressure, mechanical and chemical hydrogen energy storage which will allow for increasing new ESS technology adoption in the Southeastern US.

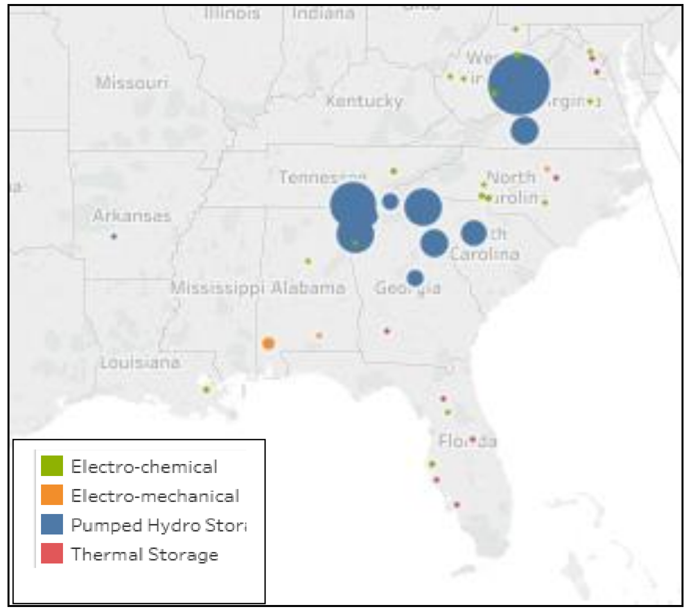

Figure 3: Southeastern U.S. ESS Deployments [2]

3 ENERGY STORAGE STANDARDS AND TESTING PROTOCOLS

As additional technologies have developed and matured, a number of entities (especially Sandia National Lab/Pacific Northwest National Lab/Oak Ridge National Lab (Ferreira et al. 2013; Conover et al. 2016) and the Electric Power Research Institute's Energy Storage Integration Council (ESIC) (Working Group 2—Testing and Characterization) have developed testing protocols to help ensure technologies are both safe and perform at the level expected (EPRI 2016b). Many of these standards have been discussed in publications from SNL and PNNL (Rosewater and Williams 2015; Gyuk et al. 2014).

Body	Safety & Performance Standards
IEEE	519, 1547, P.2030.2.1, 2030.2-2015, 693, 1625/1725, Recommended Practice & Requirements for Harmonic Control in Electric Power Systems
IEC	61000-3-15, 62116, 62620, 62897, 62281, 62133
UL	1641, 1642, 1741, 1741 SA, 2054, 9540
NFPA	70, 791, 855 (under development)
ANSI	18.3M (Part 2-2011)

Table 1: Standards Organizations and ESS Standards

Beyond the testing protocols set forth by SNL, PNNL, ORNL and EPRI's ESIC, there are also both safety and performance standards developed by a number of standards organizations (table 1). ESRC will engage in the effort and contribute to working groups focused on the development of ESS standards and testing protocols.

4 THE ESRC

Knowledge has been gained from actual deployments and operations of energy storage technologies in utility environments but much more progress is possible if we concentrate on the specific conditions in the SE and use new data analytics tools. The Energy Storage Research Center represents a collaborative research approach which is intended to address integration, demonstration, operation, and validation of energy storage systems performance in a grid-connected environment. The ESRC will complement the energy storage research activities of our collaboration partners based on energy storage integration between utilities, energy storage system developers as well as other stakeholders such as universities and national laboratoriesor other potential end users (commercial, institutional, behind the meter).

The objective of the ESRC is to support Alabama's vision as a progressive economic state that brings together experts from different stakeholder groups to drive grid transformation via leveraging disruptive technologies such as energy storage and renewables, ultimately also improving economic development in the region by attracting innovative companies. This includes the collaboration with the University of Alabama (UAB) to educate, advance discovery, and respond to needs of the community.

A review of information from various sources including the Department of Energy (DoE) and EPRI's Energy Storage Integration Council (ESIC) was performed to determine critical research needs for the deployment of energy storage systems in utility applications. Based on the findings the ESRC will conduct a portfolio of research focused on energy storage system interconnection, integration, operation and evaluation. Research performed at the ESRC will include (1) interconnection methodologies for ESS related to existing utility infrastructures, including power as well as data and control connections, (2) integration of ESS into utility planning and operations processes to get maximum benefits from the ESS, (3) ESS operation to optimize multiple value streams including an assessment of cycling on life and other performance parameters, (4) control systems which allow ESS to yield the planned operational benefits, (5) ESS monitoring in the field, and (6) evaluation of various energy storage technologies and operations.

One of the key outcomes of the research at ESRC will be the determination of the total cost of ownership (CAPEX and OPEX) for various energy storage technologies and applications. Energy storage application research for demand management, renewables integration, and backup power will be performed in cooperation with industry collaborators.

4.1 ESRC Location

The approach for the ESRC will be to demonstrate utility-scale energy storage value with different services at the transmission and distribution level analyzing, testing and demonstrating various ESS technologies in an operations and control environment. Also, the ESRC will be colocated with the Southeastern Solar Research Center (SSRC) at the Engineering Research Center campus on the west side of Birmingham, AL. This location is in close proximity with key collaborators. It will leverage existing infrastructure including PV resources, available land as well as test and evaluation capabilities at Southern Research. The selected location offers over 4,000 ft^2 of office/meeting space as well as over 40,000 ft^2 of high-bay lab space which can be dedicated to the ESRC and its industrial partners such as utilities, car manufacturers, and ESS providers.

Figure 4: ESRC Layout

4.2 ESRC Design

The design of the ESRC layout shown in figure 4 included consideration of the civil site as well as testing, utilities and other facility needs. The facility framework and key components are summarized in table 2. ESS designed for short and longer term duration at the substation, distribution feeder, and customer site level (25kW to 1MW) are targeted to be evaluated. The output from the existing 12kW PV array, non-renewable DG, and grid power may be used to charge the energy storage systems in appropriate evaluation scenarios.

Integrated throughout the ESRC facility, a supervisory control and data acquisition (SCADA) system will monitor and control experimental operations and gather real-time, time-synchronized, highly time-resolved data for collaboration and visualization. Secure, segregated accounts will allow users to access data collected from their experiments while ensuring the integrity of proprietary and sensistive information. Experimental data (voltage and current) can be acquired at selected data points and appropriate data collection frequencies to ensure valid waveform measurement with secure data storage and retention through the SCADA system.

The outdoor test areas of the ESRC allow utilities and researchers to evaluate energy storage systems with distribution level equipment. The outdoor test areas are designed for testing and integration of 120-480-V and possibly higher class systems. Up to five outdoor test areas (figure 4 shows four pads) separated into individual test pads and classified by energy storage technology type are planned for the ESRC facility with two of them already in place. Four test pads at 30'x40' each and one at 40'x62.5' are planned for mechanical, thermal, chemical, and electrochemical (battery) storage testing.

Component	Purpose
Operations/ Control Room (in place)	Runs PLCs with SCADA. Connected to office space with computers for data analysis and research.
Outdoor Test Areas including Utilities (2 pads in place)	4 pads (30'x40') and 1 pad (40x62.5) for mechanical, thermal, chemical and electrochemical research, testing, demonstration (2 of the 30'x40' pads are already there); electricity, gas, water and air supply for each pad
Main Power Supply from 13.2kV Line (in place)	Step down transformer, disconnect switches, etc. to provide electricity to the pads from 13.2kV distribution line
Additional Power Supply from SSRC (in place)	Additional electricity supply from solar field (part of SSRC) and additional diesel generators available. Infrastructure to connect with ESRC is to be added.
Communication Infrastructure (partially in place)	Infrastructure (e.g. conduits) which connects operations/control room, labs & pads. Communication lines to pads are to be added.
13.2kV Grid Connection for ESS Integration with Grid and Load Elements (to be added)	Infrastructure to integrate ESS with 13.2kV power distribution side (e.g. transformer, switches, etc) to allow for energy supply from ESS to grid. Also includes load banks, etc.
Common Areas (in place)	Office, storage and meeting space (1,500ft^2)

Table 2: ESRC Facility Design Components

The outdoor test areas facilitate easy configuration and connection of energy storage test components to the local 13.2kV distribution grid. Smaller subsections of each test area may be broken down further into individual test bays with covering or awning depending on the test requirements.

In addition to the ESS test bays, future plans for the outdoor test areas include distributed generation (DG) technology such as generator sets (natural gas or diesel) or natural gas microturbines as sources of distributed power.

The electrical distribution and communication lines represents the ESRC's internal utility infrastructure interconnecting its laboratories and test pads. It facilitates complex integrated system testing of both AC and DC energy storage systems up to 1MW scale across the laboratories and test pads.

The ESRC facility will use existing high-bay facilities at Southern Research retrofitted to hold test laboratories suitable for small scale ESS equipment and multicomponent system testing. Additional laboratory facilities may be housed on the UAB campus as required.

5 CONCLUSIONS

Based on the collaboration of Southern Research with the energy storage industry, academia, government, and technology vendors, the ESRC will develop joint energy storage research, demonstration and test projects focused on the Southeast as well as the U.S. overall. It will serve as an industry-wide resource to support emerging energy storage technologies. The ESRC will serve as an independent resource to provide third party services on energy storage systems for technology vendors and users as well as other stakeholder groups (e.g. financers and regulators). The ESRC will enable electric systems engineers/planners, energy storage system vendors, and investors to mature energy storage systems and provide for economic growth and development in the emerging energy storage market.

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