Real-time simulation and data analytics for grid-scale energy storage applications in the Southeast

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ABSTRACT

Southern Research, with support from EPRI, DoE, the State of Alabama and Southeast (SE) regional electric utilities, is developing an Energy Storage Research and Test Center (ESRC) focused on serving the SE United States; one of the facility's core competencies will be in the area of data analytics and grid modeling through a partnership with Acelerex for both infront of the meter and behind the meter energy storage applications.

Modeling grid environments, integrating energy storage systems (ESS) using hardware-in-the-loop (HIL), emulating dynamic and steady-state grid and ESS behavior in real-time, applying advanced data analytics and supercomputing represent fundamental capabilities of the evolving ESRC.

The Southern Research strategy is to adopt a software architecture that will facilitate multi energy storage unit testing with parallel use case duty cycles demonstrations of the energy storage systems providing stacked services. The software architecture is designed displace hardware investments with software emulations of the hardware.

Keywords: energy storage, data analytics, grid modeling, stacked benefits, software architecture

1 INTRODUCTION

Southern Research is targeting energy storage research to become a premier lab in the United States for energy storage application research. As described in the text of the report above, the energy storage application research proposed for this facility entails the testing of energy storage technologies at the Southern Research facilities, as well as demonstrating a broad range of use cases of the technologies. There are many labs globally that conduct energy storage cell level cycle testing and safety testing; in contrast, the approach of Southern Research is to focus on and specialize in application testing of use cases and stacked services, which is currently done by relatively few entities globally.

2 ACELEREX CAPABILITIES

There are three key components of the Acelerex platform that support the Southern Research specialization in big data analytics and modeling: grid analytics, software supported energy storage systems testing and providing a software architecture for this analysis.

2.1 Grid Analytics

Southern Research, through its partnership with Acelerex, will begin its research services offerings by analyzing the grid and looking for opportunities through the use of grid analytics to identify where energy storage can play a role more effectively than other technologies, particularly in the Southeast. The grid analytics would be facilitated with cloud computing to offset server hardware and cyber security costs of lab-run supercomputers.

With the cloud computing there will be computing power to run grid analytics platforms as well as big data, data mining, grid emulators, artificial intelligence and machine learning in addition to application program interfaces, database, blockchain and smart contract, stacked services controls for storage, sandbox coding, and other tools. The grid analytics would target six key questions of energy storage—determining the following:

1. Use Cases
2. Locations
3. Power Ratings
4. Energy Ratings
5. Timings of Installations
6. Proforma of Storage Benefits and costs

This analysis allows the ESRC to provide economic and technical support for the implementation of grid scale energy storage in the Southeastern United States.

2.2 Software-Supported Energy Storage Testing

In addition and simultaneously to grid analytics, hardware testing of energy storage will be performed at the ESRC. This testing would include energy storage use case evaluation as well as baseline system performance and functional characterization. Test service development at the ESRC is discussed in another technical paper entitled "Energy Storage Standards Development and Defining Best Practices for System Evaluation [1]."

The additional value of the software architecture as proposed is the ability to test energy storage systems to duty cycles that are derived from stacked services of energy storage rather than traditional cycle testing of individual energy storage modules or conducting a single duty cycle test.

Software emulation can be used to represent grid components and then actual demonstration energy storage can be controlled to optimize with the software emulation of the generators or other resources.

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As the energy storage is dispatched to optimize the generators or other resources the charge and discharge power can then be facilitated with a load bank and grid connection that the energy storage is connected to.

The following diagram represents the configuration of hardware and software for energy storage testing:

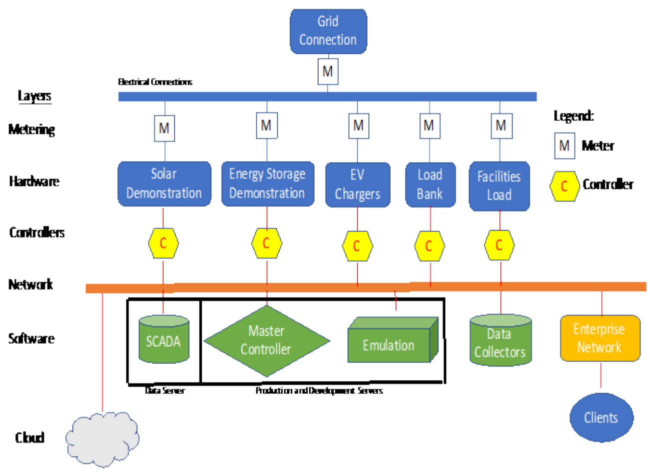

Figure 1: ESRC Infrastructure for energy storage testing.

In the above diagram there are multiple layers; there is the electrical connections, metering, hardware, controllers, network, software, and cloud layers. The software layer then can emulate additional hardware to avoid capital costs of hardware and in addition the cloud can be used to avoid capital costs of servers and computing infrastructure. Each of these components provide critical support to the implementation of the ESRC test manual.

Energy storage testing features unique to the ESRC include the following:

a. Controlled Inputs – test injection signals can be prepared to inject into the setpoint of the energy storage as well to the load banks for controlled testing purposespurposes where ESRC have developed a library of test injection signals for behind the meter and in front of the meter use cases for both at ESRC test center and for remote testing at energy storage sites.

b. Control Signals – control signals are inner loop control signals as well as outer loop control signals that are dynamic during the tests such as the power feedback from the inverter or the voltage of the connection point or other feedbacks.

c. Test Measurements – test measurements include items such as state of charge of the energy storage, power signal of the energy storage inverter, current of the energy storage, temperature of energy storage, and AC and DC voltages of energy storage or other test measurements including statuses and alarms and controls.

d. Test Signal Meta-data – the real-time staging database and data warehouse will store test metadata of test description, date, time, signals measured, injection data, and other data to recreate and document the tests.

e. ES Control Objectives – the master controller will enable activation of ES control functions such as peak shaving, frequency response, ancillary services, solar smoothing and others.

f. Define Expected Performance – the database will store expected performance as well as time series data to compare test responses to expected performance

g. Metrics to Verify Performance – metrics to verify the energy storage system meets test compliance criteria can be computed from the measured data.

2.3 Acelerex Software Architecture

The Southern Research strategy is to adopt a software architecture that will facilitate multi-energy storage unit testing with parallel use case duty cycles demonstrations of the energy storage systems providing stacked services.

The software architecture is designed to cost optimize the hardware investment costs in the lab and displace hardware investments with software emulations of the hardware. Hardware investment costs would be directed to need to have systems such as the individual storage technology types where software emulation can be used for systems that the energy storage optimize. The key components of the software architecture are as follows (also shown in Figure 2):

1. *Remote Monitoring and Control,*
2. *Visualization,*
3. *Cloud Computing,*
4. *Grid Analytics,*
5. *Site Controller for Controls Algorithm Testing,*
6. *Emulation of Power System Components,*
7. *Data Collection,*
8. *Optimizations,*
9. *Artificial Intelligence,*
10. *Grid Data.*
11. *Blockchain and Smart Contracts*

The software architecture diagram below lays out how the different software and servers are laid out to provide platform for energy storage research and data collection and cloud computing for the energy storage research.

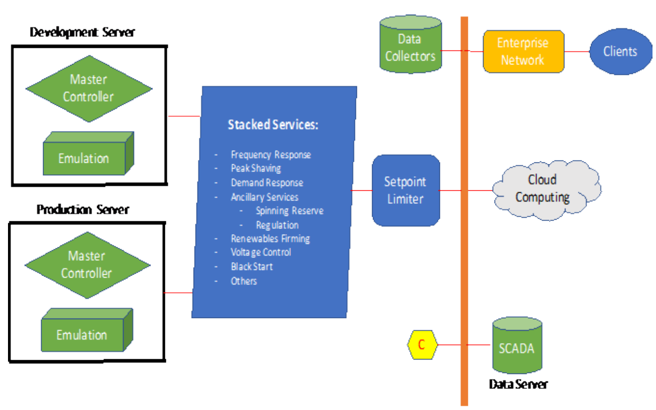

Figure 2: ESRC Software Architecture Schematic.

3 RESEARCH AND ADVISORY SERVICES AT THE ESRC

3.1 Service Development and Capabilities

Figure 3 shows the use cases that energy storage can provide. The use cases span the entire supply chain of the power sector.

An energy storage system can provide multiple services in its operation; this is referred to as stacked services and evaluating the economic and technical value of this stacking is a critical service that the ESRC provides, enabled through the Acelerex analysis platform.

Figure 3: Energy Storage Services by Scale and Application (Based on [2]).

The Acelerex platform considers both the optimum power and capacity of proposed energy storage installations in its stacked services analysis to determine the ideal size of systems to be deployed on the grid in a particular location. The diagram below (Figure 4) shows how both power and energy are nominated and allocated in the software analysis. In addition, to the two quadrants of stacking power services in the charging and discharging directions there is the full four quadrants of services including voltage and reactive power service stacking.

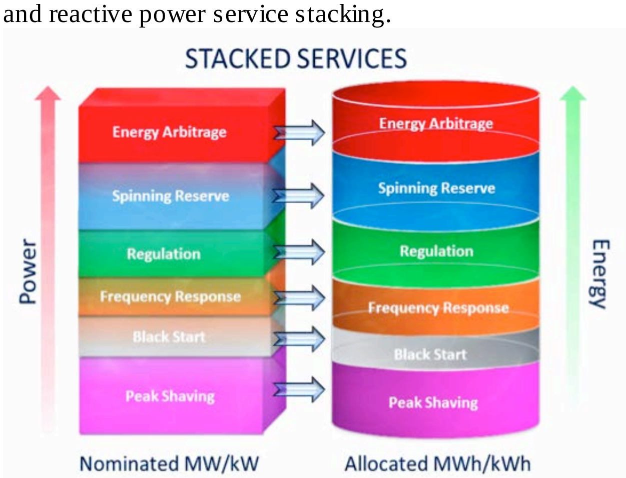

Figure 4: Stacked services overview—allocated power and capacity.

The development of research and advisory services at the ESRC will incorporate use-case testing with existing resources at the ESRC to emulate real-world conditions.

By utilizing existing infrastructure such as the Southeastern Solar Research Center (SSRC) and Engineering Research Center (ERC) at the ESRC, in combination with the Acelerex software architecture, Southern Research will be capable of replicating a variety of microgrid configurations to optimize the energy storage system with resources available in field conditions at a range of scales, which is a critical analysis need that is not currently being met by existing testing and research facilities in the region and around the coutnry. This is a highly differentiating feature of the facility in comparison to its competitors and collaborators.

3.2 Sample Analyses conducted by Acelerex

While the collaboration between Southern Research and Acelerex in the Southeastern grid is only just beginning, the staff of Acelerex have a long history of grid analysis and energy storage valuation that will provide a template of the kinds of approaches and outcomes to be produced at the ESRC.

One example of the research and analysis conducted by one of founders of Acelerex is the Massachusetts State of Charge Study, completed in late 2016 [3], of which the organization was a key collaborator. Per the report, “This study analyzes the national and Massachusetts storage industry landscape, reviews economic development and market opportunities for energy storage, and examines potential policies and programs to better support energy storage deployment in the Commonwealth [4].”

During this study, “modeling was conducted to determine:

- The optimal amount of advanced storage in MW and MWh to be added over the next 5 years – through 2020 – that will add maximum benefit to ratepayers;
- The distribution of energy storage locations across Massachusetts where adding storage will achieve maximum benefits to the ratepayers; and
- A quantification of the reduction in GHG emissions that can be achieved with the optimum level of energy storage deployments across the state.

Acelerex was also a key partner in the recently released New York Energy Storage Study. This study was used to support the targets set by Governor Cuomo in early 2018 for energy storage deployments in the state. “Cuomo kicked off 2018 with a series of clean energy proposals, including a groundbreaking energy storage pledge: to deploy 1,500 megawatts by 2025 as the state works toward 50 percent renewable energy by 2030 [5].” The study showed that this level of energy storage deployment would “produce $2 billion in gross benefits to New Yorkers by reducing reliance on costly, dirty, and inefficient infrastructure and helping scale clean energy [6].”

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In addition to the studies cited above conducted in the States of Massachusetts and New York, the analytical team at Acelerex has worked on many other studies investigating the technical and economic value of energy storage, renewables and grid investments around the world.

4 CONCLUSIONS AND FUTURE DIRECTIONS

The combined capabilities of Southern Research and Acelerex will support the development of the Energy Storage Research Center (ESRC) in Birmingham, AL and ensure its status as the premier testing, evaluation and research center for energy storage systems within the Southeastern United States.

The software architecture provided by Acelerex will support hardware testing at the ESRC and Acelerex's analytical capabilities will enable stakeholders to evaluate the technical and economic value of energy storage in their grid.

The grid analytics provided by Acelerex would be facilitated with cloud computing to offset server hardware and cyber security costs of lab-run supercomputers. The software architecture is designed to cost optimize the hardware investment costs in the lab and displace hardware investments with software emulations of the hardware.

5 ACKNOWLEDGEMENTS

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