Energy Storage Standards Development and Defining Best Practices for System Evaluation

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ABSTRACT

Energy storage systems (ESS) are beginning to be implemented in the Southeast, and their applications and impact on the grid are not have not been characterized or understood in a systematic way. ESS operation and performance depends strongly on the use cases for which they are employed. These use cases can be met by a range of technologies, power ratings and capacities. This necessitates a careful and informed understanding of use case applications in the context of established and developing codes and standards. In spite of the efforts of many organizations and institutions, the process of adopting appropriate standards for a given use case and technology remains a complex and frequently unsolved problem. This paper will provide an overview of relevant energy storage standards and test protocols and how we plan to implement them at the Energy Storage Research Center (ESRC) at Southern Research in Birmingham, AL through the development of a comprehensive test plan with detailed procedures for system evaluation.

Keywords: energy storage, system evaluation, standards development, test procedures

1 BACKGROUND

By standardizing the approach for system evaluation, Southern Research hopes to support the widespread adoption of energy storage technologies in the region and the rest of the United States.

The ESRC staff have been working to develop a draft test manual to offer a framework for evaluating energy storage system performance, with a focus on the attributes that are critical to energy storage applications in the Southeastern United States. This manual attempts to address the gaps in existing available test manuals [1]–[4] and test procedures for the prioritized attributes for the region. This manual is intended for use in the evaluation of system performance, though some of the attributes can be evaluated at smaller scales. Additionally, it incorporates a number of key standards, discussed later in this document.

The goal is that the test manual developed at the ESRC provides a step towards the standardization of grid-scale energy storage evaluation by defining and prioritizing key attributes, specifying test procedures (and identifying where new test procedures need to be developed), and identifying target ranges for performance attributes. The ESRC provides a facility which can evaluate and assist in the development and maturation of energy storage systems for the grid-scale.

2 OVERVIEW OF EXISTING TEST PROCEDURES, PROTOCOLS, AND STANDARDS

The following sections provide an overview of key standards, test procedures, and protocols currently used in the evaluation of grid-scale energy storage systems in the United States and around the world. In addition to these approaches, many test facilities and developers conduct customized evaluations of the energy storage systems. Key references are highlighted in the graphic below (Figure 1).

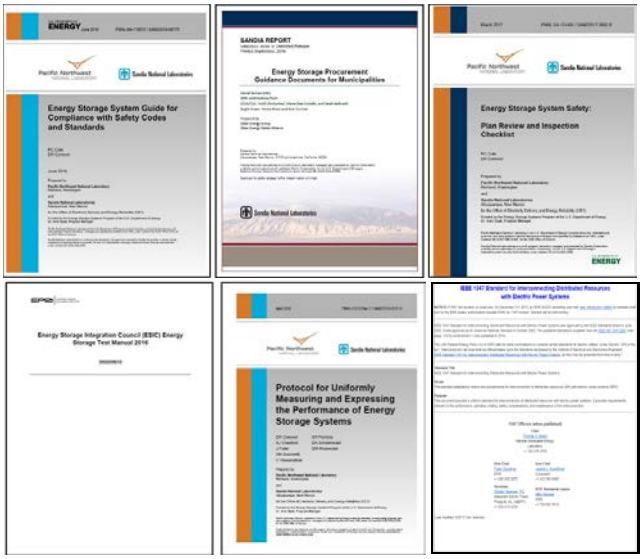

Figure 1: Key references for the development of standardized energy storage test procedures and protocols at the Energy Storage Research Center (ESRC)

2.1 ESIC Energy Storage Test Manual [4]

"This manual includes a complete table of contents that lists tests that should be considered for an energy storage system evaluation. It also contains detailed test procedures to assess energy storage system performance across several of the most important metrics… Future revisions of this manual will contain additional test procedures to complete the outline [5]." The ESIC test manual offers a framework for evaluation and suggests guidelines for the aproach to testing but stops short of prescribing detailed procedures, largely due to the variations that exist in energy storage systems and difficulties with deployment-appropriate test equipment. It focuses on the evaluation of critical

performance and functional attributes to ensure systems operate as expected.

Southern Research is currently engaged with the Energy Storage Integration Council (ESIC) as it works to continue to develop consensus around guidelines and procedures for the evaluation of energy storage systems for the grid in its testing and evaluation subgroup; future revisions of the ESIC test manual will incorporate recommendations from Southern Research to make the test manual more useful.

2.2 Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems [1]

The first version of this document was intended to be a pre-standard to provide the foundation for evaluating the performance of energy storage systems in a systematic way. This document "provides a set of "best practices" for characterizing energy storage systems (ESSs) and measuring and reporting their performance. It serves as a basis for assessing how an ESS will perform, with respect to key performance attributes, as it completes specific duty cycles associated with key use case applications [1]." The 2016 revision included additional duty cycles not previously considered.

The initial version of the document included three applications—peak shaving, frequency regulation, and islanded microgrids, and the revised document added an additional five applications—PV smoothing, volt/var, renewables firming, power quality, and frequency control.

These test protocols are intended to be used in combination with the test procedures developed by the Energy Storage Integration Council of EPRI.

2.3 Key Standards: IEEE 1547, UL 1741, and UL 9540 [6]–[8]

According to documentation from NREL, IEEE "1547 is unique as the only American National Standard addressing systems-level DER interconnected with the distribution grid. It has had a significant effect on how the energy industry does business, and it should continue to influence the way electric power systems operate far into the future [9]." In December 2013, IEEE began the process to do a complete revision to Standard 1547; in 2017 the revised version was approved. Final edits are underway which are expected for publication by Q2 2018. As a result, new capability requirements for DERs were established and are outlined in the table below [10], [11].

Function Set	Advanced Functions	IEEE 1547-2014	IEEE 1547-2018
Static	Adjustable Trip Settings	O	X
Controlling	Power Curtailment		X
	Ramp Rate Control		
Frequency Support	Low/High Frequency Ride-Through		X
Function Set	Advanced Functions	IEEE 1547-2014	IEEE 1547-2018
	Rate-of-change of Frequency Ride-Through		X
	Frequency-Watt	O	X
Voltage Support	Low/High Voltage Ride-Through (L/H VRT)		X
	Dynamic Voltage Support During L/HVRT		O
	Voltage Phase Angle Jump Ride-Through		X
	Fixed Power Factor	O	X
	Fixed Reactive Power	O	X
	Volt-Var	O	X
	Volt-Watt	O	X
	Watt-Var		X
X – Capability Required O – Allowed by Mutual Agreement			

Table 1: New capability requirements for DERs in IEEE 1547-2014 and 1547-2018

Revisions to the testing standard 1547.1 must also be made which is expected to continue through 2018. Once approved, certification agencies will be updated to agree with the revised testing standard and manufacturers can then submit their products for testing and certification. The projected timeframe before utilities will be able to use the revised 1547 standard is 2020 or even possibly later. Meanwhile, an interim solution which demonstrates safety for inverters, converters, controllers, and interconnections system equipment may be necessary for utilities, vendors, and other stakeholders. IEEE 1547 is supplemented by IEEE 1547.1 and UL 1741 SA.

UL 9540 was written in "2014 to address safety of energy storage systems. The work was based on extensive safety science and engineering efforts to effectively mitigate potential hazards for energy storage systems, and its requirements address the inherent design and performance, as well as the interface of the energy storage system with the infrastructure [12]."

3 ESRC TEST MANUAL

Southern Research performed a comprehensive review of codes, standards and regulations (CSRs) along with industry practices for testing and characterization of energy storage systems. The outcome of this review produced Version 1 of the Energy Storage Research Center (ESRC) Test Manual.

Energy storage CSRs were identified and consolidated in Stages 0 - 2 of the ESRC Test Manual which serves as a guide for documenting and validating the safety of an energy storage system during design, installation, and interconnection with electric power systems. CSR's central to the design and installation were derived by and large from Sandia/PNNL [13]. Technical specifications for testing the interconnection was aligned with IEEE 1547. Additional CSR's were identified and summarized throughout the Test Manual.

Industry practices for performance specification and verification of energy storage systems were reviewed from a number of sources [1], [4], [14]. Relevant test protocols and procedures were consolidated in Stages 3 - 6 of the ESRC Test Manual, building towards more complex testing of the system at each stage to address any performance or specification matters upfront. Protocols and procedures were categorized as characterization tests (Stage 3), duty cycle tests (Stage 4), advanced functional tests (Stage 5), and modeling and analysis (Stage 6).

Southern Research translated existing test methods into profiles representative of input/output electrical signals. Input signal(s), defined by existing test procedures, are the independent variable of the test. Output signal(s), defined by existing test procedures, are the measurement signals identified for system characterization.

The test manual stages are summarized in Figure 2.

Figure 2: Overview of ESRC staged approach to system evaluation

Southern Research is currently developing its plans for the continued implementation of best practices for energy storage system evaluation over the next two years. Objectives for this timeline are presented below.

Southern Research will work in collaboration with electric utilities, vendors, working groups and other stakeholders to address many of the gaps identified in the energy storage industry.

The key objectives for testing and verification:

1. Validate existing test procedures.
2. Design software capabilities and test procedures for advanced functions.
3. Design software capabilities and test procedures for group functions.
4. Update existing interconnection tests in accordance with revised CSRs.
5. Design functional controls and test plans to optimize energy storage systems in a microgrid setting.
6. Create methodologies for measuring and modeling lifetime reliability, efficiency, and degradation.

The first and last objectives are described in greater detail below.

The ESRC test manual is a product of existing industry sources for testing and performance characterization of energy storage systems. Southern Research will work in collaboration with electric power utilities, developers, vendors and other stakeholders to validate adopted test procedures in the ESRC Test Manual. Current test procedures include characterization tests, duty cycle tests, functional tests, and autonomous tests.

The need for an industry-wide methodology to test system parameters and model degradation based on measured values was identified as a high priority for utility stakeholders. Many factors can influencing the lifetime degradation of a system including temperature, depth of discharge, charge and discharge rates, charge cycles, system maintenance, chemistry, climate, and others.

The ESRC will focus on identifying key parameters which have the biggest influence on battery reliability, efficiency, and degradation as a function of which mode(s) and use cases the energy storage system is serving.

Critical to the development of the energy storage sector as a whole will be the aggregation of energy storage with other technologies across any makeup and scale. Figure 3 below shows how Southern Research envisions the connection between energy storage scales and applications.

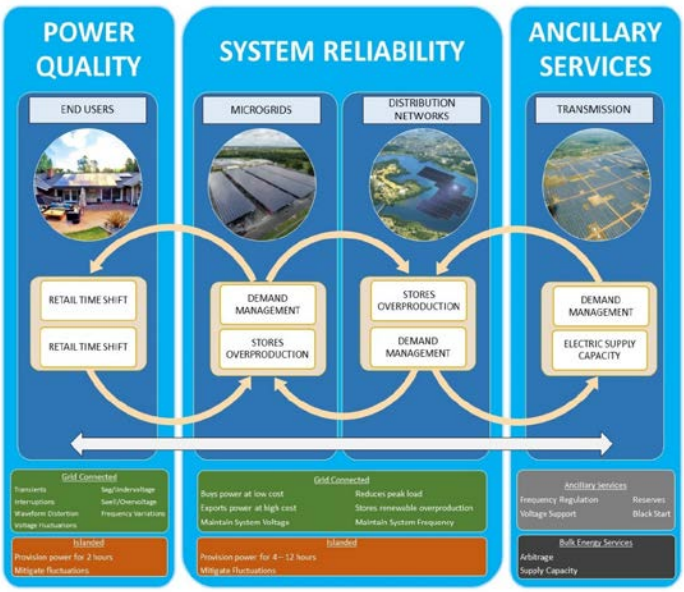

Figure 3: Overview of Future Directions for ESRC Testing and Research Services

4 CONCLUSIONS

This document provides an overview of relevant energy storage standards and test protocols and how Southern Research plans to implement them at the Energy Storage Research Center (ESRC) at Southern Research in Birmingham, AL through the development of a comprehensive test manual with detailed procedures for system evaluation. By standardizing the approach for system evaluation, we hope to support the widespread adoption of energy storage technologies in the region and the rest of the United States.

Additionally, this systematic approach to evaluation will enable us to mitigate risks associated with deployment, and we recognize that understanding risks associated with the development and installation of energy storage systems is critical to support the adoption of these technologies in the Southeast and throughout the country. Risks associated with the regulatory environment, technology, environmental impact, safety and economic valuation of energy storage systems have been identified. While some risks are unique to the Southeast, many of the risks are applicable across the US. It is critical to identify all potential risks associated with energy storage technology implementation, prioritize them in terms of likelihood and impact, and find ways to mitigate the potential for damage.

Additionally, risk assessment is being used to shape the strategic testing framework for energy storage evaluation that is under development at Southern Research. The goal of Southern Research is to support the implementation of energy storage in the Southeast to provide for the delivery of cleaner and more reliable power in the region through the provision of testing and research services at the ESRC.

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