Standardization and Semi-Automation of Battery Energy Storage System Capacity Test Reporting

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Abstract ***—*** *This project developed a standardized, semi-automated reporting framework for capacity test results in a utility-scale battery energy storage operations environment. An analysis of existing reporting workflows identified inefficiencies, prompting the implementation of a standardized reporting template and a semi-automated data processing approach. The proposed framework reduced manual data handling, improved consistency across reports from multiple vendors, and enabled repeatable application across a distributed asset portfolio. Results indicated reduced manual effort, improved report consistency, and enhanced data traceability. The project concludes that standardized and semi-automated capacity test reporting can enhance operational efficiency, reduce error risk, and provide a scalable foundation for future performance monitoring and analytics initiatives.*

Key Terms ***—*** *Asset performance monitoring, engineering operations workflows, operational efficiency, process standardization.*

INTRODUCTION

Utility-scale battery energy storage systems (BESS) have become integral components of modern power systems, supporting grid reliability, renewable energy integration, and operational flexibility. These systems are typically deployed by independent power producers, renewable energy developers, and asset owners that develop, own, and operate geographically distributed portfolios of large-scale energy storage assets. This project was conducted within the engineering operations organization of a U.S.-based renewable energy company that develops, constructs, and operates a fleet of utility-scale BESS distributed across multiple sites. The systems were developed using equipment from multiple original equipment manufacturers and configured under diverse operational strategies.

Capacity testing is a critical performance evaluation for utility-scale BESS assets. Capacity tests verify that a system can deliver its contracted energy output over a specified duration under defined operating conditions. These tests are commonly required during initial commissioning, following major maintenance activities, and periodically throughout an asset's operational life. Operators, engineering teams, asset managers, and utilities use capacity test results to assess degradation, validate warranties, and support operational and commercial decision-making.

Despite the importance of capacity testing, the reporting of test results is often dependent on original equipment manufacturers (OEMs) and third-party vendors. Test results and associated data are typically delivered in multiple formats with inconsistent structures, naming conventions, and levels of detail. Consequently, engineering and operations teams frequently relied on manual data cleaning, interpretation, and reformatting before results could be reviewed or distributed to internal and external stakeholders. These manual processes reduced efficiency, increased the risk of errors, and limited the scalability of capacity testing across large BESS portfolios.

This project addressed these challenges by developing a standardized and semi-automated reporting framework for BESS capacity testing within a utility-scale engineering operations context. The objective was to reduce manual data processing effort, improve report consistency, and enable repeatable application across multiple BESS assets. The proposed framework focused on establishing a uniform reporting structure and leveraging semi-automation techniques to streamline data extraction, validation, and presentation while maintaining compatibility with existing operational systems.

LITERATURE REVIEW

BESS Capacity Testing Fundamentals

Capacity testing is widely adopted to evaluate the usable energy capability of battery energy storage systems [1, 2]. The primary purpose of a capacity test is to quantify the energy a BESS can deliver under controlled conditions and to compare measured performance against contractual or design specifications. Capacity test results are commonly used to assess system degradation, verify compliance with warranty thresholds, and support asset valuation over time [3, 4].

Multiple testing methodologies have been employed in industry depending on system configuration, intended operating strategy, and contractual requirements [2, 5]. Common approaches include full charge-to-discharge tests at rated power, stepped discharge tests, and duration-based performance evaluations [2, 6]. Although testing objectives are generally consistent, variations in methodology and data output across vendors and projects have contributed to inconsistent reporting practices.

Industry Standards and Reporting Requirements

Industry standards and regulatory frameworks provide guidance on BESS performance testing while allowing flexibility in reporting formats [1], [5, 7]. Standards related to battery performance, grid interconnection, and system commissioning establish technical criteria for test execution, data collection, and acceptance thresholds [1, 5]. The IEC 62933 series addresses unit parameters and testing methods for electrical energy storage systems [1], while IEEE 2030.2.1 provides guidance for the design, operation, and maintenance of battery energy storage systems [5]. National laboratory studies on codes and standards for stationary energy storage have identified gaps in industry-wide standardization [7]. However, these standards primarily focus on test procedures rather than reporting structure or data presentation.

As a result, utilities and asset owners frequently receive capacity test reports that satisfy technical requirements but vary significantly in format, terminology, and level of detail [3, 4]. This lack of uniformity complicates internal review processes and increases the effort required to compare results across assets and vendors.

Existing Capacity Test Reporting Practices

Existing capacity test reporting practices are largely vendor-driven and project-specific. Reports are often delivered as static documents accompanied by raw data files in semi-structured formats [3]. Industry guidance documents acknowledge the challenges of consistent reporting across diverse vendor platforms and system configurations [3, 4]. In many cases, operators must manually extract key metrics, verify calculations, and populate internal templates or summary documents for management review.

Manual reporting workflows are common in asset-intensive industries that rely on data from multiple vendors and systems [6]. These processes are time-consuming, error-prone, and difficult to scale as asset portfolios expand. The absence of standardized reporting frameworks limits organizations' ability to automate performance monitoring and leverage historical test data for advanced analytics.

METHODOLOGY

The methodology for this project was structured into three phases to address inefficiencies in battery energy storage system capacity-test reporting. The first phase consisted of reviewing existing capacity test reporting workflows to identify manual processes, data handling challenges, and sources of inconsistency. The second phase focused on developing a standardized reporting template that defined required inputs, calculated metrics, and ensured uniform formatting. The final phase implemented a semi-automated approach to data extraction and processing to reduce manual effort while maintaining engineering oversight. Together, these phases provided a structured methodological approach for improving reporting efficiency, consistency, and scalability across multiple battery energy storage assets.

Review of Existing Capacity Test Reporting Workflow

The initial phase of the methodology involved a detailed review of existing capacity test reporting workflows in a utility-scale BESS engineering operations environment. Emphasis was placed on documenting manual data handling steps, validation procedures, and information handoffs between vendors and engineering operations teams.

Workflow analysis indicated that data were typically collected from multiple sources, including battery management systems, power conversion systems, and supervisory control and data acquisition platforms. These data were manually processed using spreadsheet-based tools to calculate capacity metrics, verify test conditions, and assemble summary tables and figures. Several inefficiencies and potential sources of error were identified, including repetitive formatting tasks and inconsistent interpretation of vendor-provided data.

Development of a Standardized Reporting Template

Based on the workflow review, a standardized reporting template was developed to provide a consistent structure for BESS capacity test reports. The template defined required inputs, calculated metrics, and standardized naming conventions to ensure uniform interpretation of results. Key performance indicators were established to align with common operational and contractual requirements while remaining adaptable to different system configurations.

The template structure was designed to support repeatable application across multiple assets and testing events. Formatting and data organization were standardized to facilitate automated processing and reduce subjective interpretation during report review.

Semi-Automated Approach

A semi-automated approach was implemented to streamline data extraction, processing, and validation while retaining human oversight for quality assurance. Data was extracted directly from operational systems where feasible, reducing reliance on manual file handling. Automated processing routines were used to calculate capacity metrics and to populate standardized report sections in accordance with predefined rules.

By combining standardized templates with semi-automated data processing, this approach aimed to reduce manual effort while preserving transparency and traceability in reporting.

RESULTS

The primary outcome of this project was the development of a standardized, semi-automated capacity test reporting framework. Figure 1 illustrates the standardized, semi-automated capacity test reporting framework and the relationships among its main components. As shown in the figure, the framework consists of four primary components: vendor and operational data sources, a standardized reporting template, a semi-automated processing layer, and standardized report outputs. Table 1 summarizes the primary components of the standardized, semi-automated capacity test reporting framework and their associated functions within the reporting process. Together, these components define the information flow from raw capacity test data through structured processing and validation to final reporting artifacts, with engineering oversight throughout.

Implementation of the standardized, semi-automated reporting framework reduced the manual effort required to prepare capacity test reports by minimizing repetitive data formatting and calculations. The standardized template improved consistency across reports from multiple vendors and system configurations, enabling more efficient internal review and cross-asset comparison of results. Table 2 summarizes the qualitative differences in reporting effort and consistency before and after implementation of the framework. These qualitative improvements reflect increased repeatability and reduced dependence on vendor-specific reporting formats.

The semi-automated approach also enhanced data traceability by reducing manual transcription and enforcing consistent calculation logic throughout the reporting process. These improvements increased overall data quality and reduced the likelihood of reporting errors, thereby supporting more efficient operational decision-making.

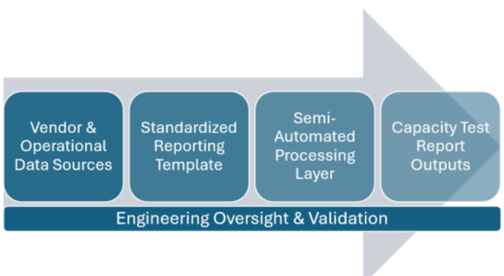

Figure 1
Standardized, semi-automated capacity test reporting framework illustrating information flow.

Table 1
Framework Components and Functions

Framework Component	Function
Vendor and operational data sources	Provide raw capacity test data and operational measurements from multiple OEM and SCADA platforms
Standardized reporting template	Define required inputs, calculated metrics, and consistent formatting across reports
Semi-automated processing layer	Extract, calculate, and populate standardized report outputs using predefined logic
Capacity test report outputs	Provide standardized capacity test reports and summary artifacts for internal and external stakeholders
Engineering oversight and validation	Ensure data accuracy, traceability, and compliance with operational and contractual requirements

Table 2
Qualitative Comparison of Capacity Test Reporting Before and After Framework Implementation

Aspect	Before Framework	After Framework
Report preparation effort	High, manual, iterative	Reduced through standardization and semi-automation
Data handling	Manual extraction and calculations	Semi-automated processing
Vendor clarification cycles	Frequent	Reduced
Consistency across reports	Low	High
Traceability of calculations	Limited	Improved

CONCLUSIONS

This project demonstrated that standardized, semi-automated capacity test reporting can improve efficiency and consistency in utility-scale battery energy storage operations. By structuring reporting workflows around standardized templates and semi-automated data processing, engineering teams can reduce manual effort, minimize error risk, and improve scalability as asset portfolios grow. The proposed framework provides a practical foundation for future enhancements, including expanded performance analytics and integration with advanced monitoring tools. Standardization of reporting practices is a critical step toward more efficient, data-driven management of utility-scale battery energy storage systems.

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