Problem Statement:
As energy storage is more widely adopted, the accurate characterization of system SOC and SOH will be critical to evaluating system warranties and asset life expectancies. This presentation will discuss the development of an online method for determining SOC and SOH for a lithium-ion battery system with the intent to expand this to other storage technologies and chemistries.

Background:
A range of factors influence the state of health of battery energy storage systems including cycle number, environmental conditions, depth of discharge, etc. These factors, some of which are more easily measured than others (measureable items have been highlighted in yellow), have been summarized in Figure 1 from Harting et al. [1]:

![Figure 1. Diagram of the various factors leading to Lithium-ion battery degradation](Image)

**Typical Methods for Estimating SOC and SOH:**

- (Enhanced) Coulomb counting method
- Voltage method
- Kalman Filter method
- Vendor-specific/proprietary method**

An online methodology for accurately measuring SOC and SOH would be of great benefit to the storage system owner/operator. Utilities and other energy storage owners/operators desire methods to monitor system performance and health as a way of verifying health and performance estimates provided by the storage systems [2-3], especially as different cycles impact the SOH of the battery differently.

**Available Data:**
The approach detailed below is based on data from a 1 MW, lithium-ion energy storage system composed of two banks with 10 racks each. Historical data is available from the system logs for a period during which the system was commissioned; more recently collected data is available for a series of duty cycles conducted in September 2018, logged on a 1-second timescale. Data included is detailed in Table 1 with sample time series in Figures 2-4.

**Benefits for the Utility Industry:**
Utilities have limited experience with the monitoring and estimation of State of Health and State of Charge of grid scale energy storage. Even though it is starting the transition from R&D to operations, much remains unknown regarding system characteristics and operational capabilities, especially as systems age. This lack of data and knowledge forces utilities to rely on the energy storage vendors to provide information regarding system performance and health that cannot be proven or measured. Values such as SOC and SOH, could have great impacts on system performance guarantees and availability. The utility industry needs a clear method for measuring these values for energy storage systems such that the values obtained from the storage systems can be justified or verified.

Key benefits for utilities of the proposed online SOC/SOH monitor have been summarized below:

- **Improved transparency in the evaluation and verification of system warranties**
- **Improved understanding of energy storage system aging mechanisms**
- **Improved ability to test and characterize energy storage through existing and proposed test protocols, especially for long-term characterization of the effects of control functions on capacity and overall system health**

**Methods:**
The method to calculate SOC and SOH online proposed here will incorporate existing best practices and advanced data analytics. Both empirical and proxy data will be used to improve the existing state-of-the-science SOC and SOH monitors for energy storage systems.

**Identifying Best Practices**
- Conduct literature review and expert elicitation to define best practices for online SOC/SOH monitoring and determination

**Recreating Best Practices**
- Recreate existing methods utilizing data from existing system(s)

**Extending Best Practices**
- Combine known methods to optimize SOC/SOH determination to create new online SOC/SOH monitor

**References**


