U.S. Codes and Standards for Battery Energy Storage Systems

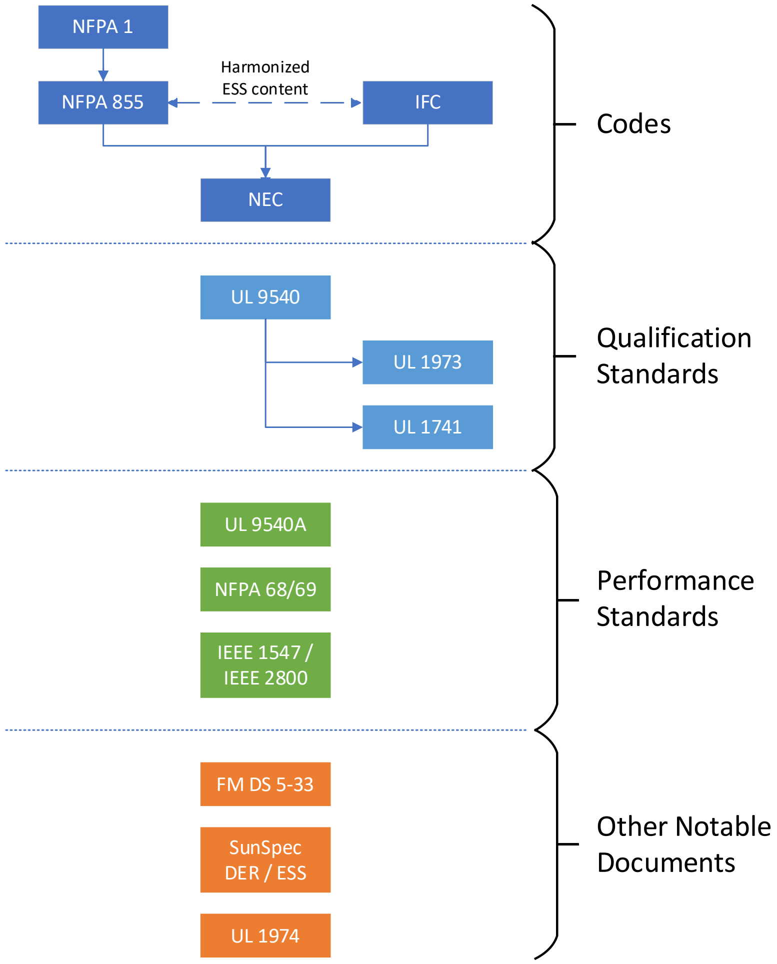
Introduction

This document provides an overview of current codes and standards (C+S) applicable to U.S. installations of utility-scale battery energy storage systems. This overview highlights the most impactful documents and is not intended to be exhaustive. Many of these C+S mandate compliance with other standards not listed here, so the reader is cautioned not to use this document as a guideline for product compliance.

This guide provides a graphic to show the hierarchy and groupings of these C+S, followed by short descriptions of each. Annex 1 summarizes some significant changes in the 2023 edition of one of the most important standards, NFPA 855, and Annex 2 provides a more detailed bibliography of the featured documents.

Graphic Overview

The following figure covers the main C+S and groups them by their applicability.



Codes

A variety of nationally and internationally recognized model codes apply to energy storage systems. The main fire and electrical codes are developed by the International Code Council (ICC) and the National Fire Protection Association (NFPA), which work in conjunction with expert organizations to develop standards and regulations through consensus processes approved by the American National Standards Institute. For these model codes to be enforceable, they must be adopted, in whole or in part, by states or local jurisdictions. This process generally results in a lag in adoption.

Below are the most relevant codes that apply to stationary energy storage systems:

NFPA 1 Fire Code[B7]. Covers the hazards of fire and explosion, life safety and property protection, and safety of firefighters. Chapter 52 provides high-level requirements for energy storage, mandating compliance with NFPA 855 for detailed requirements, effectively elevating the latter to the status of a code.

NFPA 70 National Electrical Code (NEC) [B10]. Covers practical safeguarding of persons and property from hazards arising from the use of electricity. Since 2017, Article 706 has provided specific requirements for Energy Storage Systems, applying to all ESS over 1 kWh.

NFPA 855 Standard for the Installation of Stationary Energy Storage Systems [B11]. Provides minimum requirements for mitigating the hazards associated with energy storage systems. NFPA 855 requirements apply to the design, construction, installation, commissioning, operation, maintenance, and decommissioning of energy storage systems.

International Fire Code (IFC) [B6]. With a similar scope to NFPA 1, the IFC includes ESS-related content in Section 1207 that is largely harmonized with NFPA 855.

Qualification Standards

The relevant codes for energy storage systems require systems to comply with and be listed to **UL 9540** [B19], which presents a safety standard for energy storage systems and equipment intended for connection to a local utility grid or standalone application. This document applies to the complete system and in turn requires that the major components be qualified to their own standards, the most important of which are **UL 1741** [B15] for the power conversion system and **UL 1973** [B16] for the battery. Energy storage management systems and battery management systems (BMS) are also subject to qualification, and the main applicable standards are **UL 991** [B14] and **UL 1998** [B18].

Performance Standards

Arguably the most important performance standard is **UL 9540A** [B20], covering large-scale fire and propagation testing. This test method (there are no pass/fail criteria) involves the sequential testing at the cell, module, unit (typically, a representative battery rack), and installation levels. There are 'off-ramps' that allow higher-level tests to be avoided based on lower-level test results. For example, all lithium-ion systems are subject to cell-, module-, and unit-level tests, but the installation-level test does not need to be performed if certain performance criteria are met at unit level. For example, for ESS used in large outdoor installations, the unit-level criteria are:

- No flaming beyond intended separation from exposures or excessive temperature rise at wall surfaces
- Module surface temperatures in adjacent units remain below the level at which cell venting occurs

- No explosion hazard
- Acceptable level of heating in the accessible means of egress

UL 9540A testing is required if: group (unit) energy exceeds 50 kWh; separation between groups is less than 3 ft (0.9 m); or stored energy exceeds the maximum value in Table 9.4.1 of NFPA 855 (600 kWh for lithium-ion). These deviations from the standard are subject to approval by the authority having jurisdiction (AHJ).

Section 9.6.5.6.3 of NFPA 855 requires design provisions for either explosion prevention in compliance with **NFPA 69** [B9] or explosion management according to **NFPA 68** [B8]. NFPA 69 compliance requires that the concentration of flammable gas generated from battery failure be maintained below 25% of the lower flammable limit (LFL), typically via system ventilation. NFPA 68 compliance requires a potential deflagration of battery gases to be managed via explosion venting panels or specially engineered system doors to maintain potential overpressures at safe levels. While NFPA 855 requires compliance with either NFPA 68 *or* NFPA 69, these standards are not mutually exclusive and battery systems may be designed to meet both standards.

Interconnection standards have been published by IEEE, with **IEEE Std 2800** [B5] applying to ESS connected at transmission and sub-transmission levels, and **IEEE Std 1547** [B3] for distributed energy resources (DER). IEEE recently published a new guide, **IEEE Std 1547.9** [B4] for using IEEE Std 1547 with energy storage DER.

Other Notable Documents

FM Global published its **Data Sheet 5-33** [B2] on lithium-ion ESS in 2017. There appear to have been relatively minor revisions in 2020 and none more recently. Unlike NFPA 855, the document includes minimum spacing and separation distances for BESS (or installation of structural fire barriers) that are prescriptive, rather than performance based.

The SunSpec Alliance has established information models to assist in the integration of energy storage and other DER. The **SunSpec DER model** [B12] standardizes DER communication with utility SCADA (Supervisory Control and Data Acquisition) protocol IEEE Std 1815 (DNP3) for compatibility with IEEE Std 1547. The **SunSpec Energy Storage models** [B13] are based on Modbus protocol and are important for ease of ESS integration. Models for lithium-ion systems are complete, while those for other technologies are still under development. Another group working with SunSpec is the Modular Energy System Architecture (MESA) Standards Alliance.

For companies interested in second-life EV batteries in ESS applications, **UL 1974** [B17] covers the *process* of sorting and grading battery packs for repurposing, but not their *qualification*. The document does not cover the process for remanufacturing/refurbishing/rebuilding batteries, where repair or replacement of parts may be needed. Section 9.2.4.2 of NFPA 855 mandates that repurposing be carried out by a UL 1974-compliant company. Also, section 4.6.5 requires that reused equipment, such as second-life batteries, be 'reconditioned, tested, and placed in good and proper working condition and approved.' Approval would involve listing systems to UL 9540, which necessarily includes qualification of the battery to UL 1973. Since each integrator of such systems would most likely replace the vehicle BMS with one more suitable for ESS and would probably have to perform UL 9540A testing up to at least unit level, achieving the necessary codes and standards compliance could represent a significant financial burden.

Annex 1 – Significant Changes in the 2023 Revision of NFPA 855

This commentary is not intended to cover all changes in the 2023 revision of NFPA 855 but to highlight some changes that are likely to impact ESS designs and interactions between developers, integrators, and AHJs.

Important note: While the 2023 document cannot generally be applied retroactively to existing installations, it allows an AHJ to request a hazard mitigation analysis for existing installations that are not UL 9540 listed, and to retroactively apply any portions of the new standard 'deemed appropriate to mitigate any hazards' identified as unacceptable. (See 1.4.2, 4.4.1, A.1.4.2)

- Details on firewalls, fire suppression, smoke or fire detection, gas detection, thermal management, ventilation, exhaust, and deflagration venting systems, if provided, are to be submitted to the AHJ for approval (see 4.2.1.1).
- Fire and explosion testing data are to be provided where required (see 4.2.1.3).
- There is a catch-all provision that empowers an AHJ to request a Hazard Mitigation Analysis 'to address a potential hazard … that is not addressed by existing requirements' (see 4.4.1).
- The device that manages charging and discharging within safe limits during normal operation (normally the BMS but could be the Energy Storage Management System) must be evaluated as part of the listing of the ESS (see 9.6.5.5. A.9.6.5.5)
- Chapter 14 previously covered storage areas for 'used or off-specification' batteries, and now covers 'lithium metal or lithium-ion' units, whether new or used. Areas are exempt if cells are <30% SOC. There may also be an exemption for areas with factory-assembled enclosures, although the text is unclear: 'Areas where new or refurbished batteries are installed for use in the devices, equipment, or vehicles they are designed to power.'

Annex 2 – Bibliography

The following documents are discussed in this overview. The date listed is the latest at the time of publication, but all are subject to periodic revision.

[B1] CSA C22.2 No. 340, Battery Management Systems (Draft), expected in 2023

[B2] FM Global Property Loss Prevention Data Sheet 5-33, Electrical Energy Storage Systems, January 2017, Interim Revision July 2020

[B3] IEEE Std 1547-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

[B4] IEEE Std 1547.9-2022, IEEE Guide for Using IEEE Std 1547 for Interconnection of Energy Storage Distributed Energy Resources with Electric Power Systems

[B5] IEEE Std 2800-2022, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems

[B6] International Fire Code (IFC), 2021, International Code Council, Inc.

[B7] NFPA 1, Fire Code, 2021

[B8] NFPA 68, Standard on Explosion Protection by Deflagration Venting, 2018

[B9] NFPA 69, Standard on Explosion Prevention Systems, 2019

[B10] NFPA 70, National Electrical Code, 2023

[B11] NFPA 855, Standard for the Installation of Stationary Energy Storage Systems, 2023

[B12] SunSpec DER Information Model Specification 1.0, SunSpec Alliance, 2021

[B13] SunSpec Energy Storage Models, Draft 4, SunSpec Alliance, 2016

[B14] UL 991 Ed. 3, Standard for Tests for Safety-Related Controls Employing Solid-State Devices, 2004

[B15] UL 1741 Ed. 3, Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, 2021

[B16] UL 1973 Ed. 3, ANSI/CAN/UL Batteries for Use in Stationary and Motive Auxiliary Power Applications, 2022

[B17] UL 1974 Ed. 1, ANSI/CAN/UL Standard for Evaluation for Repurposing Batteries, 2018

[B18] UL 1998 Ed. 3, Software in Programmable Components, 2013

[B19] UL 9540 Ed. 2, Energy Storage Systems and Equipment, 2020

[B20] UL 9540A Ed. 4, ANSI/CAN/UL Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 2019