Codes, standards and certification for safety and performance of distributed energy resources and systems

Standards and regulation | The advent of distributed generation and renewable energy sources is requiring a swathe of new regulatory standards to ensure safety and grid stability. Scott Picco, Laurie Florence and Tim Zgonena of UL look at some of the latest and upcoming codes designed to addressing the proliferation of battery storage systems and distributed energy resources

Credit: NEC ES

A proliferation of distributed energy resources and systems is necessitating new codes to govern safety and grid operability

Modernising the world's electric grids is a critical enabler for achieving the societal benefits and avoiding brownouts or blackouts that come from optimising the way the world generates, distributes and uses electricity. If implemented properly, distributed generation and energy storage with advanced functionality and communications capability may even increase the reliability and stability of the grid. As electric utilities continue to modernise their grids through the use of larger amounts of distributed generation and renewable energy sources, standards and regulations must adapt to meet the ever-changing needs for safety, performance and grid support functionality.

Energy storage systems: UL 9540 and UL 9540A

With the expanding use of renewable energy such as solar power, wind power and energy storage there is a need to ensure that these sources of renewable energy provide reliable power on an ongoing basis, regardless of whether the sun is shining or the wind is blowing. In order to improve reliability, energy storage is demonstrating that it is a key component to renewable power installations whether it is at the utility-scale level or even for residential installations.

If energy storage systems are going to be installed where they are needed to support renewable energy and for other applications, they will need to demonstrate a sufficient level of safety. They should be determined to be safe through compliance to an appropriate safety standard and installed in accordance with the applicable installation codes. The codes impacting energy storage include NFPA 70, National Electrical Code, NFPA 1, Fire Code and ICC International Fire Code (IFC).

There is also a new installation standard under development, NFPA 855. There has been a lot of work to bring these various codes up-to-date so that they appropriately address the safe installation of energy storage systems including those systems using newer technologies such as lithium-ion and flow batteries. All of these codes including UL NFPA require that the energy storage systems be listed, which means evaluated for compliance by a third-party organisation; and reference ANSI/CAN UL 9540, which is an American National and Canadian National safety standard for energy storage systems that is to be used for that listing. UL 9540 covers electrochemical, chemical mechanical and thermal energy storage systems that can be operated in parallel with a public utility grid, or in a standalone application, or for use in various ancillary services. UL 9540 can cover ESS for utility, commercial and residential application. The focus of the codes though has been on battery energy storage as that is the most common technology for the various applications utilising energy storage.

ANSI/CAN UL 9540, which is a bi-national standard for the USA and Canada, references critical component standards for the major portions of the energy storage systems. This includes reference to ANSI/CAN UL 1973, which is a safety standard for stationary batteries. The scope of UL 1973 is non-technology specific, and covers requirements for cell, module and battery system criteria. It includes criteria for rechargeable lithium, nickel, sodium beta, lead acid and flow battery technologies. Both UL 9540 and UL 1973 require that a safety analysis of the system (battery and energy storage system) be conducted and that any electronics and software controls including the battery management system (BMS) relied upon for safety meet appropriate functional safety standards and be demonstrated to reliably maintain the batteries and system within specified operating parameters.

Another important component standard referenced in ANSI/CAN UL 9540 is UL 1741, which is the safety standard for power converters, inverters and distributed energy resources (DERs). UL 1741 provides a means to determine that inverters and other renewable energy power conversion electronics are constructed per common industry requirements, can be installed in accordance with US codes, are operated per industry specific required ratings and perform safely under rated normal worst case conditions and foreseeable abnormal operating conditions and failure modes. In the case of energy storage applications, the converter/inverter is exposed to bi-directional power flow and as such is also subject to bi-directional fault conditions from the grid-tied output source and the battery and/or PV input source. The failure modes to which the inverter/converter are subject must be able to withstand the short circuit current contribution of all sources including PV, batteries and the grid. When comparing a battery source to a PV source the available short circuit current is a significant multiplier relative to a PV source. Where a PV source may have a short circuit contribution of 2 to 3 times the normal continuous current, a battery source may be a factor of 10-30 times depending on the size and construction of the battery. Fault testing with appropriately sized sources during abnormal testing is key in the evaluation of the inverter/converter as well as within the context of the overall energy storage system.

One of the main concerns with installing energy storage systems utilising batteries is primarily with fire hazards if these systems are to be installed within or near buildings that are of mixed uses. The methods for limiting the potential fire hazards are through limiting the energy of the systems installed and maintaining suitable separation distances between the systems and between the systems and walls or exposures to mitigate fire spread. The codes also limit the maximum aggregate energy allowed. In order to avoid strict limitations on sizes or separation distances, the codes include exceptions that large-scale fire testing and approval by the AHJ can allow for larger sized systems and smaller separation distances. UL developed a test method to meet the needs of the codes, UL 9540A, Standard for Safety for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. UL 9540A test method is a step by step process starting at the cell level and concluding at the installation level that evaluates the fire characteristics of those battery energy storage systems that have demonstrated a capability to undergo thermal runaway (Figure 1). The data generated during the UL 9540A testing can then be used to determine the fire and explosion protection required for an installation of a battery energy storage system.

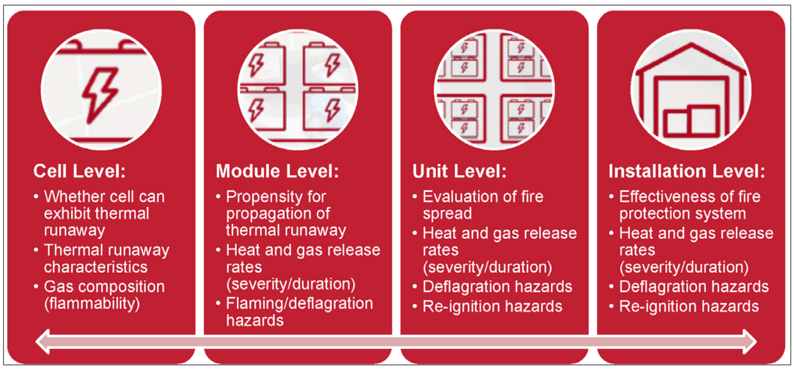

Figure 1. Fire safety concerns of batteries across different levels

In addition to the various UL battery and energy storage standards, UL published ANSI/CAN UL 1974, which covers manufacturing process requirements for repurposing batteries such as electric vehicle batteries for for another application such as stationary battery applications. UL 1974 is not a product safety standard but provides minimum criteria that should be part of a repurposing manufacturing process. ANSI/CAN UL 1974 will be referenced in the next editions of both NFPA 70, NEC and ICC IFC for battery systems utilising repurposed batteries. This provides another market for used batteries that may have as much as 80% of their energy capacity still available but do not have enough energy capacity for a vehicle application. As the use of EVs increases, this provides a means for utilising batteries that are still viable for another application, until their energy is spent and they have to be disposed of and potentially recycled.

Energy storage, especially battery energy storage, is necessary to enhance the reliability of renewable energy sources. In addition, storage systems are being installed in locations such as urban centres and mixed-use buildings, where there is a concern of potential fire and deflagration hazards from these systems. Various codes impacting these systems understand the importance of third-party listing of these systems to an appropriate safety standard such as ANSI/CAN UL 9540. In addition, the instillation of the battery energy storage system needs to be provided with protection in the event that there is around or initiating within the system. Because of the unique nature of battery fires, especially lithium-ion battery fires, UL 9540A provides the data necessary to establish the suitability of the battery energy storage system installation, including the fire suppression, the deflagration protection that may need to be provided. All of the efforts put into suitable safety standards and installation codes assure the various stakeholders that the battery energy storage system is safe and the installation has sufficient protection in the event of a fire incident. Energy storage can be a real asset to the PV installation and ensure the continued adoption of renewable energy.

Grid support utility-interactive inverters and converters

As discussed earlier, UL 1741 is the safety standard for power converters, inverters and distributed energy resources (DERs). For products that are capable of back feeding/operating in parallel with the public utility UL 1741 references IEEE 1547 and IEEE 1547.1 for utility interconnected products. IEEE 1547 and IEEE 1547.1 establish the rules for interconnecting with the public utility and include requirements for items such as voltage regulation, power quality, abnormal voltage/frequency, unintentional islanding and a variety of other interconnection requirements. For a full list see Figure 2 (next page).

In areas with high percentages of distributed generation (DG) a change was needed to shift from products that not only are interconnected but also offer grid support functionality. This change was primarily needed to account for the traditional IEEE 1547 DG approach in which DERs were required to monitor the grid for stable conditions and upon recognising instability were required to disconnect and wait for five minutes of stable grid conditions before the DER could resume normal interconnected operation. This traditional approach sometimes was referred to as the "get out of the way" approach in which the philosophy was that the DERs should remain offline until whatever the problem causing unstable grid operation was fixed before the DERs came back online. As the concentration of DERs increases this approach becomes more and more of a disadvantage to overall grid health and stability. This is due to the larger power production capacity attributed to DERs of the overall grid capacity. If all the DERs are turned off in the event of grid instability the loss of this capacity can lead to an even more unstable grid and in some serious situations the grid may experience outages.

With the above situation in mind grid support functionality was necessary to allow for stable grid operation in areas with high percentages of DERs. The UL 1741 SA standard was created to define the requirements for grid support utility interactive DERs. Under this approach, DERs are required to monitor and adapt their behavior to stabilize the grid in the event of instability. DERs are expected to stay online longer, provide a variety of power types and modify their behaviour in response to changing grid conditions. This results in an advanced DER capable of fast monitoring and reaction capability. The list of grid support functions required per UL 1741 SA are noted in Figure 3.

As outlined in Figure 3, DERs can be evaluated for a variety of safety, grid interconnected and grid support functions. Figure 4 graphically outlines the available options and how the standards partner together.

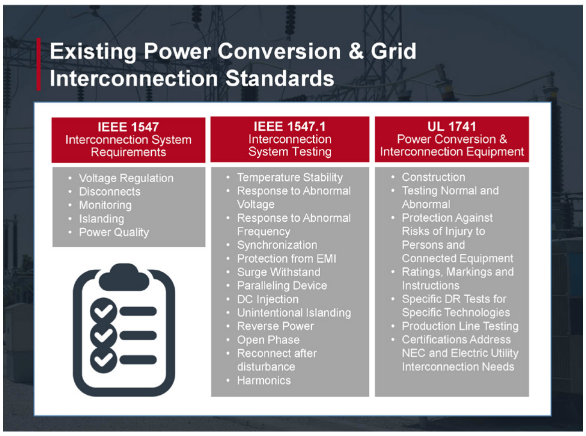

Figure 2. Existing power conversion and grid interconnection standards

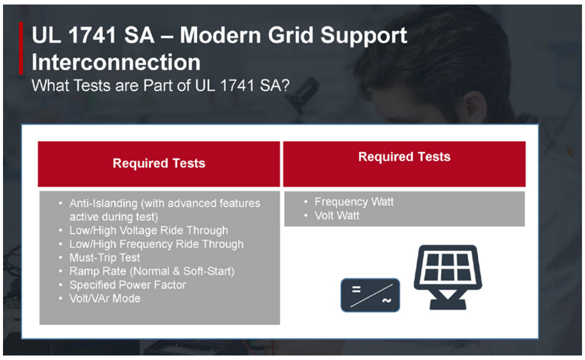

Figure 3. Modern grid support interconnection tests

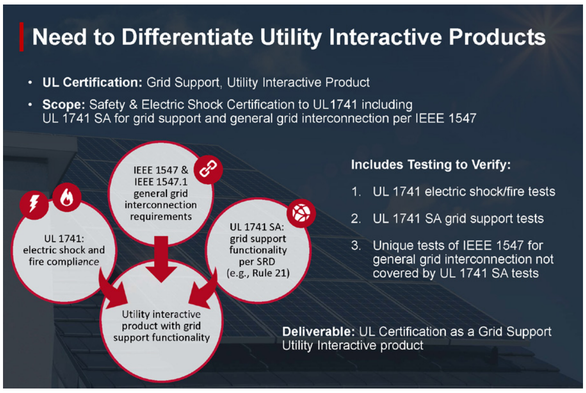

Figure 4: Safety, interconnection and grid support standards picture

Some key considerations for grid-support, utility-interactive DERs include software considerations and communications for interoperability. Software is the key safety-related component as the response times and functions required are only practically possible utilising software. Control of the software for safety-related functions is critical to ensuring not only a safe product but also ensuring a product that can deliver the required grid support functions within published tolerances. The application of software safety standards such as UL 1998 (The Standard for Software in Programmable Components) ensures software development cycles are controlled and maintained, quality control is present and changes tracked and reviewed for compliance, and if necessary validated through repeated testing for safety, grid interconnection and grid support functions.

With DERs playing important roles in maintaining a resilient and stable grid, as the percentages continue to increase, two-way communications and interoperability are becoming increasingly desirable and necessary. Today, the DERs have default settings as per the Source Requirement Document (SRD) for how and when to respond. Going forward, utilities will leverage standardised communication as per standards such as IEEE 2030.5 (Standard for Smart Energy Profile Protocol) to allow for two-way communication so that utilities can adjust the settings in grid-support DERs based upon real-time grid conditions. With the inclusion of standardised communication, cybersecurity will become an even more important key focus point in the future to ensure safety and security of DERs and their interconnection to the utility.

Distributed energy resource systems: UL 3001

Distributed energy resource systems (DERS) are likely to be comprised of sources such as photovoltaic arrays, wind turbines, or other renewable sources such as hydroelectric power or more traditional fuel-based approaches such as diesel generators. These systems may be composed of homogenous or hybrid configurations of energy storage systems, grid interfacing equipment and other related equipment to accomplish the functionality of the DER system. A new UL standard under the name of UL 3001 is intended to address microgrids, DERS and other forms of decentralised power. UL 3001 is intended to address safety and performance of DER devices not only at the individual component level but additionally at the system leve. Under its scope, the safety of system design, integration and operation as well as performance as it is related to grid operability and compatibility with installation wiring systems in various modes of system level operation are included.

The coordination of DERS equipment is required to operate safely under normal and foreseeable abnormal system conditions. There is a need to differentiate between system faults, to which equipment needs to respond, and single fault failures within a single piece of equipment. The interaction between energy source and power conversion equipment must be fully understood and accounted for at the system level. Operational ranges of all system-facing equipment must also be accounted for.

The development of UL 3001 is well underway. A Standards Technical Panel (STP) was formed in late 2018 and new UL 3001 task groups composed of various manufacturers, regulators, test labs and other relevant stakeholders have been formed to refine and deliver a draft standard. The intent is to make use of existing standards for UL, IEEE and IEC where applicable. In addition, alignment with ongoing 2020 NEC code proposals are also a key task included in the scope of the ongoing task group work. The task groups have several defined scopes including but not limited to DERS interoperability communications inside the DERS, DERs protective functions, grid connection, coordination and interoperability, lab and field testing, and electrical interaction between sources.

Outlook

Advanced inverters with grid support functionality, energy storage systems and various other distributed energy resources configured with varying renewable power sources will continue to expand. In doing so their functionality will become more advanced, requiring additional regulatory requirements, codes and standards, and system-level safety and performance considerations. UL will continue to lead and involve the DG industry in preparing manufacturers, regulators, utilities and other stakeholders with what new requirements are applicable to gain market access. It will be necessary to create an environment where new regulations meet the pace of innovation for the ongoing goal of decentralisation of power production and the continuing shift to renewable energy sources.

Authors

Scott Picco has worked for UL since 2005 and is currently the business development manager and a regional lead reviewer for distributed energy resources equipment and systems. His responsibilities include business development for new programmes and service offerings in UL's Energy Systems & E-Mobility Segment within the Energy & Power Technologies division, managing large power conversion equipment certification projects globally, and he serves as the technical sales lead for inverters and other solar equipment within UL's E&PT Division.

Laurie Florence, principal engineer (stationary/motive batteries and ESS), represents UL on a variety of UL standards technical panels as well as other industry standards and battery committees across ANSI, SAE, ISO, IEC, IECEE, CSA, and NFPA. Laurie participates on NFPA 855 installation standard for energy storage systems and is a member of the NEC CMP 13 covering the energy storage and storage battery articles. Laurie is also the convener for IEC SC21A Working Group 5 responsible for developing standards for performance and safety of industrial lithium ion batteries such as IEC 62619 and is a member of IEC TC 120 developing the IEC 62933 series of energy storage system standards. Laurie is also responsible for the certification categories related to these various battery and energy storage standards at UL.

Tim Zgonena has worked for UL since 1990 as principal engineer for distributed energy resources equipment and systems. His responsibilities include the development, maintenance and application of UL's certification requirements and delivery of UL conformity assessment services for utility grid interconnection systems equipment, inverters and converters, PV BOS equipment, engine generators, wind turbines, and wind turbine system components.