



# **IEEE 1547 and 2030 Standards for Distributed Energy Resources Interconnection and Interoperability with the Electricity Grid**

Thomas Basso  
*National Renewable Energy Laboratory*

**NREL is a national laboratory of the U.S. Department of Energy  
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Prepared under Task Nos. SS13.0550 and DP12.2014

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## Acronyms and Abbreviations

|       |   |
|-------|---|
| AHJ   | authority having jurisdiction                     |
| DER   | distributed energy resources                      |
| DOE   | U.S. Department of Energy                         |
| EPS   | electric power system                             |
| EUT   | equipment under test                              |
| IEEE  | Institute of Electrical and Electronics Engineers |
| NEC   | National Electrical Code                          |
| NREL  | National Renewable Energy Laboratory              |
| PUC   | public utility commission                         |
| SGIRM | Smart Grid Interoperability Reference Model       |
| UL    | Underwriters Laboratories                         |

## Executive Summary

Public-private partnerships have been a mainstay of the U.S. Department of Energy and the National Renewable Energy Laboratory (DOE/NREL) approach to research and development. These partnerships also include technology development that enables grid modernization and distributed energy resources (DER) advancement, especially renewable energy systems integration with the grid. Through DOE/NREL and industry support of Institute of Electrical and Electronics Engineers (IEEE) standards development, the IEEE 1547 series of standards has helped shape the way utilities and other businesses have worked together to realize increasing amounts of DER interconnected with the distribution grid. And more recently, the IEEE 2030 series of standards is helping to further realize greater implementation of communications and information technologies that provide interoperability solutions for enhanced integration of DER and loads with the grid. For these standards development partnerships, for approximately \$1 of federal funding, industry partnering has contributed \$5. In this report, the status update is presented for the American National Standards IEEE 1547 and IEEE 2030 series of standards. A short synopsis of the history of the 1547 standards is first presented, then the current status and future direction of the ongoing standards development activities are discussed.

## Keywords

Authorities having jurisdiction, communications, conformance testing, distributed energy resources, distribution grid, electric power system, electricity regulation, electricity storage, grid modernization, IEEE 1547, IEEE 2030, interconnection, interoperability, island systems, microgrids, Smart Grid, standards, test procedures, testing.

## Acknowledgments

The author would like to acknowledge the numerous volunteers who have undertaken significant tasks to establish the IEEE 1547 Interconnection series and the IEEE 2030 Smart Grid series of standards and projects. The continuing time and resources of all individuals and organizations who participate in IEEE standards development and their adoption are appreciated; these efforts will continue to accelerate further realization of the modern grid. Specifically, the author thanks the DOE Office of Energy Efficiency and Renewable Energy, and the Office of Energy Delivery and Energy Reliability for their support of the NREL leadership roles in systems standards development (e.g., IEEE Standards Coordinating Committee 21 for fuel cells, photovoltaics, dispersed generation, and energy storage), research and development, and especially for pre-standards test procedures development and validation.

# Contents

|          |   |           |
|----------|---|-----------|
| <b>1</b> | <b>Introduction: IEEE 1547 Series of Standards for Distributed Resources Interconnection and Interoperability With the Grid .....</b> | <b>1</b>  |
| <b>2</b> | <b>1547 Series of Standards .....</b>   | <b>3</b>  |
| <b>3</b> | <b>1547 Evolution Addressing Advanced Interconnection and Interoperability .....</b>  | <b>7</b>  |
| <b>4</b> | <b>Where Is IEEE 1547 Headed: Year 2014 to 2018, or Sooner? .....</b>   | <b>10</b> |
| <b>5</b> | <b>Looking Forward—1547 Evolution Supporting Technical, Regulatory, and Business Needs ...</b>  | <b>12</b> |
|          | <b>References .....</b>   | <b>14</b> |

## List of Figures

|   |   |
|---|---|
| Figure 1. IEEE 1547 standards use in the United States.....   | 2 |
| Figure 2. IEEE 1547 series of interconnection standards .....   | 3 |
| Figure 3. Smart Grid interoperability: the integration of power, communications, and information technologies ..... | 7 |
| Figure 4. IEEE SCC21 2030 series of Smart Grid standards.....   | 8 |
| Figure 5. Example applications of energy storage systems integrated with the grid (IEEE 2030.2).....                | 9 |



# 1 Introduction: IEEE 1547 Series of Standards for Distributed Resources Interconnection and Interoperability With the Grid

The Institute of Electrical and Electronics Engineers (IEEE) Standard 1547 has been a foundational document for the interconnection of distributed energy resources (DER) with the electric power system or the grid. 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. IEEE 1547 has helped to modernize our electric power systems infrastructure by providing a foundation for integrating clean renewable energy technologies as well as other distributed generation and energy storage technologies. IEEE 1547 provides mandatory functional technical requirements and specifications, as well as flexibility and choices, about equipment and operating details that are in compliance with the standard.

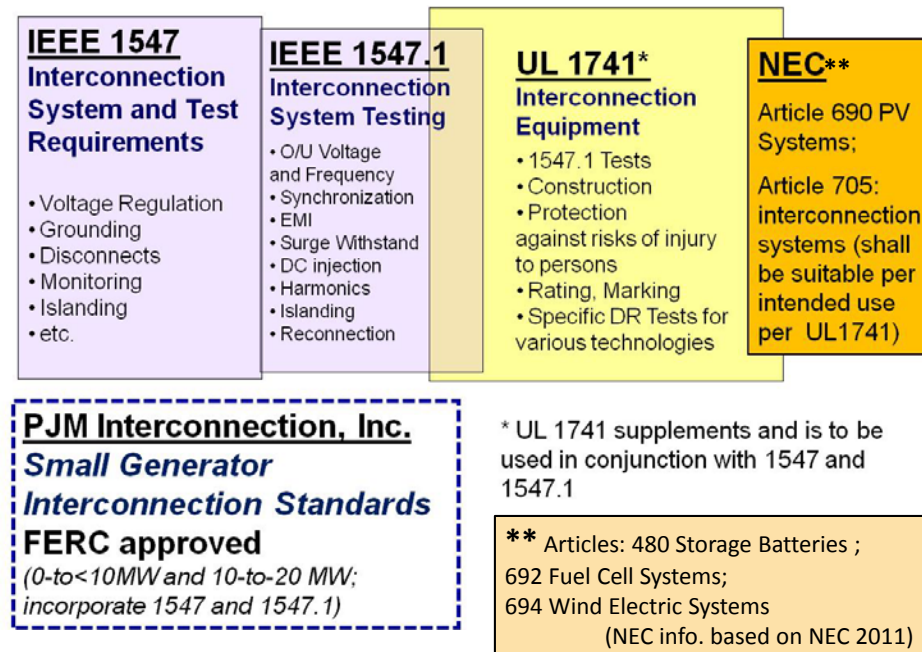
The grid is technically and operationally complex, including complexities among regulatory compliance and mandates by the various authorities having jurisdiction (AHJ) over the grid. The traditional perspective of the U.S. electricity infrastructure is large central station power plants, each of which provides hundreds of megawatts or a gigawatt level of power. From there, high-voltage transmission power lines transport the bulk electricity over often relatively long distances to distribution grids that then supply customers or consumers of that electricity. The power flow tends to be one way from the central power plant, and one way from the distribution grid circuits out to consumers' facilities.

Historically corporations could own generation, transmission, and distribution facilities. With deregulation of electricity this ownership was separated to encourage competition. Additionally, especially in the 1990s and later, distributed generation and clean, renewable energy technologies providing electricity became more cost effective. Consumers of electricity could thus own and install distributed generators and renewable technologies. This upset the traditional perspective of the electricity infrastructure, because some consumers became generators of electricity. This consumer-sited generation affected distribution grid circuits because some circuits experienced either two-way power flow or greatly reduced one-way flow at a significantly lower level than traditionally planned for, and that also affected the distribution grid ancillary equipment deployment and operations.

Federal Energy Regulatory Commission jurisdiction basically covers transmission systems and wholesale electricity transactions. The North American Electric Reliability Corporation is the Electric Reliability Organization having the mandate to ensure reliable and safe transmission grid facilities and their operations. Also at the transmission level, independent system operators and regional transmission operators are member companies that work together to standardize facilities and operations toward cost-effective and reliable transmission and wholesale electricity operations. Independently owned utilities (distribution companies) are primarily regulated by the state public utility commission (PUC) and must comply with state legislative mandates for electricity delivery. Rural electricity cooperatives and municipal electric utilities tend to

follow—or at least harmonize—their practices, including interconnection rules, agreements, and requirements, with the state PUC mandates.

As a technical standard 1547 has provided local, state, and federal regulators and policymakers a technical basis for promoting transparency, openness, and fairness in implementing DER interconnecting to the grid (Figure 1).

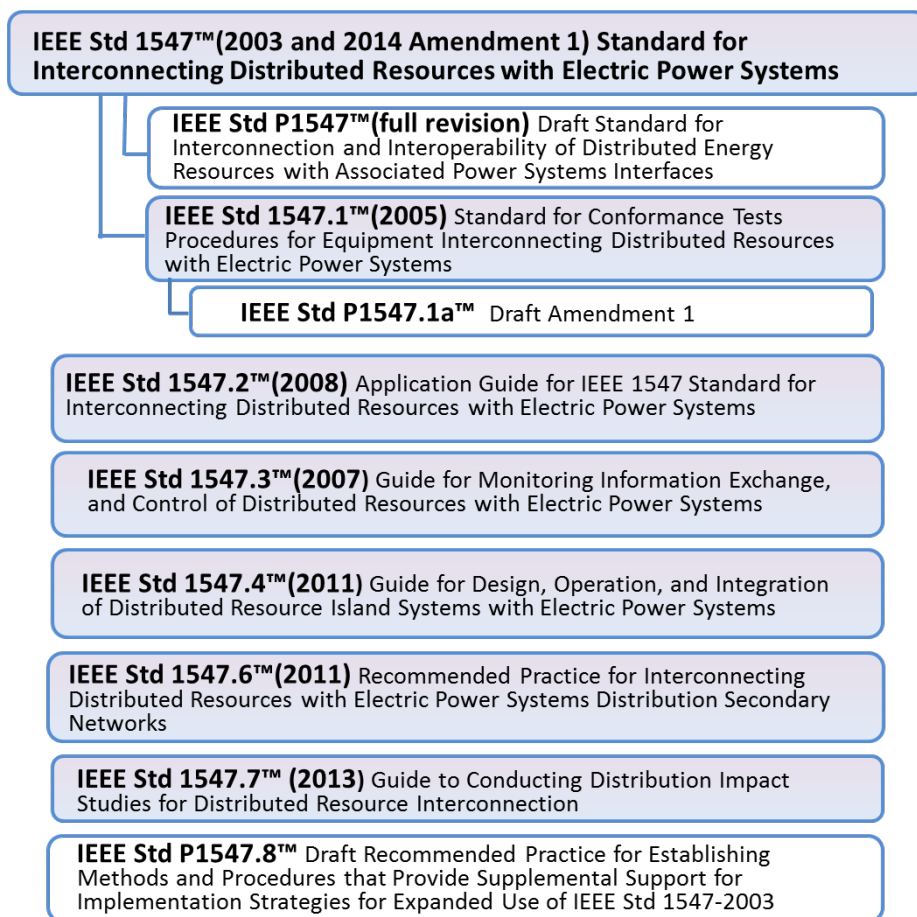


**Figure 1. IEEE 1547 standards use in the United States**

IEEE Standard 1547 was cited in the U.S. Federal Energy Policy Act of 2005, under Section 1254 *Interconnection Services*, stating “Interconnection services shall be offered based upon the standards developed by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547 for Interconnecting Distributed Resources With Electric Power Systems, as they may be amended from time to time.” Currently, three quarters of the states have adopted, referenced, or used 1547 in the development of their own PUC interconnection rules. Also, many rural electric cooperatives, municipality utility companies, and other AHJs over interconnection have adopted or follow 1547. And, the Federal Energy Regulatory Commission has approved the PJM Small Generator Interconnection Standards (0–10 MW, and >10 MW to 20 MW) for Interconnection that incorporates 1547 in its entirety with some additions and implementation prescriptions. PJM is a transmission grid organization that is an independent system operator/regional transmission operator. And for electrical codes for facilities, the National Fire Protection Agency’s National Electrical Code (NEC) requires 1547 (and 1547.1 test procedures) through referencing Underwriters Laboratories (UL) 1741 that mandates 1741 as a supplement to, and is to be used in conjunction with, 1547 and 1547.1. The NEC is used basically throughout all U.S. states. And, in 2014 the NEC initiated a group addressing utility-scale photovoltaic systems for potential publication in the 2017 NEC.

## 2 1547 Series of Standards

The 1547 series of standards are shown in Figure 2. Collectively those provide a cohesive set of requirements, recommended practices, and guidance for addressing standardized interconnection of DER. In Figure 2, the text boxes having a blue fill are published standards with the year of publication shown in parentheses; clear text boxes show documents under development.



**Figure 2. IEEE 1547 series of interconnection standards**

The 1547 series are developed under the by IEEE Standards Coordinating Committee 21 on *Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage (SCC21)* (see <http://grouper.ieee.org/groups/scc21/index.html>). The American National Standards organization open consensus process was instrumental in 1547's core development success, bringing together stakeholders from multiple disciplines including regulators, energy office officials, lawyers, engineers, entrepreneurs, and researchers.

The IEEE Standard 1547-2003 was developed and balloted by 444 individuals, approved by the IEEE Standards Board in June 2003, and approved as an American National Standard in October 2003.

The following paragraphs provide background on the 1547 series of standards. The titles and years of publication for the 1547 series documents are shown in Figure 2. The ongoing

development and updating of these standards is accomplished under the IEEE SCC21 and is open to interested parties—you do not need to be an IEEE member or engineer.

**IEEE Standard 1547 (2003)** was the first in the series of standards developed concerning DER interconnection. DER include distributed generators and energy storage systems. IEEE 1547 focuses on the technical specifications for, and testing of, the interconnection, and not on the types of DER technologies—it is technology neutral. The standard provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It includes general requirements, responses to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests.

The 1547 requirements are universally needed for interconnection of DER, including synchronous machines, induction machines, and power inverters and converters. The 1547 standard (year 2003) criteria and requirements are applicable to all DER technologies, with aggregate capacity of 10 MVA or less at the point of common coupling, interconnected with electric power systems (EPSs) at typical primary and/or secondary distribution voltages. Installation of DER on radial primary and secondary distribution systems was the main emphasis of 1547, although installation of DER on primary and secondary network distribution systems was considered. The 1547 standard was written considering that the DER are a 60 Hz source.

The 1547 standard provides the minimum functional technical requirements that are universally needed to help ensure a technically sound interconnection. Functional technical requirements allow flexibility and innovation and state the required outcome, not how to achieve that or the equipment or methods that must be used to satisfy the requirements. IEEE Standard 1547 was established as a single (holistic) document of mandatory, uniform, and universal requirements. The imposition of local requirements in addition to 1547 requirements—and the exclusion of certain 1547 requirements—should not be implemented to the detriment of the functional technical requirements holistic approach of 1547.

Although 1547 standard established criteria and requirements for interconnection, this standard is not a design handbook or an application guideline. And 1547 is not an interconnection rule or an interconnection agreement. Further, 1547 does not address DER self-protection or planning, designing, operating, or maintaining the customer/local facilities and the utility grid—1547 addresses the interconnection.

Whereas 1547 provides specifications and requirements for the interconnect tests, it does not provide test procedures. Procedures for conformance testing and evaluation are provided in **IEEE Standard 1547.1 (year 2005)**. 1547.1 specifies the type, production, and commissioning tests that shall be performed to demonstrate that the interconnection functions and equipment of DER conform to IEEE Standard 1547. The **IEEE Standard 1547.2 (year 2008)** provides background on 1547 (year 2003) requirements, providing tips, techniques, and rules of thumb. The 1547.2 document includes rationale of 1547 requirements, and provides technical descriptions, schematics, applications guidance, and interconnection examples to enhance the use of 1547. The **IEEE Standard 1547.3 (year 2007)** addresses guidelines for monitoring, information exchange, and control for DER interconnections. It defines an **Information Exchange Interface** and provides an **Information Exchange Agreement** template, which is a

framework to capture the specification of technologies and processes needed to support communications and interoperability between equipment and implementing parties.

The IEEE Standard 1547 includes requirements so DER do not unintentionally provide power to adjacent electricity customers or to the utility grid when the grid has lost its power supply from the transmission system. However, in the 1547 (year 2003) standard, intentional (planned) islanding systems and microgrids are not covered. **The IEEE Standard 1547.4 (year 2011)** provides approaches and good practices for the design, operation, and integration of microgrids, or DER island systems interconnected with the distribution grid. The 1547.4 document addresses the capability to separate from and reconnect to part of the grid while providing power to adjacent grid customers.

**The IEEE Standard 1547.6 (year 2011)** provides recommended practices that address spot and grid distribution secondary networks. The IEEE 1547 (year 2003) includes requirements for distribution secondary spot networks only—circuit topologies that are highly reliable because redundant circuits serve the customer. However, 1547 did not cover distribution secondary grid networks—grid system topologies that are highly reliable because redundant circuits and utility geographically separated facilities serve the customer. The 1547.6 document gives an overview of distribution secondary network systems design, components, and operation; describes considerations for interconnecting DER with networks; and provides potential solutions for the interconnection of DER on network distribution systems.

**The IEEE Standard 1547.7 (year 2013)** addresses criteria, scope, and extent for engineering studies of the impact on the distribution grid by DER. The addition of DER to an EPS will change the system and its response in some manner. It is beyond the scope of the 1547 standard to address methods used for performing EPS impact studies, to mitigate limitations of the grid, or to address the business or tariff issues associated with interconnection. The methodology in 1547.7 is based on a tiered approach with criteria similar to “screens used by the industry”—preliminary review criteria, conventional impact studies criteria, and special impact studies criteria. In 1547.7, criteria are described for determining the necessity of impact mitigation.

**The IEEE Standard P1547.8** recommended practices was initiated to address expanded use of 1547 through the identification of innovative designs, processes, and operational procedures. The IEEE initial ballot was successful, having closed in September 2014. It is now undergoing final revisions prior to publication (typically 3–8 months to publication). P1547.8 addresses advanced controls and communications for inverters supporting the grid and best practices addressing multiple inverters and microgrids, and provides state-of-the-art information for DER group behavior and interactions with grid equipment (both operational and safety related, including unintentional islanding) and interconnection system response to abnormal conditions, and provides application examples such as state-of-the-art protection practices and advanced unintentional islanding approaches. The practices identified in P1547.8 should lead to the development of advanced hardware and software and help streamline their implementation acceptance, resulting in higher penetration levels of DER.

**The IEEE Standard 1547a (year 2014) Amendment 1 to 1547** was published in May 2014. Since 1547 was published in 2003, there has been significant grassroots development of new interconnection lessons learned and additional engineering best practices established based on

the real-world implementation, including Smart Grid advances. In mid-2012, 1547 officials held a workshop for revision of 1547, resulting in the consensus to first establish an amendment to 1547 addressing only the top three highest priorities from the workshop—voltage regulation, voltage ride through, and frequency ride through. The IEEE ballot draft was completed in June 2013. The 1547 Amendment 1 now allows DER to support grid voltage regulation and provide voltage and frequency ride through. Amendment 1 is applicable to all the original types of DER stated in 1547—static power inverters and converters, induction machines, and synchronous machines.

In Amendment 1, the operators of the distribution grid and the DERs are required to coordinate and approve when the DER are allowed to actively participate to regulate the voltage by changes to real and reactive power. The manufacturer specifies the characteristics of its equipment as to how it will respond to provide changes in its real and reactive power output to support the grid. Generally the equipment could respond autonomously to variations in grid voltage, via communicated settings, and via a time schedule. This allowable advanced functionality will provide a more robust grid and is inherently integrated with utility grid operating practices.

Similarly in Amendment 1, under mutual agreement between the operators of the grid and the DERs, the DER is permitted much wider latitude in how it responds to grid abnormal voltage and frequency conditions, including that DER are now clearly allowed to provide voltage and frequency ride through. The required voltage and frequency equipment functionalities are greatly expanded in the Amendment and the operational flexibility is enhanced.

The **IEEE P1547.1a (testing procedures Amendment 1)** updated standard was initiated in 2013 per Amendment 1 of 1547 to cover testing for voltage regulation equipment functionality and voltage and frequency ride through. The standard went to IEEE ballot in the fall of 2014 and should be published a few months later. In P1547.1 Amendment 1, the equipment categories for DER voltage regulation support were established. The following four functionalities for interconnection equipment under test (EUT) are:

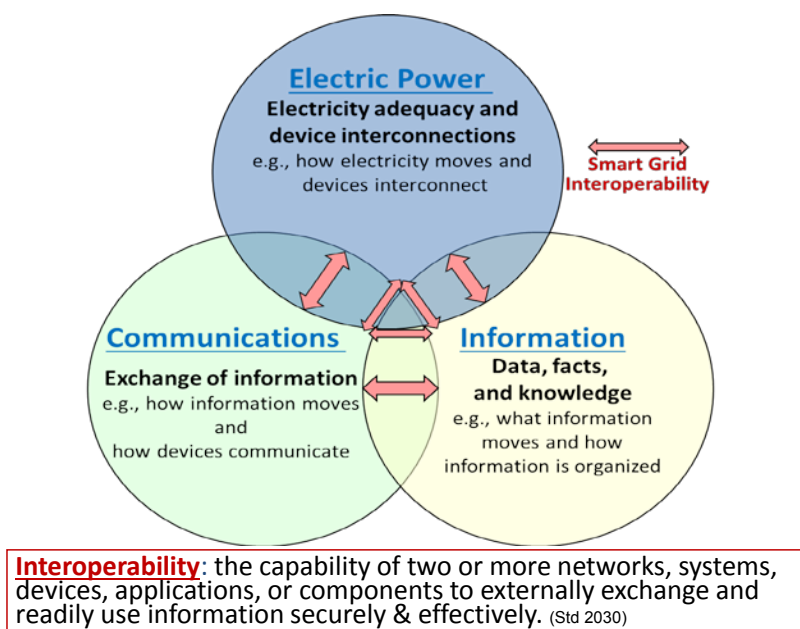
- EUT responds to variations in voltage as per the manufacturer-specified response characteristics.
- EUT responds to communicated settings as per the manufacturer-specified protocols, means of communications, and response characteristics.
- EUT responds to a time schedule as per the manufacturer-specified response characteristics.
- The EUT reactive power output changes with respect to real power output, as per the manufacturer-specified response characteristics.

These advanced test procedures thus allow certification testing for the new functionalities.

### 3 1547 Evolution Addressing Advanced Interconnection and Interoperability

Technology advances and researchers’ development of advanced DER-grid integrated operations and controls functionalities, and Smart Grid interoperability research and development are surpassing the requirements in current standards and codes for DER installations and interconnection with the distribution grid.

An IEEE SCC21 workshop was held in December 2013 to establish the revised title, scope, and purpose for full revision of IEEE 1547. There, the 80 participants reached consensus that the revised 1547 would address interoperability and associated interfaces between DER and the grid (see Figure 2 for title of 1547 full revision). For the full revision of 1547, the interoperability and associated interfaces aspects will build from IEEE Standard 2030 in addition to the 1547 series. The definition of “interfaces” related to full revision of 1547 follows: *interface - a logical interconnection from one entity to another that that supports one or more data flows implemented with one or more data links* (IEEE 2030). Figure 3 includes the definition of interoperability (IEEE 2030) and graphically depicts the interoperability focus areas for the electric power, communications, and information technologies that constitute the technological heart of the Smart Grid.

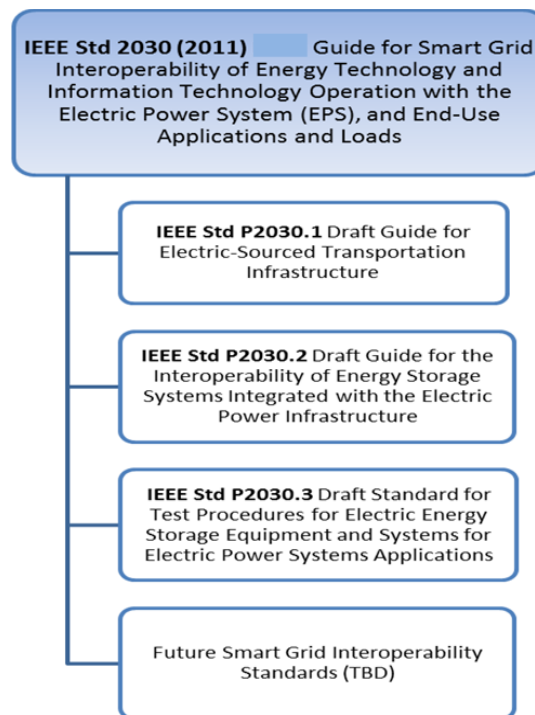


**Figure 3. Smart Grid interoperability: the integration of power, communications, and information technologies**

The IEEE 2030 series of standards published under IEEE SCC21 or in development are shown in Figure 4 (for more 2030 information visit <http://grouper.ieee.org/groups/scc21/index.html>). The **IEEE Standard 2030** (year 2011; see Figure 4 for 2030 title) was developed on a fast-track basis by IEEE working group member volunteers whose affiliations spanned three primary technical areas—electric power industry, communications technologists, and information technology subject matter experts. The 2030 standard is an IEEE guide that provides a

knowledge base addressing terminology, characteristics, and Smart Grid functional performance; it establishes the 2030 Smart Grid Interoperability Reference Model (SGIRM, which inherently allows extensibility, scalability, and upgradeability) with SGIRM defining the integrated architectural perspectives for power systems, communications technology, and information technology; the SGIRM emphasis is on functional interfaces, logical connections, and data flows; and, with IEEE Standard 2030 establishing design tables and classification of data flow characteristics, templates for establishing power perspective needs and for identifying and integrating information-communication technology protocols, standards, etc., addressing reliability, security, cyber, quality of service, and communication mediums.

**IEEE Standard 2030.2** (see Figure 4 for 2030.2 title) was affirmed by IEEE ballot in August 2014. The document addresses both distribution- and transmission-level integration of discrete and hybrid energy storage systems, including end-use applications and loads. IEEE 2030.2 builds upon IEEE Standard 2030, providing guidance in understanding and defining technical characteristics of energy storage systems, and how they may be used compatibly as part of the electric power infrastructure.



**Figure 4. IEEE SCC21 2030 series of Smart Grid standards**

Example energy storage systems applications are documented in 2030.2; e.g., some that are discussed there follow, and are depicted in Figure 5.

- Frequency regulation
- Voltage/VAr support
- Distributed energy services, customer-located



- Energy storage systems for microgrids
- Renewable energy integration, including power smoothing and peak shifting
- Multiple services combined to support the grid.

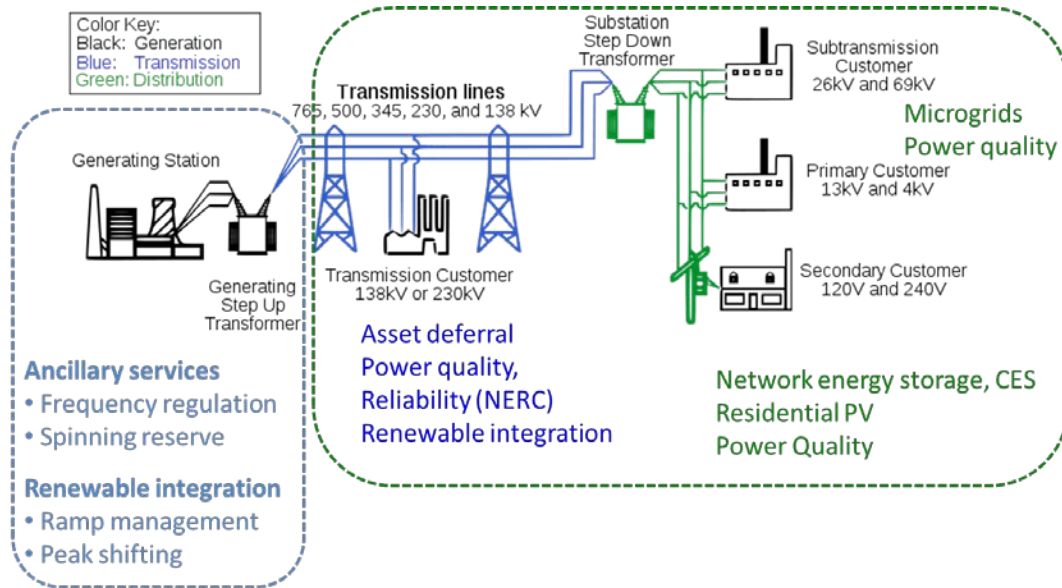


Figure 5. Example applications of energy storage systems integrated with the grid (IEEE 2030.2)

## 4 Where Is IEEE 1547 Headed: Year 2014 to 2018, or Sooner?

The full revision of IEEE 1547 is addressing DER interconnection and interoperability, including associated interfaces, and per IEEE mandate must be completed by 2018. The full revision of 1547 development has substantial participation of individual utilities and participation from a number of transmission-level AHJs. State regulatory experts have asked the National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy to accelerate the IEEE 1547 standards revisions. Also, the North American Electric Reliability Corporation and a number of transmission grid, independent system operators and regional transmission operators are actively participating in updating the 1547 standard. Full revision of 1547 issues, concerns, and updates are being coordinated with corresponding standards and codes such as the NEC and UL safety standards.

The first two meetings of the full revision of 1547 included 110 participants whose stakeholder affiliations were approximately equally distributed among utilities; manufacturers and integrators; test labs, academia, and research groups; AHJs; and general interest. Participants hail from numerous states, covering all U.S. regions and some regions outside the United States including: Virginia, Delaware, New York, Massachusetts, Connecticut, Pennsylvania, New Jersey, Maryland, Florida, Georgia, Kentucky, Illinois, Michigan, Ohio, Minnesota, Missouri, Texas, Arizona, New Mexico, Colorado, Idaho, California, Oregon, Washington, and Hawaii; and, Canada, the United Kingdom, Japan, and Israel.

PUCs and state energy stakeholders have previously sought out NREL standards and codes and DER integration subject matter experts, and a number of them continue such interactions. These interactions included NREL participation with stakeholders from Colorado, South Dakota, Utah, New Mexico, Arizona, Oregon, Washington, Iowa, California, Hawaii, New Jersey, Maryland, District of Columbia, Massachusetts, New York, Florida, Mississippi, and Alabama,

The IEEE Standards Association and 1547 working group approved purpose of the full revision of 1547 follows: *“This document provides a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). It provides requirements relevant to the interconnection and interoperability performance, operation, and testing, and, safety, maintenance and security considerations.”*

The full revision of 1547 is addressing distribution-level connected DER, which includes:

- Generation and storage, including storage as a load
- Advanced functionalities of both DER and modern grid equipment
- Distribution-transmission impacts and cross harmonization of requirements
- DER supplying adequate inertia for the grid
- Microgrids
- Very high penetration of renewables and other DERs
- Intermittency and uncertainty of renewable generation

- Two-way communications, controls, and dispatchability
- Interoperability and intelligent devices integration
- Demand response and load effects
- Potential interactive effects among advanced requirements and specifications
- Introduction and incorporation of advanced evaluation and testing approaches such as enhanced modeling and simulation requirements
- Consideration and acceptance of power hardware in the loop and control hardware in the loop technology
- Potential requirements and specifications for considering evaluations of reliability and resiliency of DER-grid interconnections.

## 5 Looking Forward—1547 Evolution Supporting Technical, Regulatory, and Business Needs

The full revision of IEEE Standard 1547 and the corresponding 2030 documents under IEEE SCC21 are establishing new requirements, recommended practices, and guidance for advanced DER interconnections and interoperability with the grid, now including transmission-level effects in addition to the distribution grid. The updated 1547 standards are poised to expand their foundational contributions for accelerating the timely realization of the modern grid. The full revision of IEEE 1547 (requirements) and the corresponding 1547.1 (testing procedures) are benefitting from national stakeholders' participation and commitment to supporting DER as another tool for both utilities and utility customers in establishing a more robust, efficient, and cost-effective modern grid. Additionally, more international experience with DER is also being brought forward to the revision of the 1547 standards, while the international DER community continues to look to U.S. national standards as a mainstay for electricity infrastructure advancement.

Implementing these updated 1547 standards and their requirements in turn supports greater robustness of the transmission grid, but must be successfully coordinated across the transmission and distribution jurisdictional boundaries. Thus, a challenge in 1547 full revision will be to overcome the traditional separateness among transmission and distribution requirements, AHJs, utility owners, and DER system owners and integrators. These standards also support electricity customer interactive opportunities to support the utility and manage their own electricity demand and usage.

An important implementation aspect of 1547 requirements (including its Amendment) is that 1547 is written to be functionally flexible and 1547 does not unilaterally mandate how DER equipment or components shall be designed in detail; for example “how” they shall provide grid support, and voltage and frequency ride through. Additionally, because there are many electricity distribution companies, there are significantly varying and differing grid operating practices based on existing grid local designs and local conditions. And the 1547 requirements are also cognizant that different DER interconnection technologies have differing technical capabilities so the requirements in 1547 and the Amendment have been established so they are transparent and fair (e.g., as technologically neutral as possible) across the broad categorization of technologies (synchronous-, induction-, or inverter-based).

The flexibility, transparency, and fairness allow for greater innovation. However, such implementation openness then makes it important for a collegial partnership among the AHJs along with the grid and DER operators. For instance, Europe's high level of DER penetration and mandate of a singular response of DER to a grid frequency abnormal condition contributed to a widespread blackout. That blackout arose from a grid frequency significant abnormal condition being further exacerbated by a large number of DER shutting down. Studies of that blackout included results indicating that instead of a single frequency value for DER to shut down, there could have been a range of shutdown frequency values or shutdown times for different DER to shut down; i.e., DER shutdown could have been time sequenced or power modulated. That sequencing, and/or power modulation, might have provided adequate time (with the DER remaining online to support the grid) for the overall grid frequency to regain stable operation.

The full revision of 1547 standard, including interoperability and associated interface aspects and the subsequent full revision of 1547.1 (conformance testing), is critical to the power industry and the evolution of the electricity infrastructure because the 1547 and 1547.1 standards provide the widely accepted engineering consensus for properly ensuring grid performance and reliability levels are at least maintained (or increased) when interconnecting DER with the grid. These revised standards:

- Enable high penetration of DER, including clean solar technologies, at levels approaching, or exceeding, 100% peak load.
- Reduce interconnection approval time for advanced DER projects.
- Reduce interconnection costs for projects.
- Accelerate conformance validation of state of the art interconnection systems for the future grid.

The interoperability, communications, and information technology integrated functionalities into interconnection systems will also:

- Enable the success of new business models and valuations for utilities and customers.
- Support transactive roles of customers.
- Help improve grid awareness of interconnected DER, including helping mitigate concerns about intermittency and dispatchability of renewable energy technologies.

Technology manufacturers, utilities, and AHJs look to—and most often require—1547 as the base standard for interconnection requirements, certification, and listing of equipment interconnecting DER with the grid. When the 1547 standards are fully revised, states' rules and AHJs will have a sound technological basis to update their implementation rules and agreements to accommodate the advanced grid support DER features and customer grid interactive features. When properly deployed, these advanced features will contribute to improving the reliability and robustness of the distribution grid and improve transmission grid performance and operations.

In closing, 1547 and 2030 interconnection and interoperability technical standards continue to evolve as foundational documents helping accelerate the realization of the future grid. However, technical standards alone are not immediately effective unto themselves. Effectiveness involves partnerships and acceptance among a broad consensus and coherent implementation across the transmission and distribution infrastructure physical boundaries, among AHJs, and, with utilities, system integrators, and customers understanding and using those standards. Improved standards and conformance programs, transparent market requirements, and ongoing research and development for hardware and software advances in power, communications, and information technologies are paramount for successfully accelerating the evolution of the future grid.

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