Inverter Standards for Distributed Energy Resources

An Online Continuing Education Course for Engineers

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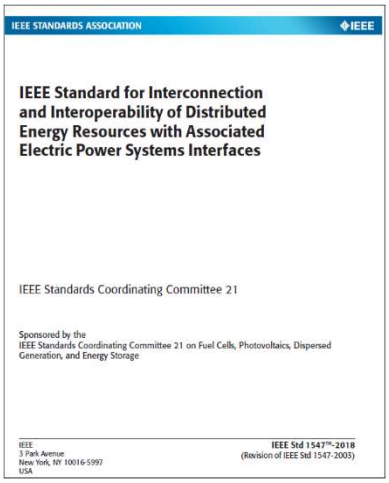
Lee Layton, P.E.

Introduction

IEEE Standard 1547-2018, titled "IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces" provides a set of criteria and requirements for the interconnection of distributed generation resources to the electric power grid. This standard significantly enhanced the performance and functional capability of DERs connecting specifically to primary and secondary distribution systems.



The purpose of IEEE Std. 1547 is to provide a uniform standard for the interconnection of distributed resources with Electric Power Systems (EPS). It provides requirements relevant to the interconnection's performance, operation, testing, safety, and maintenance.

There are three versions of IEEE Std. 1547, namely 1547-2003, 1547-2014, and 1547-2018. This course describes the differences between previous versions of the standard to the 2018 Standard.

Background

The grid is technically and operationally complex, including complexities among regulatory compliance and mandates by the various authorities having jurisdiction 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 (known as 'area electric power systems) that then supply customers or consumers of that electricity. The power flow across the transmission grid can flow either way. The distribution system (known as an area electric power system) tends to only flow one way from the transmission grid to consumers' facilities. See Figure 1.

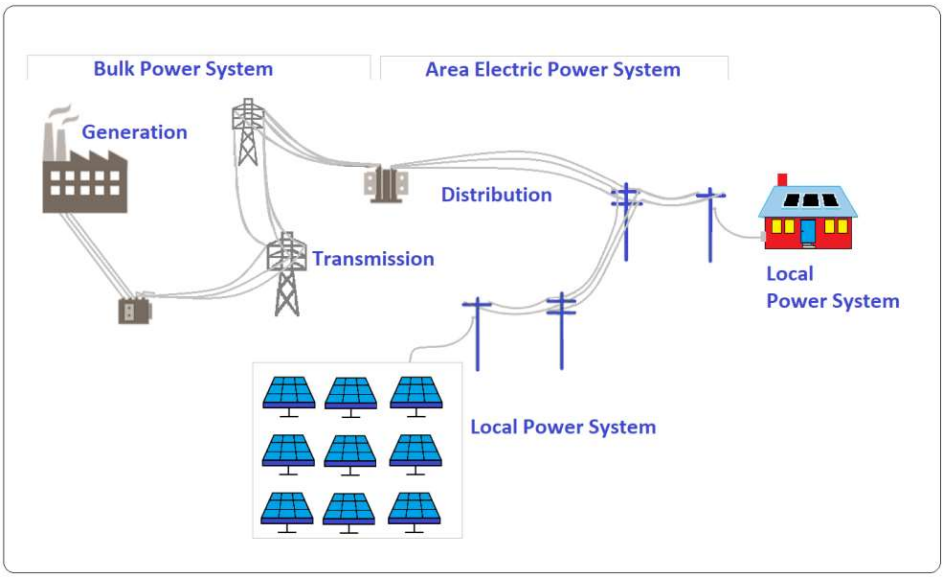


Figure 1

Historically, only monopolistic, regulated, electric utilities owned the generation, transmission, and distribution facilities. With the deregulation of electricity, this ownership was separated to encourage competition. Beginning in the early 1990s, distributed generation and renewable energy technologies became more cost-effective for providing electricity. Consumers of electricity could thus own and install distributed generators and renewable technologies. This was a change in the structural model of the electric utility industry. This consumer-sited generation affected distribution grid circuits because some circuits experienced either two-way power flow (which the distribution system was not designed to handle) or greatly reduced one-way flow to a significantly lower level than expected.

With the increasing adoption of distributed resources, the industry realized a set of standards was necessary to protect the operation of the electric power system. The utilities' concerns were system reliability, safety, and cost impacts on the electric system. Others saw the lack of national standards as a roadblock to the implementation of new distributed generation projects. The standard was intended to be universally adaptable, technology-neutral, and cover distributed resources up to 10 MVA of capacity.

The Institute of Electrical and Electronics Engineers (IEEE) Standard 1547, first published in 2003, has been a foundational document for the interconnection of *distributed energy resources* (DER) with the electric power system. IEEE 1547 has helped to modernize the electric power systems infrastructure by providing a structure for integrating renewable energy technologies as well as other distributed generation and energy storage technologies. The Standard provides mandatory functional technical requirements and specifications, as well as flexibility and choices about equipment and operating details that comply with the standard.

As a technical standard, IEEE Std. 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. However, IEEE Std. 1547 is not the only standard involved in interconnections to the electric system. Others such as IEEE Std. 1547.1, UL1741; and some articles in the National Electric Code (NEC) address the installation and interconnection of DER equipment (See Figure 2).

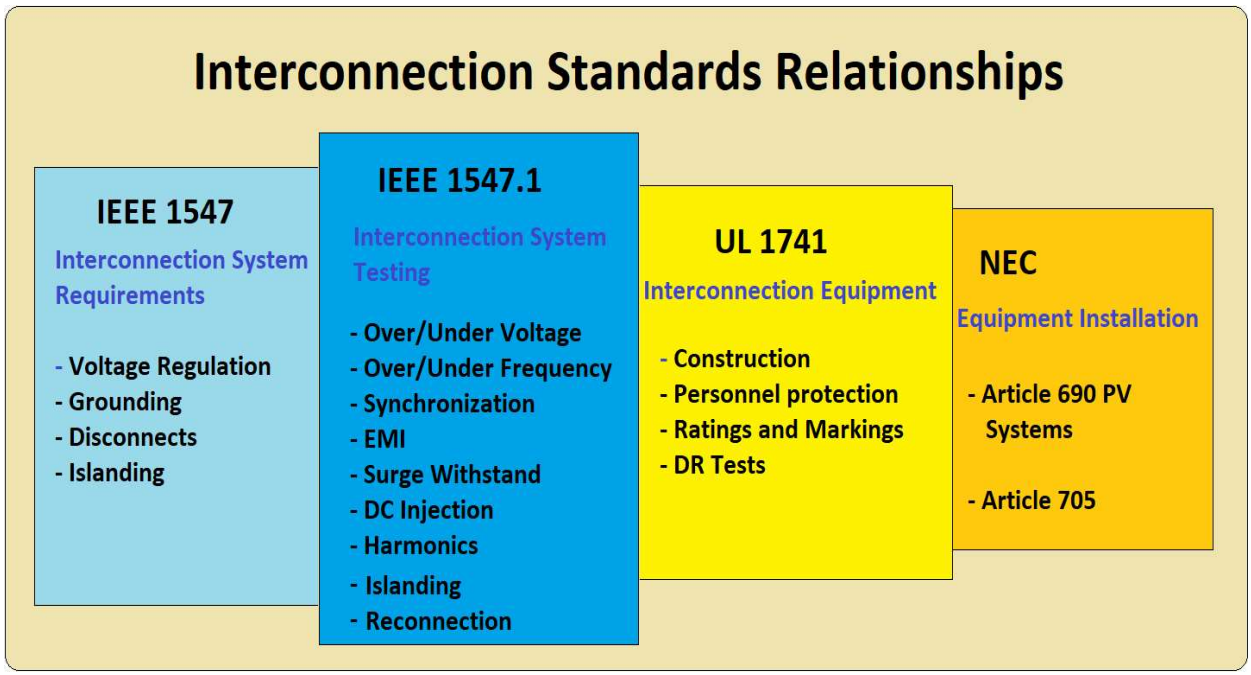


Figure 2

IEEE 1547 Series of Standards

IEEE Std. 1547 is a series of standards that address specific issues with the interconnection of the operation of DER equipment. The 1547 series of standards are shown in Table 1. Collectively these documents provide a cohesive set of requirements, recommended practices, and guidance for addressing standardized interconnection of DER.

Standard	Table 1 IEEE 1547 Standard Series
1547	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.
1547.1	Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces
1547.2	Application Guide for IEEE Std. 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems.
1547.3	Guide for Cybersecurity of Distributed Energy Resources Interconnected with Electric Power Systems.
1547.4	IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems.
1547.6	IEEE Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks.
1547.7	IEEE Guide for Conducting Distribution Impact Studies for Distributed Resource Interconnection,
1547.8	Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for 4 Implementation Strategies for Expanded Use of IEEE Standard 1547.
1547.9	Guide to Using IEEE Standard 1547 for Interconnection of Energy Storage Distributed Energy Resources with Electric Power Systems.

The following is a brief description of the other Standards.

IEEE Std. 1547.1

Specifies the type, production, and commissioning tests that shall be performed to demonstrate that DER's interconnection functions and equipment conform to IEEE Standard 1547.

IEEE Std. 1547.2

Provides background on 1547 requirements, providing tips, techniques, and rules of thumb. The 1547.2 document includes the rationale of 1547 requirements and provides technical descriptions, schematics, application guidance, and interconnection examples to enhance the use of 1547.

IEEE Std. 1547.3

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.

IEEE Std. 1547.4

Provides approaches and 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.

IEEE Std. 1547.6

Provides recommended practices that address spot and grid distribution secondary networks. IEEE Std. 1547 includes requirements for the distribution of secondary spot networks only — highly reliable circuit topologies because redundant circuits serve the customer. The IEEE Std. 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.

IEEE Std. 1547.7

Addresses criteria, scope, and extent for engineering studies of the impact on the distribution grid by DER. The addition of DER to an *electric power system* (EPS) will change the system and its response in some manner. The methodology in IEEE Std. 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.

IEEE Std. 1547.8

IEEE Std. 1547.8 was initiated to address the expanded use of IEEE Std. 1547 through the identification of innovative designs, processes, and operational procedures. IEEE Std. 1547.8

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 islan[illegible]pproaches.

IEEE Std. 1547.9

IEE[illegible] 1547-2018 for the inte[illegible]guide's scope incl[illegible]verter capable of bidir[illegible]wer to the EPS.

IEEE Std. 1[illegible]

This section is a[illegible] 2003 the Standard has pr[illegible]rids. Figure 3 shows some of t[illegible]

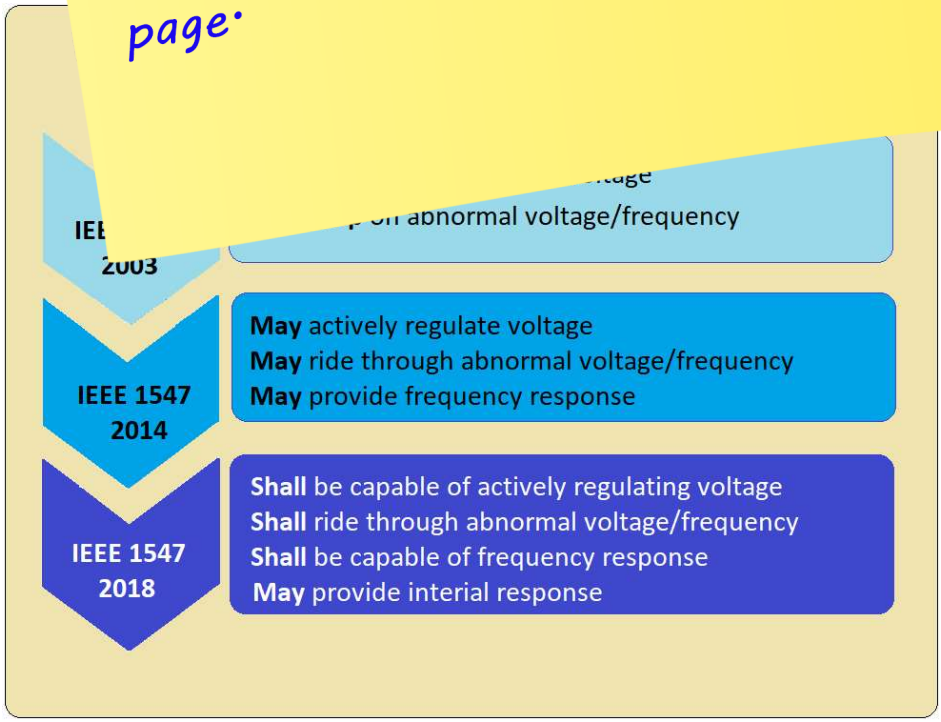


Figure 3