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Advancing Smart Grid Interoperability and Implementing NIST's Interoperability Roadmap

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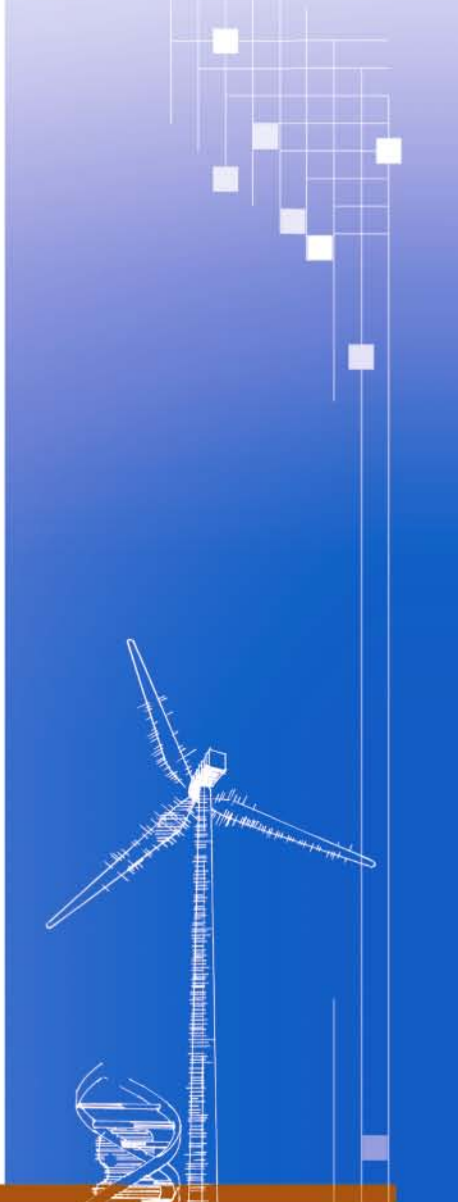

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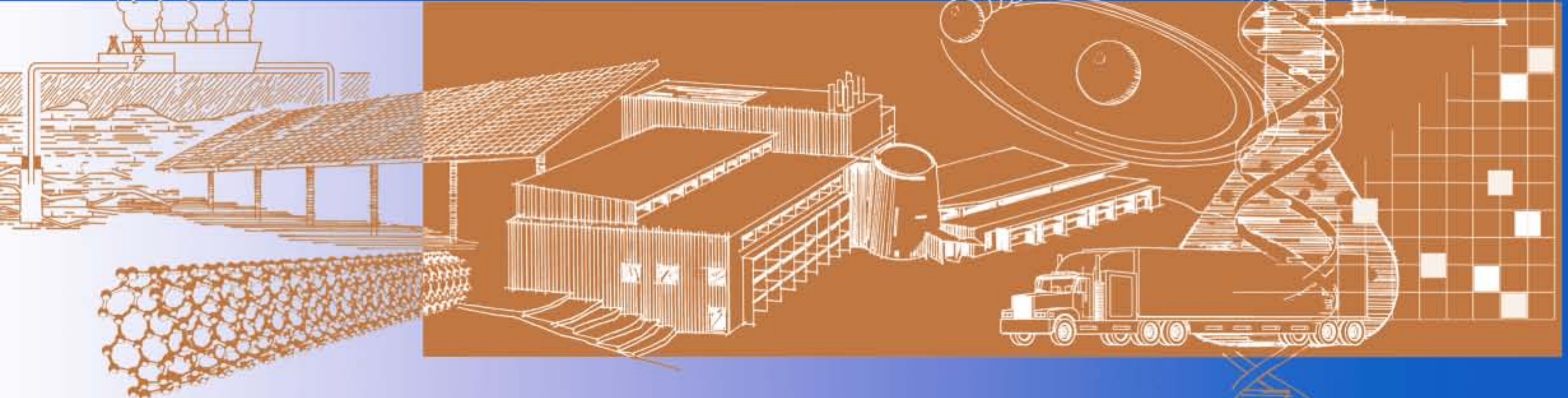

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Advancing Smart Grid Interoperability and Implementing NIST's Interoperability Roadmap: IEEE P2030^{TM} Initiative and IEEE 1547^{TM} Interconnection Standards

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Abstract

The IEEE American National Standards project P2030^{TM} addressing smart grid interoperability and the IEEE 1547 series of standards addressing distributed resources interconnection with the grid have been identified in priority action plans in the *Report to NIST on the Smart Grid Interoperability Standards Roadmap*. This paper presents the status of the IEEE P2030 development, the IEEE 1547 series of standards publications and drafts, and provides insight on systems integration and grid infrastructure. The P2030 and 1547 series of standards are sponsored by IEEE Standards Coordinating Committee 21 (SCC21).

The title of the IEEE P2030 standard is *Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation With the Electric Power System (EPS), and End-Use Applications and Loads*. The guide will provide a knowledge base addressing terminology, characteristics, functional performance and evaluation criteria, and the application of engineering principles for smart grid interoperability. P2030 involves the integration of energy, information, and communications technologies, which are necessary to achieve seamless operation for electric generation, delivery, and end-use applications to permit two-way power flow with communication and control.

The IEEE 1547 series of standards includes standards already published and projects underway. The IEEE 1547 publication establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems and the 1547.1 publication provides the conformance test procedures. The 1547.2 publication is an application guide to 1547 and the 1547.3 publication is a guide to DR monitoring, information exchange, and control. The P1547.4 project is currently underway and addresses DR planned island systems (e.g., micro-grids). This project addresses many of the technical integration issues that would need to be addressed in a mature smart grid, including issues of penetration of distributed generators and electric storage systems, grid support, end-use operational support, and load management.

I. INTRODUCTION

The Institute of Electrical and Electronics Engineers (IEEE) standards development organization is identified in the Energy Independence and Security Act (EISA) of 2007 under Title XIII, Section 1305. Therein, NIST is assigned the primary responsibility of coordinating the development of a framework that includes protocols and model standards for the smart grid. The *NIST Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0 (Draft)* [1] and its related documents identify various standards development organizations, list related standards, indicate possible standards gaps, and make recommendations for revisions to existing standards. This paper discusses the status of the IEEE American National Standards project IEEE P2030^{TM} and IEEE 1547^{TM} protocol and model standards as they relate to smart grid interoperability and distributed resource interconnection as addressed in the EISA of 2007.

The IEEE establishes its standards through a rigorous, consensus development process, approved by the American National Standards Institute (ANSI), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Additionally, IEEE often elects to develop many of its standards to qualify for designation as ANSI American National Standards. Not all standards or standards development organizations choose to meet the development requirements necessary for designation as American National Standard, however, all of the IEEE 1547 series of interconnection standards are qualified as American National Standards, including the new 1547 projects and the P2030 smart grid interoperability project.

Development of uniform IEEE 1547 interconnection standards has helped decrease the time and effort associated with DR interconnection. The IEEE 1547 series of standards is also helping to promote additional implementation approaches for eliminating barriers posed by project-specific interconnection requirements and strives toward a more secure and reliable electric infrastructure. The IEEE 1547 development approach provides a model for IEEE P2030 standards development consideration.

II. IEEE 1547 AND P2030 BACKGROUND

The IEEE 1547 series of interconnection standards and IEEE P2030 smart grid interoperability standards development are approved by the IEEE Standards Board as sponsored by the IEEE Standards Coordinating Committee 21 (SCC21) [4]. Overall, the IEEE SCC21 oversees the development of standards in the areas of fuel cells, photovoltaics, dispersed generation, and energy storage and coordinates efforts in these fields among the various IEEE societies and other affected organizations to insure that all standards are consistent and properly reflect the views of all applicable disciplines.

For technical insight into the background of interconnection and smart grid standards, it should be understood that the electric power system is a complex energy delivery system that moves energy from sources of generation to points of utilization. The electric delivery system is very dynamic with generation and loads interacting with each other at the speed of light over transmission lines, sub-transmission lines, and distribution lines. The electric utility is responsible for providing proper voltage and frequency regulation in this complex delivery system that traditionally was not designed with two-way power and two-way communication systems embedded in utility distribution systems or customer facilities.

Examples of the types of distributed energy technologies that may be interconnected with the utility grid and the functionalities of the interconnection technologies are shown in **Figure 1**. Distributed energy technologies include both generator systems as well as energy storage systems.

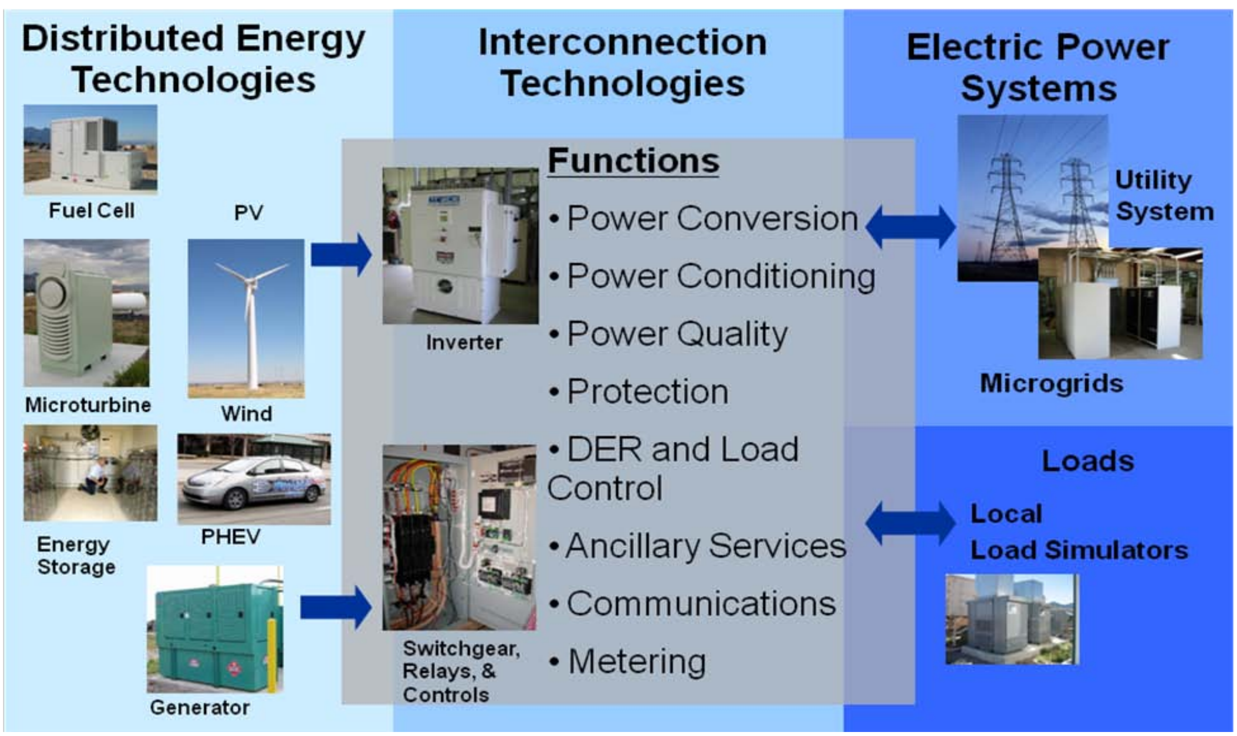


Figure 1. Distributed energy technologies and interconnection technologies

The IEEE 1547 series of standards and the P2030 standards development recognize the dynamic nature of the interconnection with the grid and all of its parts. In **Figure 2**, the interconnection and the communication and information technologies show the interfaces for the systems approach (system of systems) to the concepts needed for mature smart grid interoperability.

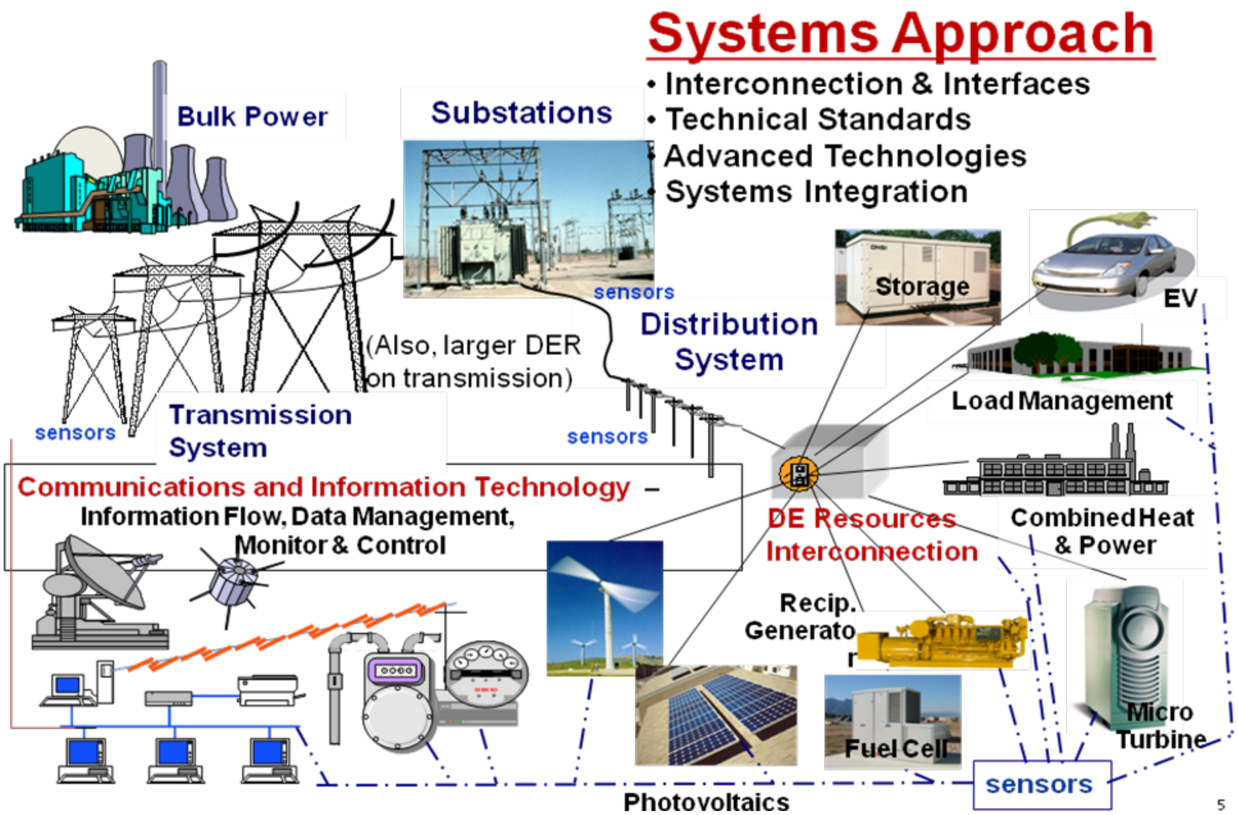


Figure 2. Interoperability smart grid concepts ("system of systems" approach)

It should be noted that there is not one universally accepted unique definition of "smart grid." Depending on the stakeholder's viewpoint, the smart grid definition would include stated benefits or desired outcomes for certain parties or for certain technologies. In a very broad sense, "smart grid" could be simply defined as "the electric delivery infrastructure from electrical generation to end-use customer, integrated with information and communication technologies." It is recognized that this definition is open for debate, but it is offered to separate the specific stakeholder benefits or use of the smart grid technology from the definition of what the smart grid actually is. In the NIST framework report there is a list of anticipated smart grid benefits, separated from the definition of smart grid. As stated in the NIST report, that document was developed based on numerous inputs, several workshops, and review comments provided.

The IEEE SCC21 standards development members are aware that the dynamic electric infrastructure system has been possible because it was designed with specific goals for interconnection operation related to achieving balance between the generation, the delivery system, and the end user requirements for energy. To achieve this balance, there has to be adequate generation and sufficient capacity in the delivery system to meet the needs of the end user. In addition, the system has to have adequate inertial energy that can be called upon instantaneously to stabilize the dynamics when abnormal conditions occur. The stabilization requires both real and reactive energy and controls.

In the case of significant dynamic penetrations (of loads, distributed energy resources, electric vehicles, etc.), it is

practically assured that the initial stabilization action has to be independent of latent communications. This was traditionally taken into consideration in the individual design of each part of the interconnected system and the overall system design that assures that generation is in balance at all times with the loads and the delivery system is not being stressed beyond its capability. However, all electric power equipment has electrical and mechanical limitations. When distributed energy resources are incorporated into the interconnected grid, the electrical and mechanical limitations of the grid have to be understood and accommodated. Rotating generation provides an inertial component for both real and reactive power. Non-rotating generation and energy sources do not provide inertia intrinsically but may need to provide the equivalent of inertia by electronic means using stored energy in order to maintain harmony with the existing system capability.

Not all distributed resources need to be served by distribution circuits. There is a finite limit to the amount of distributed resources that can be served by a distribution circuit. The limits are affected by equipment ratings, operating voltage, the dynamics of the distributed resources and the loads, and consideration for the safety of the workers and public. It is not possible to mandate the capacity of distributed resources that must be interconnected to each voltage level of the distribution system with a detailed engineering analysis. The current guidelines given in the Federal Energy Regulatory Commission (FERC) order 2003 recommend that interconnection of distributed resources with capacities greater than 20 MW, either individually or an aggregate, should be connected at the transmission level. This recommendation was not meant to imply that all distribution circuits can accept up to 20 MW. Distribution circuit topology and operating voltage can result in technical limitations that would limit the amount of distributed resources to a value lower than 20 MW.

It further should be recognized that distribution automation and other smart grid technologies add complexity to the safe and reliable operation of the distribution energy delivery system. Even today, it is not uncommon to reconfigure distribution circuits for maintenance, load balance or faults more than once in a period of hours or minutes. Thus, generation capacities may have to be re-aligned to meet the circuit's technical and operational restraints. The need to accommodate this topological flexibility can dictate the maximum generation capacity to be connected.

These constraints are very similar to constraints on the size and types of loads served from a distribution circuit, a sub-transmission circuit or a transmission circuit. The value of 10 MVA (either as individual distributed resource capacity or an aggregate capacity) behind a single point of common coupling as given in IEEE Standard 1547 is a limitation considered by technical experts to be a practical maximum limit for distributed resources connected to a distribution circuit. The 10 MVA threshold was established by a consensus vote of this standard. and ,like the FERC 20 MW limit, does not imply that all distribution circuits can accept 10 MVA of distrubited resources. Other means of serving the distributed resource capacity are available; however, because of its technology, electrical characteristics, etc. distributed resources exceeding 10 MVA should be served via other parts of the delivery system. Thus, the IEEE 1547 standard is limited to interconnections of distributed resources at the distribution level.

1.1. The IEEE 1547 Series of Standards

In June 2003, IEEE Std 1547, *Standard for Interconnection of Distributed Resources with Electric Power Systems*, was approved by the IEEE Standards Board and shortly thereafter approved as an American National Standard (ANSI/IEEE) in October 2003. This root standard of the IEEE 1547 series of standards was developed through discussions and negotiations in a series of meetings and contains input from more than 340 participants under the sponsorship of the Standards Coordinating Committee 21on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage. The IEEE Std 1547 is a benchmark milestone for the IEEE standards consensus process and successfully demonstrates a model for ongoing success in the development of further national standards and for moving forward in modernizing our nation's electric power system.

IEEE Std 1547 defines a set of uniform requirements for the interconnection of DR to the distribution segment of the electric power system (EPS). Currently, there are seven complementary standards designed to expand upon or clarify the initial standard, three of which are published.The other four are still in the draft phase.

A complete listing of the 1547 series of standards is shown in **Figure 3**.

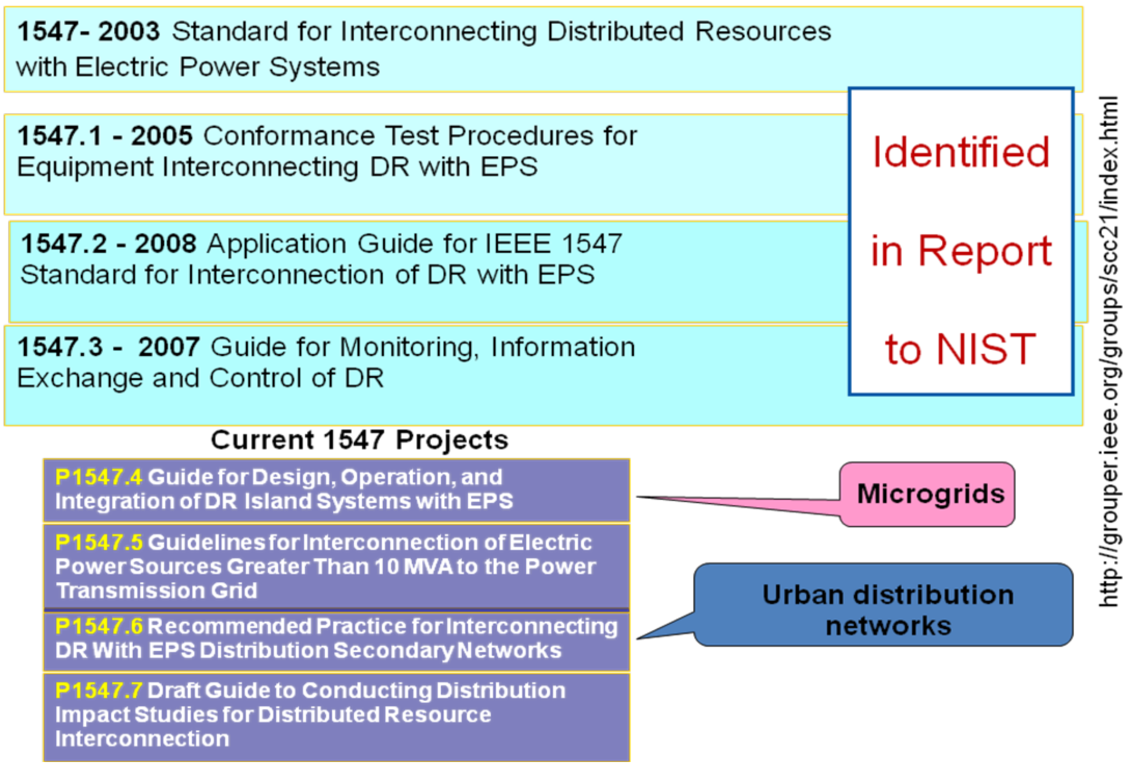


Figure 3. IEEE 1547 series of interconnection standards and projects

The IEEE 1547 series of existing, published standards are:

- IEEE Std 1547™-2003 (reaffirmed 2008), *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*
- IEEE Std 1547.1™-2005, *IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems*
- IEEE Std 1547.2™-2008, *IEEE Application Guide for IEEE Std 1547™, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*
- IEEE Std 1547.3™-2007, *IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems*

The IEEE SCC21 1547 series of standards development projects that are currently underway are as follows:

- IEEE P1547.4™, *Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems* (IEEE ballot plan first quarter 2010)
- IEEE P1547.5™, *Draft Technical Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid* (no ballot date established);
- IEEE P1547.6™, *Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Network* (IEEE ballot plan first quarter 2010);
- IEEE P1547.7™, *Draft Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection* (no ballot date established)

1.1.1. IEEE Std 1547

The IEEE Std 1547-2003 is the first in the 1547 series of planned interconnection standards and provides interconnection technical specifications and requirements as well as interconnection test specifications and requirements. The IEEE Std 1547 stated requirements are universally needed for interconnection of distributed resources that include both distributed generators as well as energy storage systems, including synchronous machines, induction machines, or power inverters/converters and will be

sufficient for most installations. Traditionally, utility electric power systems (EPS--grid or utility grid) were not designed to accommodate active generation and storage at the distribution level. As a result, there were major issues and obstacles to an orderly transition to using and integrating distributed power resources with the grid. The lack of uniform national interconnection standards and tests for interconnection operation and certification, as well as the lack of uniform national building, electrical, and safety codes, were understood.

In February 2003, P1547 received 91% affirmation from the ballot group of 230 members. In June 2003, IEEE Std 1547 was approved by the IEEE Standards Board and in October 2003 approved as an American National Standard. In the Energy Policy Act of 2005**,** IEEE 1547 standards were required to be considered for interconnection of distributed resources to the grid. In 2008, the IEEE Std 1547 was reaffirmed by 181 balloters. Reaffirmation is consensus proclamation that the standard, as currently written, is not obsolete and does not contain erroneous information.

1.1.2. IEEE Std 1547.1

The IEEE Std 1547.1-2005 provides the test procedures for verifying conformance to IEEE Std 1547-2003. IEEE Std 1547.1 provides conformance test procedures to establish and verify compliance with the requirements of IEEE Std 1547. When applied, the IEEE Std 1547.1 test procedures can provide a means for manufacturers, utilities, or independent testing agencies to confirm the suitability of any given interconnection system or component intended for use in the interconnection of DR with the electric power system (EPS). Such certification can lead to the ready acceptance of confirmed equipment as suitable for use in the intended service by the parties concerned.

1.1.3. IEEE Std 1547.2

The IEEE Std 1547.2-2008 provides technical background and application details to support understanding of IEEE Std 1547. The guide facilitates the use of IEEE Std 1547 by characterizing various forms of distributed resource technologies and their associated interconnection issues. It provides background and rationale of the technical requirements of IEEE Std 1547. It also provides tips, techniques, and rules of thumb, and it addresses topics related to distributed resource project implementation to enhance the user's understanding of how IEEE Std 1547 may relate to those topics.

1.1.4. IEEE Std 1547.3

IEEE Std 1547.3-2007 is intended to facilitate interoperability of DR interconnected with an area EPS. IEEE Std 1547.3 is intended to help stakeholders in distributed resource installations, implement optional approaches for monitoring, information exchange, and control to support the operation of their distributed resources and transactions among the stakeholders associated with the distributed resources. IEEE Std 1547.3 describes functionality, parameters, and methodologies for monitoring, information exchange, and control related to distributed resources interconnected with an area electric power system. The focus is on monitoring, information exchange, and control data exchanges between distributed resource controllers and stakeholder entities with direct communication interactions. This guide incorporates information modeling and use case approaches, but it is also compatible with historical approaches to establishing and satisfying monitoring, information exchange, and control needs for distributed resources interconnected with an area electric power system.

1.1.5. IEEE Std 1547.4

The IEEE Std P1547.4 draft guide covers intentional islands in EPSs that contain distributed resources (DR). The term “DR island systems,” sometimes interchanged with ”micro-grids,” is used for these intentional islands. DR island systems are EPSs that: (1) have DR and load, (2) have the ability to disconnect from and parallel with the area EPS, (3) include the local EPS and may include portions of the area EPS, and (4) are intentionally planned. DR island systems can be either local EPS islands or area EPS islands. The IEEE Std P1547.4 document addresses issues associated with DR island systems on both local and area islanded EPSs. It provides an introduction and overview and addresses engineering concerns related to DR island systems. The document provides alternative approaches and good practices for the design, operation, and integration of DR island systems with EPS. This includes the ability to separate from and reconnect to part of the area EPS while providing power to the islanded EPSs. This guide includes the distributed resources, interconnection systems, and participating electric power systems.

1.1.6. IEEE Std 1547.5

The IEEE Std P1547.5 draft document provides guidelines regarding the technical requirements, including design, construction, commissioning acceptance testing, and, maintenance performance requirements, for interconnecting dispatchable electric power sources with a capacity of more than 10 MVA to a bulk power transmission grid. The purpose of the IEEE Std P1547.5 project is to provide technical information and guidance to all parties involved in

the interconnection of dispatchable electric power sources to a transmission grid about the various considerations needed to be evaluated for establishing acceptable parameters such that the interconnection is technically correct. It should be noted that since the P1547.5 project was initiated, the National Energy Regulatory Commission (NERC) has been established as the electricity reliability organization that may establish standards for generation systems providing wholesale electric services on the transmission grid.

1.1.7. IEEE Std 1547.6

The IEEE Std P1547.6 draft recommended practice builds upon IEEE Standard 1547 for the interconnection of distributed resources to distribution secondary network systems. It establishes recommended criteria, requirements and tests, and provides guidance for interconnection of distribution secondary network system types of area EPS with distributed resources providing electric power generation in local electric power systems (local EPS). The IEEE Std P1547.6 document focuses on the technical issues associated with the interconnection of area EPS distribution secondary networks with a local EPS having distributed resources generation. The recommended practice provides recommendations relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. In this IEEE Std P1547.6 document, consideration is given to the needs of the local EPS to be able to provide enhanced service to the DR owner loads as well as to other loads served by the network. Equally, the standard addresses the technical concerns and issues of the area EPS. Further, this standard identifies communication and control recommendations and provides guidance on considerations that will have to be addressed for such DR interconnections.

1.1.8. IEEE Std 1547.7

The IEEE Std P1547.7 draft guide describes criteria, scope, and extent for engineering studies of the impact on area electric power systems of a distributed resource or aggregate distributed resource interconnected to an area electric power distribution system. With the creation of IEEE Std 1547, that had led to the increased interconnection of distributed resources throughout distribution systems. This IEEE Std P1547.7 document describes a methodology for performing engineering studies of the potential impact of a distributed resource interconnected to an area electric power distribution system. The impacts study scope and extent are described as functions of identifiable characteristics of the distributed resource, the area electric power system, and the interconnection. Criteria are described for determining the necessity of impact mitigation. The establishment of this IEEE Std P1547.7 guide allows distributed resource owners, interconnection contractors, area electric distribution power system owners and operators, and regulatory bodies to have a described methodology for when distribution system impact studies are appropriate, what data is required, how they are performed, and how the study results are evaluated. In the absence of such guidelines, the necessity and extent of DR interconnection impact studies has been widely and inconsistently defined and applied. The IEEE Std P1547.7 project was initiated in January 2009.

1.2. IEEE P2030 Project

The IEEE P2030 project provides guidelines in understanding and defining smart grid interoperability of the electric power system with end-use applications and loads. Integration of energy technology and information and communications technology is necessary to achieve seamless operation for electric generation, delivery, and end-use benefits to permit two-way power flow, with communication and control. Interconnection and intra-facing frameworks and strategies with design definitions are addressed in the IEEE P2030 document, providing guidance in expanding the current knowledge base. This expanded knowledge base is needed as a key element in grid architectural designs and operation to promote a more reliable and flexible electric power system. The IEEE P2030 standards development inaugural meeting was held in June 2009 with capacity in-person registration of 150 individuals and close to 200 others registered to participate via webinar. The IEEE P2030 development is on a fast-track schedule targeting the end of 2010 to have a substantive draft for public consideration.

The IEEE P2030 standards development effort was initially organized under three task force groups to provide inputs and ongoing updates to establishing the IEEE P2030 document (**Figure 4**).

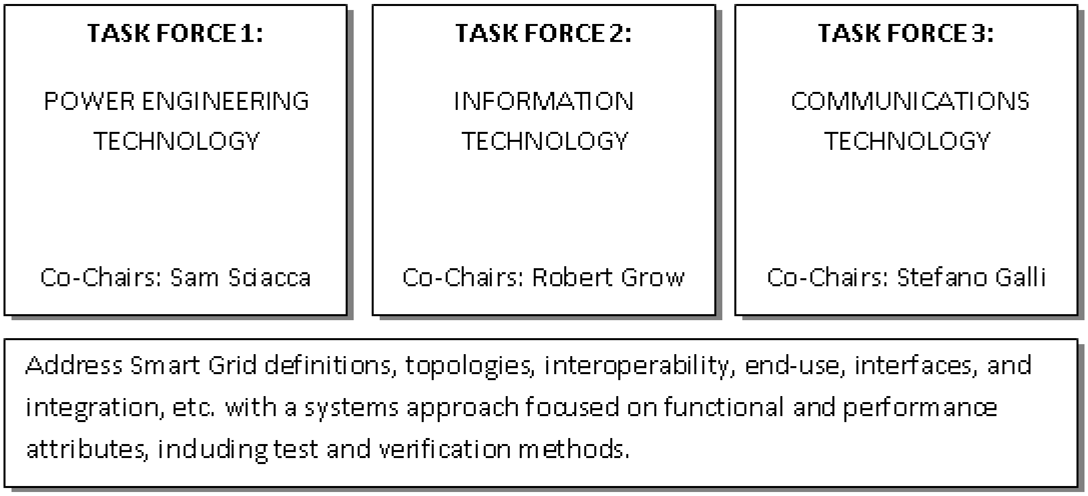


Figure 4. IEEE P2030 task force organization

The task force groups met at the initial IEEE SCC21 P2030 meeting in June 2009 and have subsequently been predominantly meeting via teleconferences and webinars. Prior to the second P2030 working group meeting held on October 27-29, 2009, a draft P2030 outline and timeline for completion was presented for consideration. On the first two days of the October P2030 meeting, each task force group met independently, and some in combined meetings. The third day of the October meeting was a full P2030 working group meeting to review task force progress and plans, discuss the draft P2030 development timeline and initial outline, and to introduce the writing group approach (Annex A in this paper includes the draft timeline and initial outline).

2. MOVING FORWARD

The IEEE 1547 and P2030 publications and development activities address various priority topics indentified in the NIST report [1] and in the workshops that led to that report. And for the future, IEEE 1547 and P2030 could readily address the NIST recommendations by either extensions of existing standards or new standard(s) projects. The scope and purpose of 1547 standards and P2030 are specifically aligned with a number of topics in the NIST reports, such as:

- Energy storage systems, e.g., for storage system specific requirements
- Distribution grid management standards requirements including communications
- Voltage regulation, grid support, etc.
- Technical management of distributed energy resources, e.g., in planned islands
- Static and mobile electric storage, including both small and large electric storage facilities
- Electric transportation and electric vehicles

As with all standards, the ultimate proof of success lies in adopting them, validating conformance to the specifications and requirements of the standards, and establishing that the standards indeed help the technology and stakeholders towards the intended use of the technology meeting the standard. At the National Renewable Energy Laboratory (NREL) there has been some testing of smart grid interoperability (**Figure 5**). However, it is paramount that conformance testing be similarly qualified to its set of applicable standards so that reciprocity among testing labs and uniform acceptance of conforming equipment and best practices is transparent.

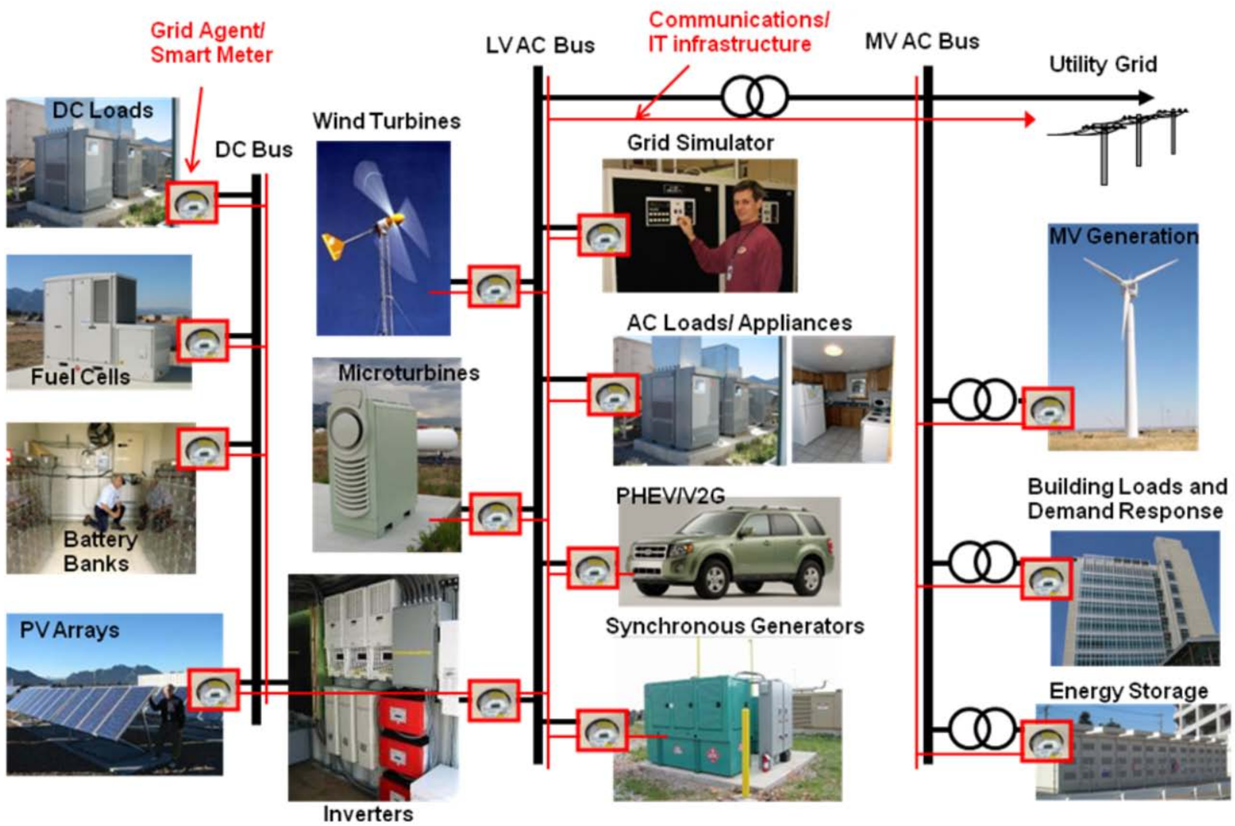


Figure 5. Example smart grid testing at NREL

The IEEE 1547 series of standards provide a model for IEEE P2030 project development. The P2030 standard will itself be a single document addressing smart grid interoperability. As experts in the standards arena know, there is never a single document that could address all standards issues associated with a "system of systems" technology area such as the smart grid. Building off existing standards and works in progress will help to accelerate standards coverage for the myriad of smart grid concerns. As an example, in the series of IEEE 1547, it appears that the IEEE Std P1547.4 (planned islands) document will provide guidance on many of the technical integration issues that would need to be addressed in a mature smart grid, including issues of penetration of distributed generators and electric storage systems, grid support, end-use operational support, and load management. However, the details for smart grid interoperability will need to be approached in a layered and evolutionary manner, building on successful experiences and learning from other experiences.

The mature smart grid will truly be a complex "system of systems" (**Figure 6**). To reach that maturity, it seems evident that technology will evolve at widely varying degrees of smartness. Establishing device interoperability must not overlook its deeper role of providing overall system smart grid interoperability.

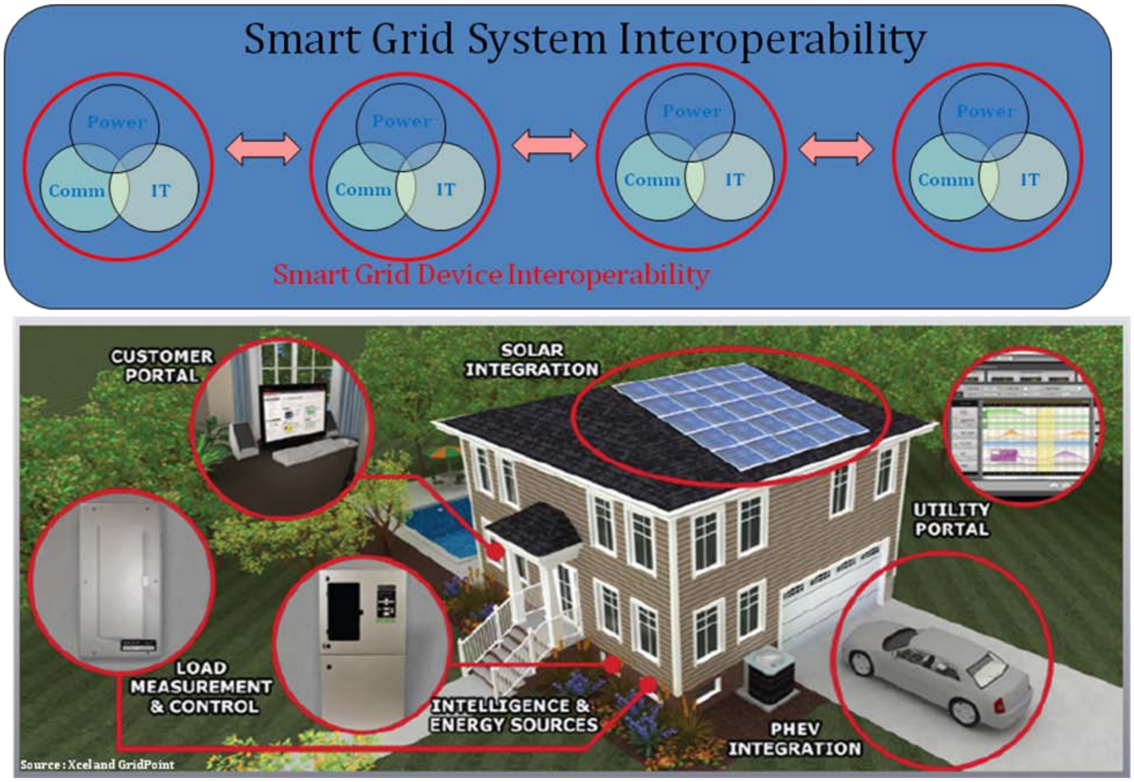


Figure 6. Smart grid (system of systems) interoperability

In closing, we want to acknowledge that both the IEEE 1547 interconnection standards and the IEEE P2030 standard development required significant undertakings from numerous volunteers. The time and resources of all individuals and organizations that participated are what has led to the success of the published IEEE 1547 standards development and their adoption. Similarly, the timely completion of the baseline P2030 standard will only see success based on the dedicated commitment by the individuals and organizations contributing to smart grid interoperability.

References

[1] NIST *Framework and Roadmap for Smart Grid Interoperability Standards Release 1.0 (Draft),* http://www.nist.gov/public_affairs/releases/smartgrid_interoperability.pdf

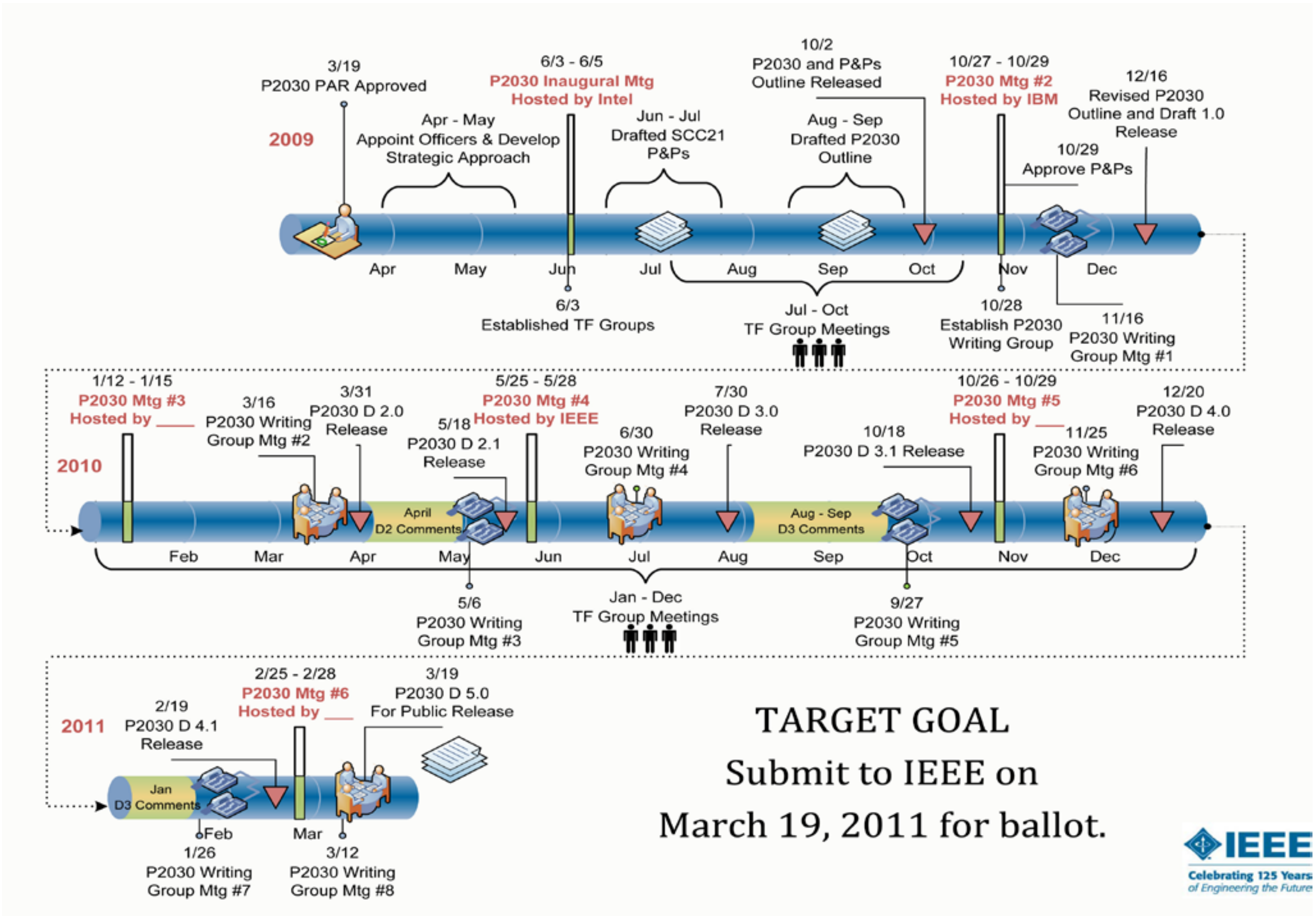
[2] IEEE P2030 Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads, http://grouper.ieee.org/groups/scc21/dr_shared/2030/

[3] 1547 Series of Standards, http://grouper.ieee.org/groups/scc21/dr_shared/

[4] IEEE Standards Coordinating Committee 21, http://grouper.ieee.org/groups/scc21/index.html

<u>Annex A: IEEE P2030 Development Approach</u>.

Annex A - Article 1. IEEE P2030 development timeline (draft Oct. 2009).



Annex A: Article 2 P2030 Initial Outline

P2030 Draft 1: Initial Outline – September 17, 2009

IEEE P2030 *Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation With the Electric Power System (EPS), and End-Use Applications and Loads*

1.0 Introduction.

1.1 Scope.

This document provides guidelines for smart grid interoperability. This guide provides a knowledge base addressing terminology, characteristics, functional performance and evaluation criteria, and the application of engineering principles for smart grid interoperability of the electric power system with end use applications and loads. The guide discusses alternate approaches to good practices for the smart grid.

1.2 Purpose.

This standard provides guidelines in understanding and defining smart grid interoperability of the electric power system with end-use applications and loads. Integration of energy technology and information and communications technology is necessary to achieve seamless operation for electric generation, delivery, and end-use benefits to permit two way power flow with communication and control. Interconnection and intra-facing frameworks and strategies with design definitions are addressed in this standard, providing guidance in expanding the current knowledge base. This expanded knowledge base is needed as a key element in grid architectural designs and operation to promote a more reliable and flexible electric power system.

1.3 Stakeholders.

The electricity delivery infrastructure smart grid primary stakeholders may be considered under the following classes: electric power system owners, planners and operators; information technology personnel; electricity consumers; equipment manufacturers; system developers; distributed energy resources personnel; integration and interconnection personnel; buildings industry; plug-in electric vehicles personnel; and, regulatory and government bodies.

1.4 Electricity Delivery Infrastructure Background.

1.4.1 Technical Aspects
1.4.2 Business Aspects
1.4.3 Regulatory Aspects

1.5 Document Overview.

2.0 References. (guidance from IEEE style manual)

3.0 Definitions.

Interoperability -
smart grid -

4.0 Smart Grid Background: Systems Engineering Approach

(Overview remarks. system of systems; hardware and software; systems engineering and component integration -- component and systems: requirements and specifications establishment, planning, designing, fabrication/installation{building}, commissioning, operating, maintaining, upgrading, and retiring; integration of power, information, and communications technologies; electricity end-use applications; loads; etc.)

5. Smart grid functional performance attributes and evaluation criteria.

6. Interoperability characteristics, design criteria, operations, and end-use applications

Systems approach (theory/concepts, methods and examples)

7. Interoperability configurations and topologies

Systems approach (theory/concepts, methods, and examples)

8. **Power systems intra-operability.**
   Systems approach (central, dispersed, and end-use applications)
9. **Information systems intra-operability.**
   Systems approach (central, dispersed, and end use applications)
10. **Communications system intra-operability**
    Systems approach (central, dispersed, and end-use)
11. **Electric power and delivery system integrated operation.**
    - Interoperability and two way power flow, communications, and control.
    - Autonomous Operation
    - Semi – Autonomous Operation
    - Interfaces, intra- faces, and interconnections
    - Etc

12. **Smart grid interoperability and legacy technologies relationships.**
13. Etc….

Annexes, e.g., Bibliography

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The IEEE American National Standards project P2030TM addressing smart grid interoperability and the IEEE 1547 series of standards addressing distributed resources interconnection with the grid have been identified in priority action plans in the Report to NIST on the Smart Grid Interoperability Standards Roadmap. This paper presents the status of the IEEE P2030 development, the IEEE 1547 series of standards publications and drafts, and provides insight on systems integration and grid infrastructure. The P2030 and 1547 series of standards are sponsored by IEEE Standards Coordinating Committee 21.

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IEEE; NREL; interconnection; smart grid; P2030; P1547; SCC21; distributed resources; interoperability; codes and standards

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