FUNDAMENTAL CHANGES TO THE ELECTRIC POWER SYSTEM POST-2018

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This article gives a glimpse of some significant changes that will occur in electric power system testing and commissioning after 2018. We will review the drivers of the oncoming change, some common themes emerging in standards and requirements, and some key topics such as interoperability, interconnection, and commissioning.

DRIVERS OF CHANGE

The first changes toward the smart grid occurred in the 2000s when the Energy Independence and Security Act of 2007 (EISA) made it the policy of the United States to modernize the nation's electricity transmission and distribution system to create a smart electric grid. IEEE was cited as a standards development organization partner to the National Institute of Standards and Technology (NIST) as the lead to coordinate a framework and roadmap for Smart Grid Interoperability standards and protocols, specifically expanding the IEEE 1547 and 2030 series.

The publication in January 2010 of the "NIST Framework and Roadmap for Smart Grid Interoperability Standards" documented progress made up to that time and laid out a conceptual framework of domains describing the electric power system (Figure 1).

Since that time, extensive efforts to revise and amend standards in multiple domains have occurred, most notably transmission, distribution, and non-bulk generation. Commissioning process and interoperability are the most significant existing gaps.

COMMON THEMES OF STANDARDS CHANGE

Commissioning

Proper commissioning uncovers quality problems with critical primary or backup systems. Once placed under expected power and load conditions, these systems can fail because the equipment was defective, damaged in transit, or not installed properly. You may be unaware of an issue until the equipment is tested under a load.

Commissioning provides a systematic way to confirm proper performance levels and identify any problems before the facility is brought on-line. In general, commissioning should be viewed as a process and should accompany all project phases. The expected requirements for equipment service are driven by the authorities having jurisdiction over a project (regulations), the electric power system operator, and the equipment manufacturers. More specificity on verification requirements for compliance may not always be a component-level test, and there is a renewed emphasis on comprehensive system testing for final verification. Commissioning may also include other verification methods such as power systems simulation and modeling, the design review (paper study), and a field evaluation that verifies critical component settings and electrical configuration. Most problems are caught during commissioning, not during subsystem or component tests.

Interoperability

Smart Grid has been defined as the integration of power, communications, and information technologies for an improved electric power infrastructure serving loads while providing for an ongoing evolution of end-use applications. An important element of the smart grid is interoperability or the capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively (Std 2030-2011). Interoperability requires the coordination of three different perspectives: power, communication, and information (Figure 2).

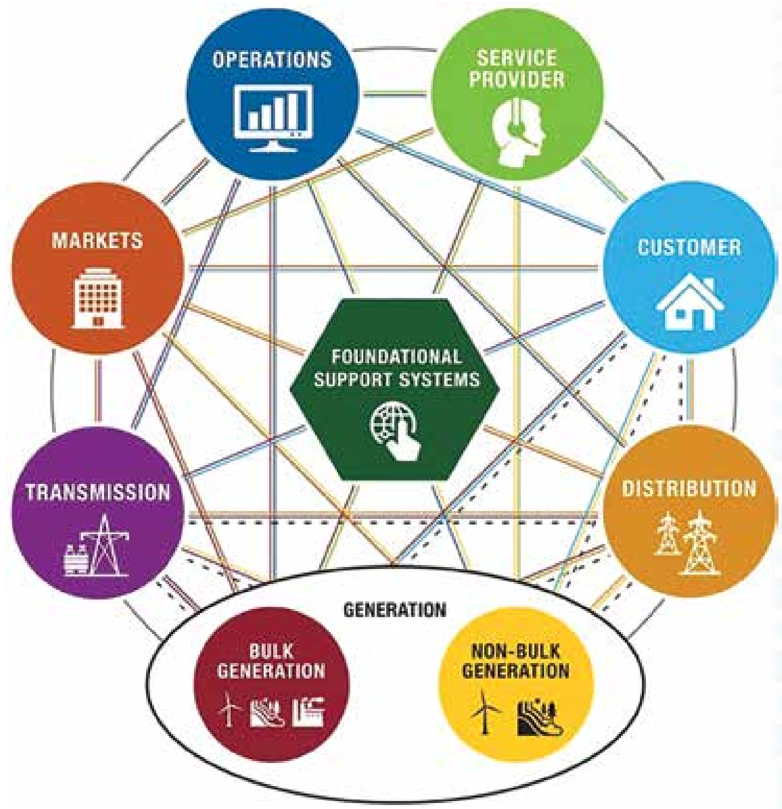


Figure 1: *NIST Smart Grid Roadmap Domains*

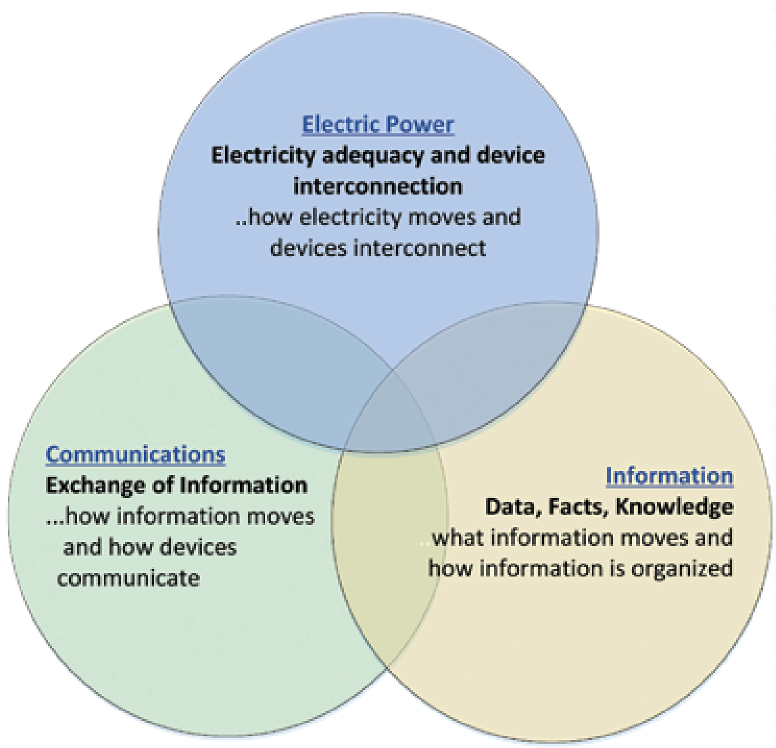


Figure 2: *Smart Grid Perspectives*

Embedding interoperability requirements into standards will occur at an increased rate as working groups comprehend future markets, as well as communication and control needs.

Interconnection

Interconnection requirements have added specific interoperability capabilities in addition to several new technical requirements. These changes create a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). It provides requirements relevant to interconnection and interoperability performance, operation, testing, safety, maintenance, and security considerations.

These requirements apply to interconnection systems, which are the collection of all interconnection equipment and functions, taken as a group, used to interconnect DER to an area Electric Power System (electric utility distribution) (Figure 3).

RECENT COMMISSIONING STANDARDS DEVELOPMENT

Distribution

The following standards have been developed to embed commissioning and interoperability into utility-scale systems:

- EPRI Guide for Energy Storage System Commissioning and Testing
- IEEE PSRC I25, Draft Best Practices in (Substation) Commissioning Report - 2016
- IEEE C37.233, Substation Protection Testing Reaffirmation - 2017

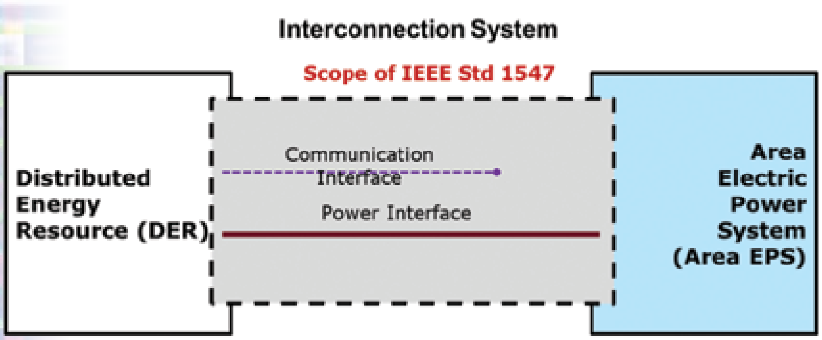


Figure 3: *Diagram of Interconnection System*

Interconnection

The following standards have been developed to improve the interoperability of the critical interconnection process:

- Interconnection: IEEE 1547 Standard, IEEE 1547.1 Test Requirements, and UL 1741 Inverters
- Smart Grid Standards: IEEE 2030 Series for Interoperability and Cybersecurity
- Energy Storage/Renewable Integration

IMPLICATIONS FOR STANDARD CHANGES

Commissioning

Most likely, the commissioning guides mentioned earlier will result in endorsement of best practices to ensure commissioning is contemplated at all phases of a protection system project. Comprehensive commissioning is an emerging best practice and should be considered when evaluating project risk. Once this becomes a best practice, commissioning without comprehending minimum thresholds for all sensor inputs can be viewed as increasing the risk or increasing liability for the project owner.

Generally, the best practices for commissioning across multiple electric power industries include:

- Elements of the commissioning process take place in all phases of project execution. The commissioning guidelines reference best practices from relevant equipment or industries.
- Set clearly defined roles and responsibilities before the project starts and reaffirm at each project phase.
- Require a clearly defined and effective comprehensive commissioning test for the overall commissioning process.
- Plan the commissioning verification method and test early in a project's planning phase, and execute it successfully prior to system turn-over.

- Subsystems type, factory acceptance test (FAT), and/or field testing are on the critical path to successful commissioning. These additional tests should also be identified, planned for, and incorporated in overall system commissioning planning and execution.

- Contingency plans should be included for special project circumstances that could affect timing of the commissioning. This could include alternative methods for verifying performance in the event critical resources are not available during the originally scheduled time frame, weather delays, or inadequate consistency in the load profile used during commissioning.

Interoperability

This area is becoming pervasive as a requirement to most domains in the electric power system. The importance of interoperability is driven by the eventual need for modular plug-and-play solutions.

The specific communication requirements are determined by the area EPS operator, subject to regulatory or contractual arrangements. The information to be exchanged falls into four categories:

1. **Nameplate data** describes the as-built characteristics of the DER.

2. **Basic settings** describe the present capacity and ability of the DER to perform functions.

3. **Monitoring** describes the present operating conditions of the DER.

4. **Management** is used to update functional and mode settings for the DER.

The DER should verify an interface capable of communicating to support the information exchange requirements specified in this standard for all applicable functions supported in the DER. Even though these may not be used in a specific application, the system capability needs to be available.

Interconnection

The revised interconnection standard anticipated for approval in 2017 includes many new technical requirements. These requirements will apply to all distributed energy resources, both inverter-based and synchronous generator-based. No upper size limit is stated in the requirements. Any system that can parallel with the electric power system for greater than 100 milliseconds may have to verify performance to these two technical requirements. Although they appear more complex, when viewed, the new requirements should simplify the execution of distributed energy resources when connecting to the electric power system.

Requirements Determination

When a DER request is received, first determine the reference point for technical requirements. Most large and complex systems must meet the requirements at the point of common coupling (PCC), which is the physical interface between the utility electric power system and the local (or customer's) electric power system. If the generation is small (or small and embedded in a customer's facility), the requirements must be met at the point of connection, which generally means that type-tested components and a field inspection may be all that's required.

The next requirements will have to be answered by the electric power system operator (electric utility) and are unique to that location or circuit. The determination on the required DER capabilities for using reactive power to regulate the voltage will be made. Additionally, the electric utility will determine the category of requirements for the DER response to abnormal conditions in the electric power system it connects to.

NEW REQUIREMENTS

Some of the new requirements likely to be in the final document include:

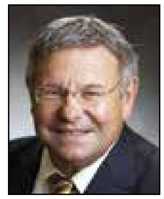
- **Verification requirements may be specifically called out for each scenario described previously.** This means less ambiguity on how to verify the system's performance and which tests to complete.

- **An installation evaluation clause may include inspection for proper installation**

and settings and that all system components are type-tested to the proper standard. Additionally, verification needs to demonstrate that the installed system meets the design agreed to by the electric power system operator. Specific areas of concern could be inverter settings, grounding, and communications. This may also include submission of fault current data for the system's primary DER device.

- **Some tests may need verification in the field, even though a type test provides full functionality.** For example, reactive power, ride-through (V and F), and power quality tests may be required when other support systems such as voltage regulation performance need to be tested as a complete installed system.
- **Recurring verification tests should be considered as systems evolve** with new software, firmware, and hardware.

The revised standards include much more specificity in the system configurations encountered in the field. Specific references to micro grids and energy storage are in the technical requirements. This should lead to less ambiguity when installing and commissioning these types of systems.



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