ELECTRIC POWER RESEARCH INSTITUTE

IEEE Standard 1547™— Communications and Interoperability

New Requirements Mandate Open Communications Interface and Interoperability for Distributed Energy Resources

The integration of distributed energy resources (DERs) into the electric power grid creates technical challenges at both bulk power system and distribution system levels. Addressing these challenges in planning and operation requires innovative approaches and collaboration across multiple stakeholders in the power industry. As a major milestone, a new reference for interconnection and interoperability requirements is currently under development to specify future DER capabilities – IEEE Standard 1547 (abbreviated 'IEEE 1547'). But even when these new DER capabilities become available, their full utilization for the benefit of the grid may require new or updated utility or third-party infrastructure.

This paper looks at one aspect of the new IEEE 1547—the communications interface and interoperability requirements for DERs. It provides an overview of the proposed revisions to the IEEE 1547 standard, considerations for future utility or third-party communication network rollouts, and insights on how this could impact control across transmission & distribution (T&D) interfaces.

WHAT IS IEEE 1547?

IEEE Standard 1547™ [1] is the de-facto basis for interconnection standards for DER in the United States. The standard was first published in 2003 as a voluntary industry standard for interconnecting distributed energy resources with electric power systems (EPSs). It was developed with a focus on distribution system safety and power quality, assuming low penetration levels and treating all DER technologies in the same way (technology-neutrality). The standard was amended in 2014 to eliminate prohibitions of advanced DER grid support such as steady-state voltage control and disturbance ride-through. The full revision of IEEE 1547 started in 2014. It specifies new DER functional and communication requirements and is aimed at supporting grid codes that mandate interoperability. IEEE 1547 is currently in the balloting stage and may be published later this year. A general overview on the new standard can be found in "Status of Revision of IEEE Std 1547 and 1547.1" [2].

WHAT ARE THE COMMUNICATION AND CONTROL REQUIREMENTS IN IEEE 1547?

The structural transformation of today's power system towards an integrated grid with high connectivity requires interoperability and communication capability from DERs. The industry has learned from countries like Germany where no standardized communication requirements were specified, preventing the realization of interoperability across inverters. The revision of IEEE 1547 provided for a historic opportunity to enable a future where power and information exchange are integrated and interoperable. While many DER may already have proprietary communication interfaces, only a standardized interface can make mass-integration of diverse brands practical. In addition, standardized interfaces at the device/plant level are necessary to ensure that DER remain manageable when vendors or third-party aggregator discontinue support for particular products and services or go out of business altogether.

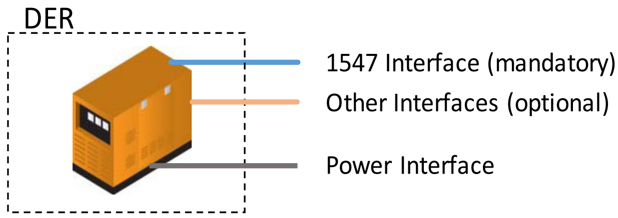

Figure 1: Power and communication interfaces required by the proposed IEEE Std 1547™.

Hence, the proposed IEEE 1547 requires a standardized local communication interface at the device/plant level for all distributed energy resources, regardless of connection voltage or nameplate capacity, see Figure 1. This universal requirement is aimed at enabling monitoring, management, and information exchange with the DER.

WHAT DOES IEEE 1547 MANDATE FOR COMMUNICATION AND INTEROPERABILITY OF DER?

IEEE 1547 identifies a set of allowed protocols and specifies the functionality that must be supported through these protocols. This standardizes the DER interface and supports interoperability by limiting options to a small number of protocols.

WHAT FUNCTIONALITY IS SUPPORTED VIA THE IEEE 1547 COMMUNICATION INTERFACE?

IEEE 1547 defines the grid-supportive functionality an inverter must support, such as control of reactive power and ride-through capabilities. The full set of required functions is listed in Table 1. It is the role of communication standards, as discussed below, to support these functional needs, but communication standards should not be viewed as creating functional requirements.

Table 1 Mandated functions in IEEE 1547 and their corresponding reference in EPRI's Common Functions for Smart Inverters – 4th Edition [3].

Mandated Communicable Functions in IEEE 1547	Corresponding Function in Common Functions for Smarter Inverters – 4th Edition. [3]
Nameplate Data	Ch 4: Basic Device Settings and Limits
Basic Settings	Ch 4: Basic Device Settings and Limits
Monitoring	Ch 26: Status Monitoring Points
Adjustable constant power factor mode parameters	Ch 10: Fixed Power Factor Function
Voltage - reactive power mode parameters	Ch 11: Volt-VAR Function
Active power – reactive power mode parameters	Ch 24: Watt-Var Function
Adjustable constant reactive power mode parameters	Ch 11: Volt-VAR Function (horizontal curve)
Voltage – active power mode parameters	Ch 12: Volt-Watt Function
Voltage trip parameters	Ch 16: Low/High Voltage Ride-Through Function
Frequency trip parameters	Ch 17: Low/High Frequency Ride-Through Function
Frequency droop parameters	Ch 13: Frequency-Watt Function (modified[1])
Enter service parameters	To be addressed in the 5th edition
Permit service setting	To be addressed in the 5th edition
Limit Maximum Active Power	Ch 6: Limit DER Power Output Function

[1] The Frequency Droop function in IEEE 1547 is slightly different from the Frequency-Watt function (Ch 13) in [3] and the new functional needs are being contributed to the IEC to maintain consistency.

These IEEE 1547 functions and parameters are based on the Common Functions for Smart Inverters [3] which are described and codified in the IEC 61850-7-420 and 61850-7-520 standards. These functions have served as the basis for grid codes worldwide, resulting in strong alignment of functional requirements internationally. During the development of IEEE 1547, some new functional needs were identified and are being contributed to the IEC to maintain consistency.

In the IEEE 1547, certain function parameters are defined to be adjustable and/or monitorable and these definitions translate into specific communication requirements. The standard establishes a minimum set of requirements, and it is understood that manufacturers may elect to support additional functions and/or additional parameters within the functions and still comply with IEEE 1547.

WHICH PROTOCOLS ARE SPECIFIED IN IEEE 1547?

IEEE 1547 requires that the communication interface to the DER support at least one of a specified list of protocols. Three options are provided:

- IEEE Std. 1815 – (DNP3)
- IEEE Std. 2030.5
- SunSpec Modbus

Allowing multiple options is not optimal because it leaves both utilities and manufacturers with uncertainty about what to use and what to expect. However, due to differences in stakeholder preferences and different needs for various DER sizes, three were allowed. At the time of the IEEE 1547 development, the three protocols listed were the only known encodings that supported the Common Functions identified in Table 1, hence their selection.

- IEEE Std. 1815 (DNP3) (AN 2013-001) DNP3 is used almost universally in North America for utility SCADA networks to control distribution monitoring and control devices and substation equipment. DNP application note AN 2013-001 provides a specific point list to achieve interoperability of solar and storage DER. Accordingly, DNP3 is of particular interest to stakeholders, particularly for commercial, industrial and utility-scale DER and has been implemented in a number of commercial DER devices.
- IEEE Std. 2030.5 IEEE 2030.5 was identified for use with DER in the recently updated California Rule 21. It was originally developed by the ZigBee Alliance as a HAN protocol. It is unclear whether California applications will use it in the DER or in the networks terminating at a gateway device at the DER. IEEE 2030.5 has not been implemented natively in a DER at this time.
- SunSpec Modbus is a specific Modbus point mapping that is managed by the SunSpec Alliance for communicating with smart inverters. Modbus has been adopted almost universally by DER manufacturers and there is broad support among these manufacturers to adopt the SunSpec point mapping. Modbus does not include application layer cybersecurity, but some utilities are using it over VPN or other secured connections (e.g. TLS) or locally between inverters and network gateways.

As noted previously, IEEE 1547 requires that manufacturers support at least one of these protocols, but allows that they could choose to support more than one. The standard states that "The protocol to be utilized may be specified by the Area EPS Operator. Additional protocols, including proprietary protocols, may be allowed under mutual agreement between Area EPS Operator and DER Operator." These additional statements point to a potential difference between satisfying the IEEE (in terms of certification and compliance) and satisfying the requirements of regional interconnection codes. They call attention to the fact that as an IEEE standard, IEEE 1547 has no legal authority unless and until referenced in local codes.

WHERE IN THE COMMUNICATION ARCHITECTURE DOES IEEE 1547 APPLY?

Figure 2 is a communication architectural sketch adapted from the IEEE 1547 standard. It supports normative text that states that the communication requirements apply at the DER. This means that an open, accessible communication interface must be provided locally, at the DER location in the field. This location is important architecturally and is the key to sustainable and scalable integration of DER over time. A recent EPRI whitepaper[1] highlighted this architectural principle and explained the reasons that open local interfaces are prudent.

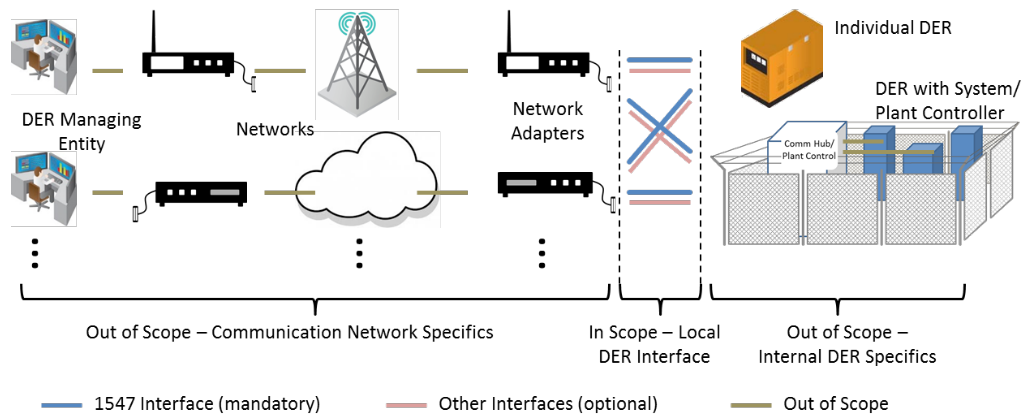

Figure 2: Point of Applicability of the IEEE Std 1547™ Communication Requirement

Figure 2 also identifies elements of the communication architecture that are out of scope, specifically:

- Protocols within a communication network are out of scope. Protocols are often purpose-designed for a given network type. For example, low bandwidth networks (like PLC), or those with a cost per data volume may use very efficient, compact protocols. On the other hand, protocols made for the Internet are often designed to be human-readable (e.g., XML) and transportable. Networks may internally use standard or proprietary languages, and IEEE 1547 has no bearing on this.
- Protocols within DER and DER plants are out of scope. Whether the DER is a single unitary device like a residential inverter or a plant made up of several devices, the IEEE 1547 has no bearing on the messages and protocols used inside these DER.

By focusing on the local interface to the DER, IEEE 1574 defines a clear point of demarcation at a strategic place in the overall architecture. It achieves communication interoperability at a point where ownership changes hands (where utility-selected networks meet consumer-selected DERs) and where short-life communication technologies meet long-life distributed resources.

Note: The point within the overall communication architecture where the IEEE 1547 applies is different than the point at which the California Rule 21 and California Smart Inverter Profile (CSIP) communication requirements apply. Specifically, the California requirements are defined to apply to the protocols within the networks, from the DER managing entity to the network adapters or gateways (the out-of-scope area to the left in Figure 2) and the local interfaces to the inverter are not specified. In this sense, the IEEE 1547 and California communication requirements are complementary.

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[1] The Value of Direct Access to Connected Devices. EPRI, Palo Alto, CA: 2016. 3002007825

HOW IS CYBER-SECURITY ADDRESSED?

Through the modular approach taken, IEEE 1547 enables, but does not directly specify, cyber security. Cyber security is expected to be addressed in the DER communication networks (which are out of scope in IEEE 1547) and in the interest of simplicity, is not mandated at the local DER interface. The basis for this approach is that the risk associated with onsite manipulation of an individual DER through its communication interface is only equivalent to the risk that exists anyway (e.g. through the keypad or disconnect switches) when physical access is gained. Because only one DER is involved in such cases, impact on power quality and grid reliability is limited.

An attack on multiple DERs via a compromised DER managing network, on the other hand, could have an aggregated effect with larger consequences for the power system and its customers. This concern is not created by the IEEE 1547 requirements, but already exists given that some DER aggregators and vendors have connectivity to large numbers of devices. To address these concerns, new standards and codes could be created that would establish requirements for DER managing networks, including reliability, coverage, and all aspects of security.

The decoupling of communication network requirements from the local DER interface requirements specified in IEEE 1547 provides flexibility for utilities and aggregators to integrate diverse DER systems using cohesive networks and up-to-date cyber-security techniques. This is a fundamental architectural need as DER use cases evolve over time, cyber security gaps are patched, and new technologies emerge. The "Network Adapters" shown in Figure 2 should be acknowledged and part of integration plans. They are particularly important because they provide the DER managing entity with a communication client that can be remotely managed and updated. Without such adapters, it would not be possible to patch functional or security flaws in the network because the firmware embedded in DER is unique to each manufacturer. In other words, network adapters should not be an integral part of the DER itself.

WHAT DO UTILITIES NEED TO DO ONCE IEEE 1547 IS RATIFIED?

The first step for utilities and governing bodies like public utility commissions (PUCs)[1] is to decide whether and to what extent IEEE 1547 will be referenced in their local codes. IEEE 1547 has no authority until it is referenced by a state or federal law. It is important to recognize that a mandate for open standard communication capability of DER may come well in advance of a decision to deploy a communication network and begin using the DER's capabilities. The requirement for open communication is simply to ensure that the integration of installed DER is possible and practical in the future when DER levels rise to the point where management is needed. Communication networks are typically not deployed until they are necessary.

When a utility decides to begin actively monitoring and managing DER, adequate communications infrastructure must be put in place, either by the utility or a third-party aggregator. Deployment timeframes and technology options may differ from one region to the next. Utilities will do four things to make use of the connected DER defined in IEEE 1547:

1. **Decide which protocol to require at the local DER interface.** This requirement should be determined and documented in grid codes immediately so that no more unmanageable DER are connected to the power system and capability begins to accumulate to support future needs.

   Key factors to consider at the DER interface:

   - Keep it simple. Interoperability is the reciprocal of complexity. At the local DER interface, many DER brands and types will be connected to many communication networks and systems.
   - The firmware inside DER is not manageable by the utility so provisions are needed for cyber security in network adapters so that systems can be patched and updated over time. Operate under the assumption that the companies that made the DER are no longer in business or no longer supporting the product.

2. **Update DER interconnection agreements and product requests.** Utilities will modify interconnection agreements and request for proposals (RFPs) to call-out the protocols determined in step 1.

[1] The Frequency Droop function in IEEE 1547 is slightly different from the Frequency-Watt function (Ch 13) in [3] and the new functional needs are being contributed to the IEC to maintain consistency.

3. **Determine when it is time to integrate DER via communication system.** The time when it is necessary to actively monitor and manage DER will differ by utility due to a range of factors.

   Factors to consider when making this decision:

   - The penetration level of DER in the service territory. Low levels of DER might be accommodated by fixed settings or occasional reconfiguration that is handled onsite.
   - Distribution circuit characteristics.
   - Differentiation by DER size/scale. It may be possible to connect only to larger DER for a time, deferring the cost of communication systems that reach all devices.
   - The availability and suitability of existing communication systems that might be leveraged for DER integration.

4. **Select communication networks and architecture.** Utilities will design the architecture and choose the communication technologies of their DER networks. At the present time, diverse approaches are being considered by utilities worldwide. Some are centralized with large numbers of DER under the management of an enterprise application. Others are decentralized with intelligence at the system edge and aggregation occurring in multiple levels. Approaches also vary regarding network ownership, with some utilities investigating what can be achieved through vendor or third-party aggregators and others using dedicated utility networks. Ultimately, the functional and performance requirements of the communication system will vary by use case. For example, some scenarios may require only occasional adjustment of DER settings whereas others may require frequent low-latency interactions.

   As part of this architecture design, utilities and/or their partners will also select the communication technologies and associated protocols of their DER networks. As noted previously, it is useful to recognize that these networks do not need to exist when grid codes begin requiring open, interoperable DER. It is also useful to recognize that communication technologies and architectures can evolve as needs change and that this evolution is made practical by the standard interface that IEEE 1547 provides at the DER.

These steps are listed in order in which they naturally occur – a utility cannot control DER without the communication infrastructure to support it. This allows utilities and manufacturers to work in parallel and make the best use of time.

HOW DOES IEEE 1547 SUPPORT CONTROL ACROSS THE TRANSMISSION & DISTRIBUTION INTERFACE?

Once a DER communication infrastructure is available, agreements may be needed to specify how the managing entities will control the DER across the T&D interface. These rules will likely be specific to the regulatory environment which may focus on different objectives. Sharing of experiences gained in Europe [4] and the U.S. [5] with expanding distribution management systems (DMS) to include DER (DERMS) and to then integrate DER group management [6] into bulk power system SCADA and control is useful. A hierarchical architecture is recommended, in which DER are integrated with distribution management systems (DMS) and DER management systems (DERMS) and these systems in turn integrated with bulk-system operations. Conflicting interests of bulk system operators and distribution operators may arise and continued collaborative research is needed to determine the optimal prioritization of commands. Bridging the gap at the T&D interface will be as much of a technological challenge as it will be a people challenge: bringing together distribution and bulk system operators and planners; utilities, DER and communication device vendors; power system and communications engineers.

CONCLUSIONS

The new interconnection and interoperability requirements for DERs specified in the proposed IEEE 1547 standard provide robust technical capabilities for integrating large quantities of DERs into power system planning and operation without compromising system reliability. The intentional architectural decoupling of 1547-related DER communication requirements specified in IEEE 1547 from any DER managing network related requirements, including those for cyber security, provides flexibility for utilities and aggregators to secure DER systems using up-to-date cyber-security techniques.

The next steps to fully utilize these new 1547-compliant DER capabilities includes collaborative learning to share experience from their early application across utilities, state regulators, and other stakeholders as well as deployment of adequate utility or third-party communication infrastructure. Thought-leadership and commitment across multiple stakeholders in the power industry is needed as the exciting transition of the power system towards an integrated grid has just begun.

REFERENCES

[1] Initial Sponsor-Ballot Draft Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems, IEEE P1547/D6.7.2, 2017.

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[3] Common Functions for Smart Inverters: 4th Edition. EPRI, Palo Alto, CA: 2016. 3002008217.

[4] EDSO, ENTSO-E, EURELECTRIC, and GEODE, "TSO-DSO Data Management Report," Jul. 2016.

[5] NYISO, "Distributed Energy Resources Roadmap for New York's Wholesale Electricity Markets," NYISO, 2017.

[6] Common Functions for DER Group Management, Third Edition. EPRI, Palo Alto, CA: 2016. 3002008215

IEEE 1547 website to learn more and voice feedback: http://grouper.ieee.org/groups/scc21/1547_revision/1547revision_logistics.html

For an overview on the new IEEE Std 1547 refer to the EPRI Fact Sheet (3002011346).

For additional EPRI commentary on the IEEE 1547 revision process, see previous PV Market Updates (3002009939, 3002008210, 3002005779, 3002005778, 3002005777, 3002005776).

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