

# IEEE 1547 – New Interconnection Requirements for Distributed Energy Resources *Fact Sheet*

## KEY POINTS

- IEEE P1547 has entered the balloting state. The new requirements can be considered robust, safe, and reliable for most cases. Additional risk assessment may be needed in limited cases. Ongoing and future EPRI research is investigating these cases.
- Balloters should carefully review the sponsor-ballot Draft 6.7.2 and submit comments for the ballot resolution. The standards committee review process will ensure that all comments submitted through the balloting process will be considered, independent of whether they are associated with “approve” or “disapprove” votes.
- Utilities may have to adapt the new requirements to their particular grid conditions to fully exploit the new standard’s capabilities. EPRI is offering two supplemental projects, one for utility-specific Application of IEEE 1547 and another one for Evolving DER Connection Processes.
- Distributed generation and energy storage systems certified for compliance with the revised IEEE 1547 may become available as early as the 2019-2020 timeframe.

## WHAT IS IEEE 1547?

Over the past several years, the primary interconnection standard for distributed energy resources (DER) in North America,<sup>1</sup> IEEE Std 1547™ (abbreviated ‘IEEE 1547’ throughout this article), has been under revision. Originally, developed in 2003 assuming a low penetration of DER, the voluntary standard has been broadly referenced in the U.S. to specify grid-connected DER capabilities and performance. Technology and economic advances, particularly within the distributed photovoltaics (PV) segment, have, however, led to rising cases of high grid penetration levels and the need for updating the IEEE 1547 standard.

Figure 1 illustrates that manner in which the standard has been referenced in individual utility generator connection agreements, state interconnection rules, national mandates, and certification tests. The standard’s primary objective is to specify and *harmonize* interconnection requirements for DER.

As a first step, an amendment to IEEE 1547™-2003 (known as IEEE Std 1547a™-2014) was adopted in May 2014 that removed restrictions against DER from actively participating in grid voltage regulation. It *allows* broader inverter support (“smart inverter”) and rotating machine support (“field and governor control”) functions, such as steady-state voltage control and disturbance ride-through. But it *does not require, nor specify*, grid support along the lines of “grid codes” or “shall” requirements.

Building on the broad flexibility the IEEE 1547a amendment provides to system operators for utilizing DER’s grid supportive func-

<sup>1</sup> In 1547-jargon, DERs represent any sources of electric power that are not directly connected to a bulk power system, including distributed generators and energy storage technologies.

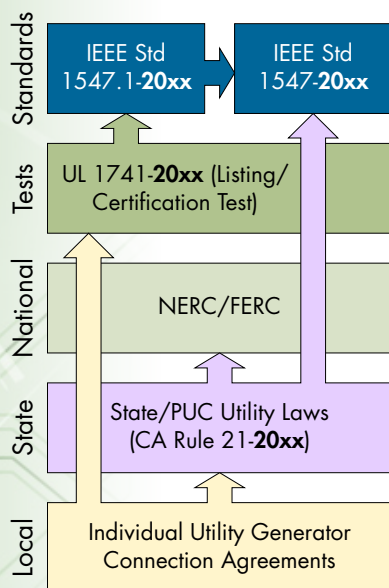


Figure 1. Context of IEEE 1547

tions (“may” requirements), revisions to IEEE 1547 now aim to specify further details to manufacturers, utilities, and testing laboratories about the performance of these functions, their default settings, level of interoperability, and range of adjustability. The charge of the Update Committee for IEEE 1547 was to help ensure that an eventual *common* standard can be both effective and actionable in interconnecting next generation DER (i.e., its “smart” functions) in ways that are beneficial to the power system. To this end, efforts to further revise IEEE 1547 have considered the special jurisdictional requirements for advanced grid support for DER in California and Hawaii.<sup>2</sup>

EPRI participates and provides technical inputs to IEEE 1547 standards-making process. This process brings together a diverse range of stakeholders – including DER manufacturers, system integrators, bulk system operators, power distributors, and state and federal regulators – to obtain the 1547 Update Committee’s consensus around appropriate grid support functions for both DER with rotating machines and DER with inverters. As part of this effort, EPRI has actively facilitated several sub-working groups and WG meetings, providing technical support and analysis, and sharing results of specific studies, testing, modeling and simulation to help inform the revision process.

At this writing, the standards revision process has reached the balloting stage, and is nearing its conclusion. All industry stakeholders, including distribution and transmission planners and operators that have joined the IEEE P1547 balloting pool by May 12, 2017, now have the opportunity to vote and submit comments to the IEEE Standards Association through June 18, 2017, and potentially progress the standard’s official publication by later this year. For those who have not joined the balloting pool, the draft standard is available for purchase and public review through July 19, 2017, at <http://publicreview.standards.ieee.org>.

What follows is a summary of the proposed new requirements, their potential impact on T&D planners and operators, and a timeframe for their adoption in state jurisdictions. In addition, procedural next steps in the revision process and related EPRI research are described. Note that EPRI is offering webcasts related to changes and two new supplemental projects, one for the application of the new IEEE 1547 and another one for evolving DER connection processes.

## WHAT ARE PROPOSED NEW REQUIREMENTS?

At a high level, the revision effort introduces four key elements, as shown in Figure 2. It expands the scope of the IEEE 1547 standard by considering distribution system issues as well as bulk system aspects such as ride-through requirements. The latter may be needed to prevent widespread voltage or frequency tripping of DER that can negatively impact bulk system reliability when interconnection-wide DER penetration levels reach a significant level. The revision also extends requirements from the interconnection system to the whole DER. That means, for example, DER auxiliary equipment will have to be capable

- ◆ The objective is to specify and *harmonize* interconnection requirements for distributed energy resources.
- ◆ IEEE 1547 is a *voluntary* industry standard; Authorities Governing Interconnection Requirements (AGIR) may adopt it in legislation, e.g., CA Rule 21 may refer to IEEE 1547 in future.
- ◆ Individual utility generator connection agreements may refer to safety standards such as UL 1741, which in turn may refer to IEEE 1547.1 in future.
- ◆ Federal and state interconnection procedures may give privilege (fast track) to IEEE 1547/.1-compliant/tested DER applications.
- ◆ The revised IEEE 1547 is aligned with NERC and FERC bulk system reliability standards.

<sup>2</sup> To date, advanced grid support requirements for DER are mandatory only in California and Hawaii.

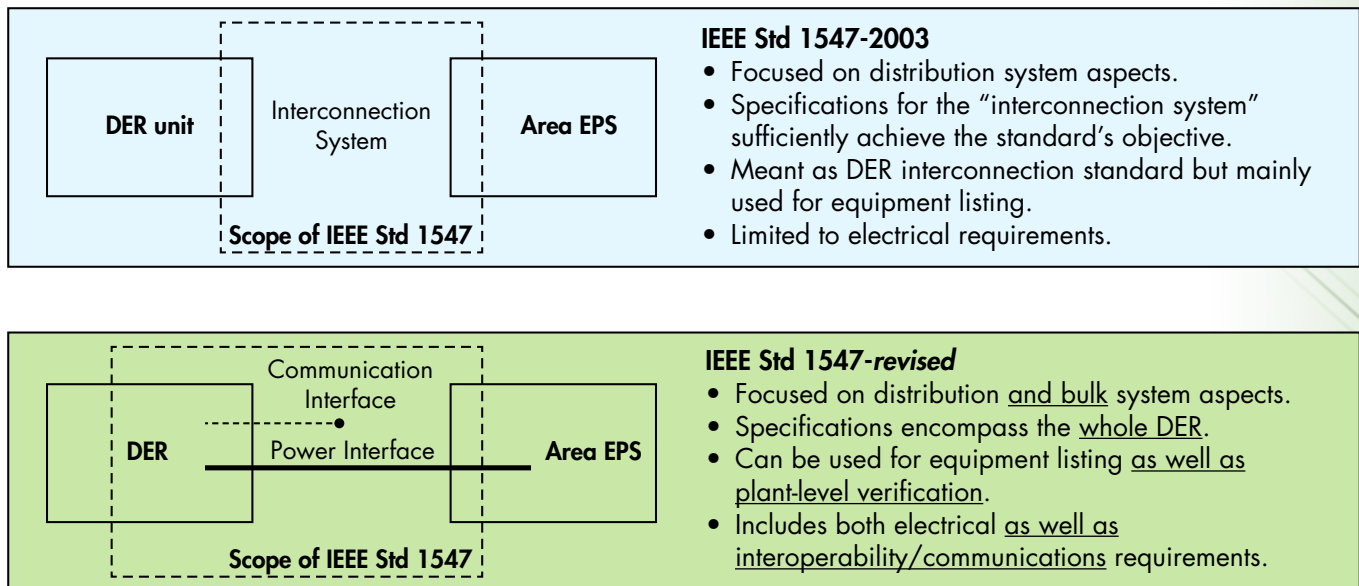


Figure 2. Changes in the scope of IEEE 1547

to withstand the specified voltage and frequency disturbances. The revised standard will further not be limited to individual equipment listing anymore but can also be used for plant-level verification. And finally, the revision specifies a mandatory, standardized, and open DER communication interface in addition to the electrical performance of the DER at its electrical connection point. Once communications networks are deployed, utilities or aggregators can communicate with this interface to monitor, control, and exchange information with DER.

More specifically, the new DER capability requirements include specifications for:

- ◆ Reactive power capability
- ◆ Regulating the DER's reactive power exchange to support voltage
- ◆ Regulating the DER's active power exchange to support frequency
- ◆ Riding through abnormal voltage and frequency conditions to maintain bulk system stability, including post-fault power restoration time performance, rate-of-change-of-frequency, as well as phase angle jump ride-through.
- ◆ Wide ranges of adjustability for DER control and trip settings, including default values
- ◆ Detecting open-phase conditions
- ◆ Power quality requirements
- ◆ Specifying the priority of DER functions
- ◆ Specifying minimum measurement accuracy
- ◆ Providing a standardized non-proprietary communication interface
- ◆ Responding to disabling permit service settings (emergency shut-down)
- ◆ Responding to active power limit set points (active power curtailment)
- ◆ Performance of DER connected to an intentional island that includes part of the utility grid
- ◆ A new concept for testing and verification of composite DER with partially compliant components

Requirements that have not substantially changed include specifications for:

- ◆ Anti-islanding detection and trip time of 2 seconds
- ◆ Low-/High-frequency trip settings (now with wide range of adjustability)
- ◆ Low-/High-voltage trip settings (now with wide range of adjustability)
- ◆ General need to verify a DER's compliance through type tests, production test, and commissioning test

		Interconnection Standards			State/PUC Rules	Listing/Certification	
Function Set	Advanced Functions	IEEE 1547a-2003	IEEE 1547-2014	IEEE 1547-2017*	CA Rule 21-2015	UL 1741(SA) 2016	IEEE 1547.1-2017*
Static	Adjustable Trip Settings		✓	‡			Δ
Controlling	Power Curtailment			‡			Δ
	Ramp Rate Control				‡	Δ	
Frequency Support	L/H Frequency Ride-Through			‡	‡	Δ	Δ
	ROCOF Ride-Through			‡			Δ
	Frequency-Watt	×	✓	‡		Δ	Δ
Voltage Support	L/H Voltage Ride-Through (L/H VRT)			‡	‡	Δ	Δ
	Dynamic Voltage Support During L/H VRT			✓			
	Voltage Phase Angle Jump Ride-Through			‡			Δ
	Fixed Power Factor	✓	✓	‡	‡	Δ	Δ
	Fixed Reactive Power	✓	✓	‡			Δ
	Volt-Var	×	✓	‡	‡	Δ	Δ
	Volt-Watt	×	✓	‡		Δ	Δ
	Watt-Var	×		‡			Δ

\*Final requirements not confirmed.

Legend: × Prohibited, ✓ Allowed by Mutual Agreement, ‡ Capability Required, Δ Test and Verification Defined.

Table 1. Comparison between various standards applicable in North America

Note: A more detailed technical review of the draft standard can be found in “Status of Revision of IEEE Std 1547 and 1547.1”.

Table 1 compares the performance, functional, and test specifications among various standards applicable in North America. The advanced functions are categorized into static and controlling as well as frequency and voltage support function sets. Once revised, IEEE 1547 and IEEE 1547.1 will encompass most functional specifications and related tests procedures. In future, state rules like CA Rule 21 may refer to the revised IEEE 1547 and UL 1741 may refer to the revised IEEE 1547.1 in large part. A remaining gap that may be filled in future IEEE 1547 revisions include, for example, dynamic voltage support during voltage ride-through; for now, it remains unspecified and allowed by mutual agreement between the utility and the DER owner.

## HOW WILL THE NEW REQUIREMENTS IMPACT T&D PLANNERS, DEVELOPERS, INTEGRATORS, AND OPERATORS?

The technology neutrality of IEEE 1547 does not allow different interconnection requirements to be established for (smart) inverters and rotating machines in state rules. (This is counter to how large-scale generating facilities are variably treated in federal rules and in most other parts of the world, such as Europe.) As a result, the proposed IEEE 1547 standard provides a framework for an Authority Governing Interconnection Requirements (AGIR) to, for example, assign appropriate DER disturbance ride-through performance requirements. Meanwhile, standardized operating performance categories have been established that specify the required technical capabilities and settings for a DER under normal and abnormal operating conditions. The normal operating performance categories are designated by alphabetical characters (Category A & B) and the abnormal operating performance categories by Roman numerals (Category I, II & III). This concept is shown in Figure 3.

The purpose is to give the AGIR latitude to assign performance categories to specific groups of DER based on technical conditions such as DER technology, application, location, or (expected) penetration levels. The performance categories

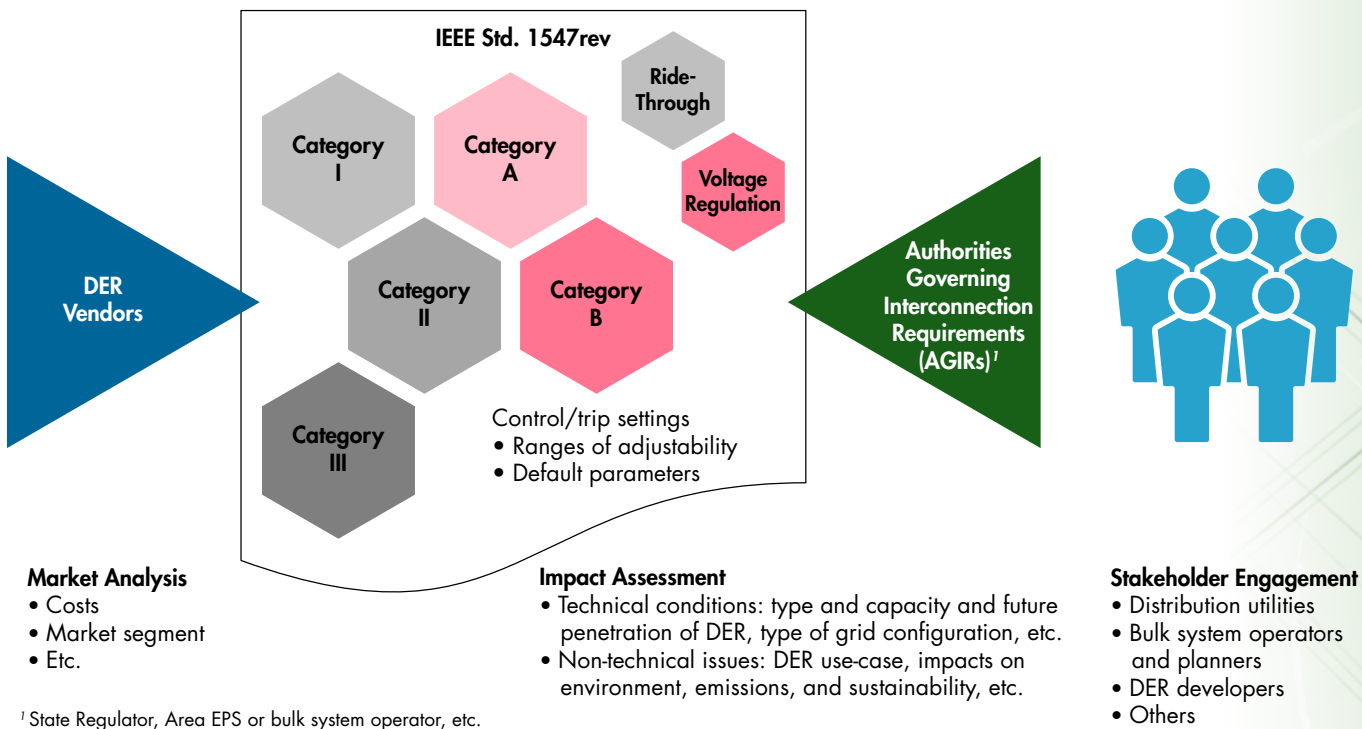


Figure 3. Application of IEEE 1547 performance categories

framework is flexible enough so that non-technical issues such as societal benefits of certain DER and broader impacts of DER on the environment, emissions, and sustainability may also be considered by an AGIR. Hence, distribution system planners, developers, integrators, and operators may have to work with their regulator, reliability coordinator, and other stakeholders to adopt IEEE 1547 in their respective jurisdictions.

DER location or evolving grid conditions may require adaptation or continued changes of functional DER parameter values. Therefore, IEEE 1547 requires certain parameters to be adjustable within a specified range of adjustability. While default values are specified in the standard that are deemed to be adequate for the majority of use cases, the distribution utility may request other parameter values within the specified ranges, based on system studies such as determination of DER hosting capacity.

## WHAT ARE THE CHALLENGES AND OPPORTUNITIES AND HOW ARE THEY ADDRESSED BY IEEE 1547?

As it is often the case when standard practices are changing, users of a new standard may have concerns that must be taken seriously. The new IEEE 1547 may particularly challenge distribution grid planners, operators, and line workers who are concerned with any of the following five issues:

- ◆ How to assess the risk of islanding with DERs that support voltage and ride-through disturbances.
- ◆ DER current contribution may disrupt protective coordination in electric power system (EPS) – facilities that deliver electric power load.
- ◆ Coordination of DER ride-through operation with Area EPS reclosing or momentary power interruption practices.
- ◆ Definition and specifications of DER cease to energize response.
- ◆ Line workers are exposed to increased risk.

Figure 4 summarizes the top three concerns and illustrates how IEEE P1547 addresses them. Overall, the draft standard aims to address these concerns so that the majority of IEEE P1547-compliant DER applications should bear no, or very small, risk. Additional risk assessment may be needed in limited cases. Future EPRI research will provide insights and analysis for selected cases.

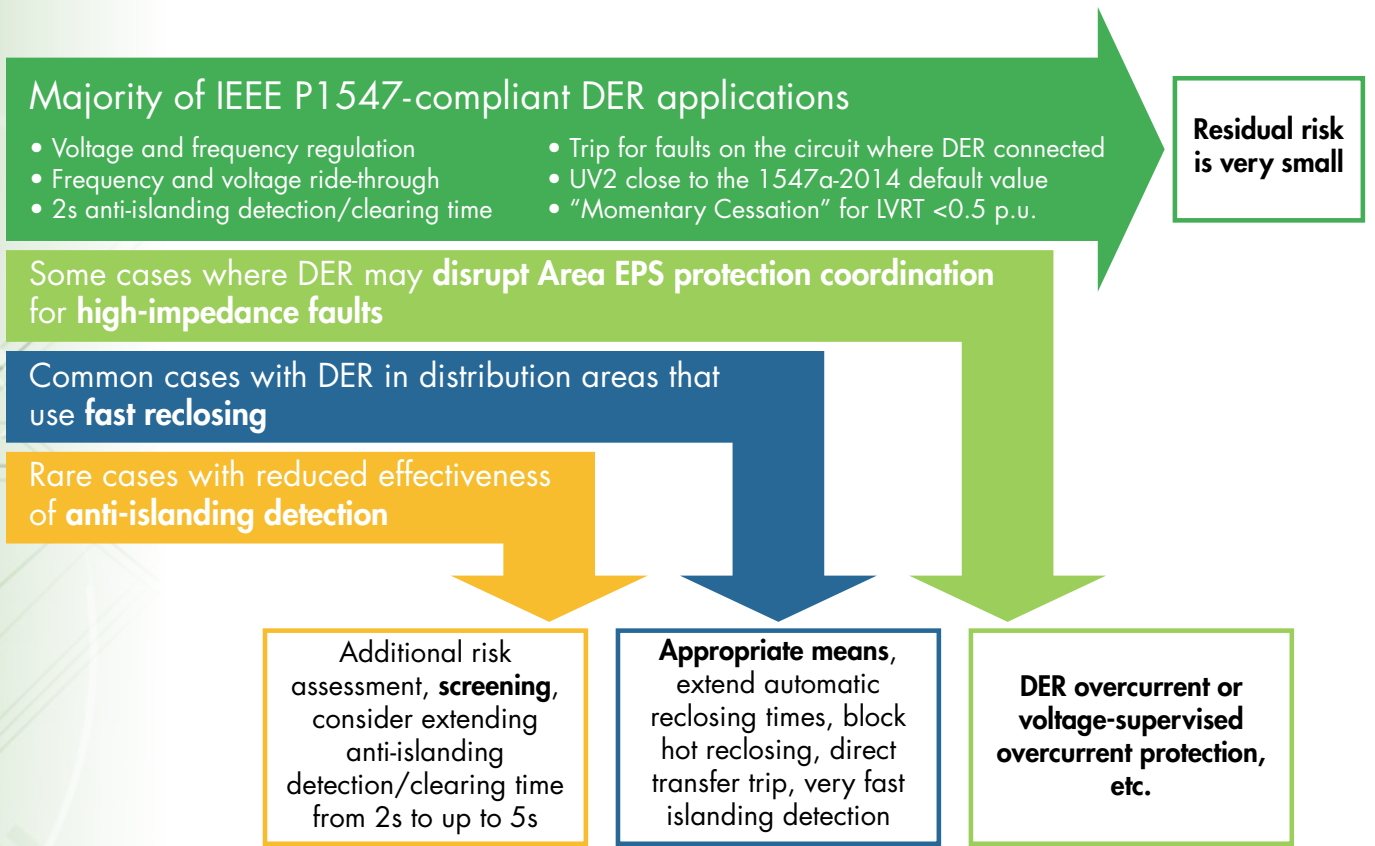


Figure 4. Top concerns of distribution grid planners, operators, and line workers and how IEEE P1547 addresses these

## WHEN WILL IEEE 1547-COMPLIANT DERS BECOME AVAILABLE?

With successful balloting, publication of the revised IEEE 1547 standard could potentially occur by the end of 2017. Parallel revision of DER testing procedures and certification requirements specified in IEEE 1547.1 are, meanwhile, expected to continue through 2018. Once both standards are published, state regulators will be able to adopt them in their jurisdictions and, in turn, assign the IEEE 1547 performance categories to specific DERs, specify control and trip settings, and implement other stipulated items. Both standards may not become mandatory until the 2019-2020 timeframe given the stakeholder review process. DER vendors will likely offer IEEE 1547-compliant "smart" DER technologies at that time.

## NEXT STEPS/ONGOING EPRI RESEARCH

Looking ahead, all industry stakeholders, including distribution and transmission planners and operators that have joined the IEEE P1547 balloting pool by May 12, 2017, have until June 18, 2017, to submit their vote and comments to the IEEE Standards Association (IEEE SA) and move the publication of the standard forward. Purchase and review of the draft standard and submission of comments is open to the public through July 19, 2017, but IEEE SA membership or an ad-hoc balloting fee is required for voting. Those interested are encouraged to visit the IEEE 1547 website to learn more and voice their feedback: [http://grouper.ieee.org/groups/scc21/1547\\_revision/1547revision\\_logistics.html](http://grouper.ieee.org/groups/scc21/1547_revision/1547revision_logistics.html).

EPRI is, meanwhile, engaged in several efforts to support greater understanding and roll out of the revised standard:

- ◆ EPRI is developing four publicly available white papers that will focus on the application of IEEE 1547. These white papers will cover issues related to DER ride-through, protection coordination, islanding, power quality, and communication interoperability.
- ◆ EPRI is initiating two research projects to support utility industry challenges for interconnecting and making best use of DER. The first one, titled "Applying New IEEE 1547 Interconnection Requirements", will support in utility-specific application of the revised IEEE Std 1547 and provide value by assisting for adopting the new standard to meet particular needs and regulatory requirements. The second one, titled "Evolving DER Connection Processes" will address gaps and opportunities for streamlining for DER interconnection processes, harmonize technical evaluations

and considerations for grid support from DER.

- ◆ EPRI will continue to facilitate standards development activities by, in particular, contributing to the ongoing revision of the IEEE Standard 1547.1 for test and verification requirements through 2018.

## REFERENCES

IEEE 1547 website to learn more and voice feedback: [http://grouper.ieee.org/groups/scc21/1547\\_revision/1547revision\\_logistics.html](http://grouper.ieee.org/groups/scc21/1547_revision/1547revision_logistics.html).

For a detailed technical review of the draft 1547 standard: [http://integratedgrid.com/wp-content/uploads/2016/10/EPRI\\_IEEE-P1547-and-P1547.1-Overview-August-2016\\_v2.pdf](http://integratedgrid.com/wp-content/uploads/2016/10/EPRI_IEEE-P1547-and-P1547.1-Overview-August-2016_v2.pdf).

The draft standard is available for purchase and public review through July 19, 2017: <https://publicreview.standards.ieee.org>

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

For EPRI's IEEE 1547 Balloting Update Webcast refer to <http://integratedgrid.com> to download the slide deck [and a recording].

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