Smart Inverters
Roadmaps for State Action

a presentation to the Delaware Public Service Commission

Center for
Renewables
Integration

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Today's Presentation

- About the Center for Renewables Integration
- What is a "smart inverter"?
- Status of standards development – IEEE-1547-2018
- Ride through
- Voltage and reactive/active power control
- Beyond IEEE-1547-2018
- Recommendations for state action

Center for Renewables Integration

Center for Renewables Integration, Inc.

is a 501(c)(3) non–profit organization,

founded in 2017,

dedicated to educating and working with state and local policymakers, and other key stakeholders

seeking to enable high levels of clean energy deployment while maintaining grid reliability at the lowest cost.

CRI's co-founders are

Jeanne Fox, Educator

former President, New Jersey Board of Public Utilities

Kerinia Cusick, Principal Consultant, Distributed Energy Innovation

former Vice President, Energy Storage and Managing Director, Government Affairs, SunEdison

Harry Warren, President, CleanGrid Advisors

former President, Washington Gas Energy Services

What is a "Smart Inverter"

"Smart Inverter" is a commonly used, but imprecisely defined, term that refers to inverters with some or all of the following advanced features:

- Autonomous "ride-through" capabilities
- Autonomous voltage and reactive/active power control capabilities
- Communication capabilities

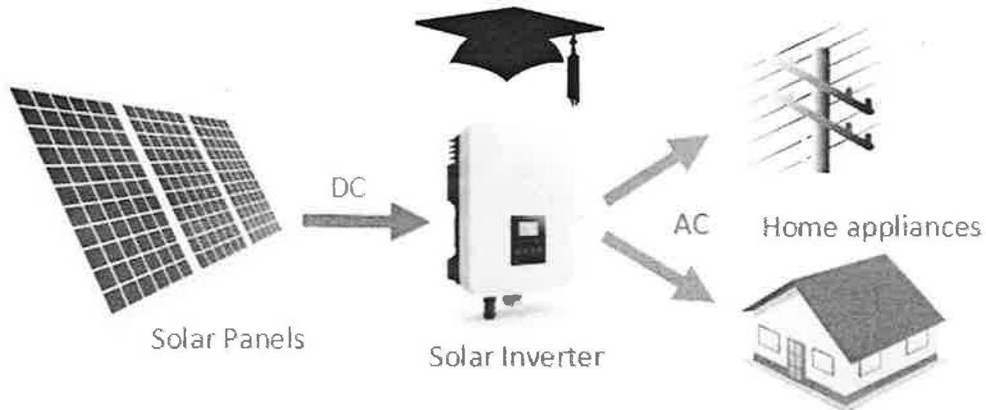
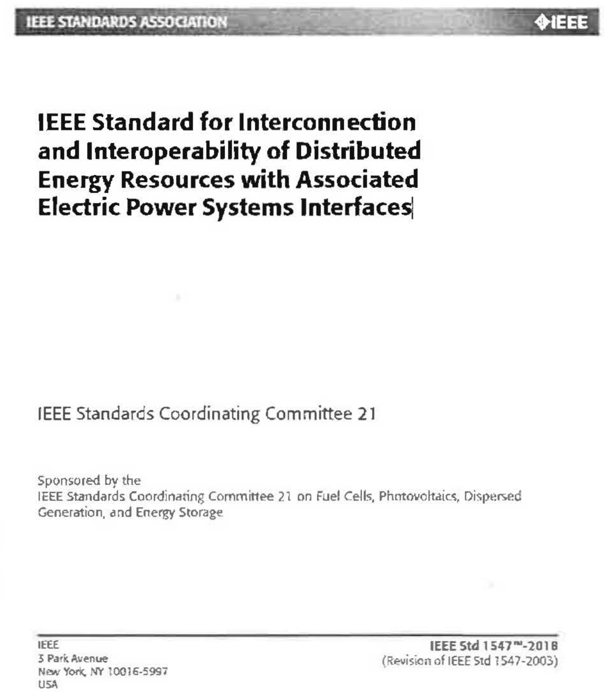


Illustration – Clean Energy Reviews

Many inverters on the market today are equipped with advanced features, and national standards are currently under development that will result in these features being incorporated into all inverters.

Status of Standards Development

- IEEE-1547-2018, “Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces” was published in April 2018.
- A companion equipment testing standard IEEE-1547.1 is under development and is scheduled for release in late 2019.
- A companion certification testing protocol UL-1741 will likely be released shortly after IEEE 1547.1
- Inverters with UL certification could be available as early as the beginning of 2021, with a broad range of certified products available by 2022.


IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Standards Coordinating Committee 21

Sponsored by the
IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1547™-2018
(Revision of IEEE Std 1547-2003)

Ride-Through

Ride-though allows an inverter to continue to function through a short frequency or voltage disturbance on the grid.

- Inverters in place today trip off line very quickly in response to frequency and voltage fluctuations, and do not resume operation quickly. As renewable energy penetration on the grid increases this could cause massive amounts of power to be lost due to transient fluctuations.
- Potential problems in states with high renewables penetration (California and Hawaii) have led those states to develop their own inverter standards (California Rule 21).

California Blue Cut Fire 2016 – Transmission Fault Cleared in 41.7 milliseconds

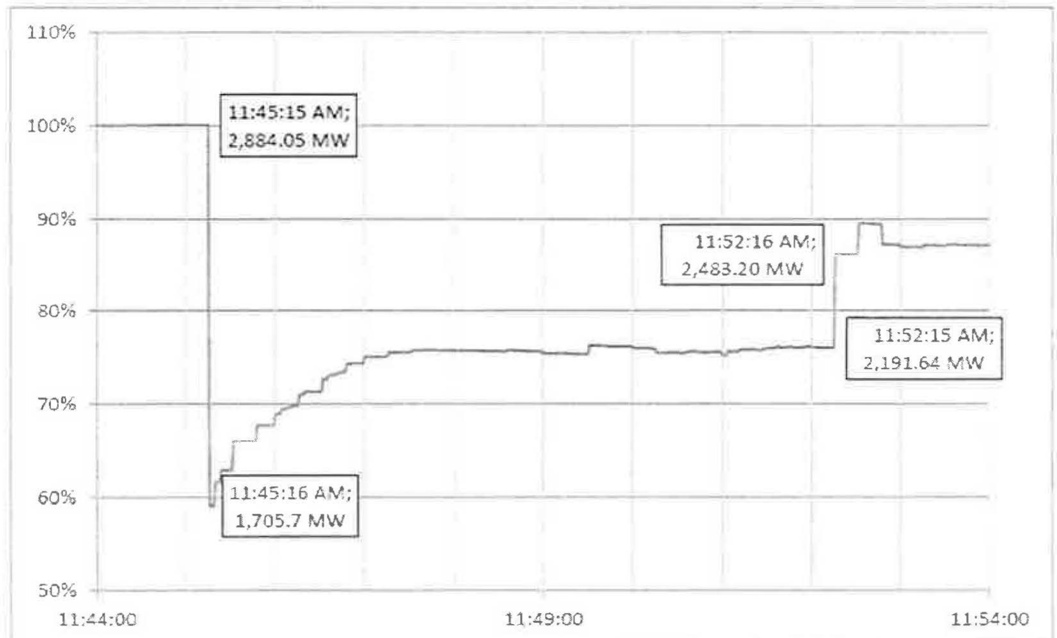
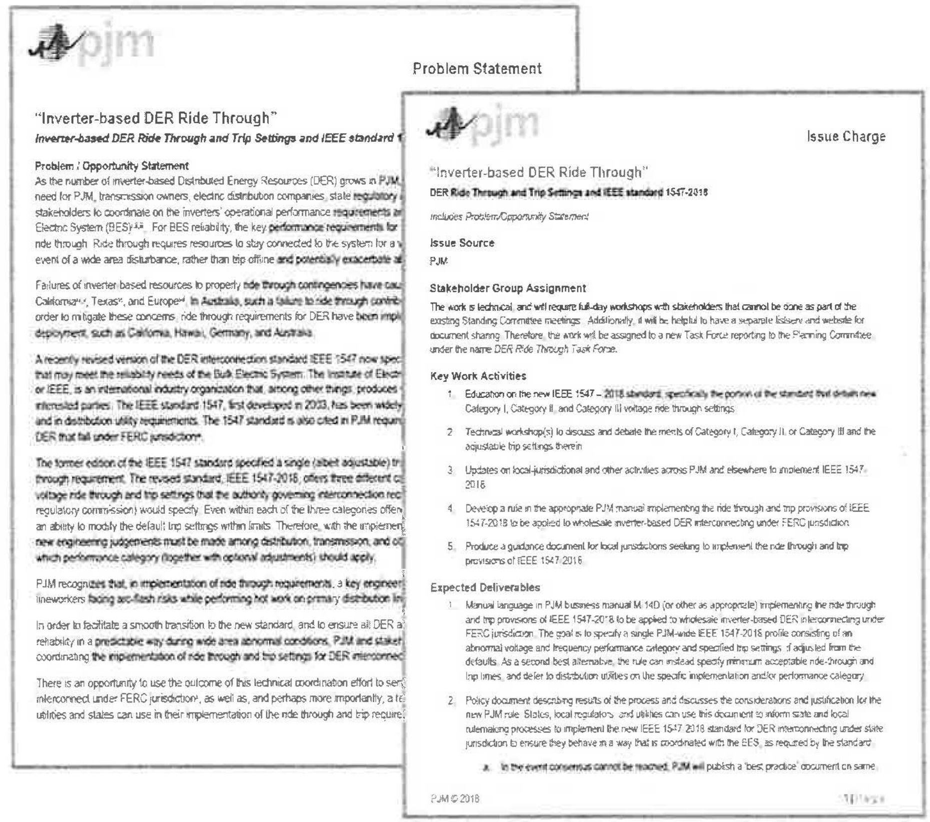


Figure - NERC

Ride-Through

A PJM stakeholder process is underway to establish the ride-through modes of operation and settings within the new IEEE-1547-2018 framework that would best assure future grid stability within the RTO.

- PJM's efforts will result in recommended practices to be adopted by states for distributed energy resources.
- PJM has no authority over distribution-connected resources, so states need to adopt the recommendations into their regulations, utility tariffs and other policies and practices as needed.


Problem Statement

"Inverter-based DER Ride Through"

Issue Charge

"Inverter-based DER Ride Through"

DER Ride Through and Trip Settings and IEEE standard 1547-2018

Includes Problem/Opportunity Statement

Issue Source

PJM

Stakeholder Group Assignment

The work is technical, and will require full-day workshops with stakeholders that cannot be done as part of the existing Standing Committee meetings. Additionally, it will be helpful to have a separate listserv and website for document sharing. Therefore, the work will be assigned to a new Task Force reporting to the Planning Committee under the name *DER Ride Through Task Force*.

Key Work Activities

1. Education on the new IEEE 1547 – 2018 standard, specifically the portion of the standard that details new Category I, Category II, and Category III voltage ride through settings
2. Technical workshop(s) to discuss and debate the merits of Category I, Category II, or Category III and the adjustable trip settings therein
3. Updates on local-jurisdictional and other activities across PJM and elsewhere to implement IEEE 1547-2018
4. Develop a rule in the appropriate PJM manual implementing the ride through and trip provisions of IEEE 1547-2018 to be applied to wholesale inverter-based DER interconnecting under FERC jurisdiction
5. Produce a guidance document for local jurisdictions seeking to implement the ride through and trip provisions of IEEE 1547-2018

Expected Deliverables

1. Manual language in PJM business manual M-14D (or other as appropriate) implementing the ride through and trip provisions of IEEE 1547-2018 to be applied to wholesale inverter-based DER interconnecting under FERC jurisdiction. The goal is to specify a single PJM-wide IEEE 1547-2018 profile consisting of an abnormal voltage and frequency performance category and specified trip settings, if adjusted from the defaults. As a second best alternative, the rule can instead specify minimum acceptable ride-through and trip times, and defer to distribution utilities on the specific implementation and/or performance category.
2. Policy document describing results of the process and discusses the considerations and justification for the new PJM rule. States, local regulators, and utilities can use this document to inform state and local rulemaking processes to implement the new IEEE 1547-2018 standard for DER interconnecting under state jurisdiction to ensure they behave in a way that is coordinated with the BES, as required by the standard.
   a. In the event consensus cannot be reached, PJM will publish a 'best practice' document on same.

PJM © 2018

Voltage and Reactive/Active Power Control

Distributed energy resources that use inverters (solar PV systems and batteries) can introduce voltage fluctuations into distribution grids as their power production or discharge vary over time. They also need to respond to distribution grid voltage status.

- Smart inverter voltage control features can mitigate impacts on the distribution system by modulating real and reactive power through one of a number of operating mode alternatives.
- By mitigating distribution system impacts, smart inverters can increase the "hosting capacity" of distribution circuits, allowing deeper penetration of renewables without costly distribution system upgrades.
- There is the potential for smart inverters to improve voltage control on distribution lines being caused by other factors (e.g. load fluctuations).

Table 6—Voltage and reactive/active power control function requirements for DER normal operating performance categories

DER category	Category A	Category B
Voltage regulation by reactive power control		
Constant power factor mode	Mandatory	Mandatory
Voltage—reactive power mode[a]	Mandatory	Mandatory
Active power—reactive power mode[b]	Not required	Mandatory
Constant reactive power mode	Mandatory	Mandatory
Voltage and active power control		
Voltage—active power (volt-watt) mode	Not required	Mandatory

[a]Voltage-reactive power mode may also be commonly referred to as "volt-var" mode.
[b]Active power-reactive power mode may be commonly referred to as "watt-var" mode.

Table 9—Active power-reactive power settings for normal operating performance Category A and Category B DER

Active power-reactive power parameters	Default settings		Ranges of allowable settings	
	Category A	Category B	Minimum	Maximum
P_3	P_{rated}		$P_2 + 0.1\ P_{rated}$	P_{rated}
P_2	$0.5\ P_{rated}$		$0.4\ P_{rated}$	$0.8\ P_{rated}$
P_1	The greater of $0.2\ P_{rated}$ and P_{min}		P_{min}	$P_2 - 0.1\ P_{rated}$
P'_1	The lesser of $0.2 \times P'_{rated}$ and P'_{min}		$P'_2 - 0.1\ P'_{rated}$	P'_{min}
P'_2	$0.5\ P'_{rated}$		$0.8\ P'_{rated}$	$0.4\ P'_{rated}$
P'_3	P'_{rated}		P'_{rated}	$P'_2 + 0.1\ P'_{rated}$
Q_3	25% of nameplate apparent power rating, absorption	44% of nameplate apparent power rating, absorption	100% of nameplate reactive power absorption capability	100% of nameplate reactive power injection capability
Q_2	0			
Q_1	0			
Q'_1	0			
Q'_2	0			
Q'_3	44% of nameplate apparent power rating, injection			

NOTE—P_{rated} is the nameplate active power rating of the DER.
P'_{rated} is the maximum active power that the DER can absorb.
P_{min} is the minimum active power output of the DER.
P'_{min} is the minimum, in amplitude, active power that the DER can absorb.
P' parameters are negative in value.

Tables – IEEE-1547-2018

Beyond IEEE-1547-2018

IEEE-1547-2018 covers certain inverter capabilities needed to allow utilities to control and communicate with inverters. This control could provide improved grid management.

- Utility control over smart inverters raises additional issues, however, such as secure, low cost communications systems and distributed resource management systems (DERMS)

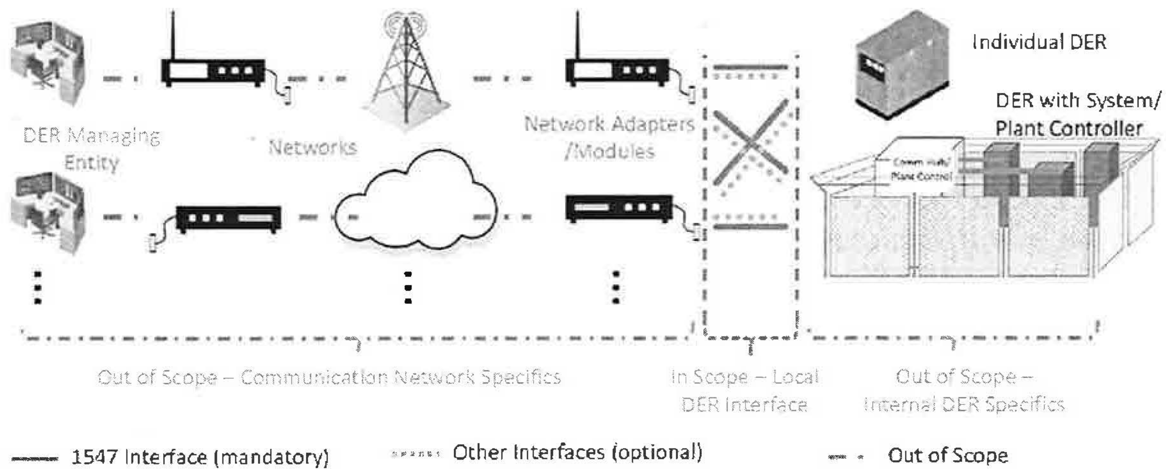


Figure 4 —Control protocol in/out of scope mapping

Figure – IEEE-1547-2018

Beyond IEEE-1547-2018

Battery storage systems require inverters /charge controllers, and include additional controls to manage various operating modes.

These issues are not fully covered under IEEE-1547-2018 and need to be addressed separately.

Proposed Use: The operational characteristics of a small generator facility upon which the applicant's technical review is based and under which the small generator facility is bound to operate upon the execution of the interconnection agreement. The proposed use for a small generator facility may include a combination of electric generators and **energy storage devices operating in specified modes during specified time periods including but not limited to export, load management, backup, and market participation.**

Net System Capacity: The nameplate capacity of a small generator facility, or the total of the nameplate capacities of the units comprising a small generator facility, as designated by the manufacturer(s) of the unit(s) minus the consumption of: electrical power of the unit(s), and if applicable, as limited through the use of a control system, power relay(s), or other similar device settings or adjustments.

Inadvertent Export: The unscheduled export of active power from a Generating Facility, beyond a specified magnitude and for a limited duration, generally due to fluctuations in load-following behavior.

CRI's Recommendations for State Action

CRI recommends developing a "roadmap" to implement IEEE-1547-2018, begin discussions of utility control, and establish battery standards.

CRI is chairing the Smart Inverter Subgroup in Maryland's PC-44 grid modernization docket.

The Subgroup is developing a roadmap that identifies tasks and sets timelines.

PHI is an active member of the Subgroup, contributing significantly based on its advanced work in demonstrations and field tests.