RECOMMENDATIONS FOR ADOPTION OF ADVANCED INVERTERS

NEW MEXICO ADVANCED INVERTER WORKING GROUP

VERSION2 – DRAFT, AUG. 18, 2022

Note to Readers

Substantive changes from Aug. 4 version include:

- Summary of Recommendations added
- Rec 2. - addressed warrantee replacement considerations
- Rec. 2 - included testing and certification in (instead of mentioning only in communications interoperability, Rec. 5)
- Rec. 4.a – added allowance of Cat A and Cat I as minimum requirements.
- Rec. 4.b and 4.c – attempted to clarify differences between changes to DEFAULT ACTIVATION FUNCTIONS and changes to SETTINGS (after system commissioning) and inserted some possible elements for both.
- Added the IEEE definition of interoperability to Rec. 5 and noted the coordination required between the electric service provider and the DER owner/operator to satisfy interoperability requirements. Extended the timelines of the phases.
- Added Rec. 6 regarding establishing a technical working group to include both electrical interconnection and communications interoperability evolution
- Removed ANNEX information that was redundant with text in the body of the report. Added EPRI URP chart to ANNEX E, with permission from and credit to EPRI.
- Inserted IREC decision options matrix, July DRAFT. Note that a published version may be available by Sept. 7. A question for the group is whether to include the published version (which will not be NM specific) or to include a version which reflects any consensus items for this working group.

Contents

SUMMARY

The New Mexico Advanced Inverter Working Group prepared a set of recommendations during Phase II of the New Mexico Public Regulation Commission's Interconnection stakeholder engagement efforts. These recommendations support the integration of distributed energy resources into the state's electric power system through adoption of IEEE 1547™-2018 (entitled "*IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*") and implementation of advanced inverters.

The recommendations are summarized below:

1) Consider policy decisions to set guidance for applying IEEE 1547™-2018 in New Mexico yet include many specific details in the electric service provider's Technical Interconnection and Interoperability Requirements (TIIR) documents.

2) Affirm that these requirements apply to DER systems up to and including systems of 10 MW in size. Affirm testing and certification requirements.

3) Clarify the reference point of applicability to define location where IEEE 1547™-2018 requirements apply.

4) Define normal and abnormal performance categories; specify default activation functions; settings; and processes for allowed changes.

5) Allow implementation of the three eligible communications protocols listed in IEEE 1547™-2018 and begin a three-phased approach over 4-5 years to implement full communications interoperability.

6) Form a technical working group to allow for shared learning, informed policy, and effective implementation the rapidly changing DER integration landscape

STATE WHETHER OR NOT THE RECOMMENDATIONS REFLECT GENERAL CONSENSUS.

MOTIVATION AND PROCESS

Interconnection of Distributed Energy Resources (DER) into New Mexico's electricity system is guided by many laws, statutes, rules, and technical standards. One of these standards is IEEE 1547™-2018. This standard for interconnection and interoperability of distributed energy resources with associated electric power systems interfaces, is substantially updated from the previous version, IEEE 1547™-2003, the standard referenced in New Mexico's current interconnection rule and manual.

In late 2020, the New Mexico Public Regulation Commission recognized the need for updating the state's distributed energy resources interconnection rules and embarked on a significant stakeholder engagement effort on this topic in 2021 as part of case 20-00171-UT. Case 21-00266-UT replaced case 20-00171-UT as the Interconnection Rulemaking evolved. Phase I stakeholder engagement activities related to this rulemaking resulted in a Report of the NM Interconnection Rules: Report and Recommendations, October 2021. Though the Phase I report included basic recommendations regarding adoption of the IEEE 1547™-2018, it was clear that adoption would involve decisions on many complex technical and operational subjects.[1] A Phase II effort was initiated in February of 2022 to continue to engage stakeholders in this topic with the goal of developing a set of recommendations for the NM PRC to consider. In parallel the Commission continued its formal process regarding the state's Interconnection Rules.

[1] A decision matrix which lists the many decisions and choices associated with adoption of IEEE 1547™-2018, prepared by the Interstate Renewable Energy Council, is included in Annex B.

During Phase II, the New Mexico Advanced Inverter Working Group met 12 times, over 8 months to develop the recommendations in this report. Two subgroups met between working group meetings to create proposals for the working group to consider. Over 50 individuals representing 20 organizations participated through attendance at meetings and contributions to the recommendations. Meetings were facilitated by Gridworks and a DOE Solar Innovator on assignment at the NM PRC. For more details on the meetings and participating organizations, see Annex C.

ADD COMMENTS REGARDING CONSENSUS RECOMMENDATIONS. One idea is to refer to a version of the IREC decision options matrix that shows any consensus items for the NM AIWG or simply list any consensus items. (Refer to Annex B for more details.)

RECOMMENDATIONS

RECOMMENDATION 1. Elements Recommended for Policy and Elements Recommended for Technical Interconnection & Interoperability Requirements Documents

The working group acknowledges the technical complexities and dynamic nature of IEEE 1547™-2018 adoption. Key decisions, regulatory direction/oversight, or statements of policy are offered for 7 elements and 2 elements are suggested for incorporated into electric system providers' Technical Interconnection & Interoperability Requirements (TIIR) documents.[2] These elements are summarized in Table 1.

TABLE 1. Suggested Policy Elements and Elements for Electric System Provider's TIIR Documents

Policy Elements	Elements for EPS Operators' TIIR Documents
Applicable to DER systems up to and including 10 MW and as defined by IEEE 1547™-2018	
Reference Point of Applicability	
Category Determination	
Functions and Default Activations (Table 2)	
Setting Ranges (as prescribed by IEEE 1547™-2018)	Specific settings for functions
Allowance of all three eligible communication protocols.	Communication protocol requirements (for specific site locations)
Phased approach to communications interoperability.	

RECOMMENDATION 2. Applicability and Certification

All distributed energy resources up to and including systems of 10 MW in size,[3] installed after March 28, 2023, or date when certified equipment is widely available, and connected to a New Mexico electric system, shall comply with the IEEE 1547™-2018 requirements. DER systems installed prior to March 28, 2023, are not required to conform to IEEE 1547™-2018 requirements but upon replacement due to end-of-life cycle must be replaced with equipment that meets these requirements.

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[2] Technical Interconnection & Interoperability (TIIR) documents are public documents, often utility specific. According to EPRI, they can include requirements for interconnection, interoperability, capabilities, and their utilization (settings), and grid integration (e.g., protection coordination, telemetry). For more information, see "*Generic Technical Interconnection and Interoperability Requirements (TIIRs): A Generic Template Including DER Interconnection Technical Review Criteria and Standardized Forms for DER Functional Settings*," EPRI Technical Update, Aug. 13, 2021. https://www.epri.com/research/products/000000003002022563

[3] New Mexico Interconnection Rules do not apply to systems over 10MW in size.

An issue to be considered is whether inverters replaced under warrantee are required to meet IEEE 1547™-2018 requirements. Complications to be considered are multiple inverters in a system (compatibility), equipment rating differences, contractual compensation for more capable equipment, and provisions for previously acquired "spare" parts or equipment. One possibility is to allow both options: 1) upgrades to equipment which meets the new standard, and, 2) "like-kind" replacements for the life of a system, with a review process for equipment updates.

Some emergency backup power and standby DER systems are exempt from some requirements defined by the standard (See subclause 4.13 of IEEE 1547™-2018 for more information.)

Equipment shall be tested and certified according to IEEE 1547.1™-2020 requirements or be certified using UL 1741 Third Edition, Supplement SB.

RECOMMENDATION 3. Reference Point of Applicability

The Reference Point of Applicability (RPA) for all performance requirements shall be the Point of Common Coupling (PCC) unless allowed by alternate options described in IEEE 1547™-2018. The proposed RPA(s) shall be identified in the interconnection application and one-line diagram.[4] If the electric service provider determines that the applicant's preferred RPA is inappropriate because it is not in conformance with IEEE 1547™-2018, subclause 4.2, the applicant may select a different RPA that will bring the system into conformance. [5] In all cases, the RPA shall be documented in the Interconnection Agreement. See Annex D for additional information pertaining to this recommendation.

RECOMMENDATION 4. Categories, Functions and Settings

The advanced inverter working group prepared a three-part recommendation for adoption of the IEEE 1547™-2018 standard as it pertains to the categories, functions, and settings of advanced inverters. Technical details of this recommendation are included in Annex E and additional background information is available from the Interstate Renewable Energy Council.[6] The recommendation is intended to ensure that DER systems shall be capable of actively regulating voltage, shall ride-through abnormal voltage/frequency, and are able provide the greatest degree of grid support possible. In addition, the recommendation provides an interconnection framework that accommodates the largest amount of DER penetration while preserving electric system reliability and safety. Finally, the recommendation aims to make advanced inverter settings transparent to all interested parties.

This recommendation addresses the definitions, activations and settings of the autonomous functions required by IEEE 1547™-2018 and its amendment 1547a-2020. A recommendation regarding the categories for performance, specific functionalities, and settings are included, as these determinations are critical for implementation of the IEEE 1547™ requirements.

Recommendation 4.a – Category Determination: Rotating equipment-based systems (both induction and synchronous) must meet at least Category A requirements for normal performance and Category I requirements for abnormal performance (equipment meeting Category B and Category II or III is also

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[4] Note that a system might have alternate RPAs for multiple points of connection, or for fault sensing versus voltage sensing.

[5] This process may interfere with interconnection process timelines. It could potentially be streamlined by including a specific process for RPA review with timelines of its own. See recommendations on this topic in the BATRIES toolkit, chapter VIII. https://energystorageinterconnection.org/resources/batries-toolkit/

[6] Interstate Renewable Energy Council. See *"Making the Grid Smarter, Primer on Adopting the New IEEE 1547™-2018 Standard for Distributed Energy Resources,"* January 2019. https://irecusa.org/resources/making-the-grid-smarter-primer-on-adopting-the-new-ieee-standard-1547-2018/

allowed). Inverter-based systems must meet Category B requirements for normal performance and Category III requirements for abnormal performance.

Recommendation 4.b – Function Activation: Inverter and rotating equipment functions shall be activated by default according to Table 2. The set of functions shown in Table 2 is known as the "autonomous functions," as they allow the DER system to operate in the absence of real time information exchange between the EPS and the DER equipment. Function activations other than the default settings may be allowed with approved technical justification by electric service provider.

Note that the term "disabled" in Table 2 means that an advanced inverter is likely to have this capability, but this function is initially disabled to comply with New Mexico interconnection requirements.

The recommendation for voltage regulation is to enable volt-var as the reactive power function and volt-watt as the active power function. This combination of functions provides active adjustment of the DER as conditions change on the circuit, thus allowing for better voltage regulation as DER penetration increases over time. In addition, implementation of these two voltage regulation functions avoids the need to study and determine a static control setting, thus possibly simplifying the interconnection application review process.

Three options for changes to the Default Activations of the Autonomous Functions include the following:

1) Selection of an alternative voltage regulation strategy, if warranted by a distribution system study, may be documented by a system operator, submitted as a variance for commission approval, and if approved, reflected in an EPS operator's published TIIR documents.[7]
2) Selection of an alternative default activation, if warranted by a distribution system study, may be documented by a system operator, submitted as a variance for commission approval, and if approved, reflected in an EPS operator's published TIIR documents.
3) Selection of alternative default activation of any function, if warranted by a process defined by the EPS operator and approved by the commission, may be employed if documented in the provider's TIIR documents.

TABLE 2. Functions, Default Activation, and Purpose

Function	**Default Activation and Purpose**
Reactive Power Functions. Only one of the four options below can be activated:	**Voltage regulation**
Voltage-Reactive Power Control (volt-var)	Enabled for Categories A & B. Modulates reactive power in relation to measured grid voltage.
Constant Power Factor	Disabled. No voltage support is realized when this function is enabled with its default setting. Constant Power Factor does not respond directly to voltage and as such, in this mode, the DER might be injecting or absorbing reactive power when it is not needed.
Active Power-Reactive Power Control (watt-var)	Disabled. Modulates reactive power in relation to active power output (and absorption of active power for systems that can store energy). Watt-var does not respond directly to voltage and as such, in this mode, the DER might be injecting or absorbing reactive power when it is not needed.

[7] The Advanced Inverter Working Group recognizes the need for processes related to developing, reviewing, sharing, and updating TIIRs, but did not have time to compose recommendations on this topic.

Constant Reactive Power Control	Disabled. Does not allow reactive power to adjust as power output from DER fluctuates.
Active Power Function	**Voltage regulation**
Voltage-Active Power Control (volt-watt)	Enabled for Category B. Reduces active power to reduce voltage (normally only once voltage is outside of the normal range)
Voltage and Frequency Disturbance Functions	**Supports bulk system stability and maximizes grid support from DERS**
Voltage Disturbance Ride-Through and Trips	Required for both inverter-based & rotating DER systems
Frequency Disturbance Ride-Through and Trips	Required for both inverter-based & rotating DER systems
Enter Service Functions	**Avoids abnormal voltages**
Enter Service	Enabled
Enter Service Ramp Rate or Randomized Start Time, depending on system size and capability, or mutual agreement	Enabled
Anti-Islanding Function	**Avoids unintentional islanding**
Anti-Islanding	Enabled

Recommendation 4.c –Settings: Default settings for the functions outlined in Table 2 above are to be based on IEEE 1547™-2018 (as amended in IEEE 1547a-2020). Allowed settings also include site-specific settings as determined by System Impact Study and documented in the Interconnection Agreement. File formats for settings shall conform to the EPRI guidelines documented in "Common File Format for Distributed Energy Resources Settings Exchange and Storage."[8] Site specific settings shall be documented as Utility Required Profiles in the TIIR documents. (See Annex E for more information.)

The process for making changes to systems settings after a system has been commissioned have been reviewed by the working group, yet this topic has received limited discussion. Four elements considered include:

1) Changes to settings (requested by either the EPS operator or DER owner/operator) should be documented in the interconnection agreement, as they are likely to be site specific. For sites without EPS-DER communications connectivity, changes should be limited. Note that the commission might need to determine who pays for such changes, given that a site visit may be necessary to implement the changes.
2) Changes to settings (requested by either the EPS operator or DER owner/operator) which change the amount of power delivered to the electric grid, are to be reported to the commission through a yet to be determined process.
3) The utility shall notify the DER owner of the need to modify trip settings. The request for setting modification shall not exceed one per year.

Changes to settings requested by the EPS operator shall be made by the DER operator within timeframes specified in the interconnection agreement.

[8] Common File Format for Distributed Energy Resources Settings Exchange and Storage (epri.com), EPRI Technical Update, Dec 10, 2020. https://www.epri.com/research/products/000000003002020201

RECOMMENDATION 5. Communications Protocols

The Advanced Inverter Working Group proposes that a communications interoperability policy include the following elements:

a) DERs up to and including 10MW are to be enabled with communications interoperability[9] as specified in IEEE 1547™-2018. (Note that testing and certification is addressed in Recommendation 2 above.)
b) New Mexico electric power system (ESP) operators shall be allowed to use any of the three eligible protocols defined by IEEE 1547™-2018 (but no others). Guidance regarding allowed protocols shall be documented in the electric service provider's TIIR documents.

Coordination between the EPS operator and DER owner/operator will be required to satisfy the interoperability requirements. It is recommended that the protocol and interface device for a specific interconnection be identified by the EPS operator and communicated to the interconnection applicant. If a Pre-Application Report is requested, the communications protocol shall be identified in the report. If the EPS operator's communications capability is not in place at time of commissioning, certified equipment will be acceptable. It is recognized that additional interface hardware and software could be required.

c) Communications interoperability of DER is expected to mature in the following three phases:
    i. Inverter autonomous functions enabled. Experiences, learnings, challenges, and best practices shall be reported to the PRC 18 months after implementation of the IEEE 1547™-2018 requirements date (currently envisioned as March 28, 2023). (The process for reporting was not specifically addressed.) Synchronization with other communications investments by the ESPs and visibility of DER systems at the distribution level are considerations during this phase.
    ii. Electric service providers propose pilot programs to monitor and interact with DER equipment connected to their systems. Based on these pilot programs, suggestions for communication interoperability standards shall be submitted (via some process yet to be determined) to the PRC 36 months after adoption of the Interconnection Rule.
    iii. After due consideration, decisions, and implementation of communication interoperability standards, EPS operators and DER operators with the ability to exchange "interactive information" to enable full functionality of DER – electric system interactions.

This phased approach is warranted due to the lack of maturity of interoperability capabilities of both New Mexico EPS operators as well as DER equipment providers. Evolution of interoperability must address information and control systems capabilities as well as cyber security.

RECOMMENDATION 6. Technical Working Group

It is recommended that a New Mexico-based technical working group be supported to continue the learning and dialogue on electric and communications interoperability following adoption of the Interconnection Rule. The rapid evolution of DER hardware, electric power controls technologies, and communications infrastructure is expected to continue. Though best practices from other states are valuable, the continued engagement of state agencies, electric service providers, equipment manufacturers, and DER owners/operators is critical to DER integration.

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[9] Interoperability is defined by IEEE as the capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively.

New Mexico also needs to stay informed of developments in electric power cyber security. Two standard efforts worthy of following are IEEE 1547.3 (Interoperability and Cyber Security, currently in balloting) and IEEE 1547.10 (Gateways, working group currently being formed.)

ANNEX A – Background

Interconnection of distributed energy resources into New Mexico's electricity system is guided by many laws, statutes, rules, and technical standards. One of these standards is IEEE Std 1547™. This standard for interconnection and interoperability of distributed energy resources with associated electric power systems interfaces, as amended by IEEE 1547a-2020, including use of IEEE 1547.1-2020 testing protocols to establish conformity is substantially updated from IEEE 1547-2003, the standard referenced in New Mexico's current interconnection rule and manual.

The Final Report of the New Mexico Interconnection Rules: Report and Recommendations, October 15, 2021, in 20-00171-UT, page 45-46, which was developed during Phase I of the interconnection stakeholder engagement effort, included the following language:

Capability for the following three grid support functions provided by IEEE 1547™-2018 shall be required for all DER installed after December 31st, 2022.

1. Shall be capable of actively regulating voltage.
2. Shall be capable of frequency response. Frequency response is the capability to modulate power output as a function of frequency. Mandatory capability for Categories II and III under high-frequency conditions, mandatory for Categories II and III under low-frequency conditions, optional for Category I.
3. Shall ride-through abnormal voltage/frequency.

In addition, capability for a fourth grid support function shall be optional:

4. May provide inertial response. Inertial response is the capability for DERs to modulate active power in proportion to the rate of change of frequency.

While capabilities for functions (1) and (2) are mandatory, their utilization is at the discretion of the Area Electric Power System (EPS) Operator.

For function (3), when determining ride-through requirements, the Area EPS operator shall specify which of abnormal operating performance Category I, Category II, or Category III performance is required. This may be subject to regulatory requirements that are outside the scope of this standard and may consider DER type, application purpose, future regional DER penetration, and the Area EPS characteristics.

The Area EPS operator shall notify the DER owner of the need to modify ride-through settings. The request for setting modification shall not exceed one per year.

Not specified as part of this proposal, but still needing determination are:
Ride-through settings for abnormal voltage/frequency and frequency response
Settings for active voltage regulation

The NOPR under case 21-00266-UT, which replaced case 20-00171-UT, included the following language:

17.9.568.11 IEEE 1547™-2018 ADOPTION
A. Capability for the following three grid support functions provided by IEEE 1547™-2018 shall be required for all DER installed after March 28, 2023.

(1) Shall be capable of actively regulating voltage.
(2) Shall be capable of frequency response. Frequency response is the capability to modulate power output as a function of frequency.
(3) Shall ride-through abnormal voltage/frequency.

(4) In addition, capability for a fourth grid support function shall be optional: may provide inertial response. Inertial response is the capability for DERs to modulate active power in proportion to the rate of change of frequency.

D. While capabilities for functions one and two are mandatory, their utilization is at the discretion of the area electric utility. For function three, when determining ride-through requirements, the utility shall specify which of abnormal operating performance is required. This may be subject to regulatory requirements that are outside the scope of this standard and may consider DER type, application purpose, future regional DER penetration, and the area characteristics.

E. The utility shall notify the DER owner of the need to modify ride-through settings. The request for setting modification shall not exceed one per year.

F. Existing inverters are not required to conform to the standards adopted above in Subsection A., but upon replacement due to end-of-life-cycle or other reasons, must be replaced with advanced inverters. G. Replacement of existing inverters with those that conform to the standards adopted above in subsection A. will not be considered a major modification of operations, so long as the total output of the generating facility, or its export limits as previously approved remain unchanged.

[17.9.568.11 NMAC – Rp, 17.9.568.11 NMAC, xx/xx/2022]

ANNEX B – Advanced Inverter Adoption Decision Matrix

The working group greatly appreciates the assistance and insights provided by the Interstate Renewable Energy Council (IREC) throughout the working group efforts. Below is a matrix developed by IREC which lists decisions required to implement IEEE 1547™-2018. The matrix also includes options that can be chosen for each decision.

Note that a published version of the matrix, which will not be specific to the New Mexico AIWG, may be available by Sept. 7. A question for the group is whether to include the published version or to include a version which reflects any consensus items for this working group. INSERT IREC PREAMBLE AND LOGO.

IEEE 1547 Adoption: Decision Options Matrix, DRAFT as of July 2022

IF A NM SPECIFIC VERSION IS INCLUDED, NEED TO REVIEW TO BE SURE THE SELECTED OPTIONS REFLECT THE REPORT TEXT.

Key:

Suggested for TIR	Original color
Suggested for Rule	
Rule or TIR	
Other	

			Decisions To make	
NearTerm	**Issue**	**What to consider?**	**Decision Option (DO) Description**	**Utilize?**
	Adoption Timeline	Consider equipment availability, the use of UL 1741 SA certification in the interim (if needed), and whether naming a date is necessary. Compliance requirements are usually based on the interconnection application submission date. Some projects have long interconnection review and lead times and may not be installed long after the application date. A mechanism to require some of those projects with earlier application dates to be 1547-2018 compliant once installed could be beneficial for grid support. Installed MW with 1547-2018 compliance could be increased if compliance is based on installation date, but this may be challenging for developers from a planning perspective, as they may have to specify equipment that is not yet certified for 1547-2018. This issue may be mitigated if UL 1741 SA inverters are utilized, which can have similar features as those required by UL 1741 SB/1547-2018. Also consider how an interim adoption period will be implemented, allowing for 1547-2018	**DO 1a-1:** Comply with IEEE 1547-2018 beginning [some date before ~April 1, 2023].	☐
			DO 1a-2: Comply with IEEE 1547-2018 beginning ~March 28, 2023 based on installation.	☒
			DO 1a-3: Comply with IEEE 1547-2018 when the equipment is readily available (TBD by Commission action).	☐
			DO 1b-1: Base compliance date on application submission.	☐
			DO 1b-2: Base compliance date on installation (may be useful for larger projects with long lead times).	☐
			DO 1b-3: Differentiate compliance date mechanism between smaller and larger projects.	☐
			DO 1c-1: Allow interim compliance with IEEE 1547-2018 beginning April 1, 2022.	☐
			DO 1c-2: Define another interim compliance pathway.	☐

		compliance before the deadline. Widely available UL 1741 SB certified equipment is expected on the market by around April 1, 2023.		
	Abnormal Operating Performance Category	Consider input from transmission operators or regional reliability coordinator when assigning ride-through categories, plus local distribution utility protection practice.	**DO 2-1:** IEEE 1547-2018 Category III Ride-Through capabilities must be supported for inverter-based DER. Rotating DER must meet Category I Ride-Through capabilities.	☒
			DO 2-2: IEEE 1547-2018 Category II Ride-Through capabilities must be supported for inverter-based DER. Rotating DER must meet Category I Ride-Through capabilities.	☐
	Normal Operating Performance Category	The selection of A or B will impact the use of voltage regulation controls. Some DER types cannot meet the full scale of reactive power support. Consider specifying category assignment based on technology type.	**DO 3-1:** Inverter-based DER shall meet reactive power requirements with 1547-2018 Category B. Rotating DER must meet Category A.	☒
			DO 3-2: All DER types (Inverter-based and rotating) shall meet reactive power requirements with 1547-2018 Category A.	☐
	Alternative Performance Category	If a technology that cannot meet the specified Abnormal or Normal Operating Performance Category, a defined process may be useful for determining that the technology can safely interconnect without unduly impacting grid support requirements.	**DO 4-1:** Define process for how exceptions to these category assignments are handled (e.g., for an inverter-based technology that cannot meet Category III capabilities).	☐
			DO 4-2: Leave process undefined for how exceptions to these category assignments are handled.	☐
	Voltage Trip Settings & Ranges	Consider local distribution utility protection practices and make sure appropriate trip settings are selected. As desired, select default settings or settings within the adjustable range. Trip settings should not hinder ride-through capability required at the transmission level.	**DO 5-1:** Align default settings with 1547.	☐
			DO 5-2: Select other default settings within 1547 ranges of adjustment.	☐
	Frequency Trip Settings & Ranges	Ensure that the UF and OF trip settings are coordinated between the utility and transmission operator. As desired, select default settings or settings within the adjustable range. Trip settings should not hinder ride-through capability required at the transmission level.	**DO 6-1:** Align default settings with 1547.	☐
			DO 6-2: Select other default settings within 1547 ranges of adjustment.	☐
	Frequency Droop Settings	This capability is required for all DERs (with some limitations on Category I types) during the under/over frequency conditions.[10] Consider using default settings or adjust within ranges of allowable settings. Consider input from transmission operators or regional reliability coordinator.	**DO 7-1:** Align default settings with 1547.	☐
			DO 7-2: Select other default settings within 1547 ranges of adjustment.	☐
	Voltage regulation modes by reactive power[11]	If desired, consider activating a non-unity power factor, volt-var, watt-var, or constant var function. Also, consider statewide (or similar) default settings for such mode.	**DO 8a-1:** Adjustable constant power factor is activated.	☐
			DO 8a-2: Utilize volt-var without autonomously adjusting Vref.	☒
			DO 8a-3: Utilize volt-var with autonomously adjusting Vref.	☐
			DO 8a-4: watt-var is activated.	☐

[10] Per IEEE 1547-2018, this function cannot be disabled

[11] The voltage support functions by reactive functions (constant power factor, volt-var, watt-var, constant var) are mutually exclusive. By default, these functions are deactivated – meaning certified equipment will come out of the box to operate at unity power factor.

			DO 8a-5: constant var[12] is activated.	☐
			DO 8b-1: Align default settings with 1547.	☒
			DO 8b-2: Select other default settings within 1547 ranges of adjustment.	☐
			DO 8c-1: Specify process for selecting settings on site-by-site basis.	☐
			DO 8c-2: Leave process undefined.	☐
	Voltage regulation modes by active power[13]	If desired, consider statewide (or similar) activation of volt-watt function (with default setting). Notably, the utilization of volt-watt will require changes to the interconnection applications forms (online portals) to allow an applicant to specify how volt-watt is implemented.	**DO 9-1:** Volt-watt[14] is activated with default 1547 settings.	☒
			DO 9-2: Volt-watt is activated with non-default settings.	☐
			DO 9-3: Volt-watt is not activated.	☐
	Interconnection Rule	Update interconnection rule to be inclusive of IEEE 1547-2018.	**DO 10a-1:** Change 1547 date and title in standards references.	☐
			DO 10b-1: Define timeline for adoption of new requirements in line with 1547-2018 per DO 1.	☐
			DO 10c-1: Update applicable power quality or other references (such as IEEE 519 or IEEE 1453) to IEEE 1547-2018.	☐
Mid-term	Reference Point of Applicability (RPA)	Consider process related improvement that allows RPA designation by applicant and for utility to review. This may involve changes to application forms (such as online application portals), initial reviews processes and provision to allow RPA review/discussion scoping meeting.	**DO 11-1:** Require RPA to be noted in the application forms and use RPA recommended language from Appendix E and F of BATRIES Toolkit as a starting point.	☐
			DO 11-2: Specify elsewhere how the RPA information is processed.	☐
			DO 11-3: (Do nothing) Do not introduce new requirements related to the RPA.	☐
	Enter service settings	It is important to consider whether non-default enter service settings are preferred for voltage and frequency ranges, delay time, and ramp rate. The standard allows for the duration of *enter service* period (ramp rate) to be adjustable over 1-1000 second with a default time of 300 seconds. For DERs less than 500kVA, individual DER units may use a randomized time delay with a default maximum interval at 300 seconds as an alternative to ramping. It is likely even the smallest inverter-based DER can utilize the enter service ramp. Enter Service ramp rate is also known as connect/reconnect or soft start ramp rate.	**DO 12a-1**: Utilize 1547 default settings for voltage range, frequency range, delay and duration.	☐
			DO 12a-2: Specify default settings within the ranges allowed by 1547.	☐
			DO 12b-1: Give further guidance on how randomized delay times are to be used for DER smaller than 500 kVA (consider application form addition).	☐
			DO 12b-2: Leave process for randomized delay selection undefined for DER smaller than 500 kVA.	☐
	Normal ramp rate	This capability is based on SA certification (not SB), consider whether the capability is utilized (if available).[15] Though not required by 1547-2018, this feature may be useful, especially for energy storage technologies. Per CA Rule 21, the default value is 100% of	**DO 13a-1**: Normal ramp rate certification is required, and ranges of adjustment are specified.	☐
			DO 13a-2: Normal ramp rate **c**apability/certification is optional, and ranges of adjustment are specified.	☐

[12] Note: "constant var" mode is only required for normal performance Category B.
[13] The voltage support by active power (volt-watt) is deactivated by default – if desired, consider statewide (or similar) default setting for volt-watt.
[14] Note: "volt-watt" mode is only required for normal performance Category B.
[15] The Normal Ramp Rate (NRR) is used when transitioning between energy output levels over the normal course of operation.

		maximum current output per second (with an adjustable range of between 1% to 100%).	**DO 13a-3**: Normal ramp rate is not required.	☐
			DO 13b-1: Normal ramp rate is activated by default using specified settings.	☐
			DO 13b-2: Normal ramp rate is not activated by default.	☐
	Communication protocols & ports	Consider specifying protocols and ports if known and of interest to utilities.	**DO 14-1**: Specify protocols and ports to be used at the DER interface.	☐
			DO 14-2: Do not specify protocols and ports at the DER interface.	☐
	Utility Required Profile (URP)	Finalize URP with all default settings and consider posting that in the EPRI URP database (publicly available).	**DO 15-1**: Utility to create and post URP of default settings.	☐
			DO 15-2: Do not create and post URP of default settings.	☐
	Application Forms	Update application forms (including online portals) for the following items: RPA selection Enter service randomized delay Volt-watt implementation Limit active maximum power function implementation Frequency droop implementation Intentional islanding Emergency backup systems DER communication capabilities Export/import limiting Power Control Systems (PCS) Inverter fault current	**DO 16-1**: Update application forms (use recommended language from Appendix F of BATRIES toolkit as a starting point).	☐
			DO 16-2: Do not update application forms.	☐
	Volt-watt process/reporting	Volt-watt can have impact on customer's energy production. Curtailment is based on utility voltage that the customer has no control of. Consider a reporting process to understand if volt-watt curtailment becomes an issue for customers now or in the future.	**DO 17-1:** Implement a reporting process	☐
			DO 17-2: Do not implement a reporting process	☐
	Nameplate ratings	Consider addressing nameplate ratings issues related to volt-watt, limit maximum active power, and frequency droop. The interconnection application forms may need to allow applicants to describe how the functions are achieved.	**DO 18a-1:** Provide guidance on volt-watt implementation i.e., whether the DER unit(s) implement volt-watt based on the same or different per unit curves, and individual or total nameplate ratings (see BATRIES Toolkit Chapter VIII and IEEE 1547.2).	☐
			DO 18a-2: Do not provide further guidance on volt-watt nameplate ratings designation.	☐
			DO 18b-1: Provide guidance on how limit maximum active power function is implemented i.e., via PCS, via plant controller, or other means (see BATRIES Toolkit Chapter VIII and IEEE 1547.2).	☐
			DO 18b-2: Do not provide further guidance on how limit maximum active power is implemented.	☐
			DO 18c-1: Provide guidance on frequency droop implementation i.e., whether the DER unit(s) implement frequency droop based on individual or total nameplate ratings (see IEEE 1547.2).	☐

			DO 18c-2: Do not provide further guidance on how frequency droop is implemented.	☐
	Standard Interconnection Agreements	As required, include provisions for adhering to default functional settings and updating settings over time.	**DO 19-1:** Update interconnection agreement to meet contractual obligations (operating requirements).	☐
			DO 19-2: Do not update interconnection agreement to meet contractual obligations	☐
	Interconnection screens and study	The Fast Track and detailed study interconnection review processes should be updated based on 1547-2018 and additional information supplied by 1547.1 certification testing. Address the following issues: Shared secondary transformer screen Line configuration screen Effective grounding/supplemental grounding review Inverter fault current	**DO 20a-1:** Update "shared secondary transformer screen" based on likelihood of overvoltage occurring with default voltage regulation settings.	☐
			DO 20a-2: Keep screen conservative as is.	☐
			DO 20a-3: Determine alternative methods for screening overvoltage risk with voltage regulation.	☐
			DO 20b-1: Update line configuration screen to treat inverters and rotating machines distinctly (see BATRIES Toolkit Chapter VIII).	☐
			DO 20b-2: Use existing or alternative line configuration screens.	☐
			DO 20c-1: Revise Supplemental Review to include new grounding review for three-phase inverters based on LN connected load (see BATRIES Toolkit Chapter VIII).	☐
			DO 20c-2: Revise Supplemental Review to utilize a tool to determine supplemental grounding needs for inverters (see BATRIES Toolkit Chapter VIII).	☐
			DO 20c-3: Use existing or alternative grounding review practices.	☐
			DO 20d-1: Revise review practices for provision of inverter fault current test data (see BATRIES Toolkit Chapter VIII).	☐
	Power Control Systems (may be optional or long-term)	Include certification requirements for PCS in interconnection rule and/or technical requirements. Revise interconnection application to note if PCS is used and denote on one-line diagram.	**DO 21-1:** Include specific certification requirements for PCS in interconnection rule (see BATRIES Toolkit Chapter III).	☐
			DO 21-2: Add information on PCS to application forms (see BATRIES Chapter VIII).	☐
Long-term	DER communications/ control roadmap	Identify goals and strategies for deploying IEEE 1547 standardized communications/control of DER over time. Consider timeline for utilization of monitoring data, changes to autonomous function settings, scheduled function changes, and continuous direct control. Consider deployment for larger systems versus numerous small systems, and utility communications infrastructure versus DER aggregator model. Will communications infrastructure, DER equipment requirements and protocols be harmonized to any degree amongst utilities? How can investments in ADMS, DERMS or AMI be optimized to meet various goals? Consider linkage to grid modernization discussions.	**DO 22-1:** Establish a formal roadmap development process to take into account Commission's, stakeholders' and utilities' DER management goals.	☐
			DO 22-2: Allow individual utilities to determine needed communications investments based on internal DER management goals without external direction.	☐
			DO 22-3: Avoid directive management of communications deployment.	☐

	Communications deployment	DER communications deployment is still nascent and best practices for interconnection rules and technical requirements are still in development. The decision option list at right is a list of potential actions to consider, but is not intended to be exhaustive. Consider the need to change the interconnection rule's "telemetry," "SCADA," or "monitoring" DER size threshold. What requirements apply to the DER site/equipment? What actions need to be taken to adopt a DER aggregator model?	**DO 23a:** If not done previously, specify protocols and ports to be used at the DER interface or aggregator.	☐
			DO 23b: Define equipment requirements for DER or aggregator.	☐
			DO 23c: Create or reference guide for utilization of communications protocol (e.g., California Common Smart Inverter Profile).	☐
			DO 23d: Update "telemetry" requirements to change size threshold.	☐
			DO 23e: Update "telemetry" and/or other communication requirements to reference IEEE 1547 communications requirements.	☐
			DO 23f: Include certification/validation requirements for communications equipment (e.g., California Common Smart Inverter Profile).	☐
			DO 23g: Define standard aggregator requirements and agreements.	☐
	Interconnection agreement updates for communications/ control	As DER communications becomes deployed more widely, standard interconnection agreements should reflect such utilization. Control of the reactive power, volt-watt, limit maximum active power, permit service and other functions can affect energy production/delivery and have financial repercussions on the affected DER. It should be understood and agreed as to how these functions will be used. These aspects should be memorialized in the interconnection agreement. A standardized agreement can be developed to help establish expectations and limits while streamlining the interconnection process.	**DO 24a-1:** Develop standard interconnection agreements language to define whether a communications pathway is required and of which type it will be (e.g., utility direct to inverter, utility direct to gateway, or aggregator participation).	☐
			DO 24a-2: Establish communication requirements within each individual interconnection agreement.	☐
			DO 24b-1: Define expectations for control in the standard interconnection agreement (e.g., when and how long will the DER be curtailed or controlled and over what range of adjustment for specific parameters).	☐
			DO 24b-2: Establish expectations for control within each individual interconnection agreement.	☐
	Prioritization vs. export limiting	TBD	**DO 25-1:**	☐
			DO 25-2:	☐
	Ongoing reevaluation of default settings	Investigate whether fielded functional settings (voltage regulation and voltage/frequency settings) are optimized. Address the following: Are voltage regulation settings working well or should they be revised? Are new functionalities or insights available that can be leveraged to improve grid integration? Are volt-watt issues present that need to be addressed?	**DO 26-1:**	☐
	Evaluation/ commissioning	TBD	**DO 27-1:**	☐
			DO 27-2:	☐

ANNEX C – Working Group Process Description and Participants List

Twelve facilitated meetings of the Advanced Inverter Working Group were held between February and September of 2022. Over 50 people from 20 different organizations attended the working group's meetings which were facilitated by NM PRC staff and Gridworks.

The following organizations participated in the working group activities:

Electric Service Providers	Industry	Other
EPE	Affordable Solar	Community Solar Access
PNM	Enphase	EPRI
SPS/Xcel	Fronius	IREC
	Positive Energy	PACE Fund NM
	REIA of NM	NM PRC
	SMA-America	NM Office of the Attorney General
	Sunrun	NM State University
	Synapse Energy Economics	Sandia National Laboratories
	Tesla	
	Trimark	

The list of meetings below includes links to the meeting recordings and summaries.

Feb. 10, 2022

- https://www.youtube.com/watch?v=cEDbpI3_fUg
- https://onedrive.live.com/edit.aspx?cid=5891771fba4aff14&page=view&resid=5891771FBA4AFF14!2865&parId=5891771FBA4AFF14!2863&authkey=!AJKlY_S0wfPCqb8&app=Word

Feb. 24, 2022

- https://www.youtube.com/watch?v=iL9fitx55lo
- https://onedrive.live.com/?authkey=%21AJKlY%5FS0wfPCqb8&cid=5891771FBA4AFF14&id=5891771FBA4AFF14%212874&parId=5891771FBA4AFF14%212866&o=OneUp

Mar. 24, 2022

- https://www.youtube.com/watch?v=hV5G6_VDZg0
- https://onedrive.live.com/?authkey=%21AJKlY%5FS0wfPCqb8&cid=5891771FBA4AFF14&id=5891771FBA4AFF14%212874&parId=5891771FBA4AFF14%212866&o=OneUp

Apr. 14, 2022

- http://www.youtube.com/watch?v=b4fpVLg1Jus
- https://onedrive.live.com/edit.aspx?cid=5891771fba4aff14&page=view&resid=5891771FBA4AFF14!2894&parId=5891771FBA4AFF14!2882&authkey=!AJKlY_S0wfPCqb8&app=Word

May 26, 2022

- https://www.youtube.com/watch?v=4lMpCvG8aB0
- https://onedrive.live.com/edit.aspx?cid=5891771fba4aff14&page=view&resid=5891771FBA4AFF14!2909&parId=5891771FBA4AFF14!2896&authkey=!AJKlY_S0wfPCqb8&app=Word

Jun. 9, 2022

- https://us02web.zoom.us/rec/share/P7D4m27KU3fCQfWCVFpKN5MOcWj44pOB4HUUvPbGlu364YVYw8mmCjVOvgRO5XaS.WlGOAf37S3bjLtBp
  Passcode: NnGQi#L4

- https://onedrive.live.com/?authkey=%21AJKlY%5FS0wfPCqb8&cid=5891771FBA4AFF14&id=5891771FBA4AFF14%212917&parId=5891771FBA4AFF14%212902&o=OneUp

Jun. 30, 2022

- https://www.youtube.com/watch?v=70auf67yKb4
- https://onedrive.live.com/edit.aspx?cid=5891771fba4aff14&page=view&resid=5891771FBA4AFF14!2922&parId=5891771FBA4AFF14!2903&authkey=!AJKlY_S0wfPCqb8&app=Word

Jul. 14, 2022

- http://www.youtube.com/watch?v=Ml1I543nHPw
- https://onedrive.live.com/edit.aspx?cid=5891771fba4aff14&page=view&resid=5891771FBA4AFF14!2933&parId=5891771FBA4AFF14!2904&authkey=!AJKlY_S0wfPCqb8&app=Word

Jul. 28, 2022

- https://www.youtube.com/watch?v=pjjeGcTaugs
- https://onedrive.live.com/edit.aspx?cid=5891771fba4aff14&page=view&resid=5891771FBA4AFF14!2937&parId=5891771FBA4AFF14!2905&authkey=!AJKlY_S0wfPCqb8&app=Word

Aug. 11, 2022

- https://us02web.zoom.us/rec/share/5mYfnqQIXViEhbqdX07eMyjzx34LE0y8RDFAld1KyfFXEjOc3-U92StQj8PN4Hky.IuqMNQhfvPVHY0aA
  Passcode: ?&Y84Q$D
- https://onedrive.live.com/?authkey=%21AJKlY%5FS0wfPCqb8&cid=5891771FBA4AFF14&id=5891771FBA4AFF14%212943&parId=5891771FBA4AFF14%212906&o=OneUpAug. 25, 2022

Aug. 25, 2022

- recording
- summary

Sept. 8, 2022

- recording
- summary

Two subgroups were formed during this process: a functions and settings proposal subgroup and a communications interoperability subgroup. The working group appreciates the work of the people who provided their time and expertise to develop Recommendation 4 (Functions and Settings). Key contributors were Travis Dorr (SPS), Brian Lydic (IREC), Midhat Mifazy (IREC) and Michael Ropp (SNL). Critical input was also received from Tom Key (EPRI) and Steve Wurmlinger (SMA). Jose Cordova (EPRI) supported the effort as well by making a presentation to the group on June 9.

The working group also appreciates the knowledge and participation of the following individuals for developing the basis of Recommendation 5 (Communications Interoperability). Key individuals were Travis Dorr (SPS), Jon Hawkins (PNM), Michael Ropp (SNL), Tracy VanSlyke and Jerry Delgado (EPE). Bob Fox (SunSpec Alliance) also provided invaluable assistance in this effort.

ANNEX D – Additional Information: Recommendation 3 (Reference Point of Applicability)

Per IEEE 1547-2018, the reference point of applicability (RPA) is the location where the interconnection and interoperability performance requirements specified in this standard apply. The location of the RPA is affected by system rating and export capability, load demand, and zero-sequence continuity. The point of common coupling (PCC) is the point of connection between the Area EPS and the Local EPS. The point of DER connection (PoC) is the point where a DER unit is electrically connected in a Local EPS and meets the requirements of this standard exclusive of any load present in the respective part of the Local EPS. Figures H.1 and H.2 of IEEE 1547™-2018 provide decision trees regarding the determination of the RPA and the IREC BATTRIES Toolkit[16] includes recommendations on this topic.

Definitions from IEEE Std 1547-2018

Point of DER connection (PoC): "The point where a DER unit is electrically connected in a local EPS and meets the requirements of this standard exclusive of any load present in the respective part of the local EPS."

Supplemental DER device: "Any equipment that is used to obtain compliance with some or all of the interconnection requirements of this standard."

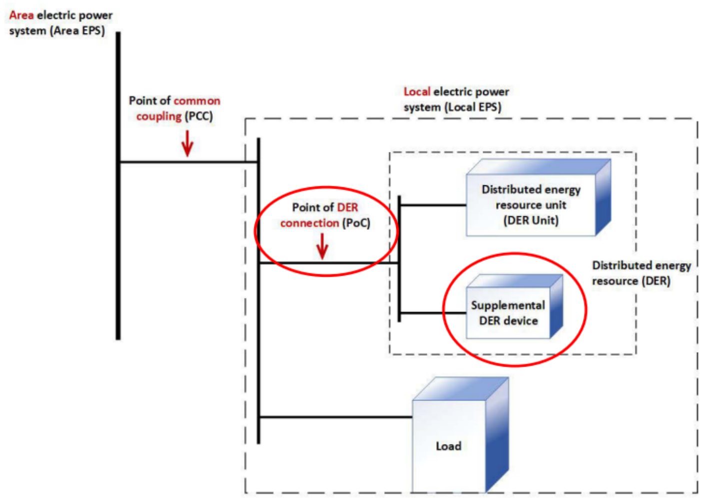


Figure courtesy of NREL

This process may interfere with interconnection process timelines. It could potentially be streamlined by including a specific process for RPA review with timelines of its own. See BATRIES chapter VIII. Otherwise, it could be considered part of completeness review. Perhaps the best alternative (a la BATRIES) in lieu of changes to the IX rule, would be to process the RPA changes in parallel with initial review screens to not introduce further delays, but this could potentially mean the utility would beholding the application after the review timeline has passed to clear up the RPA. RPA for detailed study could be discussed at a scoping meeting and included in the study agreement.

[16] https://energystorageinterconnection.org/resources/batries-toolkit/

ANNEX E – Additional Information: Recommendation 4 (Categories, Functions and Settings)

Selection of categories for both normal and abnormal operating performance impacts which advanced inverter functions are to be enabled as well as the settings for these control functions. The normal operating performance category (choices are Category A or B) specifies how the Distributed Energy Resource (DER) system should perform with regards to voltage control during normal grid operations, and therefore impacts the use of voltage regulation controls. The abnormal operating performance category (choices are Category I, II, or III) specifies DER performance or "ride-through" capabilities during a grid disturbance such as a transmission fault or loss of a generator.

Recommendation 4.a – Category Determination: Equipment is allowed to meet the requirements of the highest category it is capable of being certified to, with category B being higher than category A (under normal performance) and category III being the highest under abnormal performance.

Recommendation 4.b – Function Activation:

Table 3 provides details regarding the autonomous functions for DERs in New Mexico.

TABLE 3. Functions, Activations, and Settings Summary

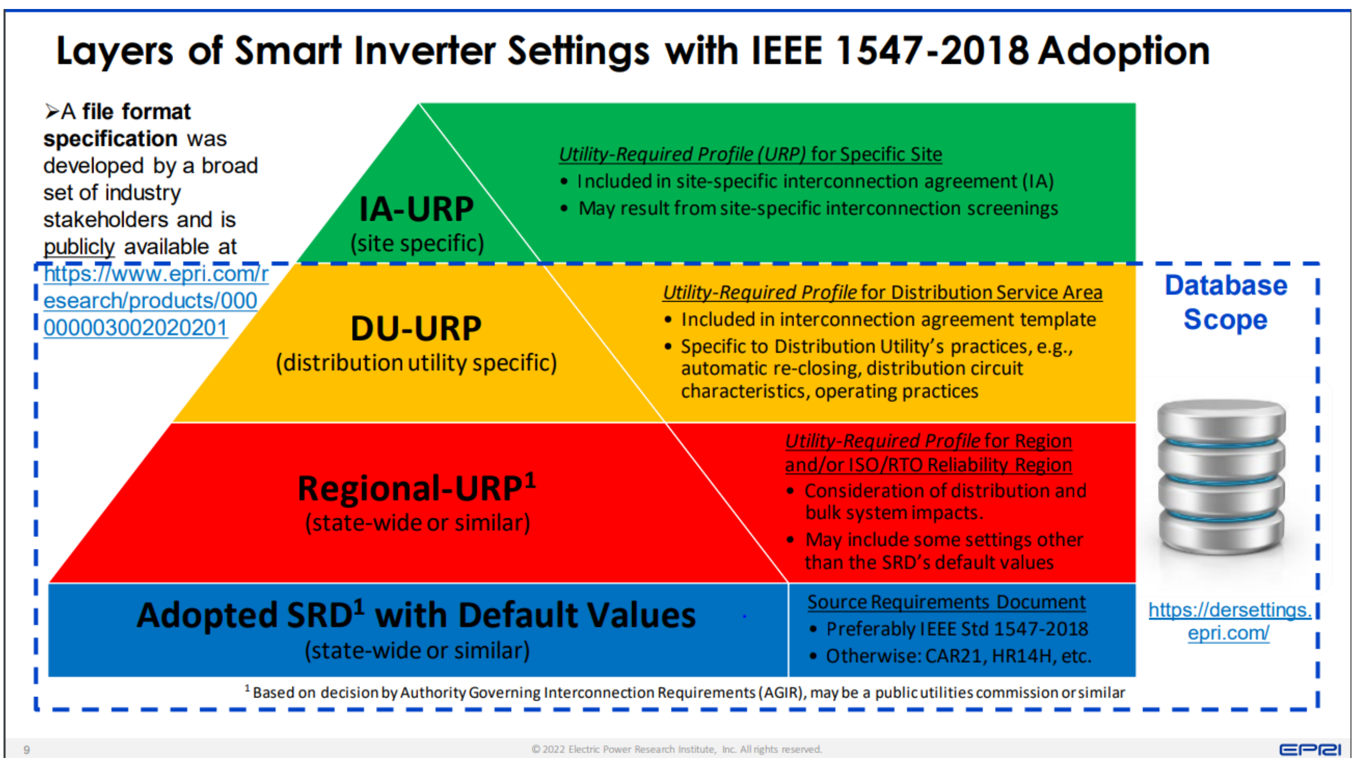
Function	Activation	Purpose
Voltage-Reactive Power Control (volt-var)**	Enabled for Categories A & B; utilize category-appropriate default settings in IEEE 1547-2018, Table 8	Voltage Regulation
Constant Power Factor	Disabled***	Voltage Regulation
Active Power-Reactive Power Control (watt-var)	Disabled	Voltage Regulation
Constant Reactive Power Control	Disabled	Voltage Regulation
Voltage-Active Power Control (volt-watt)	Enabled for Category B; use default settings in IEEE 1547-2018, Table 10	Voltage Regulation
Voltage Disturbance Ride-Through and Trips	Rotating DERS use Category I defaults, inverter-based DERS systems, use Category III defaults	Bulk System Stability; maximum grid support from DERS
Frequency Disturbance Ride-Through and Trips	Rotating DERS use Category I defaults, inverter-based DER systems, use Category III defaults	Bulk System Stability; maximum grid support from DERS
Enter Service	Use default settings from IEEE 1547-2018, Table 4	Avoidance of abnormal voltages
Enter Service Ramp Rate	DER installations shall use the ramp rate specified in IEEE 1547-2018, 4.10.3. DERS smaller than this limit may use the randomized start time described in IEEE	Avoidance of abnormal voltages

	1547-2018, 4.10.3, Exception 1 if mutually agreed to by the system operator.	
Anti-Islanding	Enabled	Avoid unintentional islanding

**Regarding volt-var settings: the autonomously adjusting Vref function should also be turned off by default unless otherwise determined as advantageous by System Impact Study.
***Under normal circumstances, the Constant Power Factor control function will be disabled by default. However, in some cases, the Area EPS operator has the jurisdiction to specify in the Interconnection Agreement (IA) when Constant Power Factor control function is to be enabled. If this function is enabled, Voltage-Reactive Power Control (volt-var) must be disabled. If the IA does not specify a power factor or if an interconnection agreement is not required for interconnection, then assume -0.98 (absorbing).

Recommendation 4.c –Settings:

The use of Utility Required Profiles is suggested for documenting settings. Work by EPRI on this topic is appreciated. The following graphic, used by permission from EPRI, summarizes the various levels of URPs and provides helpful resources on this topic.



ANNEX F – Additional Information: Recommendation 5 (Communications Protocols)

Recommendation 5.a – Applicability:

EXPLANATION: DER systems up to and including 10MW are included in this communications interoperability requirement. (Systems larger than 10MW are outside the scope of the NM Interconnection Rules). If a collection of DER equipment is aggregated and interfacing with the electric service provider as if it were one system, a single communications interface is allowed.

RATIONALE: taking advantage of the aggregated resources represented by DER systems will require them to be visible and interactive with the distribution system.

Note that testing and certification of interoperability is covered by recommendation 2.

Recommendation 5.b – Allowed Protocols:

New Mexico allows any of the three IEEE 1547™-2018 eligible protocols (but no others) to be employed by the electric service providers.[17] Providers are allowed to implement any of the three in different parts of the distribution system, depending on the use case and infrastructure in place at a given location. Guidance regarding allowed protocols shall be documented in the electric service provider's TIIR documents.

EXPLANATION: A summary of eligible protocols is included in Annex F, and highly simplified version is shown in Table 1. Communications interfaces may be different depending on the infrastructure available at the DER system interconnection site. For example, in some locations, connection to the electric service provider's SCADA system might be preferred and hence, the IEEE Std 1815 (DNP3) may be the chosen protocol. In another location a DER inverter that uses the SunSpec Modbus protocol will need a gateway device to communicate with an electric service provider's demand side management system that uses the IEEE Std 2030.5 (SEP2) protocol.

Table 1. Eligible protocols (see IEEE 1547™-2018, subclause 10 for additional details)

	Current uses include…	**Considerations**
IEEE Std 2030.5 (SEP2)	Many AMI and home energy mgt devices	Common web interface platform.
IEEE Std 1815 (DNP3)	Utility SCADA systems	Allows for granular level control, high speed communications. Must have the appropriate DER information content integrated to be IEEE 1547 compliant.
SunSpec Modbus	Many modern inverters	Submaps (content) added for specific applications.

Note that cyber security challenges are present regardless of the chosen protocol and must be addressed in partnership with the involved entities across the entire communications and control system.

RATIONALE: It is expected that gateway devices will be available to translate between the communications protocol used by the DER equipment and the electric service provider's communications network to which the DER will be connected, whereas the EPS operator's communication system has limited configurability. In addition, communications technologies are evolving, so some flexibility is recommended.

Recommendation 5.c – Information Management:

Communications interoperability of DER is expected to mature in the following three phases:

i. Inverter autonomous functions enabled.
ii. Electric service providers propose pilot programs to monitor and interact with DER equipment connected to their systems.
iii. After due consideration, decisions, and implementation of communication interoperability standards, ESPs and DER operators will the ability to exchange "interactive information" to enable full functionality of DER – electric system interactions.

[17] The IEC 61850 standard, though used in some electrical system communication infrastructures, is not currently included in the list of eligible protocols.

Phase i) relies on the autonomous functions of the IEEE 1547™-2018 compliant inverters to manage the performance of the DER system. It also offers the EPS operators and DER operators opportunities to learn how the two interact based on the advanced inverters autonomous functions. Most of New Mexico's electric service providers do not yet have visibility of DER resources and this first step is necessary before "interactive" capabilities can be implemented. Experiences, learnings, challenges, and best practices shall be reported to the PRC 18 months after adoption of the Interconnection Rule.

Phase ii) enables the EPS operators to design and implement explicit pilot programs for communications interoperability. Pilot programs could include both monitoring as well as interactive management and should be identify best practices and develop solutions to challenges (e.g., cyber security). Note that cyber security (which was out of scope for IEEE 1547-2018) is a critical issue that is being worked at the national level. Suggestions for communication interoperability standards shall be reported to the PRC 36 months after adoption of the Interconnection Rule.

Phase iii) enables full functionality of distributed resource - system interactions, takes advantage of the DER to support grid operations.

Reference Information Regarding Communications Interoperability Protocols

The working group expresses great appreciate to Bob Fox, Principal Engineer at the SunSpec Alliance, for his attendance at the working group's July 14, 2022, meeting. Mr. Fox summarized the history, uses, and considerations regarding the IEEE 1547™-2018 compliant communications protocols. The synopsis below was developed by the Gridwork's meeting facilitator.

SunSpec Modbus

Modbus was developed in the 1970's as an industrial control protocol and is used across millions of devices, mostly in industrial automation applications. It is a simple to implement. It is a command-response model and is a vehicle for exchange of information. A requestor makes requests from Modbus compliant devices, which are organized as a set of registers. Content is added via Modbus "maps" to allow for interactions with specific devices. Modbus was popular among many, but not all, DER manufacturers. SunSpec modified Modbus by adding standardized submaps (information arrays) that could be defined and chosen by equipment manufacturers. Submaps were developed for functional groups such as inverters, environmental devices, metering, trackers, storage, and others. SunSpec also provides a discovery mechanism to find needed submap content for specific applications. In other words, SunSpec added maps (information models) to the original Modbus exchange protocol. This updated version of Modbus can be deployed using the physical layer of RS-485 (serial layer) or TCP/IP over Ethernet. Specific documents pertaining to IEEE 1547-2018 and implementation of SunSpec Modbus to comply with the standard are available. More information is available at www.sunspec.org.

With regards to security, Modbus can be contained in a (physically secure) gateway which can translate between 2030.5 and Modbus formats. Modbus can also operate over TCP/IP with Transport Layer Security (TLS) for added security.

IEEE Std 1815 (DNP3)

This command response protocol was developed in the 1980's and it involves a requester sending or receiving information to or from a device. It is, like Modbus, a vehicle for exchanging information, and has a register model for storing information. All application specific information must be supplied separately. This protocol has more functionality than Modbus but is more complicated to deploy and may be more expensive to deploy. DNP3 has the capability of exchanging information asynchronously. A DER application node organizes the relevant information for DNP3 compatibility. See DNP3.org users group for more information about such an application. The Modular Energy Storage Association/Alliance (MESA) also developed a DNP3 information application that is harmonized with this protocol. DNP3 is commonly used in SCADA systems, where control functions are required at a granular level. An equipment manufacturer usually supplies the information content map, or it can be customized by the user. These applications typically involve higher speed communications commensurate with control functions. Customization and high-speed control features are the reasons for the higher costs. There are likely many DNP3 systems currently in use, but they will not be IEEE 1547-2018 compliant unless they have the appropriate DER information content integrated. This protocol gets the least amount of attention, currently, but is being seen in many large-scale storage systems. Support for the *DNP3 Profile for Communications with Distributed Energy Resources (DERs)* (referenced as DNP3-AN-2018-001 at DNP3.org) is required for 1547-2018 DNP3 support.

IEEE Std 2030.5 (SEP2)

This protocol was developed by ZigBee (meter manufacturer) as a smart energy protocol (SEP1) and was revised to manage home energy management devices (SEP2). (Note: the US National Institute of Standards and Technology, NIST, selected SEP2 as a standard for home energy management devices in 2009.) The 2030.5 (SEP2) protocol runs HTTP (application layer) over TCP/IP and uses a RESTful webservice paradigm, which is now very common in many web-interfacing systems. It also runs with a TLS layer.

In 2015 this protocol was transferred to IEEE where it became IEEE 2030.5-2015. It was updated in 2018 to support the IEEE 1547-2018 standard. DER related content (metering, demand control, pricing, and many other functions) has been developed and the information models are integrated into the 2030.5 protocol. This is in contrast with the Modbus and DNP3 protocols where additional information models are required to be integrated. In contrast to Modbus and DNP3 which are command and response protocols, a 2030.5 client (DER in this case) pulls configuration and control information from the 2030.5 server either periodically or when notified of a change. The technology used in the 2030.5 protocol stack (TCP/IP, HTTP, TLS) is proven, well-worn, and understood by many engineers today. It is also currently being updated. For more information on this protocol, see www.sunspec.org.

California has adopted 2030.5 as the default interface for resources interfacing with electric utilities. CA has developed a Common Smart Inverter Profile for defining how 2030.5 is used for DER deployment and outlining certification requirements. Australia is adopting this protocol with some additions to the CA profile.

Other Topics

Security Discussion - It was noted that many entities have a role to play in cyber security of these systems and partnerships among parties to address the whole system are critical. The physical environment as well as the communications environment are to be considered. Security will be an active conversation for the foreseeable future and will have different approaches in different applications. This is true for all three protocols. Other industries (e.g., banking) have had to address similar security challenges. Protocols that are broadly deployed and continuously being updated may have stronger security profiles. One source of information on this topic is a workgroup that SunSpec and Sandia currently lead. For more information see: https://sunspec.org/cybersecurity-work-group/

AMI Implications – Bandwidth of some AMI systems has historically been a constraint for interoperability with DER control protocols, but this could be changing.

Applicability – An option to consider is to use SunSpec Modbus locally for individual, small DER systems and consider another protocol, such as 2030.5 for larger, wide area systems that will interface with the utility in a more sophisticated way. SunSpec Modbus is the simplest way to achieve IEEE 1547-2018 compliance in the short term, particularly for local applications.

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