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March 30, 2023

VIA ELECTRONIC FILING

Ms. A. Shonta Dunston, Chief Clerk
North Carolina Utilities Commission
4325 Mail Service Center
Raleigh, North Carolina 27699-4300

RE: *DEC's and DEP's IEEE Standard 1547-2018 Implementation Status Report*
Docket Nos. E-100, Sub 101 and E-100, Sub 101B

Dear Ms. Dunston:

Enclosed for filing with the North Carolina Utilities Commission ("Commission") on behalf of Duke Energy Carolinas, LLC ("DEC") and Duke Energy Progress, LLC ("DEP" and together with DEC, "Duke Energy" or the "Companies") is the Companies' *IEEE Standard 1547-2018 Implementation Status Report*, which is being filed in response to the Commission's March 2, 2021 *Order Requiring Reports and Scheduling Presentation* ("IEEE 1547 Informational Order").

Background

IEEE Standard 1547 is a technical standard that is published by the IEEE Standards Association ("IEEE SA") for the uniform interconnection and interoperability of distributed energy resources ("DER") with electric power systems.

On June 14, 2019, the Commission issued its *Order Approving Revised Interconnection Standard and Requiring Reports and Testimony* in Docket No. E-100, Sub 101 (2019 Order) which, among other things, required the electric utilities to host stakeholder meetings on IEEE Standard 1547-2018 and to file a report with the Commission by April 1, 2020. On April 1, 2020, the Companies filed the required report explaining their IEEE Standard 1547-2018 implementation efforts.

On March 2, 2021, the Commission issued its IEEE 1547 Informational Order, advising that the Commission would like to stay informed of IEEE Standard 1547-2018 implementation efforts in North Carolina and, therefore, requesting that the Companies annually file: (A) the most recent version of IEEE Standard 1547, (B) the most recent version of the Companies' Implementation Guidelines, and (C) a narrative explanation of any stakeholder meetings that have occurred since the Companies' previous filing. In accordance with the IEEE 1547 Informational Order, the Companies filed their first Annual Report for 2020-2021 on March 15, 2021 and an Annual report for 2021-2022 on March 15, 2022. The Companies now hereby provide the Commission the requested information for 2022-2023.

Annual Report for 2022-2023

A. IEEE Standard 1547-2018

The *IEEE 1547-2018 – IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces* developed and published by the IEEE SA is a copyrighted standard that is not publicly available for reproduction and distribution. The Companies are therefore unable to publicly file a copy of IEEE Standard 1547 with the Commission. The IEEE Standard 1547 is available at the following link: https://standards.ieee.org/standard/1547-2018.html, and additional information about procuring a copy may be obtained by contacting IEEE SA. However, the Companies note for the Commission that IEEE Standard 1547-2018 has not been updated in the last year.

B. IEEE 1547-2018 Implementation Guidelines for Duke Energy Carolinas and Duke Energy Progress

Included as Attachment A to this letter is a copy of the Companies' *IEEE 1547-2018 Implementation Guidelines for Duke Energy Carolinas and Duke Energy Progress* (the "Implementation Guidelines" or the "Guidelines"). This is Revision 10 of the Guidelines as most recently updated on October 26, 2022, and it reflects input received from stakeholders during regular IEEE 1547 informational sessions held during quarterly meetings of the Companies' Distributed Energy Resource ("DER") Interconnection Technical Standards Review Group ("TSRG"). The Companies have revised the Implementation Guidelines to reflect stakeholder feedback and their own ongoing efforts to refine the implementation process after each of the four TSRG meetings that have taken place since March 15, 2022.

1. *Status of Implementation Guideline Development*

The Implementation Guidelines contain three main subtopics for each section of Standard 1547: (1) technical requirements; (2) interoperability requirements; and (3) test and verification requirements. In Revision 10, the interoperability requirements are complete for all sections of the Standard, while the technical requirements and test and verification requirements are complete for approximately 90% of the sections. The sections that require further revisions remain open pending the conclusion of ongoing studies, projects and/or resolution of implementation issues.

2. *Generator Ride-Through Capabilities and Inverter Settings*

The Commission's November 22, 2021 *Order Requiring Comments and Filings Regarding Risks Posed by Inverter-Based Resources* (the "IBR Risk Order"), directed the utilities to include in their next annual IEEE Standard 1547 report a discussion of "their plans for implementing those portions of IEEE Standard 1547 that address generator ride-through capabilities and inverter settings[.]" The status of the Companies' efforts to address these topics and implement IEEE Standard 1547 in their Implementation Guidelines are described below.

First, the Companies are in the process of completing an enterprise-wide protection study, which involves a comprehensive review of all protective devices across the Companies' electric system assets, and have engaged a third party to conduct the core research for the study. This includes the trip and ride-through settings for inverters connecting to those systems. At the conclusion of the third-party's research, which is expected to be complete during Q3 2023, Duke Energy will begin converting the research results into operational settings for the DER recloser and inverters. The Companies will then field-test these settings. The voltage settings under evaluation for overvoltage (OV) & undervoltage (UV) settings are similar to the default voltage settings shown in IEEE 1547-2018, Category II. The clearing times are also within the ranges of allowable settings included in the Standard.

While the final settings selected during the study may fall within Category II of the Standard, Duke Energy's Implementation Guidelines will require Category III performance because that Category includes all the performance requirements of Category II and provides additional capability should future reliability concerns arise and require settings within the range of Category III. The mandatory operation capability of the Category III inverters also provides greater ride through capability which may provide added stability to the grid. Field testing is expected to begin in Q3 2023 and conclude by Q4 2024.

Second, the Companies' implementation of the Smart Inverter Pilot Project is progressing. Construction is now complete for one plant that was tested and place in service in 2022. At the end of the year, Duke Energy engaged the Electic Power Research Institute ("EPRI") to review data and analyze the performance. EPRI's review is not yet complete. Two additional plants are nearing completion of construction. Duke Energy has reviewed test procedures for those plants, but the test dates have not yet been scheduled.

3. *Summary of Next Steps*

The Implementation Guidelines are now complete for the topics included in the proposed Phase 1 implementation. One topic remains open in each of Phases 2 and 3, and those will be closed before implementation of those requirements begins.

As described below, the Companies have continued to discuss potential implementation timelines with stakeholders. Based on this discussion, the Companies plan to implement IEEE Standard 1547 in three phases, with a majority of the Implementation Guidelines included as part of Phase 1. The final implementation schedule will consider the most recent projections for UL certified inverters to be on the market. Last year, the Companies reported that UL certified inverters were expected to reach market in late 2022, with 80% projected to be certified by April 2023. Unfortunately, industry testing is behind sechedule and 50% may be a better estimate for April.

C. Stakeholder Meetings Regarding Implementation of IEEE 1547-2018

As already discussed, the Companies' approach to implementation of IEEE Standard 1547-2018 has been developed through the TSRG. The TSRG is a Duke Energy-specific forum made up of North and South Carolina interested stakeholders that meets quarterly to address technical issues regarding the interconnection and operation of renewable generation in Duke's service territories. The quarterly TSRG meetings are held in January, April, July and October of each year, and all meeting information is publicly available on the TSRG website, available at https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg. At each TSRG meeting, the Companies provide stakeholders with an opportunity to share comments during the meeting as well as a form soliciting written feedback and comments. The Companies consider all of the input received, and the Implementation Guidelines reflect this ongoing collaboration.

Since the filing of the Companies' last report on March 15, 2022, four quarterly TSRG meetings have occurred. Copies of the TSRG presentations are included as Attachment B to this letter. The descriptions below summarize the actions and discussions at each TSRG meeting conducted since the Companies' last report.

1. *April 2022 TSRG Meeting*

There are three main categories of information in the Guidelines: (1) technical; (2) interoperability; and (3) commissioning. At the time of the April 2022 TSRG Meeting, all interoperability sections were completed, and the technical and commission topics were 70% complete. In addition, the Companies had just begun discussions were with 2-3 reactive power sites to participate in the Smart Inverter Pilot Program, but no tests or installations had yet occurred. Accordingly, the IEEE 1547 informational session was focused on application of the Implementation Guidelines to existing interconnection requests and and uncertified equipment. Duke Energy reminded the group that once it selected a date for implementation, projects requesting interconnection thereafter must comply with the Implementation Guidelines. Conversely, Duke Energy confirmed that the

Implementation Guidelines would not apply before the implementation date. The Companies also noted that the Implementation Guidelines will apply only to IEEE 1547-2018 certified equipment and *not* to equipment without such certification. Duke Energy also shared that industry sources suggested that device certifications were behind schedule, meaning that most inverters would not be tested and certified before April 2023. Stakeholders made no significant comments on the Guidelines document, itself.

Finally, Duke Energy shared with the TSRG its preliminary three-step plan for phased roll-out of the Implementation Guidelines. Duke Energy explained that a majority of the Guidelines would be implemented in Phase 1, and the remaining guidelines split between implementation in Phase 2 and Phase 3. A phased implementation is very common method of applying the IEEE Standard. Duke Energy requested input from Stakeholders on the high level tasks for implementation, but no stakeholder provided input.

2. *July 2022 TSRG Meeting*

At the July 2022 TSRG Meeting, Duke Energy shared that it completed five (5) more sections of the Guidelines. The group continued discussing Duke Energy's three-step plan for phased roll-out of the Implementation Guidelines. Specifically, Duke Energy proposed that approximately 75% of the Guidelines would be implemented in Phase 1, 15% in phase 2, and 10% in Phase 3. Duke Energy requested stakeholder comment on the Guidelines and the content of the requirements in each proposed Phase of implementation. No stakeholder provided comments. Duke Energy proposed that Phase 1 could possibly begin with the 2023 DISIS, requiring use of UL 1741 SB inverters certified to IEEE 1547. Phase 2 would then begin with the 2024 DISIS.

The TSRG also discussed how the Guidelines applied to or enabled ancillary services. Duke Energy representatives explained that the Guidelines are focused on requirements for interconnection and not for the provision of ancillary services. Topics like reactive power control are included from a technical perspective, but application or use of that function for market or services is beyond the scope of the Guidelines.

Finally, Duke Energy updated the Stakeholders on the Smart Inverter Pilot Program. Of the seven (7) projects participating, two (2) were in study to verify and update the reactive power control settings. Duke Energy completed the studies, and one site was tested in May and the plant placed in service with reactive power control. Duke Energy provided an update to the TSRG on lessons learned and a general timeline for writing the test procedure and performing the test. There were no Stakeholder comments or discussion on the pilot or test procedure development process.

3. *October 2022 TSRG Meeting*

At the October 2021 TSRG meeting, Duke Energy presented for discussion the 10th version of the draft Implementation Guidelines. Duke Energy explained that the changes from the 9th revision were mainly editorial. The Companies called for final comments on the Guidelines and none were provided. Duke Energy noted that latest industry reports suggested that inverter testing remained slow and requested input from Stakeholders regarding their expectations as to when the new inverters would be readily available. No one provided an expected timeframe.

4. *January 2023 TSRG Meeting*

There was no discussion of the Implementation Guidelines by the Companies or the Stakeholders at the January 2023 TSRG Meeting.

Thank you for your consideration in this matter. Please do not hesitate to contact me with any questions.

Sincerely,

Jason A. Higginbotham

cc: Parties of Record

ATTACHMENT A

IEEE 1547-2018 Implementation Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 10

October 26, 2022

DUKE ENERGY®

IEEE 1547-2018 Implementation Guidelines for Duke Energy Carolinas and Duke Energy Progress

Revision	Date	Description
0	3/31/2020	Draft, Initial issue
1	7/21/2020	Draft, General update prior to Jul. 2020 TSRG meeting
2	10/28/2020	Draft, General update prior to Oct. 2020 TSRG meeting
3	1/20/2021	Draft, General update prior to Jan. 2021 TSRG meeting
4	4/28/2021	Draft, General update prior to Apr. 2021 TSRG meeting
5	7/20/2021	Draft, General update prior to Jul. 2021 TSRG meeting
6	10/19/2021	Draft, General update prior to Oct. 2021 TSRG meeting
7	1/19/2022	Draft, General update prior to Jan. 2022 TSRG meeting
8	4/20/2022	Draft, General update prior to Apr. 2022 TSRG meeting
9	7/20/2022	Draft, General update prior to Jul. 2022 TSRG meeting
10	7/20/2022	Draft, General update prior to Oct. 2022 TSRG meeting

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INTRODUCTION

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

Note to the format of this document. This guideline is meant to be a living document, for now. It documents where Duke Energy is in the process of implementing IEEE 1547-2018. AT THIS TIME, THIS DOCUMENT IS A DRAFT AND NOT FINAL. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

DEFINITIONS USED IN THE GUIDELINES

In general, the Guidelines use the same definitions as the IEEE 1547 Standard. Additional clarifications are noted below.

DER: Defined the same as the standard. Also includes multiple DER units in the Local EPS or at the RPA.

RDER: Net meter and smaller DER with ratings below 250 kW.

UDER: Large DER with ratings 1 MW and above.

CONSIDERATION OF IEEE 1547 SECTIONS THAT COULD INCREASE INTERCONNECTION CAPABILITY

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

i) 4.6.2 Capability to limit active power
ii) 5.3 Voltage and reactive power control
iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

CONSIDERATION OF IEEE 1547 SECTIONS THAT IMPACT GRID SUPPORT

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation.

Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

PRIORITY OF IMPLEMENTING THE IEEE 1547 TECHNICAL SPECIFICATIONS AND REQUIREMENTS

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress, constant pf initially	Monitor or Control	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress, not used initially	Monitor or Control	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Ops Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	No Reqmt	Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	Info Exchange	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	Info Exchange	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	No Reqmt	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	No Reqmt	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Study in progress, accept 1547 initially	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Accept 1547	No Reqmt	TBD, Eval + Comm Test
2 (DUK-103)	8.1	Unintentional islanding	activate anti-islanding	No Reqmt	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547	No Reqmt	Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547, with notes	Control	Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547, static limits	Monitor / Control	Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	3 Hz/s, ROCOF tripping off	No Reqmt	Eval + Comm Test
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547	No Reqmt	Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547	Monitor	Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547, with notes	No Reqmt	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547, with notes	No Reqmt	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 ; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 ; consider clarifications; part of ongoing study	No Reqmt	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with notes	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 with notes	No Reqmt	Eval + Comm Test
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547	No Reqmt	Type Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547	Now- No Reqmt Future- TBD	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	-	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-
- (DUK-104)	8.2	Intentional islanding	TBD	TBD	-
- (DUK-105)	11	Test and verification	Addressed in each 1547 section	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	Accept 1547 with notes	Yes	-
- (DUK-107)	10.5	Monitoring information	Addressed in each 1547 section	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	-	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	TBD
- (DUK-110)	6.5.2.8	Inertial response	Not required	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	Accept 1547 with notes	Yes	-
- (DUK-112)	10.3	Nameplate Information	Addressed in each 1547 section	Yes	-
- (DUK-113)	10.4	Configuration information	Addressed in each 1547 section	Yes	-
- (DUK-114)	10.6	Management information	Addressed in each 1547 section	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	Accept 1547 with notes	Yes	-
- (DUK-116)	10.8	Communication performance requirements	Accept 1547 with notes	Yes	-
- (DUK-117)	10.9	Cyber security requirements	Accept 1547 with notes	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	Accept 1547	No Reqmt	Type Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	TBD	TBD

LOGISTICS OF IMPLEMENTING IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the associated interoperability and test requirements will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification.

Duke Energy has no plans to implement the new functions of IEEE 1547-2018 for existing inverters. Not only is it not a common practice at Duke to retroactively apply standards, it is really not even a valid option because existing inverters do not have many of the 1547-2018 capabilities and were not tested to UL 1741 SB. If a 1547-2018 function is implemented and there is a comparable IEEE 1547a-2014 function for inverters certified to UL 1741 SA, then Duke Energy and the DER Owner may mutually agree to implement those available functions as needed. Similarly, some functions like voltage and frequency tripping have existed throughout all versions of 1547. Revising pre-existing settings is not considered implementation of a new function.

PLANT REQUIREMENTS

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title. Also, each section applies to RDER and UDER unless otherwise indicated.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke accepts the requirements in the Standard.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

Inverter-based DER:	Category B
Synchronous machine DER:	Category A

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 4.2 – REFERENCE POINTS OF APPLICABILITY (RPA)

Duke accepts the requirements in the Standard.

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling), which is also known as the point of delivery or change of ownership point on the medium voltage side of the DER transformer(s). For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The RPA for net meter installations (RDER) is the PoC (point of connection) at the inverter terminals.

See the decision trees in the informative Annex H of the Standard and the decision tree in IEEE 1547.2.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will review DER design documents to confirm the location of the RPA is correct.

SECTION 4.3 – APPLICABLE VOLTAGES

Duke accepts the requirements in the Standard. The Method of Service Guidelines addresses interconnection voltages.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: The applicable voltages will be established during the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

SECTION 4.5 – CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service setting to “disabled” as described in IEEE 1547 subsection 4.6.1.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to verify an inbuilt function or identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

SECTION 4.6 – CONTROL CAPABILITY REQUIREMENTS

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

Duke accepts the requirements in the following Standard sections as written:

- 4.6.1 Capability to disable permit service
- 4.6.2 Capability to limit active power
- 4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication interface.

4.6.1 Capability to disable permit service

The expectation is that Standard compliant inverters will have disable permit service capability inbuilt, but Duke will not use it at this time for DER < 250 kW. Future dispatch or emergency response functionality could possibly require this functionality for system reliability.

Duke policy requires a utility owned interconnection recloser for UDER ≥ 1MW. In this case, the permit service is implemented by controlling the utility owned recloser. For DER ≥ 250kW and <1MW, Duke allows the option of installing the small DG interface (automation controller) instead of the utility owned recloser. In this case, the permit service is implemented at the DER unit through the small DG interface.

Interoperability requirements: The present automation controller implementation includes a disable permit service control.

Verification and test requirements: Duke will review UL certification tests, type tests, design documents, and equipment specifications to identify the capability of the DER to meet this performance requirement. DER with the permit service signal will be field tested during commissioning as follows: 1) the DER shall not energize the EPS without a permissive signal; and 2) the DER shall cease to energize and trip when the permissive signal is removed.

4.6.2 Capability to limit active power

The expectation is that Standard compliant inverters will have limit active power capability inbuilt, but Duke will not use it at this time for DER < 250 kW.

Active power limits can be static or dynamic. Static limits are fixed and is essentially part of the system impact study (SIS) process now because the maximum active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other variables. Adjusting the limit in real time is a dynamic limit.

Duke does not plan to implement real-time control during the initial implementation of the Standard. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Significant technical studies are required to address real-time control of the active power limit. In response to a NC/SC rate case commitment, Duke Energy began the DER Dispatch Project to enhance control at both the transmission and distribution levels. That project will define the scope and implementation of real-time controls for active power.

Interoperability requirements: No control is required for static power limits. The automation controller has the capability to provide a limit active power Analog Output sent via SCADA to control active power, however, this control is not currently used.

Verification and test requirements: The existing inspection and commissioning process covers the verification of the static power limit.

4.6.3 Execution of mode or parameter changes

This section applies to UDER, and Duke accepts the requirements in the Standard. There are no modes or parameter changes that are executed remotely at the current time. Transition time periods will be determined as needed when the respective functions become required.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: No specific requirements for this section.

SECTION 4.7 – PRIORITIZATION OF DER RESPONSES

Duke accepts the requirements in the Standard and expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review UL certification testing, type tests results, and design documents to evaluate if a DER can meet this requirement.

SECTION 4.8 – ISOLATION DEVICE

Duke Energy accepts the requirements in the Standard and requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, Requirements for Electric Service and Meter

Installations (the White Book), and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

SECTION 4.9 – INADVERTENT ENERGIZATION OF THE AREA EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized, therefore accepts the Standard. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

SECTION 4.10 – ENTER SERVICE

Duke Energy requires the DER to meet the requirements of all the following subsections:

- 4.10.2 Enter service criteria
- 4.10.3 Performance during entering service
- 4.10.4 Synchronization

Section 6.6 of the Standard is also encompassed by the requirements of Section 4.10.

4.10.2 Enter service criteria and 4.10.3 Performance during entering service

When entering service or returning to service after a trip, the DER shall not energize the Area EPS until the following conditions are met at the RPA (these are the defaults in the Standard):

Enter service value	Parameter Label	Setting
Minimum Voltage	ES_V_LOW	≥ 0.917 p.u.
Maximum Voltage	ES_V_HIGH	≤ 1.05 p.u.
Minimum Frequency	ES_F_LOW	≥ 59.5 p.u.
Maximum Frequency	ES_F_HIGH	≤ 60.3 p.u.

Note: The parameter labels are based on the publicly available EPRI technical update document number 3002020201, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020.

The maximum frequency setting was increased over the Standard default to accommodate applications within microgrids.

The final UDER settings are still under evaluation. Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The DER shall not enter or return to service or ramp faster than the times stated below. The Standard allows an optional randomized time delay, but that option is not used and shall be Off. As noted in the standard, DER increasing active power steps greater than 20% of Nameplate Active Power rating shall require approval during the system interconnection study process.

Time Delay	Parameter Label	RDER < 500 kVA (seconds)	RDER < 1000 kVA (seconds)	UDER setting (seconds)
Enter Service Delay	ES_DELAY	300	300	300
Enter Service Ramp Period	ES_RAMP_RATE	100	200	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off	Off

While the active power is ramping during the enter service period, the reactive power shall follow the configured mode and settings.

When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is dependent on the Configuration Active Power Rating per the table below:

Rate of Change Duration	Parameter Label	RDER setting (seconds)	UDER setting (seconds)
ESS ≤ 1 MW	None	2	n/a
ESS > 1 MW	None	n/a	ESS MW range / (2 MW/sec)

The ESS MW range is the sum of the charge and discharge capability.

4.10.4 Synchronization

Duke Energy accepts the requirements in the Standard as written.

Interoperability requirements: Duke may require the voltage and time settings be provided at the control interface in alignment with the interoperability requirements in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement. For 4.10.4, Duke plans to review UL certification tests, type tests, and design documents to evaluate DER's synchronization capability meeting this requirement. The on-off test during commissioning will field verify DER's synchronization capability.

Implementation of this section requires publishing the final technical position and applying the interoperability functionality in the local interface.

SECTION 4.11 – INTERCONNECT INTEGRITY

Duke accepts the requirements in the Standard as written for the following subsections:

4.11.1 Protection from electromagnetic interference
4.11.2 Surge withstand performance
4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

SECTION 4.12 – INTEGRATION WITH AREA EPS GROUNDING

Duke accepts the requirements in the Standard and that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below. Therefore, configurations that are not listed are not approved. It is possible for an IC to submit another winding configuration, however the technical review will significantly delay evaluation of the IR.

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection	
			Inverter	Rotating
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

RDER transformer winding configurations are typically dictated by the EPS primary system construction and the load requirements.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

SECTION 5.2 – REACTIVE POWER CAPABILITY OF THE DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is most readily available and can be recorded in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following voltage and reactive power performance category:

Inverter-based DER:	Category B
Synchronous machine DER:	Category A

Category B requires a DER reactive power injection capability (lagging) of 44% of the nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. The Standard adopted "44%" as the injection capability for 0.90 pf, but the percentage is actually slightly less, 43.6%. Duke will consider capabilities 43.6% and higher also meet the intent of the 44% requirement. As a good practice, Duke recommends that all facilities be designed to operate across this pf range of in case the facility would want to utilize any additional capability over the life of the facility. Consistent with the Standard, operation at any active power output above 20% of the contracted active power shall not constrain the reactive power capability, up to the Category B requirements.

Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The reactive capability shall be provided on an inverter capability curve (P-Q graph) and shall be based at the rated voltage of the device (1 pu) and an ambient temperature of 35° C. The DER may choose to submit reactive capability data on a higher ambient temperature basis, however that data will still be applied as the 35° C capability (Duke cannot temperature adjust manufacturer data).

[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

Because operating points on the chart can be difficult to accurately determine graphically, it is recommended that the DER provide the numerical data that defines critical points on the capability curve. Those points include the Nameplate and Configuration apparent, active, and reactive power ratings at the leading, lagging, and unity power factors.

Some facilities have operational, design, or other limitations that prevent utilization of the full reactive capability of the device(s). If that is the case, the DER shall specify any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions). If no limitations are submitted, then Duke will consider that the facility has no reactive capability limitations. Duke recommends submittal of an additional facility capability curve that includes any limitations.

Supplemental Devices

If the DER includes supplemental devices, capability data must be provided for each device at rated voltage of the device and an ambient temperature of 35° C. Subject to the same conditions above, the DER may elect to submit data at a higher ambient temperature. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a brief written description and an acceptable power flow model of the device. If the supplemental device is static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified. Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

Again, any limitations that prevent the full reactive capability of the device(s) to be utilized shall be specified and Duke recommends submittal of a facility capability curve that includes the limitations.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for the DER to demonstrate its reactive power capability. The capability test will be consistent with the modes of operation and power factor requirements in the Voltage and Reactive Power Control section (5.3).

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

Voltage and reactive power control is only used to facilitate interconnection of the DER. This control is not used for a grid service at this time.

Listed below are the Standard voltage and reactive power control options and the default status for Duke interconnections:

Control Mode	**Default Status**
Constant power factor (fixed pf)	On, 1.0 pf
Constant reactive power (fixed VAR)	Off

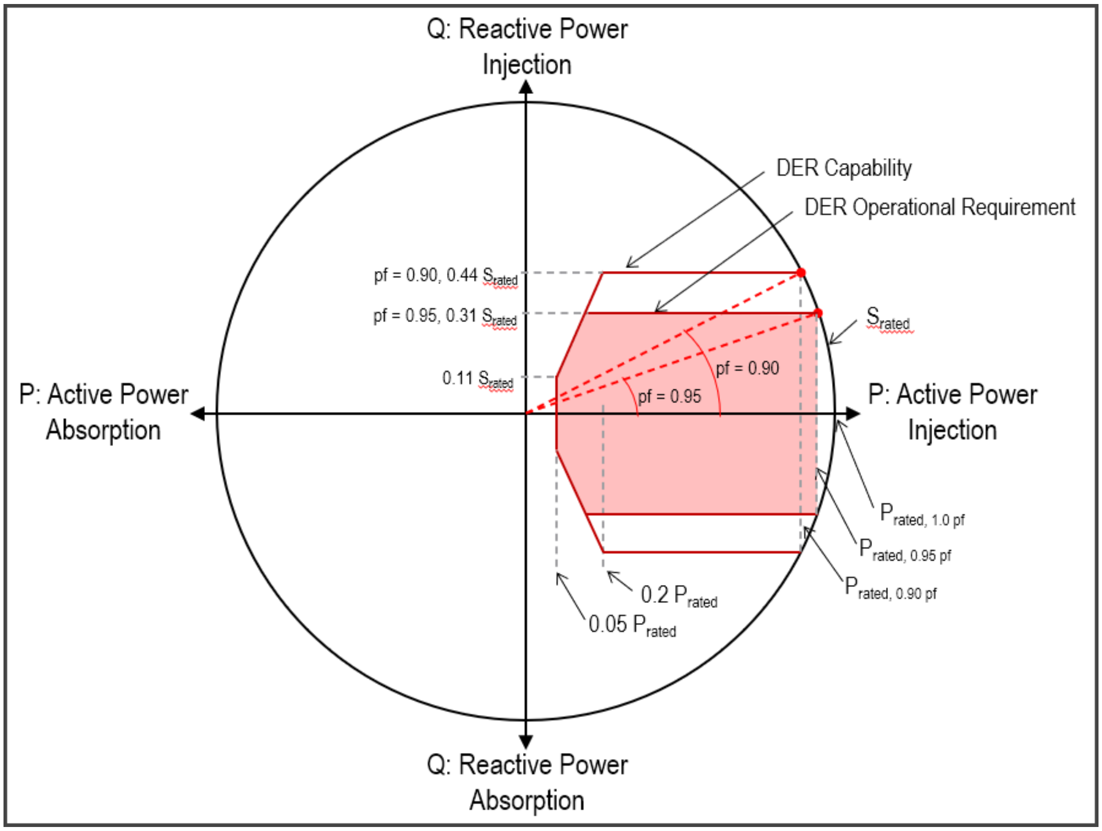
Voltage-reactive power (Volt-VAR)	Off
Active power-reactive power (Watt-VAR)	Off

Constant reactive power is not considered a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings. All parameters for reactive power control are measured at the RPA (see Section 4.2). To deliver reactive power means to inject or absorb power as required by the control settings. To ensure that reactive power is available to support the reactive power control function, the DER shall be operated in the reactive power priority mode. This mode gives precedence to reactive power when needed to maintain DER operation within the apparent power limit and provide reactive power control at the same time. The exception to reactive power priority is fixed power factor mode with unity power factor setting.

Because the system impact of DER reactive injection can be significant, Duke limits the reactive capability that can be used for reactive power control to 0.95 power factor. The DER shall have the capability to absorb or inject reactive power at the RPA equivalent to that of 0.95 power factor at the contracted active power output. Consistent with the Standard, operation at any active power output above 20% of the rated active power shall not constrain the reactive power output below the reactive power required at the 0.95 power factor level.

This range of operation is shown by the shaded region in the figure below:



In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed. Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration for residential-scale inverters as well. The reactive control method and settings should consider existing operational requirements as well as mitigation of the high voltages that can occur with the addition of DER. No change can be made on one part of the system that does not affect another part. Therefore, the study will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts, remediation of impacts, and controlling the impact on the transmission system. Distribution Providers must comply with agreements and requirements of the transmission entities. As such, an evaluation of transmission impacts is important.

Significant technical studies are required to evaluate these functions and analyze the consequences. The studies began at the end of 2019 and will continue in 2021. This will continue to be an agenda item for the TSRG meetings will focus on the most useful control modes and settings that are applied locally in the inverter and are autonomous. The plan is to implement the Standard in phases. In this case, reactive power control will be fixed at unity power factor for the initial phase of implementation but may be implemented in a later phase.

Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision.

Interoperability requirements: There will be few, if any, requirements for fixed power factor DER. For other control modes, the interoperability requirements align with those in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-var settings and field settings verification. Verification and test requirements will change based on the method of control implication. With a central plant computer control of reactive power, the controller must be field tested. With an inverter-based control, verification will depend on the implementation. Control systems that were verified during Certification may request exemption. Otherwise, the controller must be field tested. After the DER is in service, operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 5.4 – VOLTAGE AND ACTIVE POWER CONTROL

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control.

The default status for Voltage-active power control is Off.

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3. The plan is to implement the Standard in phases. In this case, volt-watt control will be Off for the initial phase of implementation but may be implemented in a later phase.

Interoperability requirements: The interoperability requirements align with those in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Verification and test requirements will change based on the method of control implication. With a central plant computer control of reactive power, the controller must be field tested. With an inverter-based control, verification will depend on the implementation. Control systems that were verified during Certification may request exemption. Otherwise, the controller must be field tested. After the DER is in service, operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 6.2 – AREA EPS FAULTS AND OPEN PHASE CONDITIONS

Duke accepts the requirements in the Standard.

There is a possibility that these requirements could be impacted by an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. Since the plan is to implement the Standard in phases, if anything does impact the current plan, then any changes could be considered for a later phase.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

SECTION 6.3 – AREA EPS RECLOSING COORDINATION

Duke accepts the requirements in the Standard as written.

There is a possibility that these requirements could be impacted by an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. Since the plan is to implement the Standard in phases, if anything does impact the current plan, then any changes could be considered for a later phase.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

SECTION 6.4.1 – MANDATORY VOLTAGE TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. As placeholders, the present trip setpoints are added to the Guidelines.

For new DER installations, the present voltage tripping setpoints are provided in the table below as placeholders and are not final.

Parameter	Voltage	Time (seconds)
Undervoltage, UV Level 1	0.88 pu	2
Undervoltage, UV Level 2	0.5 pu	0.16
Overvoltage, OV Level 1	1.1 pu	1
Overvoltage, OV Level 2	1.2 pu	0.16

Interoperability requirements: Duke may require the voltage and time settings be provided at the control interface in alignment with the interoperability requirements in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.4.2 – VOLTAGE DISTURBANCE RIDE-THROUGH REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

See Section 1.4 for the abnormal performance category.

Interoperability requirements: No specific requirements for this section.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: To be determined.

SECTION 6.5.1 – MANDATORY FREQUENCY TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements. As placeholders, the present trip setpoints are added to the Guidelines.

For new DER installations, the present frequency tripping setpoints are provided in the table below.

Parameter	Frequency	Time
Underfrequency, UF	57 Hz	10 cycles
Overfrequency, OF	60.8 Hz	10 cycles

Interoperability requirements: Duke may require the frequency and time settings be provided at the control interface in alignment with the interoperability requirements in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.5.2 – FREQUENCY DISTURBANCE RIDE-THROUGH REQUIREMENTS

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)

Duke requires DER ride through a 3 Hz/s frequency excursion in accordance with abnormal operating performance Category III. DER tripping for ROCOF should be off, disabled, or above 3 Hz/s and at the ROCOF capability of the DER equipment. The DER shall certify that protective relay settings and DER controls are not designed or configured in such a way as to interfere with ROCOF performance.

6.5.2.6 Voltage phase angle changes ride-through

The UL 1741 SB certification shall be considered sufficient for individual inverter based DER devices meeting ride through requirements for this function. The DER shall certify that protective relay settings & controller settings of the completed DER facility do not intentionally trip for the voltage phase angle changes specified by the Standard.

6.5.2.7 Frequency-droop (frequency-power) capability

Duke accepts the default operation conditions and settings in the Standard as written:

Operation for low-frequency conditions	Mandatory, On
Operation for high-frequency conditions	Mandatory, On

Parameter	**Setting**
dbOF, dbUF (Hz)	0.036
kOF, kUF	0.05
T-response (small-signal) (s)	5

At this time, a frequency deadband of 36 mHz and a droop of 5% are considered acceptable for inverter and non-inverter sources. As the mix of generation sources transition over time, it may be necessary to transition to a lower values in the future to maintain EPS reliability.

This function is still under evaluation as part of an ongoing project involving the Protection and Transmission Planning groups. Per Standard table 24, a specification of the droop, deadband, and associated parameters is required for Category II and III.

Interoperability requirements: Duke may require the mode and settings be provided at the control interface in alignment with the interoperability requirements in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

6.5.2.8 Inertial response

Inertial response is not required at this time.

Interoperability requirements: Duke may require any settings be provided at the control interface.

It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required. Also note for the individual functions, that Duke reserves the right to verify that protective relay settings & controller settings do not interfere with or prevent proper performance the various ride-through requirements.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 7.1 – LIMITATION OF DC INJECTION

Duke Energy accepts the requirements in the Standard.

Interoperability requirements: A Duke Energy power quality meter is currently required for DER of 1 MW or greater.

Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results, and examine design documents to evaluate dc injection.

SECTION 7.2.2 – RAPID VOLTAGE CHANGES

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria, stated below, is consistent with the Standard.

Rapid Voltage Change analysis is performed for all facilities 1 MW capacity and larger using appropriate modeling techniques (e.g. PSCAD). The study evaluates the effect of transformer energization, with the voltage change evaluated anywhere on the circuit to assure a change no greater than 3%. The study will consider combinations of residual flux and closing angle that cause a large voltage dip. When the RVC limit cannot be met without some form of mitigation, the method of mitigation must also limit inrush such that the RVC is no greater than 3%.

A Controlled Switching Device (CSD) shall also limit the transformer inrush voltage change to 3%. For CSDs that must learn or be calibrated in order to provide maximum inrush current reduction, a 6% RVC limit is temporarily applicable only during that limited calibration time (the higher inrush is only expected for the minimum amount of closes needed to calibrate the CSD). The higher limit only applies to special situations such as CSD commissioning, or following breaker maintenance or replacement, or the CSD undergoes some upgrade or repair and does not apply to normal operation conditions.

Interoperability requirements: A Duke Energy power quality meter is currently required for DER of 1 MW or greater and no additional requirements are proposed for the revised Standard.

Verification and test requirements: The installation verification is currently included in the scope of Duke's interconnection inspection process. Duke will develop a test procedure and criteria to evaluate the performance of an RVC mitigation solution as part of the commissioning tests.

SECTION 7.2.3 – FLICKER

Duke Energy accepts the requirements in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: A Duke Energy power quality meter is currently required for DER of 1 MW or greater.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A Duke Energy power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

SECTION 7.3 – LIMITATION OF CURRENT DISTORTION

Duke Energy accepts the requirements in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate harmonics greater than the 50th order to no greater than 0.3% of the fundamental DER rated current at the RPA. In addition, any Adverse Operating Effects must be addressed as specified in the DER Interconnection Agreement. Harmonic limits shall be aggregated and applied during the DER hours of operation, not just at peak or rated output.

Interoperability requirements: No specific requirements for this section. Installation of a Duke Energy power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

SECTION 7.4.1 – LIMITATION OF OVERVOLTAGE OVER ONE FUNDAMENTAL FREQUENCY PERIOD

Duke Energy accepts the requirements as written in the Standard.

Part of 7.4.1 is based on the inverter design and operation and part is based on the specific design of the interconnection and the Area EPS itself. The ability of the inverter to detect and limit overvoltage will be verified by UL certification testing. However, the DER facility must still be analyzed during system impact study to verify the impact of the combined inverter and Area EPS is below the limits of the Standard. The limits defined in parts a) and b) must be verified by power system study. In addition, any Adverse Operating Effects must be addressed as specified in the DER Interconnection Agreement.

Interoperability requirements: No specific requirements for this section. Installation of a Duke Energy power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results, and examine design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

SECTION 7.4.2 – LIMITATION OF CUMULATIVE INSTANTANEOUS OVERVOLTAGE

More industry experience or analysis could be essential to address this issue. Duke does not plan to implement this section until IEEE 1547.1 is revised and UL 1741 certification tests include this verification. At that time, Duke expects to accept the requirements as written in the Standard.

Interoperability requirements: No specific requirements for this section. Installation of a Duke Energy power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

SECTION 8.1 – UNINTENTIONAL ISLANDING

Duke accepts the requirements in the following Standard sections as written:

8.1.1 General
8.1.2 Conditional extended clearing time
8.1.3 Area EPS with automatic reclosing

The anti-islanding function shall be activated.

The standard clearing time for an unintentional island is 2 seconds or less. The DER shall identify and provide the method of islanding detection* used for all DERs above 250 kW.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: To be determined.

* Such as one of the six groups listed in section 2.3 Generic Island Detection Groups and Response Models of Inverter-Onboard Islanding Detection Assessment: Final Project Report. EPRI, Palo Alto, CA:2020. 3002014051.

SECTION 8.2 – INTENTIONAL ISLANDING

Duke Energy has not determined the guidelines for this section.

SECTION 10.1, 10.7, 10.8, 10.9 – GENERAL INTEROPERABILITY AND PROTOCOL REQUIREMENTS

These sections of the Standard relate more directly to the hardware requirements of the DER interface. Duke Energy adopts these requirements of these sections as written in the Standard.

Duke requires an interconnection recloser interface for DER rated >= 1MW and the default protocol is DNP3. If mutually agreed upon by the Area EPS operator and DER operator, Modbus may be used as the only exception to DNP3.

For DER >= 250kW and <1MW, Duke requires an automation controller interface and with Modbus protocol.

In all applications, there shall be one point of interface between a single Duke automation controller and a single DER automation controller or a single DER source (e.g., one individual inverter).

Verification and test requirements: Operation of the hardware, point mapping, information exchange, and communication of data will be part of the commissioning tests requirements.

SECTION 10.2, 10.3, 10.4, 10.5, 10.6 – DATA, MONITORING, AND CONTROL INFORMATION

These sections of the Standard contain both general and specific data, monitoring, and control information for DER that require an interface. Sections 10.3 and 10.4 primarily contain general information such as DER ratings and configuration characteristic data that does not change often, if ever. This is the basic information provided by each DER interface. On the other hand, 10.5 and 10.6 provide real-time monitoring, control, and status information that is dependent upon the specific functions in use. Therefore, the specific parameters in the interface point map will be based on the Standard and the DER functions that are enabled. Each section of the Guidelines contains an "Interoperability requirements" subsection that defines the associated data, monitoring, and control requirements in addition to any Standard requirements.

Verification and test requirements: Operation of the hardware, point mapping, information exchange, and communication of data will be part of the commissioning tests requirements.

Additional discussion about ratings and limits:
Sections 10.3 and 10.4 address the two broad types of information available through the local DER communication interface. Section 10.3 specifies various DER ratings and 10.4 specifies configuration settings, which are often more clearly thought of as limits. While there is some commonality, the intent of the nameplate and configuration terms are different.

The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configured Apparent Power Maximum Rating
Apparent Power Limit

Nameplate Active Power Rating (unity power factor)
Configured Active Power Rating (unity power factor)
Active Power Limit

The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
  - The rating is the <u>most</u> capacity the system is <u>designed</u> to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.
  - Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.
- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

UNADDRESSED REQUIREMENTS OF IEEE 1547-2018

The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the completion of the higher priority topics. Concerning the clauses and sections not addressed in this document, Duke Energy expects that the DER shall conform to the Standard itself as written.

APPENDIX – IEEE 1547-2018 BENCHMARKING

Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant Consulting, Inc.

TABLE B.1. BENCHMARKING OF IEEE 1547-2018 FUNCTIONALITIES IMPLEMENTATION

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

ATTACHMENT B

Update and Discussion: Implementation of 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

Operations & Technical Standards

April 20, 2022

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ATTACHMENT B

Agenda

- Current version is “Duke Energy IEEE 1547 Implementation Guidelines, Rev 8”
- Rev 7A is the red marked version

Recent Activities

- Focused on getting internal alignment on content
  - Internal stakeholder meetings
  - Internal confirmation of content
  - Continued discussions on timeline
- Completed 8th revision of the Guidelines
  - Not a ‘final’ document, still a record of progress and open issues
    - Clarified in the Draft status in the revision table and Introduction
  - More than 25 sections have the draft technical requirements complete
    - Approximately 10 others are related to ongoing protection or reactive power studies
    - The sum of these account for all the items on the current prioritization list
  - All topics now have the interoperability requirements defined
  - Testing/commissioning requirements have stats similar to the technical sections

Updates

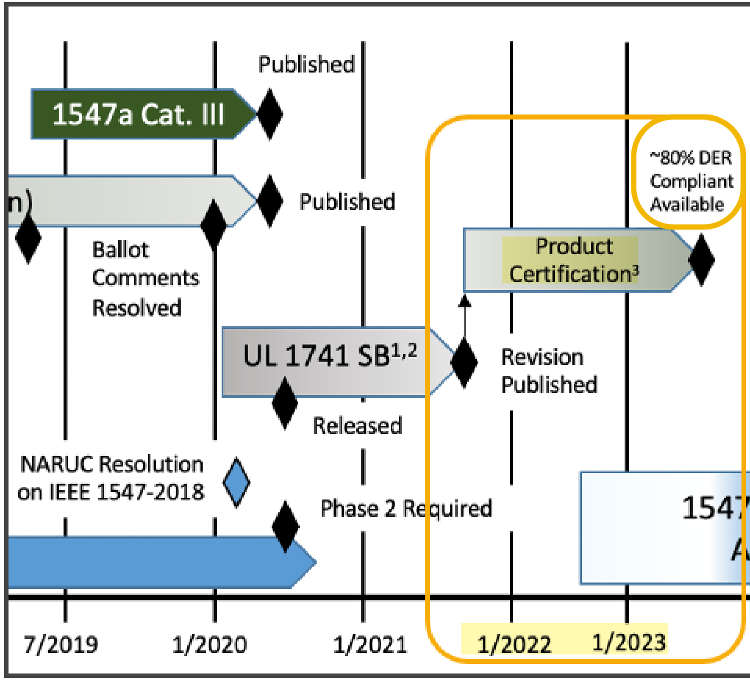
- Reactive Power
  - Working through the pilots identified the need for more details
  - Clarified there are two tests: Reactive capability test and a reactive control verification test
  - Pilot update
    - Held discussions with 2-3 pilot sites
    - Working through testing procedure details
    - Expect to perform tests for one site soon
- Enterprise protection study
  - Includes the trip and ride-through settings for inverters
  - Core research, performed by a third-party consultant, is expected to be complete by the end of the second quarter 2022
  - Duke will then proceed to verify and integrate the research results into operational settings
    - This includes initiating field testing by the end of the year
  - Updates and coordination with the TSRG throughout the process

Next Steps

- Continue development of the Guidelines – internally and with TSRG
- Address the remaining lower priority 1547 topics
- Address residential / commercial (RDER) applicability
  - Phase 1: Enter service, reactive capacity, abnormal trip and ride through, freq droop, anti-islanding
  - Phase 2: Reactive power control
- Others?
- Origination of a timeline for a phased implementation – internally and with TSRG

ETA for Certified Inverters

- A few certified inverters are expected mid to late 2022
- Based on recent EPRI information – April 2023 is more likely
- Then the earliest Interconnection Requests could include them is the 2023 window
- The 'Request' date must consider completion of technical and interconnection requirements
- The 'Implementation' date must include completion of test requirements and readiness to perform commissioning tests
- Deadtime must be included
- Not all requirements at once – phased plan



Notes

[1] The new UL 1741 Supplement SB will directly refer to IEEE 1547.1-2020 and will be the only test procedure to certify IEEE 1547-2018 compliance. The existing Supplement SA will remain for the time being for those codes that continue to reference UL 1741 SA.

[2] UL 1741 SB revision (Oct 2021) to clarify inverter certification for 1547-2018 conformance

[3] Inverter products not generally available to market until April 2023.

Major 1547 Topics by Phase – for Discussion Only

PHASE 1 – NC / SC

4.10 Enter service

5.2 Reactive power capability

6.2 Area EPS faults

6.4.2 Voltage trip and ride-through

6.5.2 Frequency trip and ride-through

6.5.2.7 Frequency-power

7* Power Quality

8.1 Unintentional islanding

10* Information, monitoring, control

11 Test and verification

Guidelines Priority Groups

≠

Implementation Phases

PHASE 2 – NC / SC

5.3 Voltage and reactive power control

5.4 Voltage-active power control

6.5.2.5 Rate of change of frequency (ROCOF)

6.5.2.6 Voltage phase angle changes ride-through

PHASE 3 – NC / SC

4.6.2 Active power limit

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Phase 1 - General Technical Specifications

1.4	General remarks and limitations
4.2	Reference points of applicability (RPA)
4.3	Applicable voltages
4.5	Cease to energize performance requirement
4.6.1	Capability to disable permit service
4.6.2	Capability to limit active power, static (Duke to DER)
4.7	Prioritization of DER responses
4.8	Isolation device
4.9	Inadvertent energization of the Area EPS
4.10.2	**Enter service criteria // 6.6 Return to service after trip**
4.10.3	**Performance during entering service**
4.10.4	Synchronization
4.11.1	Protection from electromagnetic interference
4.11.2	Surge withstand performance
4.11.3	Paralleling device
4.12	Integration with Area EPS grounding

Phase 1 - Specific Technical Specifications

5.2	**Reactive power capability of the DER**
6.2	Area EPS faults and open phase conditions
6.3	Area EPS reclosing coordination
6.4.1	Mandatory voltage tripping requirements (OV/UV)
6.4.2	**Voltage disturbance ride-through requirements**
6.5.1	Mandatory frequency tripping requirements (OF/UF)
6.5.2	**Frequency disturbance ride-through requirements**
6.5.2.7	**Frequency-droop (frequency-power) capability**
7	**Power Quality**
8.1	**Unintentional islanding**
9	Secondary network
10	Information, monitoring, control
11	Test and verification

Phase 2 - Specific Technical Specifications

4.13	Exemptions for Emergency Systems and Standby DER
5.3	**Voltage and reactive power control**
5.4	**Voltage-active power control**
6.4.2.5	Ride-through of consecutive voltage disturbances
6.4.2.6	Dynamic voltage support
6.4.2.7	Restore output with voltage ride-through
6.5.2.5	**Rate of change of frequency (ROCOF)**
6.5.2.6	**Voltage phase angle changes ride-through**

Overall Plan

- Discussion on the overall plan:
  - Phased implementation
  - Content of the phases
  - Incorporating 1547-2018
    - Reference IEEE 1547-2018 in the IP / IA
    - Identify the specific requirements by referencing the Guidelines

Timeline Considerations

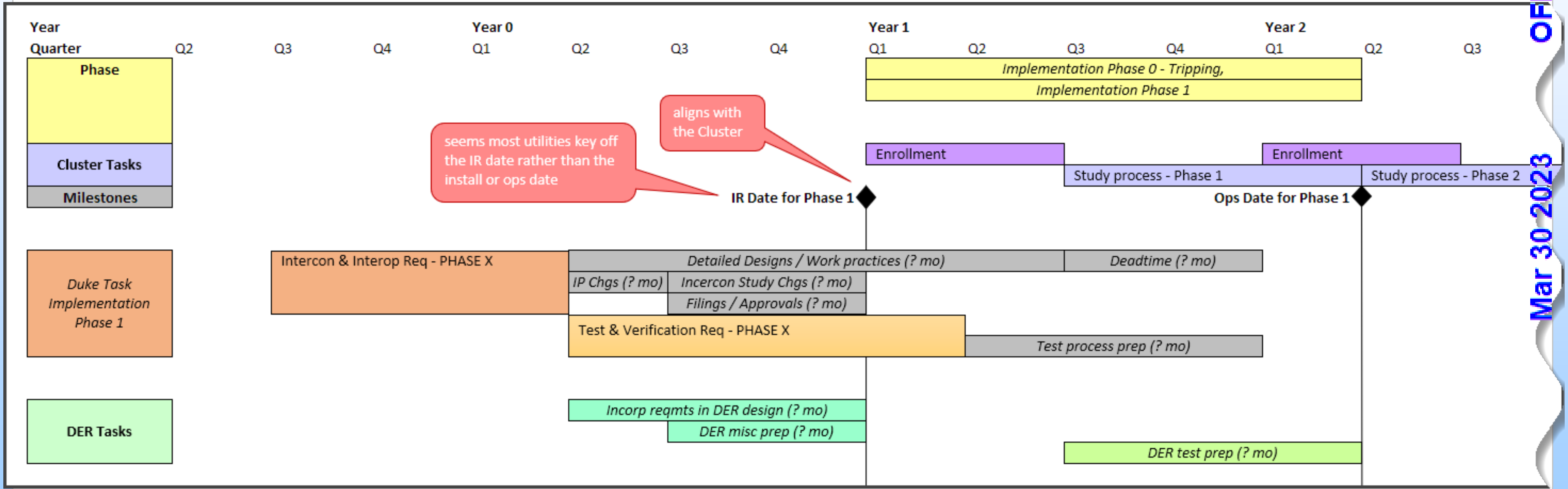
- Duke
  - Interconnection and Interoperability requirements
    - Complete any design work, update work practices
    - Implement any SIS changes
    - Complete any filings and approvals
  - Test and verification requirements
    - Create test procedures / process
    - Update inspection documents
- DER
  - Absorb requirements / incorporate into IR
  - Make test preparations

- Predecessor / Successor
- Deadtime

- Certified inverters are available
- Alignment with cluster study process

ATTACHMENT B

High-level Organization of Tasks



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Overall Timeline

- Discussion on the overall timeline:
  - Does (Requirements) Schedule support interconnection submittals for 2023 cluster?
    - 2024?
    - Alignment with annual cluster study enrollment window; availability of these inverters
  - Does (Test / Verification) Schedule support Permission To Operate
    - Should occur much later
  - Right tasks included?
    - Any left out?
  - Tasks in proper order?
  - Enough deadtime between tasks?

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Feedback

- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide both comments and also propose a specific change:

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
example Recommendation format	10	3	The types of faults is too limited. Include single line to ground faults.	Include SLG faults

  - Suggesting the exact change to the Guidelines reinforces the main point of the comment and provides more information that Duke can specifically address
- Comments will be taken during the meeting and the form will be distributed after the meeting
- Stakeholders may provide written feedback using the feedback form

Format of the Guidelines Document

- Philosophy
  - Focus on Duke-specific information that supplements the Standard
  - It is not a repeat of the standard or a stand-alone document
- General organization – by technical requirement
  - Technical
  - Interoperability / SCADA
  - Verification and Testing
- Highlighted paragraphs or "boxes"
  - Denote portions that still need to be added and topics to be addressed
- Portions without highlight are complete

SECTION 4.5 – CEASE TO ENERGIZE PERFORMA REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady- conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service sett described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipr identify the interconnection device that provides the cease-to-energize function. The e and commissioning process tests to verify the device meets the performance requirem

This section is ready to be implemented.

SECTION 4.6 – CONTROL CAPABILITY REQUIRE

Duke Energy will consider if there is a need to clarify any technical points for the final v guideline, but the expectation is that the capabilities in the following sections will be a

Duke accepts the capabilities in the following sections as written:

4.6.1 Capability to disable permit service
4.6.2 Capability to limit active power
4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DI interface.

For UDER, Duke Energy is still considering implementing the permit service at the inver at the local EPS.

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Additional TSRG Information

When prompted, set the state to NC or SC to access

- Website https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg
- Technical Standards / Commissioning / Meetings
- Meeting Agendas / Presentations / Documents

Past Meeting Information

Meeting 11 (January 20, 2021) —

Duke Energy Virtual Meeting

- Agenda
- Minutes and attendance
- Presentation – IEEE 1547 implementation plan
- Presentation – Periodic self-inspection plan update
- Presentation – Second Volt-VAR study update
- Reference – 1547 Implementation Guidelines with edits
- Reference – 1547 Implementation Guidelines latest revision

Meeting 10 (October 22, 2020) +

Meeting 9 (September 2, 2020) +

Carolinas TSRG Updates

Welcome to the central resource page for the Duke Energy Distributed Energy Resource (DER) Interconnection Technical Standards Review Group (TSRG). This TSRG was initiated by Duke Energy to bring together Duke Energy engineers with technical personnel of DER developers and installers actively involved in interconnection projects in Duke Energy Carolinas and Duke Energy Progress, in both North Carolina and South Carolina.

TSRG Documents

- Duke Energy Carolinas / Duke Energy Progress Interconnection TSRG – Structure and inaugural meeting agenda

Duke Energy Technical Standards

- Method of Service Guidelines
- Sequential Switching Requirements
- Service Requirements Manual (sometimes called the "White Book"; contains Distribution System interconnection requirements)
- Transmission System, Generator Interconnection Requirements
- January 2020 Commission Order on EPRI Report and Duke Compliance Filing
- DEC and DEP Response to the EPRI Report, E-100, Sub 101
- EPRI Review of Duke Energy Fast Track Criteria for DER

IEEE Standard 1547-2018 Implementation

- Implementation of IEEE 1547-2018 Guidelines, March 31, 2020
- NCUC April 2020 filing, Report on IEEE 1547-2018

ATTACHMENT B

Update and Discussion: Implementation of 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

Operations & Technical Standards

July 20, 2022

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Agenda

- Review main revisions
  - Newest version is “Duke Energy IEEE 1547 Implementation Guidelines, Rev 9”
  - Rev 8B is the red marked version
- Recent activities
- Timeline discussion

Recent Activities

- Completed 9th revision of the Guidelines
  - Revised sections as needed for residential / commercial (RDER) applicability
  - Completed several sections of the Guidelines
    - Unintentional Islanding, ROCOF, frequency-droop, inertial response, phase angle changes
    - Remember - interoperability and testing/commissioning requirements are defined with the technical requirements, not is separate sections
    - Not a ‘final’ document, still open for comment
- Continued discussions on timeline

Updates

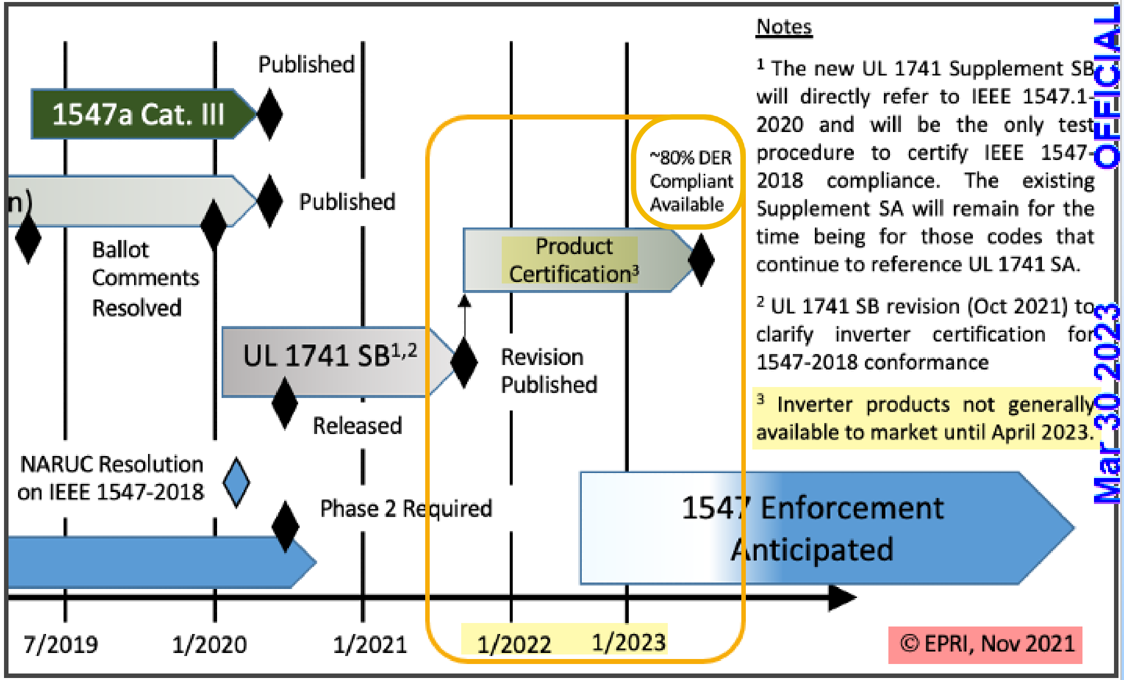
- Reactive Power
  - Pilot update provided separately
- Enterprise protection study
  - Core research by third party consultant remains ongoing
  - Duke will verify and convert the research results into operational settings
    - This includes field testing the settings during 2023

Next Steps

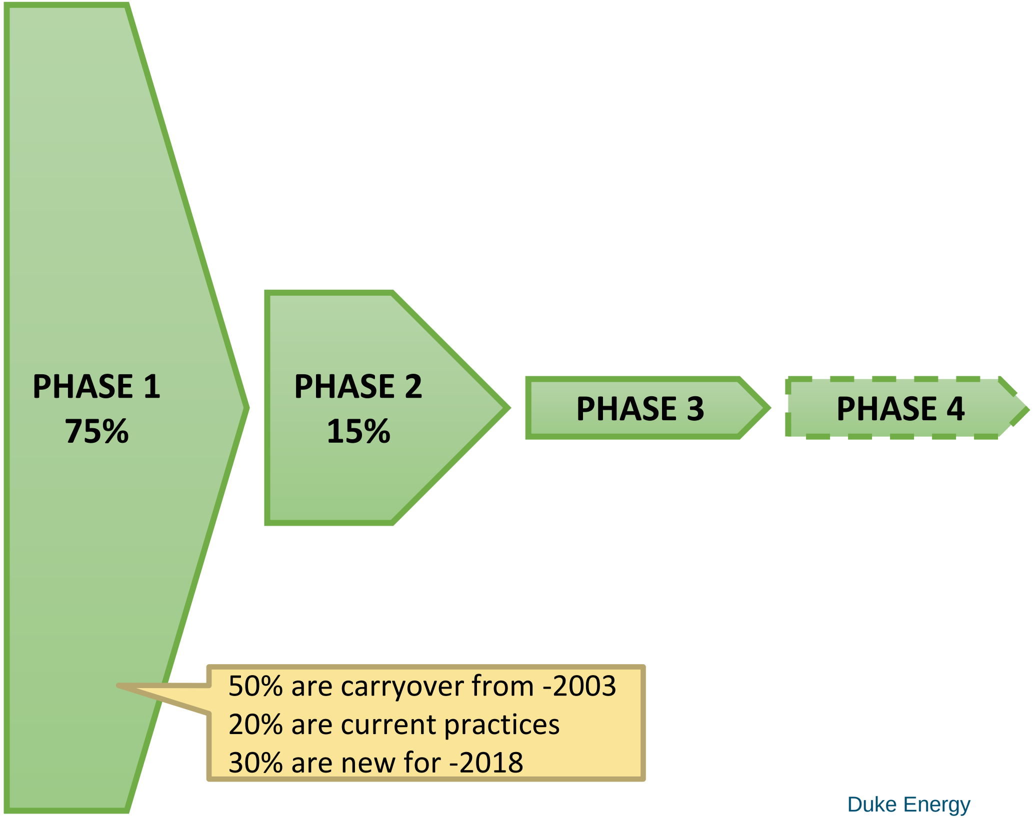
- Encourage final comments on the Guidelines
  - Needed in order to finalize for Phase 1
- Address the remaining lower priority 1547 topics
- Develop timeline for a phased implementation – internally and with TSRG
- Make any Commission filings
- ~~Address residential / commercial (RDER) applicability~~
- Others?

ETA for Certified Inverters

- First inverter certified May 2022
- Most inverters expected to market by April 2023
- Then the earliest Interconnection Requests could include them is the 2023 window
- The 'required in the design' date must align with the completion of the technical Guidelines, inverter model specs, and the interconnection process
- The 'in service by date' must align with the completion of test requirements, readiness to perform commissioning tests, and availability of the inverters



What might the schedule look like?



- The Duke Energy Guidelines for Implementation of IEEE 1547-2018 are sufficiently developed now to start defining the process of shifting to the new standard
- Staged implementation: 3 phases, maybe 4
- Phase 1 – Front loaded with most of the requirements
  - Proposal: require facilities in the 2023 DISIS to use UL 1741 SB inverters
- Phase 2 – After the prerequisite work is completed
  - Proposal: target 2024 DISIS
- Last phases depend on a few future functions with considerable lead time and technical issues to address
- Work with internal and external stakeholders to finalize timing of Phases by the Oct TSRG
  - Any plan is conditional on Commission approval

- Thoughts or comments on the
  - Guidelines
  - Phase 1 and 2 timeframes

Feedback

- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide both comments and also propose a specific change:

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Format of the Guidelines Document

- Philosophy
  - Focus on Duke-specific information that supplements the Standard
  - It is not a repeat of the standard or a stand-alone document
- General organization – by technical requirement
  - Technical
  - Interoperability / SCADA
  - Verification and Testing

  1547 Standard sections 10 & 11
- Highlighted paragraphs or "boxes"
  - Denote portions that still need to be added and topics to be addressed
- Portions without highlight are complete

SECTION 4.5 – CEASE TO ENERGIZE PERFORMA REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady- conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service sett described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipr identify the interconnection device that provides the cease-to-energize function. The e and commissioning process tests to verify the device meets the performance requirem

This section is ready to be implemented.

SECTION 4.6 – CONTROL CAPABILITY REQUIRE

Duke Energy will consider if there is a need to clarify any technical points for the final v guideline, but the expectation is that the capabilities in the following sections will be a

Duke accepts the capabilities in the following sections as written:

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4.6.2 Capability to limit active power
4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DI interface.

For UDER, Duke Energy is still considering implementing the permit service at the inver at the local EPS.

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Additional TSRG Information

When prompted, set the state to NC or SC to access

- Website https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg
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- Reference – 1547 Implementation Guidelines latest revision

Meeting 10 (October 22, 2020) +

Meeting 9 (September 2, 2020) +

Carolinas TSRG Updates

Welcome to the central resource page for the Duke Energy Distributed Energy Resource (DER) Interconnection Technical Standards Review Group (TSRG). This TSRG was initiated by Duke Energy to bring together Duke Energy engineers with technical personnel of DER developers and installers actively involved in interconnection projects in Duke Energy Carolinas and Duke Energy Progress, in both North Carolina and South Carolina.

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- January 2020 Commission Order on EPRI Report and Duke Compliance Filing
- DEC and DEP Response to the EPRI Report, E-100, Sub 101
- EPRI Review of Duke Energy Fast Track Criteria for DER

IEEE Standard 1547-2018 Implementation

- Implementation of IEEE 1547-2018 Guidelines, March 31, 2020
- NCUC April 2020 filing, Report on IEEE 1547-2018

ATTACHMENT B

Update and Discussion: Implementation of 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

Operations & Technical Standards
October 26, 2022

DUKE ENERGY®

Agenda

- Newest version is "Duke Energy IEEE 1547 Implementation Guidelines, Rev 10"
- Rev 9A is the red marked version

Recent Activities

- Completed 10th revision of the Guidelines
  - No material changes
  - Editorial only
- Continued discussions on timeline

Updates

- Reactive Power
  - Pilot update provided separately
- Enterprise protection study
  - Core research by third party consultant remains ongoing
  - Duke will verify and convert the research results into operational settings
    - This includes field testing the settings during 2023

Abnormal Event Tripping and Ride Through

Table 12—DER response (shall trip) to abnormal voltages for DER of abnormal operating performance Category II (see Figure H.8)

Shall trip—Category II				
Shall trip function	Default settings[a]		Ranges of allowable settings[b]	
	Voltage (p.u. of nominal voltage)	Clearing time (s)	Voltage (p.u. of nominal voltage)	Clearing time (s)
OV2	1.20	0.16	fixed at 1.20	fixed at 0.16
OV1	1.10	2.0	1.10–1.20	1.0–13.0
UV1	0.70	10.0	0.0–0.88	2.0–21.0
UV2	0.45	0.16	0.0–0.50	0.16–2.0

Table 13—DER response (shall trip) to abnormal voltages for DER of abnormal operating performance Category III (see Figure H.9)

Shall trip—Category III				
Shall trip function	Default settings[a]		Ranges of allowable settings[b]	
	Voltage (p.u. of nominal voltage)	Clearing time (s)	Voltage (p.u. of nominal voltage)	Clearing time (s)
OV2	1.20	0.16	fixed at 1.20	fixed at 0.16
OV1	1.10	13.0	1.10 – 1.20	1.0 – 13.0
UV1	0.88	21.0	0.0 – 0.88	~~21.0~~ 2.0 – 50.0
UV2	0.50	2.0	0.0 – 0.50	~~2.0~~ 0.16 – 21.0

Table 18—DER response (shall trip) to abnormal frequencies for DER of abnormal operating performance Category I, Category II, and Category III (see Figure H.10)

Shall trip function	Default settings[a]		Ranges of allowable settings[b]	
	Frequency[c] (Hz)	Clearing time (s)	Frequency (Hz)	Clearing time (s)
OF2	62.0	0.16	61.8–66.0	0.16–1 000.0
OF1	61.2	300.0	61.0–66.0	180.0–1 000.0
UF1	58.5	300.0[c]	50.0–59.0	180.0–1 000
UF2	56.5	0.16	50.0–57.0	0.16–1 000

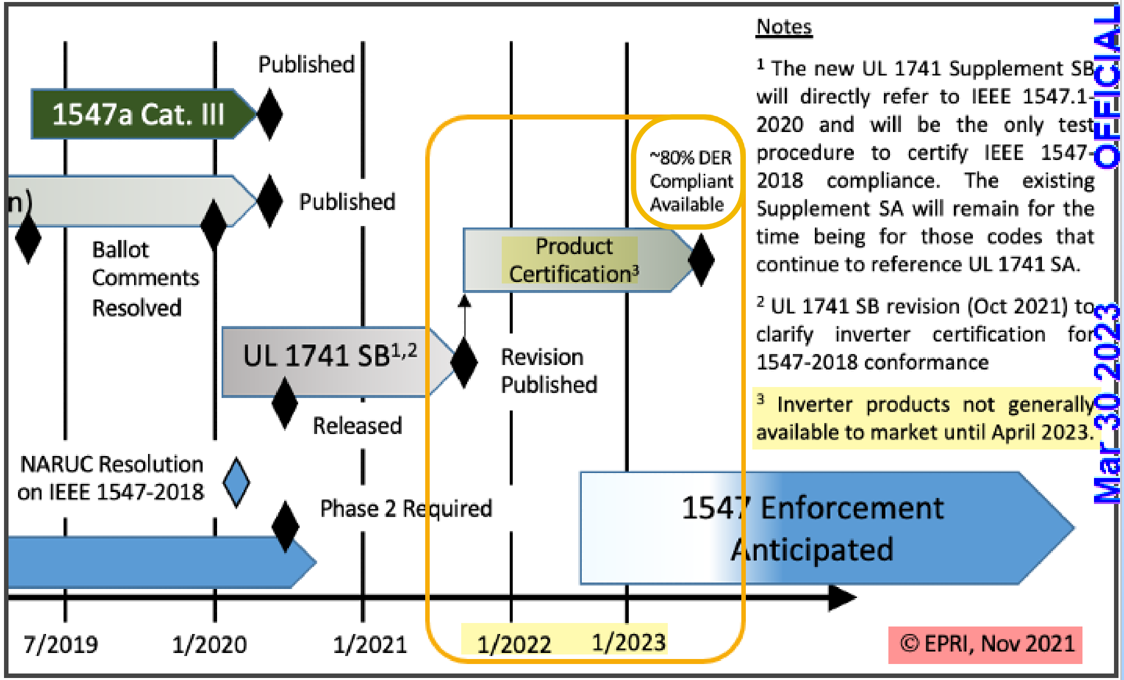
- Recloser Voltage Setting: The voltage protection settings under evaluation for overvoltage (OV) & undervoltage (UV) settings are similar to the default voltage settings shown in IEEE 1547-2018, Category II.
- Recloser Clearing Times:
  - The OV clearing times are also expected to be similar to the default values.
  - The UV1 clearing time is expected to be closer to the minimum of the range and
  - The UV2 is expected within the Standard's range however the specific value is still under evaluation
- Inverter: The settings for the DER site medium voltage protective device and inverter settings are still under review but expected within the range of allowable settings.
  - Note: The expectation is to have a bounding calculation for inverter settings that accounts for voltage drop from the inverter to the Reference Point of Applicability (PCC). Duke may require analysis by the customer that verifies the site-specific application does not exceed the bounding value.
- All settings within ranges allowed for Category III as well

Next Steps

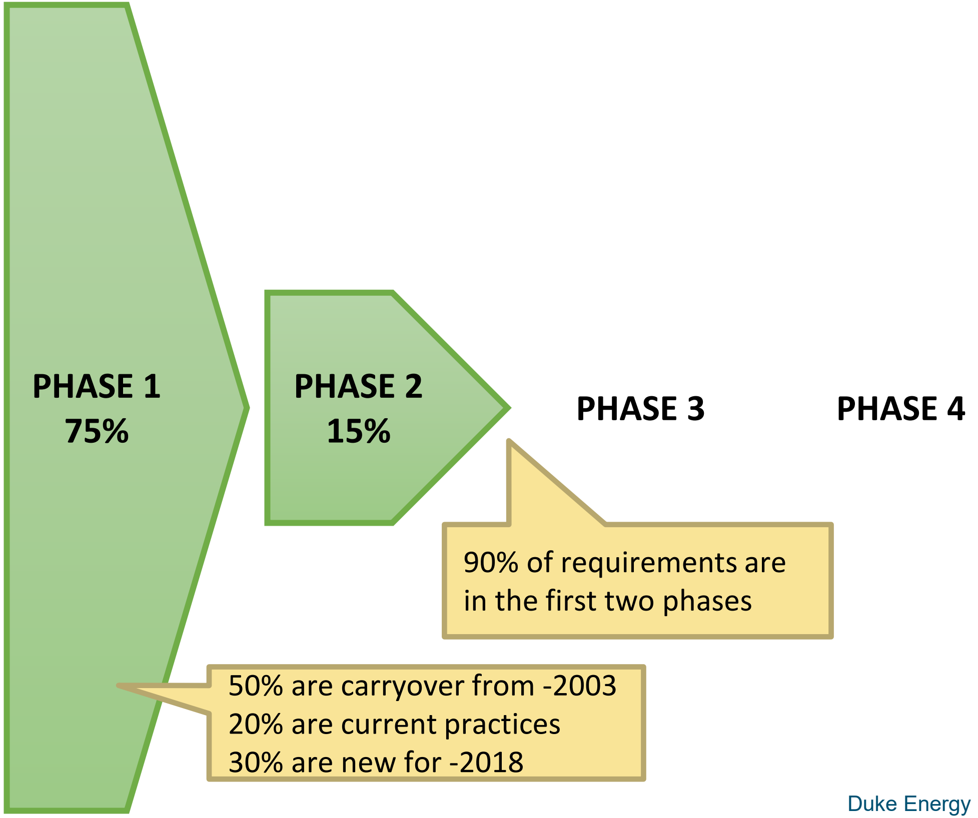
- Encourage final comments on the Guidelines
  - Needed in order to finalize for Phase 1
- Address the remaining lower priority 1547 topics
- Develop timeline for a phased implementation – internally and with TSRG
- Make any Commission filings

ETA for Certified Inverters

- First inverter was certified May 2022
- Progress is still rather slow, ~10%
- Most inverters so far are the smaller units, not the utility scale central units
- Most inverters expected to market by April 2023; way behind on that goal
- If require 1741 SB in 2023, likely require split dates for RDER and UDER
- The 'required in the design' date must align with the completion of the technical Guidelines, inverter model specs, and the interconnection process
- The 'in service by date' must align with the completion of test requirements, readiness to perform commissioning tests, and availability of the inverters



What might the schedule look like?



- Staged implementation: 3 phases, maybe 4
- Phase 1 – Front loaded with most of the requirements
  - Proposal: require utility scale facilities in the 2023 DISIS to use UL 1741 SB inverters
  - Proposal: require smaller facilities shortly after most 1741 SB inverters are available to market; late 2023 or early 2024
- Phase 2 – After the prerequisite studies are completed
  - Proposal: target 2024 DISIS / mid year
- Phases 3 & 4 depend on a few future functions with considerable lead time and technical issues to address; not ETA
- Work with internal and external stakeholders to finalize timing
  - Any plan is conditional on Commission approval

- Thoughts or comments on the
  - Guidelines
  - Availability of certified inverters
  - Phase 1 and 2 timeframes

TSRG Website Location

- The TSRG webpage address stays the same
  - Existing links remain valid
- From the **Generate Your Own Renewable Energy** website, the navigation to TSRG has changed
  1. Select Connecting to the Grid
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List of 1547-2018 Topics in 1547-2003

IEEE 1547-2018 Section	IEEE 1547-2018 Topic	IEEE 1547-2003 Section
1.4	General remarks and limitations	3.1
4.8	Isolation device	4.1.7
4.9	Inadvertent energization of the Area EPS	4.1.5
4.10.2	Enter service criteria // 6.6 Return to service after trip	4.2.6
4.10.4	Synchronization	4.1.3
4.11.1	Protection from electromagnetic interference	4.1.8.1
4.11.2	Surge withstand performance	4.1.8.2
4.11.3	Paralleling device	4.1.8.3
4.12	Integration with Area EPS grounding	4.1.2
6.2	Area EPS faults and open phase conditions	4.2.1
6.3	Area EPS reclosing coordination	4.2.2
6.4.1	Mandatory voltage tripping requirements (OV/UV)	4.2.3
6.5.1	Mandatory frequency tripping requirements (OF/UF)	4.2.4
7.1	Limitation of dc Injection	4.3.1
7.2.3	Power Quality, Flicker	4.3.2
7.3	Limitation of current distortion	4.3.3
8.1	Unintentional islanding	4.4.1
8.2	Intentional islanding	4.4.2
9	Secondary / spot network	4.1.4.1, 4.1.4.2
10.1	Interoperability requirements	4.1.6
11	Test and verification	5
5.1	Voltage within ANSI limits	4.1.1
0	Loss of Synchronization (only for -2003 standard)	4.2.5

List of 1547-2018 Topics that are Current Practice

IEEE 1547-2018 Section	IEEE 1547-2018 Topic	IEEE 1547-2003 Section
4.2	Reference points of applicability (RPA)	Note 8
4.3	Applicable voltages	Note 8
4.6.1	Capability to disable permit service	Note 8, @2018
4.6.2	Capability to limit active power, static (Duke to DER)	Note 8, @2018
4.10.3	Performance during entering service	Note 8
5.2	Reactive power capability of the DER	Note 8
5.3	Voltage and reactive power control	Note 8, @2014
7.2.2	Power Quality, Rapid voltage change (RVC)	Note 8
7.4.1	Limitation of overvoltage contribution	Note 8

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List of 1547-2018 Topics in Phase 1 that are new

IEEE 1547-2018 Section	IEEE 1547-2018 Topic	IEEE 1547-2003 Section
4.7	Prioritization of DER responses	@2018
4.5	Cease to energize performance requirement	@2018
6.4.2	Voltage disturbance ride-through requirements	@2018
6.5.2	Frequency disturbance ride-through requirements	@2018
6.5.2.7	Frequency-droop (frequency-power) capability	@2014
10.2	Monitoring, control, and information exchange requirements	@2018
10.3	Nameplate Information	@2018
10.4	Configuration information	@2018
10.7	Communication protocol requirements	@2018
10.8	Communication performance requirements	@2018
10.9	Cyber security requirements	@2018

DUKE ENERGY

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Feedback

- Written feedback and comments will be solicited using comment form
  - Note questions then let's discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide both comments and also propose a specific change:

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
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Reactive Power Control Pilot

Anthony C Williams, P.E.
Principal Engineer

Operations & Technical Standards

July 20, 2022

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Overview

- Duke is conducting a pilot in the Carolinas to evaluate smart inverters: focused on voltage control using reactive power
- Completed studies to evaluate effectiveness of the reactive power control and develop methods for determining the control settings
- Implementing controls at sites now
- Power system and DER operating parameters will be reviewed to assess the effectiveness and overall operational performance

Refresher

- Traditional control: fixed pf
- Confluence of

  1547-2018 review
  +
  Commission request
  +
  queue settlement
  =
  pilot

IEEE 1547 evolution of grid support functions

IEEE 1547-2003	• Shall NOT actively regulate voltage • **Shall** trip on abnormal voltage/frequency
IEEE 1547a-2014 (Amendment 1)	• May actively regulate voltage • **May** ride through abnormal voltage or frequency • **May** provide frequency response
IEEE 1547-2018	• Shall be **capable of** actively regulating voltage • **Shall** ride through abnormal voltage/frequency • **Shall be capable of** frequency response

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Scope

- 7 sites are participating
- Focus only on mitigation of overvoltage caused by interconnection
  - Not system VAR support
- Pilot considers volt-var and watt-var controls (volt-watt)
  - If and when to use
  - How to set
  - System operations impact
- Does not include modification of local or central/integrated system VAR & voltage controls
- All sites are utility scale
- TBD for residential

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

Voltage and reactive power control is only used to facilitate interconnection of the DER. This control is not used for a grid service at this time.

Listed below are the Standard voltage and reactive power control options and the default status for Duke interconnections:

Control Mode	Default Status
Constant power factor (fixed pf)	On, 1.0 pf
Constant reactive power (fixed VAR)	Off
Voltage-reactive power (Volt-VAR)	Off
Active power-reactive power (Watt-VAR)	Off

On?

Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings.

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Review of the pilot process

- Complete
  - 2 studies
    - Impact and effectiveness of reactive power control based on location along the feeder
    - Comparison of control methods, multiple settings, interaction with voltage regulators
- Ongoing
  - Implement pilots
    - 7 sites total: because of construction schedules, unsure how many sites ultimately the pilot
    - Gather study input data
    - Perform control setting studies
    - Develop / approve test procedures
    - Execute tests
    - Review test data
- Upcoming
  - Track and trend pilot sites
  - Identify any system and DER specifications
  - Inform Duke decision on use of inverter reactive power control for interconnections

Lessons Learned

- Define test requirements
  - Minimum 4 – 6 weeks, expect longer
  - Gather study input data
  - Perform control setting studies
  - Understand how the DER user-designed control works
    - Prefer use of industry developed models (e.g., previously developed by the automation controller manufacturer)
- Write test procedures
  - Minimum 4 – 6 weeks, expect longer
  - Develop / approve test procedures
  - Have procedure review and coordination meetings
- Execute tests
  - 2-3 weeks to schedule
  - May shift a few days the week-of for weather
  - Fast data recording equipment (e.g., 1 sec)
- Correct issues with control performance and repeat test
  - 4 – 6 weeks
- Review test data
  - 2 weeks

Summary

- Pilot includes a maximum of 7 utility-scale DER with either volt-var or watt-var controls to mitigate overvoltage caused by the UDER interconnection
- So far so good
  - Good progress on settings methodology
  - Improving procedure development process with developers
  - Improving performance specifications for control
- Time will tell on performance
  - Only one facility with control in service
  - No reports of operational issues at this time

Duke Energy Utility Scale Volt-Var Function Pilot

TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

Renewable Integration

October 19, 2022

DUKE ENERGY®

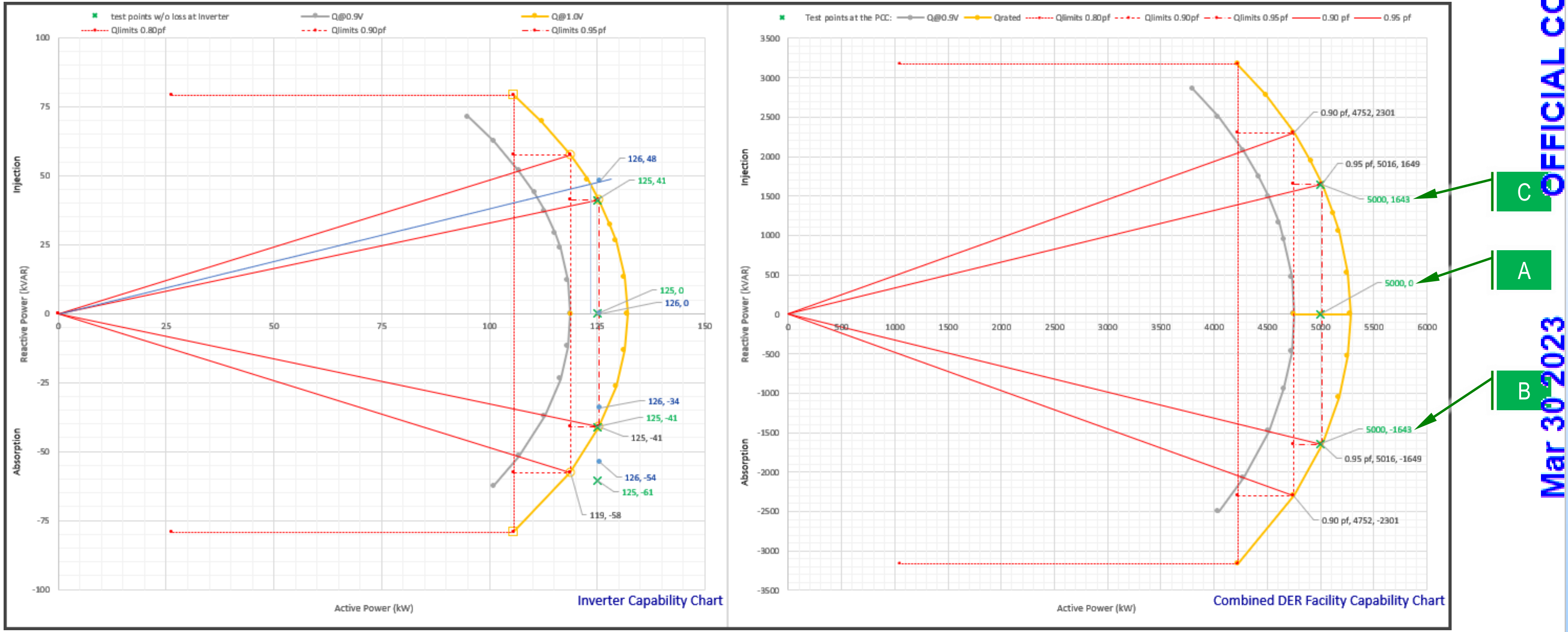
Overview

- Duke is conducting a pilot in the Carolinas to evaluate voltage control using reactive power for utility scale DER
- Everything is the traditional fixed pf control
- Confluence of
  1547-2018 implementation + NC Commission interest + queue settlement = pilot
- Implementing Volt-VAR controls at pilot sites now

Review of the pilot process

- Complete
  - 2 studies
    - If and when to use:
      Impact and effectiveness of reactive power control based on location along the feeder (head, middle, end)
    - How to set:
      Comparison of control methods, multiple settings, interaction with voltage regulators (opt v-v selection, interaction)
- Ongoing
  - Does not include modification of local or central/integrated system VAR & voltage controls
  - Implement pilots
    - 7 sites total: because of construction schedules, unsure how many sites ultimately the pilot
    - Gather study input data
    - Perform control setting studies
    - Develop / approve test procedures
    - Execute tests
    - Review test data
- Upcoming
  - Power system and DER operating parameters will be reviewed to assess the effectiveness and overall operational performance
  - Track and trend pilot sites
  - Identify any system and DER specifications
  - Inform Duke decision on use of inverter reactive power control for interconnections

Data to Owner: Reactive Requirements



Test points at the PCC:			
P	Q	S	
5000	-1643	5263	0.95 reqmt at Pcontract (absorbing)
5000	0	5000	Pcontract at unity
5000	1643	5263	0.95 reqmt at Pcontract (injecting)

- Provide the capability curve along with the critical test points
- Note that inverter terminal conditions are not the POI points

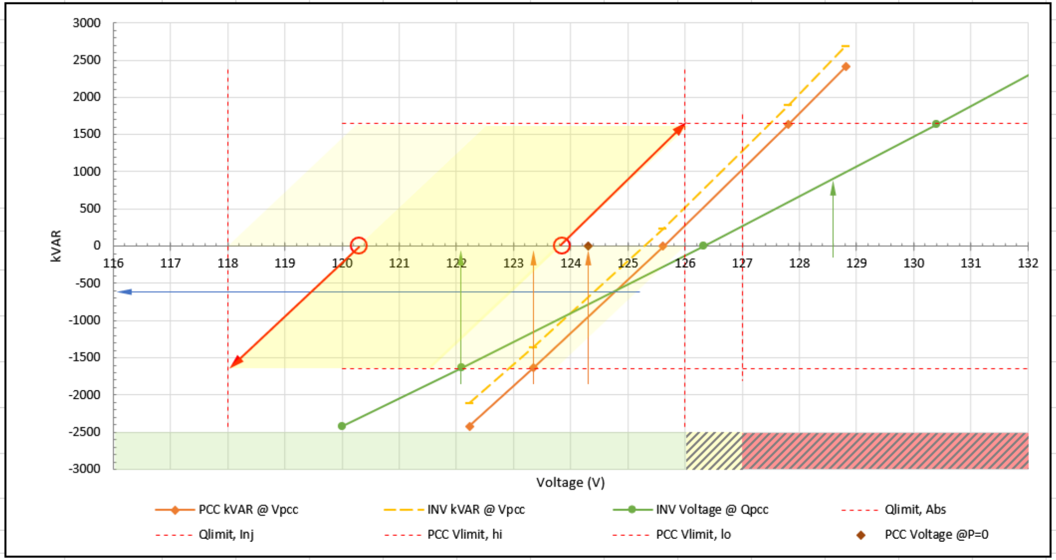
Data to Owner: Operational Limits for Testing

- Based on the PCC voltage at the time of the test, it is possible to predict the voltage change caused by DER reactive power changes
- The maximum and minimum initial voltages will be specified for each DER
- When the PCC voltage is outside this voltage range, Duke may decide to reconfigure the system to accommodate the test or, in some cases, the test may need to be postponed

<u>inverter</u> VAR and Voltage must be read off separate lines as noted below:

At a given PCC voltage, the PCC vars and Inv VARs can be compared (solid orange vs dashed orange)

At a given PCC VAR output, the PCC voltage and Inv voltage can be compared (solid orange vs solid green)



		22.86			600
	V at PCC	PCC base		V at INV	INV base
95% pf Full injection dV:	2.18		95% pf Full injection dV:	4.1	20
Highest pre-injection voltage:	**123.8**	**23.59**	95% pf Full injection dV from PCC:	2.6	13
95% pf Full absorption dV:	-2.27		**Highest possible voltage, full injection:**	**128.6**	**643**
Lowest pre-absorption voltage:	**120.3**	**22.91**	95% pf Full absorption dV:	-4.2	-21
1088 kVAR causes voltage step of	1.5		95% pf Full absorption dV from PCC:	-1.3	-6

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Example Procedure Development + Test Schedule

- Define test requirements
  - Minimum 4 – 6 weeks, expect longer
  - Gather study input data (multiple iterations with owner)
  - Perform control setting studies
  - Understand how the DER user-designed control works
    - Prefer use of industry developed models (e.g., previously developed by the automation controller manufacturer)
- Write test procedures
  - Minimum 4 – 6 weeks, expect longer
  - Owner writes procedures
  - Have procedure review and coordination meetings
  - Duke approves test procedures
- Execute tests
  - 2-3 weeks to schedule
  - May shift a few days the week-of for weather
  - Fast data recording equipment (e.g., 1 sec)
- Correct issues with control performance and repeat test
  - 3 – 6 weeks, if needed
- Review test data and summary report
  - 2 weeks

Summary

- Pilot includes a maximum of 7 utility-scale DER with either volt-var or watt-var controls to mitigate overvoltage caused by the UDER interconnection
- So far so good
  - Good progress on settings methodology
  - Improving procedure development process with customer
  - Improving performance specifications for control
- Time will tell on performance
  - Only one facility with control in service
  - No reports of operational issues

DUKE ENERGY®

Anthony Williams
Anthony.Williams@duke-energy.com

CERTIFICATE OF SERVICE

I certify that a copy of Duke Energy Carolinas, LLC and Duke Energy Progress, LLC's *IEEE Standard 1547-2018 Implementation Status Report*, in Docket Nos. E-100, Sub 101 and E-100, Sub 101B, has been served by electronic mail, hand delivery, or by depositing a copy in the United States mail, postage prepaid, properly addressed to parties of record.

This the 30th day of March, 2023.

/s/ Tracy S. DeMarco

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Attorney for Duke Energy Carolinas, LLC and Duke Energy Progress, LLC