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ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 1 of 108

February 17, 2022

VIA ELECTRONIC FILING

The Honorable Jocelyn G. Boyd
Chief Clerk and Executive Director
Public Service Commission of South Carolina
101 Executive Center Drive, Suite 100
Columbia, SC 29210

Re: Petition of Duke Energy Carolinas, LLC and Duke Energy Progress, LLC for Approval of CPRE Queue Number Proposal, Limited Waiver of Generator Interconnection Procedures, and Request for Expedited Review
Docket No. 2018-202-E

Informational Update on Most Recent DER TSRG Meeting

Dear Ms. Boyd:

Pursuant to the Public Service Commission of South Carolina's ("Commission") Order No. 2019-247 issued on April 9, 2019, in the above-captioned docket, Duke Energy Carolinas, LLC and Duke Energy Progress, LLC (together, the "Companies") hereby provide the Commission an informational update on the Companies' most recent Distributed Energy Resources ("DER") Technical Standards Review Group ("TSRG") meeting held on January 19, 2022.

The following attachments enclosed with this update provide a more detailed account of the previous TSRG meeting and issues discussed:

- **Attachment A:** January 19, 2022 Meeting Agenda
- **Attachment B:** January 19, 2022 Minutes and Attendance
- **Attachment C:** Update and Discussion-Action Plan to Implement 1547-2018
- **Attachment D:** IEEE 1547-2018 Implementation Guidelines (Redline)
- **Attachment E:** IEEE 1547-2018 Implementation Guidelines (Clean)
- **Attachment F:** DER Commissioning Update

As described in the Companies' June 6, 2019 Report in this docket, the TSRG webpage, https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg, provides meeting materials from each prior TSRG meeting, as well as other technical standards documents. The next TSRG meeting is tentatively scheduled for April 20, 2022.

Kind regards,

Sam Wellborn

Attachments

cc: Parties of Record (via email with attachments)

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 2 of 108

Attachment A

Technical Standards Review Group (TSRG)
Duke Energy Carolinas/Progress
Meeting Agenda
January 19, 2022

In-person meeting converted to web meeting to follow distancing guidelines for COVID-19

9:00	Meeting Administrator remarks & Safety
9:02	Welcome – Wes Davis, Duke
9:05	IEEE 1547 implementation update – Anthony Williams, Duke
10:00	Inspection and commissioning update – Kevin Chen, Duke
10:30	BREAK
10:40	General Discussion and Updates • Mike Whitson will be taking the Industry Lead position over from Mike Wallace
10:40	Wrap up & next meeting date – Wes Davis, Duke (Recommend April 20)
12:00	ADJOURN

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 3 of 108

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

January 19, 2022

I. Opening

This is a regular meeting called to order at 9:02 AM. The meeting was conducted by web conference.

Meeting facilitator: Anthony Williams

Minutes: Anthony Williams

II. Record of Attendance

Member Attendance

Name	Affiliation	Attendance
Kevin Chen	Duke Energy	present
Wes Davis	Duke Energy	present
Ken Jennings	Duke Energy	absent
Huimin Li	Duke Energy	present
Darren Maness	Duke Energy	present
Orvane Piper	Duke Energy	present
Bill Quaintance	Duke Energy	present
Scott Reynolds	Duke Energy	absent
Anthony Williams	Duke Energy	present
Stephen Barkaszi	Duke Energy	absent
Ben Brigman	Ecoplexus	present
Paul Brucke	Brucke Engineering	present
David Brueck	Southern Current	absent
Matt Delafield	R-E Services	absent
Jason Epstein	Southern Current	absent
Adam Foodman	O2 Energies EMC	present
Bruce Fowler	BAM Energy	absent
Sean Grier	Duke Energy	absent
Scott Griffith	Duke Energy	absent
John Gajda	Strata Solar	absent
Chuck Ladd	Ecoplexus	present
Bruce Magruder	BAM Energy	absent
Brad Micallef	Solar Operations Solutions	present
Luke O'Dea	Cypress	absent
Luke Rogers	Birdseye Renewable Energy	absent
Chris Sandifer	SCSBA	present
Mauricio Martinez-Galicia	Ecoplexus	present
Mike Whitson	PowerOn Energy	present
John Wilson	Southern Current	absent
James Wolf	Yes Solar Solutions	absent
Jay Lucas	NC Public Staff	absent
James McLawhorn	NC Public Staff	absent

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 4 of 108

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

January 19, 2022

Name	Affiliation	Attendance
Dustin Metz	NC Public Staff	present
Tommy Williamson	NC Public Staff	present
Dawn Hipp	SC Office of Regulatory Staff	absent
Gretchen Pool	SC Office of Regulatory Staff	present
Sarah Johnson	SC Office of Regulatory Staff	absent
Robert Lawyer	SC Office of Regulatory Staff	absent
Morgan O'Neil	SC Office of Regulatory Staff	present

Guest Attendance

Name	Affiliation	Attendance
Terri Edwards	Duke Energy	present
Kelsy Green	Advanced Energy for Duke Energy	present
Shawn Fitzpatrick	Advanced Energy for Duke Energy	present
Staci Haggis	Advanced Energy for Duke Energy	present

III. Current agenda items and discussion

1) The agenda was emailed prior to the meeting.
2) Wes Davis provided the welcome

3) PRESENTATION: IEEE 1547 implementation update – Anthony Williams, Duke
   A) Presentation will be provided with the meeting minutes
   B) Industry question – Where is the latest Guideline document on TSRG website?
      (i) Duke response – The latest version is under the most recent meeting information. The current version at the time of each meeting is also there for past meetings. When the TSRG link is selected, be sure to set the state to either NC or SC.
   C) Discussion – Duke asked for input on whether the applicability date should be based on the Interconnection Request Date or the Operational Date and indicated that Duke prefers the former. A stakeholder recommended using the IR date.
   D) Industry question – Some of the 1547 functions are grid-supporting. The industry asked about commercial / PPA impacts related to implementing 1547.
      (i) Duke response – In general, commercial and PPA issues are not directly related to or addressed within the scope of the TSRG. The grid-support functions in 1547 are related to reliability concerns and not commercial applications. While some DER may participate in RTO services in some regions, that would seem more dependent on the services in that region than on the IEEE Standard requirements themselves. This is probably best discussed for specific topics.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 5 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 6 of 108

E) Industry question – The EPRI slide referenced enforcement. What does enforcement mean for Duke?
   (i) Duke response – Duke refers to this as implementation. Implementation of 1547-2018. The initial thoughts is that 1547 will be implemented in Phases. Each phase will involve implementing more functions and capabilities from 1547 than the previous Phase. As later Phases are implemented, there is no plan to make the most recent requirements applicable to previously installed 1547-2018 inverters. However, that would not preclude a DER owner from requesting permission from Duke to put newer functions in service that were not applicable to that facility.

F) Industry question – Would Duke require the inverter be 1547 certified before the interconnection request is accepted?
   (i) Duke response – Just as it is now, all inverters require certification to proceed in the study process. The current certification is UL 1741 and the new one will be UL 1741 SB. Also, there is a field review to verify the inverter certification.

G) Discussion – Duke began discussions concerning the sequence of tasks and durations in order to create an implementation timeline. In particular, need information related to the time for the DER owner / developer to related absorb the requirements and incorporate them into an interconnection request. The time in question is that between the requirements being finalized and the IR date. The same is also asked for testing requirements, but that duration there between tasks should be much longer and not expected to be critical to the overall project timeline.
   (i) <u>ACTION ITEM – The industry lead took an action item to discuss the "Timeline Considerations" slide and identify tasks and provide an initial estimate for the duration of the task [Attachment 2.A.].</u>

H) Industry question – Is it an objective of the implementation effort to minimize testing and the associated costs?
   (i) Duke response – Duke agrees that testing should be reserved for only those things that need it. However, the new 1547 inverters incorporate more advanced functions, therefore it is also expected that more testing is a likely and necessary consequence. See the Duke Guidelines for the anticipated test and verifications for each section of the Standard.

4) PRESENTATION: Inspection and commissioning update – Kevin Chen, Duke
   A) Presentation will be provided with the meeting minutes
   B) Discussion – Automatic reclosing noted in the presentation is not the same as reclosing that Duke uses for line reclosers. This only means that if there is a customer owned disconnect device at the interconnection, that it automatically closes back after voltage is restored on the utility side of the device.

C) Industry question – Explain the cease-to-energize and trip requirement during the commissioning test and clarify Duke's requirements on device performance in meeting the requirements.
   (i) Duke response – The Q4 2021 tests did not raise any concern from either the customer or Duke regarding this cease-to-energize and trip requirement as defined in IEEE 1547. Duke will have offline conversation to discuss technical details behind this question.

5) Operations update – Darren Maness, Duke
   A) There was no presentation given
   B) Discussion – A general update concerning recent outages for a snow storm was provided.

6) General Discussion and Updates
   A) Industry leadership change
      (i) Mike Whitson will be taking the Industry Lead position over from Mike Wallace

7) Wrap up & next meeting date – Anthony Williams, Duke
   A) Next meeting planned to be a web conference.
      (i) Recommended April 20, 2022

IV. Closing

This meeting concluded at 11:00 AM

V. Attachments

1) Agenda, "TSRG Agenda 2022_0119, Rev 0.pdf"
2) Presentations
   A) IEEE 1547 implementation update, "TSRG Implement 1547 Update, Jan 19 2022, Rev 0.pdf"
   B) Inspection and commissioning update, "DER commissioning_TSRG_01192022.pdf"
3) References
   A) 1547 Guidelines with edits, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 6B"
   B) 1547 Guidelines latest version, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 7"

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 7 of 108

Update and Discussion: Action Plan to Implement 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

Operations & Technical Standards
January 19, 2022

Attachment C

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ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke
2018-202-E - Page 8 of 108

Agenda

- Review main revisions
  - Current version is “Duke Energy IEEE 1547 Implementation Guidelines, Rev 7”
  - Rev 6B is the red marked version
- Recent activities
- Timeline discussion

Attachment C

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 9 of 108

Recent Activities

- Focused on getting sections closed out
  - Little to no large-scale revisions
    - Internal stakeholder meetings
    - Internal confirmation of content
  - 6. Abnormal conditions: Confirmed status of protection-related topics
  - 7. Power Quality: Complete
    - 7.1 DC Injection section added
  - 10. Interoperability: Vertical slice done, performing review
- Completed 7th revision of the Guidelines
  - Not a 'final' document, still a record of progress and open issues
  - 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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 10 of 108

Next Steps

- Continue development of the Guidelines – internally and with TSRG
- Address the remaining lower priority 1547 topics
- Address RDER applicability
  - Phase 1: Enter service, reactive capacity, abnormal trip and ride through, freq droop, anti-islanding
  - Phase 2: Reactive power control

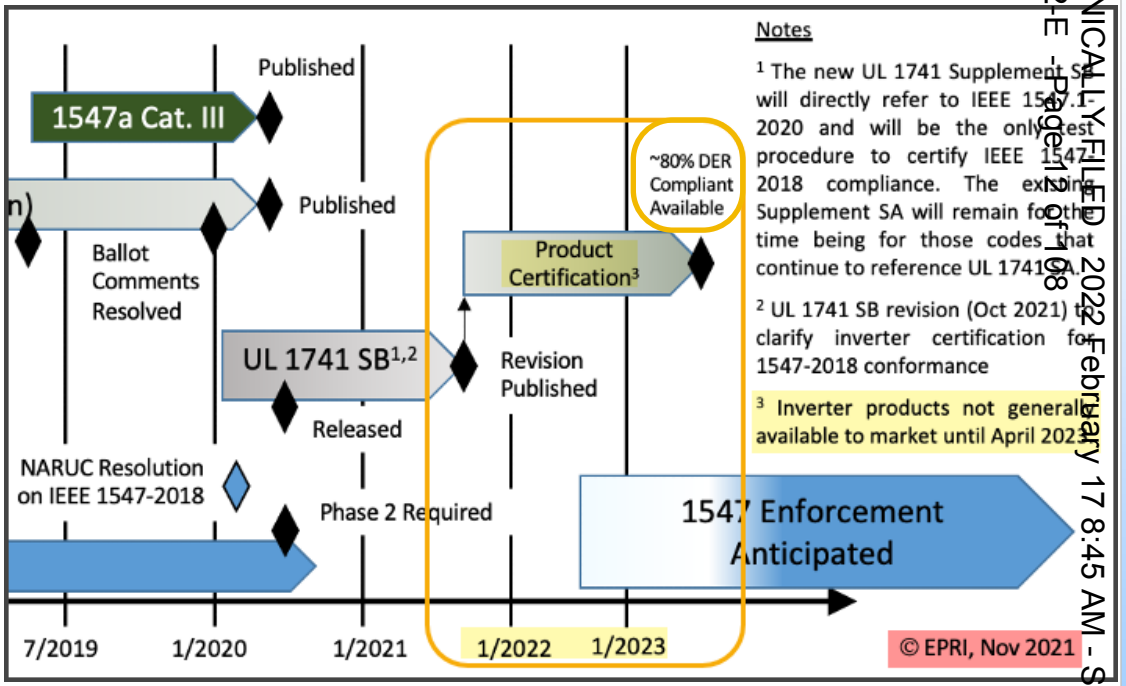
- Others?

- Origination of a timeline for a phased implementation – internally and with TSRG

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke
2018-202-E - Page 11 of 108

ETA for Certified Inverters

- Many expected inverters to complete testing during 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



ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 12 of 108

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

Attachment C

Duke Energy

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 13 of 108

Phase 1 - General Technical Specifications

- Planned for Phase 1

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke
2018-202-E - Page 14 of 108

Phase 1 - Specific Technical Specifications

- Planned for Phase 1

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 15 of 108

Phase 2 - Specific Technical Specifications

- Planned for Phase 2

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**

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke
2018-202-E - Page 16 of 108

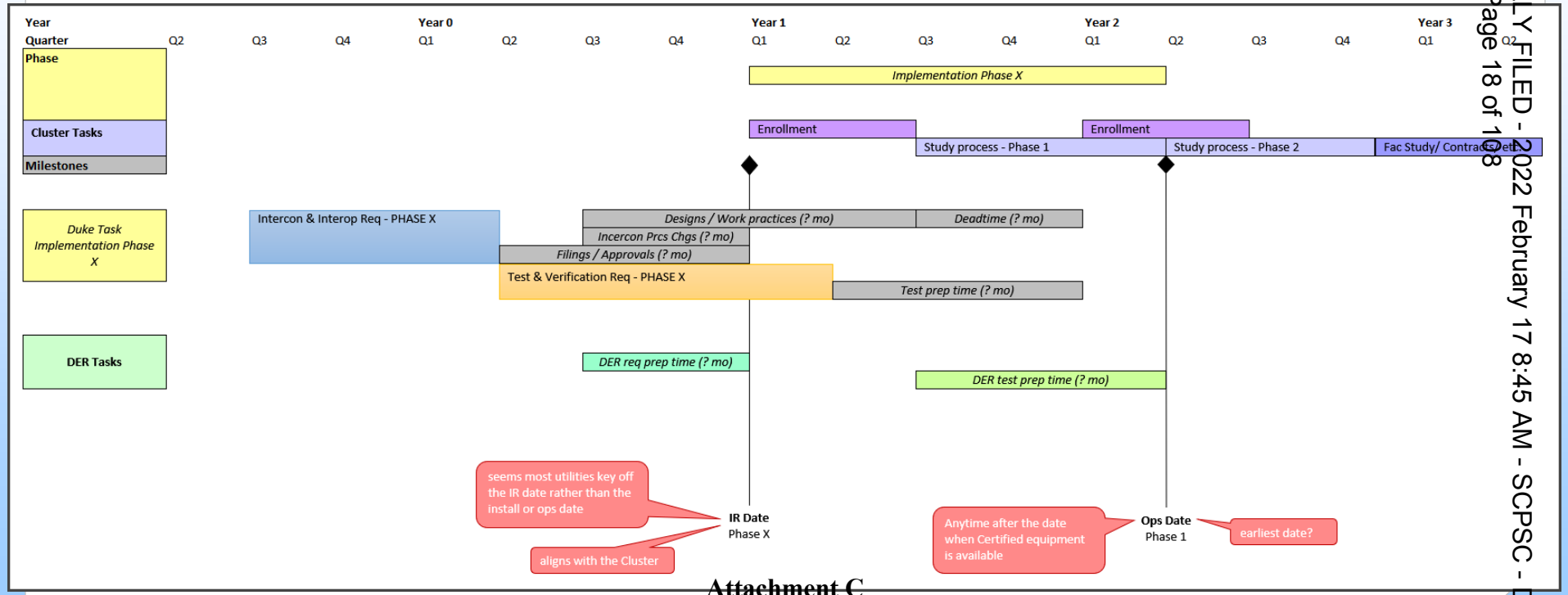
Timeline Considerations

- What are the tasks and timeframes
  - 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
- What are the task interdependencies
  - Predecessor / Successor
  - Deadtime
- Assumptions
  - Certified inverters are available
  - Alignment with cluster study process

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 17 of 108

High-level Organization of Tasks

- Only an EXAMPLE FOR DISCUSSION
- Keys off cluster enrollment window



Attachment C

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 18 of 108

Discussion

- What high-level DER tasks were left out?
  - Technical / Interoperability preparation
  - Testing preparation
  - Others?
- Recommendations on how to determine the timeframes for DER tasks
- Any need to key testing tasks off of the study completion?
  - Or know that there will be construction time much further down the line
    - After facility study, after IA, etc.
- Others?

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 19 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke
2018-202-E - Page 20 of 108

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Attachment C

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 21 of 108

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 servic set 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 equipm identify the interconnection device that provides the cease-to-energize function. 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 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 D interface.

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke # 2018-222-E - Page 22 of 108

Additional TSRG Information

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 23 of 108

Attachment D

~~Implementation of~~ 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 6B

January 19, 2022

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 24 of 108

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

Revision	Date	Description
0	3/31/2020	Initial issue
1	7/21/2020	General update prior to Jul. 2020 TSRG meeting
2	10/28/2020	General update prior to Oct. 2020 TSRG meeting
3	1/20/2021	General update prior to Jan. 2021 TSRG meeting
4	4/28/2021	General update prior to Apr. 2021 TSRG meeting
5	7/20/2021	General update prior to Jul. 2021 TSRG meeting
6	10/19/2021	General update prior to Oct. 2021 TSRG meeting
6B	1/19/2022	Red marked changes for Jan. 2021 TSRG meeting

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 25 of 108

CONTENTS

Introduction 1
Definitions Used in the Guidelines 2
Consideration of IEEE 1547 sections that could increase interconnection capability 2
Consideration of IEEE 1547 sections that impact grid support 2
Priority of implementing the IEEE 1547 technical specifications and requirements 3
Logistics of Implementing IEEE 1547-2018 7
Plant requirements 8
Section 1.4 – General remarks and limitations 8
Section 4.2 – Reference points of applicability (RPA) 9
Section 4.3 – Applicable voltages 9
Section 4.5 – Cease to energize performance requirement 9
Section 4.6 – Control capability requirements 10
Section 4.7 – Prioritization of DER responses 11
Section 4.8 – Isolation device ..... 12~~11~~
Section 4.9 – Inadvertent energization of the Area EPS 12
Section 4.10 – Enter service 12
Section 4.11 – Interconnect integrity 14
Section 4.12 – Integration with Area EPS grounding 14
Section 5.2 – Reactive power capability of the DER 15
Section 5.3 – Voltage and reactive power control 16
Section 5.4 – Voltage and active power control 17
Section 6.2 – Area EPS faults and open phase conditions 18
Section 6.3 – Area EPS reclosing coordination 19
Section 6.4.1 – Mandatory voltage tripping requirements 19
Section 6.4.2 – Voltage disturbance ride-through requirements 20
Section 6.5.1 – Mandatory frequency tripping requirements 21
Section 6.5.2 – Frequency disturbance ride-through requirements 22
Section 7.1 – Limitation of dc Injection 24
Section 7.2.2 – Rapid voltage changes 24
Section 7.2.3 – Flicker ..... 26~~25~~
Section 7.3 – Limitation of current distortion ..... 26~~25~~
Section 7.4.1 – Limitation of overvoltage over one fundamental frequency period ..... 27~~26~~

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 26 of 108

Section 7.4.2 – Limitation of cumulative instantaneous overvoltage ..... 27~~26~~
Section 8.1 – Unintentional islanding ..... 28~~27~~
Section 8.2 – Intentional islanding ..... 28~~27~~
Section 10.1, 10.7, 10.8, 10.9 – General Interoperability and protocol requirements ..... 28~~27~~
Section 10.2, 10.3, 10.4, 10.5, 10.6 – Data, Monitoring, and Control information ..... 29~~28~~
Unaddressed Requirements of IEEE 1547-2018 ..... 30~~29~~
Appendix – IEEE 1547-2018 Benchmarking ..... 31~~30~~

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 27 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 28 of 108

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 captures where Duke Energy is in the process of implementing IEEE 1547-2018. 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 29 of 108

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: Smaller DER with ratings below 250 kW.

UDER: Larger 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 30 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 31 of 108

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	~~Yes~~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~~Yes~~	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 + ~~Comm~~ 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	~~TBD~~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~~TBD~~	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	No Reqmt~~TBD~~	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	No Reqmt~~TBD~~	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	Study in progress	No Reqmt	TBD, Eval + Comm Test
2 (DUK-103)	8.1	Unintentional islanding	activate anti-islanding	No Reqmt~~Yes~~	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	~~Yes~~Control	Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547, static limits	Monitor / Control~~Yes~~	Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	3 Hz/s, ROCOF tripping off	No Reqmt~~TBD~~	Eval + Comm Test
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547~~; consider clarifications~~	No Reqmt	Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547~~; consider clarifications~~	~~Yes~~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~~TBD~~	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with ~~clarifications~~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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 32 of 108

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547	No Reqmt	Type Test
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~~, Yes~~	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	~~Yes~~TBD	-
- (DUK-105)	11	Test and verification	~~TBD~~Addressed in each 1547 section	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	Accept 1547 with notes~~TBD~~	Yes	-
- (DUK-107)	10.5	Monitoring information	Addressed in each 1547 section~~TBD~~	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	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	Accept 1547 with notes~~TBD~~	Yes	-
- (DUK-112)	10.3	Nameplate Information	Addressed in each 1547 section~~TBD~~	Yes	-
- (DUK-113)	10.4	Configuration information	Addressed in each 1547 section~~TBD~~	Yes	-
- (DUK-114)	10.6	Management information	Addressed in each 1547 section~~TBD~~	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	Accept 1547 with notes~~TBD~~	Yes	-
- (DUK-116)	10.8	Communication performance requirements	Accept 1547 with notes~~TBD~~	Yes	-

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 33 of 108

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-117)	10.9	Cyber security requirements	Accept 1547 with notes~~TBD~~	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	Accept 1547	No Reqmt	Type Test
- (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	~~No Reqmt~~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 ~~implementation~~ 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 34 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 35 of 108

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.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke accepts the requirements in the Standard.

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 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:

Voltage and Reactive Power Category B

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 36 of 108

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). The RPA for net meter installations 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. ~~This can be an inbuilt function of the source or by disconnecting from the local EPS. The former is the preferred method.~~

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 37 of 108

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

~~For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting at the local EPS. The expectation is that Standard compliant inverters will have this capability inbuilt.~~

Application to RDER has not been assessed. The expectation is that Standard compliant inverters will have this capability inbuilt, but Duke will not use it at this time. 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. ~~The automation controller has the capability to provide a limit active power Analog Output sent via SCADA to control active power.~~

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 38 of 108

4.6.2 Capability to limit active power

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. ~~Significant technical studies are required to address concerns and consider remote real-time control of the active power limit.~~ 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 ~~concerns and consider remote~~ 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

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 39 of 108

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	≤ 60.1 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 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	~~300~~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: ~~No specific requirements for these sections.~~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.

~~Duke will evaluate if there is value in monitoring the enter service settings.~~

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 40 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 41 of 108

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 42 of 108

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 performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of 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 at these pf ratings should the situation arise over the life of the facility that the facility would want this capability.

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).

Because operating points on the chart can be difficult to accurately determine, 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 a facility capability curve that includes any limitations.

Supplemental Devices

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 43 of 108

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 ~~prove~~ demonstrate its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

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 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. Because the system impact of ~~U~~DER reactive injection can be significant~~large~~, Duke limits the reactive capability that can be used for reactive power control to 0.95 power factor.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 44 of 108

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. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test ~~on this topic~~. 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 45 of 108

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. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 46 of 108

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.

~~Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.~~

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 47 of 108

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

Parameter	Voltage	Time
Undervoltage, UV Level 1	0.88 pu	10 cycles
Undervoltage, UV Level 2	0.5 pu	6 cycles
Overvoltage, OV Level 1	1.1 pu	10 cycles
Overvoltage, OV Level 2	1.2 pu	6 cycles

Interoperability requirements: ~~To be determined.~~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.~~To be determined.~~

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 48 of 108

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.~~To be determined.~~

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 49 of 108

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 within 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.

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 50 of 108

settings of the completed DER facility do not intentionally trip for the voltage phase angle changes specified by the Standard.

This function, either at the inverter or the utility PCC recloser, is still under evaluation as part of an ongoing project involving the Protection and Transmission Planning groups. Duke anticipates adopting the requirements above if that is supported by the ongoing project.

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

Duke Energy has not determined the guidelines for this subsection. This capability is not required by the Standard but is permitted.

Interoperability requirements: ~~To be determined.~~ 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 51 of 108

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 52 of 108

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 ~~and no additional requirements are proposed~~.

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 ~~noted~~ 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 53 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 54 of 108

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 ~~noted~~ 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 55 of 108

SECTION 8.1 – UNINTENTIONAL ISLANDING

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 expected requirement is noted below.

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

If there is the option to activate or deactivate the anti-islanding function, it shall be activated or the status On.

The standard clearing time for an unintentional island is 2 seconds. 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~~No control points are expected. Need to determine if any monitoring is necessary~~.

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. 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
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

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).

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 56 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 57 of 108

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 most capacity the system is designed 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	

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 58 of 108

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]			

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 59 of 108

Attachment E

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 7

January 19, 2022

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 60 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 61 of 108

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

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

CONTENTS

Introduction 1
Definitions Used in the Guidelines 2
Consideration of IEEE 1547 sections that could increase interconnection capability 2
Consideration of IEEE 1547 sections that impact grid support 2
Priority of implementing the IEEE 1547 technical specifications and requirements 3
Logistics of Implementing IEEE 1547-2018 7
Plant requirements 8
Section 1.4 – General remarks and limitations 8
Section 4.2 – Reference points of applicability (RPA) 9
Section 4.3 – Applicable voltages 9
Section 4.5 – Cease to energize performance requirement 9
Section 4.6 – Control capability requirements 10
Section 4.7 – Prioritization of DER responses 11
Section 4.8 – Isolation device 11
Section 4.9 – Inadvertent energization of the Area EPS 12
Section 4.10 – Enter service 12
Section 4.11 – Interconnect integrity 14
Section 4.12 – Integration with Area EPS grounding 14
Section 5.2 – Reactive power capability of the DER 15
Section 5.3 – Voltage and reactive power control 16
Section 5.4 – Voltage and active power control 17
Section 6.2 – Area EPS faults and open phase conditions 18
Section 6.3 – Area EPS reclosing coordination 19
Section 6.4.1 – Mandatory voltage tripping requirements 19
Section 6.4.2 – Voltage disturbance ride-through requirements 20
Section 6.5.1 – Mandatory frequency tripping requirements 21
Section 6.5.2 – Frequency disturbance ride-through requirements 22
Section 7.1 – Limitation of dc Injection 24
Section 7.2.2 – Rapid voltage changes 24
Section 7.2.3 – Flicker 25
Section 7.3 – Limitation of current distortion 25
Section 7.4.1 – Limitation of overvoltage over one fundamental frequency period 25

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 62 of 108

Section 7.4.2 – Limitation of cumulative instantaneous overvoltage 26
Section 8.1 – Unintentional islanding 26
Section 8.2 – Intentional islanding 27
Section 10.1, 10.7, 10.8, 10.9 – General Interoperability and protocol requirements 27
Section 10.2, 10.3, 10.4, 10.5, 10.6 – Data, Monitoring, and Control information 27
Unaddressed Requirements of IEEE 1547-2018 29
Appendix – IEEE 1547-2018 Benchmarking 30

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 63 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 64 of 108

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 captures where Duke Energy is in the process of implementing IEEE 1547-2018. 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 65 of 108

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: Smaller DER with ratings below 250 kW.

UDER: Larger 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 66 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 67 of 108

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	Study in progress	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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 68 of 108

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	TBD	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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 69 of 108

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 70 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 71 of 108

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.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke accepts the requirements in the Standard.

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 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:

Voltage and Reactive Power Category B

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 72 of 108

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). The RPA for net meter installations 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 73 of 108

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

Application to RDER has not been assessed. The expectation is that Standard compliant inverters will have this capability inbuilt, but Duke will not use it at this time. 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

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 74 of 108

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

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 75 of 108

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	≤ 60.1 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 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 76 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 77 of 108

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

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 78 of 108

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 performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of 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 at these pf ratings should the situation arise over the life of the facility that the facility would want this capability.

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).

Because operating points on the chart can be difficult to accurately determine, 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 a 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.

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 79 of 108

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. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

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 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. 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.

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,

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 80 of 108

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. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test. 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. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 81 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 82 of 108

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
Undervoltage, UV Level 1	0.88 pu	10 cycles
Undervoltage, UV Level 2	0.5 pu	6 cycles
Overvoltage, OV Level 1	1.1 pu	10 cycles
Overvoltage, OV Level 2	1.2 pu	6 cycles

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 83 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 84 of 108

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 85 of 108

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 within 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.

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

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.

This function, either at the inverter or the utility PCC recloser, is still under evaluation as part of an ongoing project involving the Protection and Transmission Planning groups. Duke anticipates adopting the requirements above if that is supported by the ongoing project.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 86 of 108

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

Duke Energy has not determined the guidelines for this subsection. This capability is not required by the Standard but is permitted.

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

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 87 of 108

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 88 of 108

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 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 expected requirement is noted below.

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

If there is the option to activate or deactivate the anti-islanding function, it shall be activated or the status On.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 89 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 90 of 108

The standard clearing time for an unintentional island is 2 seconds. 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. 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
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 91 of 108

- 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.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 92 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 93 of 108

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]			

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 94 of 108

DER Commissioning Update

Attachment F

Kevin Chen 1/19/2022

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ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke
2018-202-E - Page 95 of 108

Agenda

- 2021 Solar Commissioning Summary
- Uninspected Facilities Self-administered Compliance Program MOA
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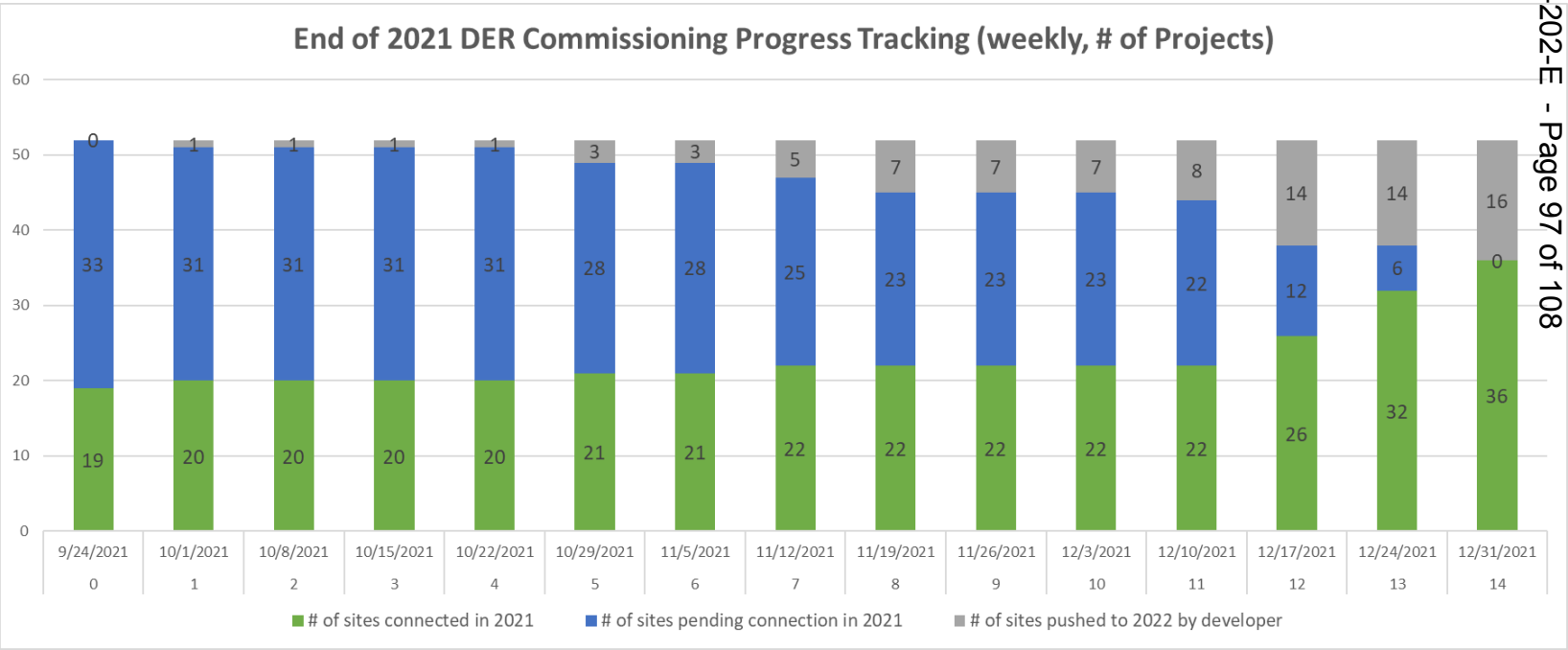
ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 96 of 108

2021 Solar Commissioning Summary



Year	Total Connected	Between Q1 - Q3	In Q4	Full process	Conditional PTO
2021	36	19	17	23	13
2020	49	10	39	21	28
2019	49	21	28	31	18

Attachment F

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 97 of 108

2021 Solar Commissioning Summary

- Inspection and commissioning process changes implemented since July 2021:
  1) Duke and AE had 1-on-1 meeting with each developer that had active projects in the 2nd half of 2021 to go over the commissioning process and answer any technical questions about construction standards or good utility practice.
  2) Reduced the scope of MV inspection to only include electrical equipment from the secondary side of the MV transformers to the point of interconnection.
  3) Some less significant MV construction issues were not considered as "required corrections".
  4) Updated the commissioning test scope to include confirming and verifying the expected performance in the commissioning test.

- Comparison of inspection and commissioning resources:
  1) Before July 2021 – Average number of site visits: 3.22; Average number of pages in report: 37.2.
  2) After July 2021 – Average number of site visits: 2.12; Average number of pages in report: 19.2.
  - About 1/3 of reduction in site visits, and 1/2 of reduction in report length.

Attachment F

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 98 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 99 of 108

Observed Improvements

- Experienced developers and their contractors
- Mature technology, improved device
- Minimum weather impact
- Better communication

Challenges

- Supply chain delay impacted both developer and Duke
- Peak workload was after the usual deadline
- Decisions made under pressure

Forecast of 2022

- We anticipate higher workload in 2022, with new challenges from smart inverter pilot projects.
- The process will continue to update and improve from the lessons learned.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 100 of 108

Specific Topics

- The IR modification and updated SLD of equipment change must go through Duke study team review and receive approval before the site can be permitted to operate.
- The facility construction must complete:
  - Security fence must be complete before Duke can energize the site (NESC requirement).
  - Overall facility must be capable of generating rated AC power (with enough panels and all inverters).
- Duke and AE do not require reclosing function if the facility is not designed to do so.
  - AE may have multiple conversations with the EPC contractor and developer engineering staff to confirm the case during the documentation review, inspection, and commissioning test.
  - Duke may need the interconnection customer to issue a letter to confirm the decision of not implementing automatic closing function.
- Relay programming for same device may vary across different contractors.

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ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 101 of 108

NCUC October 8th 2021 Order

NCUC Order on 10/8/2021 Clarifying Generator Interconnection Standards, Requesting Comments, and Requiring Filing of Remediation Information.
(https://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=c1761ece-ee25-4b30-8c96-01ae88fd394c)

- *…All other Interconnection Customers with Uninspected Facilities shall work with Duke develop similar self-inspection programs, memorialized in memoranda of agreement.*
- *All Interconnection Customers that own Uninspected Facilities must enter into a self-inspection agreement with Duke by **no later than February 1, 2022**, and must complete self-inspections of the Uninspected Facilities within three years from the date of execution of the agreement with Duke.*
- *Duke shall file a report with the Commission by February 23, 2022, as to the status of the self-inspection agreements entered into and any remaining Uninspected Facilities that are not covered by an agreement.*
- *…The Commission shall take additional action, as necessary, with respect to the inspection of the Uninspected Facilities should Interconnection Customers and Duke not be able to reach agreement on the timely self-inspection of the Uninspected Facilities.*

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 102 of 108

Actions Taken

1. On October 22, 2021, Duke served a copy of the Commission's Order on all North Carolina Interconnection Customers that own or operate Uninspected Facilities as directed by Ordering Paragraph No. 3.
2. On December 7, 2021, Duke filed the Response to the Commission's Request for Remediation Information as directed by Ordering Paragraph No. 2.
3. Since October 2021, Duke developed a template MOA providing Interconnection Customers that own or operate Uninspected Facilities with an option to implement self-administered inspection programs that comport with appropriate safety and reliability standards and meet the requirements of NCIP Sections 6.5.2 and 6.5.3 (the "Pro Forma MOA") as directed by the Order.
4. In December 2021 and early January 2022, Duke sought feedback from stakeholders, including the Public Staff, Carolina Clean Energy Business Association ("CCEBA"), and Strata Solar, LLC, regarding the Pro Forma MOA.
5. The Pro Forma MOA is finalized and ready to be distributed.

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 103 of 108

Plan of Moving Forward

1. Duke will file a motion to NCUC to extend the February 1st deadline.

2. Duke plans to distribute the Pro Forma MOA to all interconnection customers with uninspected facilities on January 21, 2022.

3. Duke plans to host an informational meeting with Interconnection Customers to answer questions about the pro forma MOA and Self-Administered Inspection Process.

4. Available supporting technical documents have been posted on the TSRG website.

Attachment F

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 104 of 108

Agenda

- 2021 Solar Commissioning Summary
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ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 105 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 106 of 108

Transmission Connected IBR Commissioning

- Duke is developing an inspection and commissioning process for transmission-connected IBR facilities to ensure the facilities meet the interconnection reliability requirements.
- Duke paused on the pilot inspection in Q4, 2021 to avoid causing delay or confusion for those projects seeking for COD and PTO letter by the end of 2021.
- The pilot inspection will resume in Q1, 2022.
- Once Duke has drafted a process, it will be presented to and reviewed by the TSRG.

IEEE 1547 Education and Credentialing Program

- IEEE Standards Association is finalizing the education lecture materials.
- Pilot training may be in early Q2, 2022, offered by IEEE-SA (not Duke).
- Duke will share updates in the future TSRG meetings.

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ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docket # 2018-202-E - Page 107 of 108

ELECTRONICALLY FILED - 2022 February 17 8:45 AM - SCPSC - Docke
2018-202-E - Page 108 of 108

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Attachment F