Improvements to Large and Small Generator Interconnection Procedures and Agreements

EPRI Comments on FERC's NOPR issued on June 16, 2022, Docket No. RM22-14-000

3002025703

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Technical Update, October 2022

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ACKNOWLEDGMENTS

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This report describes research sponsored by EPRI.

Acknowledgement: This material is, in part, based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number DE-EE0009019.

This publication is a corporate document that should be cited in the literature in the following manner:

Improvements to Large and Small Generator Interconnection Procedures and Agreements: EPRI Comments on FERC's NOPR issued on June 16, 2022, Docket No. RM22-14-000. EPRI, Palo Alto, CA: 2022. 3002025703.

ABSTRACT

The Electric Power Research Institute (EPRI) respectfully submitted these comments (This Response) in response to the Federal Energy Regulatory Commission's (FERC) Improvements to Generator Interconnection Procedures and Agreements Notice of Proposed Rulemaking (NOPR) issued on June 16, 2022, Docket No. RM22-14-000. This Technical Update is a re-print of those comments with minor editorial changes. In its role, EPRI conducts independent research and development relating to the generation, delivery, and use of electricity for public benefit by working to help make electricity more reliable, affordable and environmentally safe. EPRI's comments in This Response addressed a subset of the questions issued by FERC on the topic, specifically those related to i) ride-through requirements, ii) modeling requirements, and iii) incorporating alternative transmission technologies into the generator interconnection process. EPRI's comments do not necessarily reflect the opinions of those supporting and working with EPRI to conduct collaborative research and development. Where appropriate, EPRI's comments addressed additional questions that have not been included in the NOPR but which may help to inform a final order. This Response is also available in FERC's eLibrary at https://elibrary.ferc.gov/eLibrary/filedownload?fileid=AD71793A-769B-C856-91EB-83D327900000.

Keywords

Generation interconnection, model validation, performance requirements, inverter-based resources, grid enhancing technologies

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UNITED STATES OF AMERICA

BEFORE THE

FEDERAL ENERGY REGULATORY COMMISSION

Improvements to Generator Interconnection Procedures and Agreements Notice of proposed rulemaking	)))	**Docket No.** RM22-14-000

June 16, 2022

Comments on Improvements to Generator Interconnection Procedures and Agreements Notice of proposed rulemaking. October 13, 2022

I. INTRODUCTION

1. The Electric Power Research Institute (EPRI)[1] respectfully submits these comments (This Response) in response to the Federal Energy Regulatory Commission's (FERC) Improvements to Generator Interconnection Procedures and Agreements Notice of Proposed Rulemaking (NOPR) issued on June 16, 2022. EPRI closely collaborates with its members inclusive of electric power utilities and Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs), as well as numerous other stakeholders, domestically and internationally.

[1] EPRI is a nonprofit corporation organized under the laws of the District of Columbia Nonprofit Corporation Act and recognized as a tax-exempt organization under Section 501(c)(3) of the U.S. Internal Revenue Code of 1996, as amended, and acts in furtherance of its public benefit mission. EPRI was established in 1972 and has principal offices and laboratories located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass. EPRI conducts research and development relating to the generation, delivery, and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety, and the environment. EPRI also provides technology, policy and economic analyses to inform long-range research and development planning, as well as supports research in emerging technologies.

In its role, EPRI conducts independent research and development relating to the generation, delivery, and use of electricity for public benefit by working to help make electricity more reliable, affordable and environmentally safe. EPRI's comments on this topic are technical in nature based upon EPRI's research, development, and demonstration experience over the last 50 years in the planning, analyzing, and developing technologies for electric power.

2. EPRI research and technology transfer deliverables are accessible on its website to the public, either for free or for purchase [1]. The publicly available and free-of-charge milestone reports from a U.S. Department of Energy (DOE)- and EPRI member-funded research project, abbreviated "PV-MOD", substantiate many of the comments made in This Response [2].

3. While not a standards development organization (SDOs) itself, EPRI facilitates knowledge transfer and consensus building that SDOs may, at times, use to inform technical and regulatory standards development, such as in IEEE, IEC, CIGRE, and NERC.[2]

4. EPRI's comments in This Response address—in descending order of priority—a subset of the questions issued by FERC on the topic, specifically those related to i) ride-through requirements, ii) modeling requirements, and iii) incorporating alternative transmission technologies into the generator interconnection process. All comments are aimed at providing independent technical information to respond to the questions posed based on EPRI's research and development results and associated staff expertise and do not necessarily reflect the opinions of those supporting and working with EPRI to conduct collaborative research and development. Where appropriate, EPRI's comments address additional questions that have not been included in the NOPR but which may help to inform a final order.

[2] For transparency, we would like to disclose that IEEE and EPRI collaborate; however, EPRI is not a standard-setting organization. EPRI research is often considered by IEEE in the development of recommendations that are not determinative.

II.
GENERAL COMMENTS IN RESPONSE TO NOPR

A. Section I.C.3. Modeling and Performance Requirements for Non-Synchronous Generating Facilities

5. FERC recognized recent efforts made by NERC in publishing disturbance reports and reliability guidelines for inverter-based resources (IBRs), as well as revisions to existing and the creation of, where appropriate, new NERC reliability standards in light of recent IBR plants performance issues. NERC documented those IBR plants performance issues with support from industry stakeholders, including EPRI, for the Blue Cut Fire (2016) [3], Canyon Fire 2 (2017) [4], Angeles Forest and Palmdale Roost (2018) [5], San Fernando (2020) [6], and Odessa (2021) disturbances. Based on the cited NERC reports and further analysis by EPRI in the context of its DOE- and member-funded PV-MOD project [2], it was found that, (i) normally-cleared faults on the transmission system can cause a temporary wide area loss of power injection from IBR plants into the grid if the inverters and/or plant controller in those plants lack certain capabilities or are configured with non-conforming performance settings; (ii) the documented performance issues were likely due to misconfigurations of the plant's IBR units' (i.e., inverters') performance settings that lead to either overly sensitive inverter tripping, or to momentary cessation (i.e., current blocking), or both; (iii) restoration of the power injection from the IBR plants following the temporary reductions in power was caused either by a too slowly configured ramp rate setting (as observed for momentary cessation performance) or by a too long configured intentional delay (as observed for inverter tripping), or both; (iv) additional performance issues that were documented include a) inverter tripping due to AC under- or overvoltage, under- or overfrequency, AC overcurrent, abnormal DC voltage, feeder AC overvoltage, or feeder

underfrequency, b) PLL Loss of Synchronism, and c) inverter uninterruptible power supply (UPS) failure.

6. EPRI research and industry collaboration, as well as a recently updated report by the International Renewable Energy Agency (IRENA), show that uniform technical minimum capability and performance requirements, including ride-through requirements, can support system reliability in the longer term with increasing penetration of inverter-based resources [7]-[9]. Failure of specification—and verification—of such requirements can increase the risk of regularly occurring IBR performance issues that adversely impact bulk power system reliability in the future, possibly creating barriers to the achievement of federal and state policy goals like the decarbonization of electricity supply [10].

7. EPRI research supports that the latest suite of published and publicly-available consensus technical standards like <u>IEEE 2800-2022 (for large generators) and IEEE 1547-2018/1547a-2020 (for small generators) sufficiently specify technical minimum capability and performance requirements</u> for newly interconnecting generating and storage resources, and those existing (legacy) resources that may be significantly upgraded [11], [12].[3] That is, i) IEEE 2800-2022 harmonizes interconnection requirements for large solar, wind and storage plants connected to transmission and sub-transmission grids, including those connected via VSC-HVDC like offshore wind; and ii) IEEE 1547-2018, amended by IEEE 1547a-2020 to provide more flexibility for adoption of abnormal performance category III, has become a common reference in State Public Utility Commissions and distribution utility's technical interconnection requirements (TIRs) for distribution connected synchronous and non-synchronous generators and

[3] Refer to References [1], [2], [7], and [8] for a collection of EPRI technical updates that partially evaluate and support the technical minimum requirements set forth in IEEE 2800 and IEEE 1547.

energy storage resources. Consistent use of the definitions of applicable terms from these IEEE standards may also create more coherency in technical performance requirements.

8. FERC should consider the benefits of referencing the relevant IEEE interconnection performance standards and their definitions of applicable terms given that (1) these IEEE interconnection performance standards have been developed through a rigorous, open, and collaborative process comprising hundreds of stakeholders with many perspectives and sets of expertise and the standards have gained approval rates above 90% of working group members and balloters [13]; [4] (2) EPRI's research shows that the resulting performance requirements included in IEEE 2800 and 1547 provide for IBR performance that supports system reliability while providing sufficient flexibility for regional adoption by RTOs/ISOs, and to interconnection customers for innovations in plant design to achieve the specified capability and performance; and (3) inverter original equipment manufacturers (OEMs) have publicly stated that state-of-the art equipment already has the majority of the capabilities required by IEEE 2800 [14].

9. If FERC decides to rule on any ride-through performance requirements, FERC should consider i) narrowly specifying such requirements by reference to the cited IEEE standards, ii) aligning all applicable definitions proposed in the NOPR with these standards, and iii) evaluating potential benefits and processes of aligning additional definitions or performance specifications with potential future revisions of the cited IEEE standards, as these may occur over time, to keep

[4] *"The IEEE standards development process is rooted in consensus, due process, openness, right to appeal and balance. It adheres to and supports the principles and requirements of the World Trade Organization's (WTO) Decision on Principles for the Development of International Standards, Guides and Recommendations. In particular, the IEEE operates in active agreement with the WTO principle that standards should not create unnecessary obstacles to trade, and whenever appropriate, should specify requirements in terms of performance rather than design or descriptive characteristics.",* Source: Website of the IEEE Standards Association (IEEE SA): Developing Standards. [Online] https://standards.ieee.org/develop/ (last accessed, August 7, 2022).

pace with advancements in technology and standardization.[5] Failing to recognize the significant advancements in the standardization of interconnection and interoperability requirements by the IEEE over the past five years could create undue technical barriers to inverter-based resources. Further, paraphrasing of IEEE standards rather than directly referencing the standards' requirements could lead to an inhomogeneous implementation of the final FERC order in different regions across the U.S. and with insufficient reliability benefits.

10. If FERC decides to rule and specify its own ride-through performance requirements, we recommend, as an alternative but less preferred approach than the one recommended in paragraph 9, that FERC use the precise language and definitions as published in the industry standards.

11. While it would go far beyond what FERC proposes in the NOPR, FERC may consider aligning with leading international practice and "grid codes" for generators [15]-[17] to ready the bulk power system to potentially operate, at times, at 100% inverter-based generation and

[5] There is precedence of FERC Orders and NERC reliability standards that refer to IEEE standards, including:

1. FERC Order 828 (Requirements for Frequency and Voltage Ride Through Capability of Small Generating Facilities) states, "Once finalized, IEEE Standard 1547 may be used as a technical guide to meet the requirements adopted herein."
2. FAC-008-3 (Facility Ratings) refers to ANSI and IEEE industry standards in general, if they developed through an open process such as IEEE or CIGRE.
3. PRC-002-2 (Disturbance Monitoring and Reporting Requirements) explicitly refer to C37.111, IEEE Standard for Common Format for Transient Data Exchange (COMTRADE), revision C37.111-1999 or later and C37.232, IEEE Standard for Common Format for Naming Time Sequence Data Files (COMNAME), revision C37.232-2011 or later.
4. PRC-019-2 (Coordination of Generating Unit or Plant Capabilities, Voltage Regulating Controls, and Protection) list as associated documents IEEE C37.102-2006, IEEE Guide for AC Generator Protection and IEEE C50.13-2005, IEEE Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above.
5. PRC-023-4 (Transmission Relay Loadability) refers by footnote to C57.109-1993, IEEE Guide for Liquid-Immersed Transformer Through-Fault-Current Duration, Clause 4.4, Figure 4, and to C57.91, Tables 7 and 8, and Annex A.
6. PRC-025-1 (Generator Relay Loadability) list as associated document IEEE C37.102-2006, Guide for AC Generator Protection.
7. PRC-27-1 (Coordination of Protection Systems for Performance During Faults) refers by footnote to ANSI/IEEE Standard C37.2, Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations.
8. NERC project 2007-07 (Transmission Vegetation Management) reviewed the suitability of IEEE 516-2003 standard for minimum vegetation clearance and has been approved by FERC. The project found that the use of IEEE 516-2003 in version 1 of FAC-003 was a misapplication and laid out a preferred technical method. Among other factors when looking at changes to some technical data in FAC-003-1 was the identified problem of associated with referring to tables in another standard (IEEE 516-2003).

storage in the future <u>by fully adopting the "capability before utilization concept" laid out in the IEEE 2800 and IEEE 1547 standards, along with all the requirements specified in those IEEE standards.</u> According to IEEE 2800-2022,

> *A "capability requirement" in this standard specifies that the IBR plant (and where applicable, IBR unit[s]) shall be able to provide a function, configuration, or performance as determined by design, installation, and operational status of equipment and control systems. A "performance requirement" in this standard specifies the IBR plant's (and where applicable, the IBR unit's) behavior when executing a specified function or mode, or when responding to a change in conditions.*
>
> *NOTE 1—<u>A "capability requirement" is, in colloquial terms, a requirement that ensures the IBR plant (or IBR unit) is "ready to go at the flip of a switch."</u> This is more stringent than a "readiness requirement" that is in colloquial terms a requirement that ensures the IBR plant (or IBR unit) is "almost ready to go," for example, by having at least all interfaces that are needed to (easily) retrofit the IBR with certain equipment and controls that can provide a specified capability. The concept of readiness is not used in this standard.[…]*
>
> *NOTE 2—A "performance requirement" is not an "utilization requirement." An "utilization requirement" is, in colloquial terms, a requirement that ensures the IBR plant (or IBR unit) is "actually providing" a specified performance, for example, by enabling a specified capability that makes the IBR continuously deliver a performance consistent with the specified default values for functional settings. As clarified in the list*

> *of what remains outside the scope of this standard below, requirements for utilization of any of the capabilities specified in this standard are outside the scope of this standard.*
> Source: IEEE 2800-2022, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems. https://standards.ieee.org/ieee/2800/10453/ (last accessed, October 3, 2022)

Adopting all of the consensus technical minimum capability and performance requirements of IEEE 2800 (for large inverter-based generators) and IEEE 1547 (for any small generators)—even if the capabilities specified in those IEEE standards are not immediately utilized when the plants enter commercial operation—could be a cost-effective [14] approach to mitigate the risk of future retrofit programs as have become necessary in other countries around the world in the past [18]-[19]. Both standards put forth sufficiently high expectations for capabilities and technical performance of future large non-synchronous generators and small generators of any technology while not requiring an undue burden on interconnection customers. Examples from EPRI research show utilization of capabilities such as fast dynamic voltage support in distribution connected inverters help improve the stability of the network with high percentage of distributed resources [20]. A similar concept can also be applied to transmission network connected inverter based resources wherein stability can be improved by shifting voltage control from the plant controller (which is traditionally a slower form of control) to the inverter controller (whose control system is an order of magnitude faster). EPRI research [21]-[23] has observed that utilization of fast voltage control at the inverter level for transmission connected inverters can greatly improve the stability of low short circuit networks with high percentage of inverters. Similar findings have also been obtained in studies carried out in Australia [24].

III.
COMMENTS IN RESPONSE TO NOPR QUESTIONS RELATED TO LARGE GENERATORS (PROPOSED CHANGES TO THE PRO FORMA LGIP AND LGIA)

A. Section I.C.3.c.ii) Ride-Through Requirements

1. Paragraph 338: Whether adherence to FERC proposed requirements would be readily achievable through changes to control settings and whether such changes to control settings could be made at a relatively minor cost?

12. To answer this question of FERC, we observe that even though the NOPR refers to NERC IBR guidelines, the proposed reforms do not seem entirely aligned with, nor are they as intentional and clear as the applicable industry standards like the recently published IEEE 2800-2022. We also observe, among others, the following <u>significant improvements in IEEE 2800 over the NERC reliability guidelines</u> that FERC should consider if it decided to rule on ride-through requirements.

13. For example, FERC proposes to revise article 9.7.3 of the *pro forma* LGIA and article 1.5.7 of the *pro forma* SGIA to include the following statement regarding ride-through capability:

> *"To maintain power production at pre-disturbance levels unless providing primary frequency response or fast frequency response, and must have the ability to provide dynamic reactive power to maintain system voltage in accordance with the generating facility's voltage schedule".*

From a technical perspective, we have the following observations and concerns which have also been discussed in detail by the IEEE 2800 working group and SA balloters:

a. While we agree that extending FERC's definition of "ride-through" from applying only to abnormal frequency conditions to also include abnormal voltage conditions is necessary based on NERC and EPRI findings and attempts to fill a critical gap, FERC's revised definition and the lack of clear performance specification may fall short of achieving the goal of supporting bulk system reliability.

b. First, FERC's performance requirement stated above is vague in the sense that it does not specify what is meant by "power" (i.e., active or reactive power?); presumably it means "active power" as it refers to frequency and fast frequency response in the remainder of the sentence. Given that "power" is the product of "voltage times current", an IBR plant would not be able to "maintain power reduction at pre-disturbance levels" during low voltage conditions, unless its inverters were significantly overrated; thus, specification of IBR plant performance requirements should address active and/or reactive "current" instead of "power" for the period during an abnormal voltage condition (fault period), and requirements for the restoration of active power output in the post-fault period when voltage returns to normal condition.

c. Second, the ongoing revision of NERC PRC-024 may revise the "no-trip zone" to align with IEEE 2800-2022 [11] that allows for "permissive operation" (including momentary cessation) below 0.1 pu voltage, where injection of active current by an IBR plant could lead to local plant voltage angle instability[25]. The NERC IBR reliability guidelines cited by the NOPR did not fully consider all technical and stakeholder concerns considered by IEEE 2800, and thus, those NERC guidelines are contradicting the IEEE 2800-2022 consensus requirements.

d. Third, maintaining active power to 100% of the pre-disturbance level during and after the abnormal voltage period (i) may not be a practical requirement for voltage ride-through; (ii) may not be needed to sufficiently support bulk power system reliability, given that voltage disturbances tend to be limited to a region relatively close to the fault location; and (iii) neither is it aligned with IEEE 2800-2022 or other international requirements such as the corresponding German technical requirements specified in the VDE Application Guides VDE-AR-N 4120 [26] and 4130 [27], because:

    i. IEEE 2800-2022 and VDE-AR-N 4120/4130 allow for 10% power reduction in the post-fault period if the voltage at the Point of Measurement (POM) falls below 50% during the fault.

    ii. IEEE 2800-2022 requires positive and/or negative sequency reactive current injection (for balanced and/or unbalanced faults) in the fault period, that could—depending on IBR plant configuration with active or reactive current priority mode—result in the intentional reduction of active current (and power) output during the ride-through period.

14. Clause 9.7.3 in LGIA could benefit from additional modifications that <u>differentiate between the ride-through requirements between large non-synchronous and synchronous large generators</u> because the two technologies have inherently different technical capabilities and operating principles. For instance, synchronous machines may have less capability to "stay connected" for severe under-voltage or over-voltage conditions compared to inverter-based resources. Their response to abnormal grid conditions is also less configurable compared to highly configurable IBR plants. While <u>IEEE 2800-2022 specifies stringent voltage and frequency</u>

ride-through requirements that many OEMs consider as achievable and cost-effective in the near-term [14], it only applies to non-synchronous generators and storage plants. And while NERC PRC-024-03 applies to both synchronous and non-synchronous large generators, it currently is a protection setting standard and not a ride-through standard such as IEEE 2800-2022. Any ongoing or future efforts by NERC to extend the scope of PRC-024-03 or to develop a separate performance ride-through reliability standard for synchronous machines may face opposition from OEMs as had occurred when PRC-024 was developed in the first place.

15. Take, as another example, the part of Clause 9.7.3 that reads,

> *"Interconnection Customer shall implement under-frequency and over-frequency relay set points for the [Large]Generating Facility as required by the [Applicable Reliability Council] Electric Reliability Organization to ensure frequency "ride through" capability of the Transmission System. [Large]Generating Facility response to frequency deviations of pre-determined magnitudes, both under-frequency and over-frequency deviations, shall be studied and coordinated with Transmission Provider in accordance with Good Utility Practice. Interconnection Customer shall also implement under-voltage and over-voltage relay set points, or equivalent electronic controls, to ensure voltage "ride through" capability of the Transmission System."*

16. The statement regarding implementation of under/over frequency/voltage relay to ensure ride-through requirements does not appear to be aligned with NERC IBR reliability guidelines, nor the "capability before utilization concept" laid out in IEEE 2800-2022.

   e. First, "relay settings" as per the Electric Reliability Organization do not determine ride-through "capability" but more so "the degree to which the ride-through capability of a large generator is utilized".

f. Second, the implementation of frequency and voltage protection relay settings should not be exactly aligned with the PRC-024 curves, but rather be based on the actual limits of equipment capability with the objective to avoid potential damages. Equipment must then be designed such that its capability meets or exceeds the no-trip zones in PRC-024, or the IEEE 2800-2022 ride through capability requirements. NERC's investigation of disturbance events in California and Texas identified some of PV facilities that tripped during those disturbances had frequency/voltage trip settings which were exactly set to the boundary of PRC-024 curves even though the actual equipment capability could have allowed a wider range of relay trip settings.

17. With all the above said, we recommend to revise the language in clause 9.7.3 of the *pro forma* LGIA with respect to the proposed ride-through performance requirements for IBRs to align with IEEE 2800, and where appropriate also with NERC reliability guidelines, as shown in the following redlines. The inclusion of the parts in red font and placed into square brackets ("[…]") narrowly focus the proposed changes to the scope of the NOPR; while striking those parts would extend the scope of a final FERC order, there could be associated bulk power system reliability benefits for FERC to consider.

9.7.3 ~~[Under-Frequency and Over Frequency Conditions]~~Ride Through Capability and Performance. *The Transmission System is designed to automatically activate a load-shed program as required by the ~~[Applicable Reliability Council]~~Electric Reliability Organization in the event of an underfrequency system disturbance. Interconnection Customer shall design the Large Generating Facility with sufficient frequency "ride through" capability and utilize this capability by implementing under-frequency and over-frequency relay set points for the*

~~[~~Large~~]~~Generating Facility as required by the~~[Applicable Reliability Council]~~ Electric Reliability Organization to ensure adequate frequency "ride through" ~~capability~~ performance of the Transmission System. ~~[~~Large~~]~~Generating Facility response to frequency deviations of pre-determined magnitudes, both under-frequency and over-frequency deviations, shall be studied and coordinated with Transmission Provider in accordance with Good Utility Practice. Interconnection Customer shall also design the Large Generating Facility with sufficient voltage "ride through" capability and also utilize this capability by implementing under-voltage and over-voltage relay set points, or equivalent electronic controls, to ensure adequate voltage "ride through" ~~capability~~ performance of the Transmission System. The term "ride through" as used herein shall mean the ability of a Generating Facility to ~~stay connected to and synchronized with~~ withstand voltage or frequency disturbances of the Transmission System ~~during system disturbances within a range of~~ inside defined limits of under-frequency, ~~[and]~~over-frequency, under-voltage, and over-voltage conditions, and to continue operating as specified in accordance with Good Utility Practice and consistent with any standards and guidelines that are applied to other Generating Facilities in the Balancing Authority Area on a comparable basis.[Insert footnote 1] During abnormal i) frequency conditions and ii) voltage conditions~~ within the "no trip zone" defined by Reliability Standard PRC-024-2 or its successor standards~~, non-synchronous Generating Facilities ~~must~~ shall ~~maintain real power production at pre-disturbance levels unless providing primary frequency response or fast frequency response and must provide dynamic reactive power to maintain system voltage in accordance with the Generating Facility's voltage schedule~~ conform with the capability and performance requirements specified in IEEE Std 2800™, that is i) Clause 7.3.2 (Frequency disturbance ride-through

requirements) [except for 7.3.2.4 (Voltage phase angle changes ride-through)] and ii) 7.2.2 (Voltage disturbance ride-through requirements) [except for 7.2.2.4 (Consecutive voltage deviations ride-through capability)].

New footnote 1 FERC recommends, as a technical reference to specify and meet the requirements adopted herein, the use of IEEE 2800, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems, a voluntary industry standard that specifies a uniform set of technical minimum requirements for the interconnection, capability, and performance of IBRs interconnecting with electrical transmission and sub-transmission systems. The standards can be obtained for purchase from the IEEE at https://standards.ieee.org/ieee/2800/10453/.

B. Section I.C.3.c.i) Modelling Requirements

1. Paragraph 335, Question 1: Whether these proposed reforms are necessary and/or sufficient to ensure that interconnection customers proposing non-synchronous generating facilities submit models during the generator interconnection process that accurately reflect the behavior of their proposed generating facility?

18. The NOPR proposed a number of modelling requirements and submissions for interconnection customers including validated user-defined RMS models, appropriately parameterized generic RMS models and validated EMT model (if requested by the transmission provider). EPRI research and industry findings support that all models should be validated and appropriately parameterized to reflect the actual behavior and response of a generation resource in applicable studies and deliver meaningful results. As such, EPRI recommends FERC modify the language in LGIA and SGIA to ensure that all models are validated and appropriately parametrized as shown in the following redlines:

"*For a non-synchronous Generating Facility, Interconnection Customer must provide (1) a validated and* appropriately parameterized *user-defined root mean squared (RMS) positive sequence dynamics model; (2) a validated and ~~an~~ appropriately parameterized generic library RMS positive sequence dynamics model, including model block diagram* *of the inverter control and plant control systems, as defined by the selection in Table 1 or a model otherwise approved by the Western Electricity Coordinating Council, that corresponds to Interconnection Customer's Generating Facility; and (3) ~~an~~ a validated and appropriately parameterized electromagnetic transient model if Transmission Provider performs an electromagnetic transient study as part of the interconnection study process."*

19. The NOPR comes short of providing adequate directions and requirements with respect to model validation, testing, verification, and conformity assessment. Such activities are required during various stages of interconnection process including:

g. Pre-commissioning stage to perform plant model design evaluation to ensure conformity with interconnection requirements. This activity would occur in early stages of the interconnection process and is similar to a screening process.

h. Post-construction as-built evaluation and comparison against pre-commissioning design.

i. Continuous monitoring post-construction and model validation to ensure conformity with interconnection requirements during the operation stage considering ride-through and recovery assessment transmission system faults, switching events, etc.

20. In addition, the NOPR is not specific with respect to the model details and what should be included in the model (e.g., an IBR unit model, an IBR plant model, or both; are "supplemental IBR devices" included or not, etc.). From the language it can be inferred that the intent is to provide a plant-level model including all equipment in the IBR plant such as supplemental devices (both IBR and non-IBR, e.g., synchronous condensers). However, a

"validated" plant model would not be available during interconnection stage because validation of the plant model is not possible—within reasonable efforts—until after the commissioning and commercial operation of the plant has started. Alternatives, which are being explored in IEEE P2800.2, include requiring generic models which are appropriately parametrized and conform to IEEE 2800-2022 requirements. Additionally, an industry accepted generic EMT model may also be required with appropriate parameters in lieu of a validated EMT model at the time of interconnection studies. EPRI has recently published a proposal for a generic EMT model as one of the PV-MOD deliverables and intends to explore the willingness of EMT software developers to incorporate that model into their standard libraries for ready application by transmission planning or interconnection engineers [28].

21. EPRI, its staff, and its contractors have published a large body of research related to generic model development, validation, and improvement[6], with the DOE- and EPRI member

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[6] Example publications related to generic model development, validation, and improvement include:

1) EPRI Report: Generic Models and Model Validation for Wind and Solar PV Generation: Technical Update, Product ID: 1021763, Technical Update, December 2011 **(free to the public at: https://www.epri.com/research/products/000000000001021763)**

- This is one of the original R&D reports on the development of the 2nd generation generic models, and shows verification of the proposed model structures against numerous field data for WTGs (including many vendor's cases)

2) Proposed Changes to the WECC WT3 Generic Model for Type 3 Wind Turbine Generators: Prepared by EPRI (Under Subcontract No. NFT-1-11342-01 with NREL), Issued 3/26/12 (revised 9/27/13) **https://www.wecc.org/Reliability/WECC-Type-3-Wind-Turbine-Generator-Model-Phase-II-012314.pdf [wecc.org]**

- This is one of the original R&D reports on the development of the 2nd generation generic models. It clearly shows the efficacy of the models through multiple validation cases of individual WTGs (type 3 from various vendors) against actual measured data. Note: countless other runs were performed, but not shown.

3) Proposed Changes to the WECC WT4 Generic Model for Type 4 Wind Turbine Generators: Prepared by EPRI (Under Subcontract No. NFT-1-11342-01 with NREL), Issued 12/16/11 (revised 1/23/13) **https://www.wecc.org/Reliability/WECC-Type-4-Wind-Turbine-Generator-Model-Phase-II-012313.pdf [wecc.org]**

- This is one of the original R&D reports on the development of the 2nd generation generic models. It clearly shows the efficacy of the models through multiple validation cases of individual WTGs (type 4 from various vendors) against actual measured data. Note: countless other runs were performed, but not shown.

4) Asmine, M.; Brochu, J.; Fortmann, J.; Gagnon, R.; Kazachkov, Y.; Langlois, C. E.; Larose, C.; Muljadi, E.; MacDowell, J.; Pourbeik, P.; Seman, S. A.; and Wiens, K., "Model Validation for Wind Turbine Generator

Models" IEEE Transactions on PWRS, August 2011, pages 1769 - 1782.
https://ieeexplore.ieee.org/document/5671567 [ieeexplore.ieee.org]

- This paper was an AdHoc IEEE TF effort between WECC, IEEE and IEC group members to illustrate the efficacy of generic models as they were be developed.

5) P. Pourbeik, J. Sanchez-Gasca, J. Senthil, J. Weber, P. Zadehkhost, Y. Kazachkov, S. Tacke and J. Wen, "Generic Dynamic Models for Modeling Wind Power Plants and other Renewable Technologies in Large Scale Power System Studies", IEEE Trans. on Energy Conversion, September 2017. **https://ieeexplore.ieee.org/document/7782402 [ieeexplore.ieee.org]**

- This is a WECC TF paper that reports on the 2nd generic models.
- The paper shows clear evidence of the generic models validated against:
    i. Individual type 3, type 4 WTGs and PV inverters
    ii. Large wind plants validated for both volt/Var and frequency response based on field measurements and disturbance monitoring
    iii. The models having been benchmarked across the four major software tools
    iv. Important Note: On page 3 of this paper the "limitations" of the generic models are clearly explained. Some of these limitations have been since addressed (by *REGC_B* and *REGC_C* – see below).

6) P. Pourbeik, S. Soni, A. Gaikwad and V. Chadliev, "Providing Primary Frequency Response from Photovoltaic Power Plants", CIGRE Symposium 2017, Dublin, Ireland, May 2017. **(Published in the October 2018 issue of CIGRE Science and Engineering)**

- This paper shows clear evidence of the efficacy of the 2nd generation generic models in representing overall PV plant performance for both volt/Var and frequency response simulations, based on actual field tests by the vendor.

7) P. Pourbeik and J. K. Petter, "Modeling and validation of battery energy storage systems using simple generic models for power system stability studies", CIGRE Science and Engineering, October 2017, pp. 63-72.

- This paper illustrates the efficacy of the 2nd generation generic models in representing the volt/Var and frequency response characteristics of a battery energy storage system, by comparing the 2nd generation generic models against highly-details and proprietary 3-phase equipment design models. Moreover it does show the limitations of the models for trying to emulate the response to an unbalanced fault.

8) P. Pourbeik, N. Etzel and S. Wang, "Model Validation of Large Wind Power Plants Through Field Testing", IEEE Transactions on Sustainable Energy, July 2018 **(http://ieeexplore.ieee.org/document/8118170/ [ieeexplore.ieee.org])**

- Validation of large wind power plants using the generic models; validation shown both at individual turbine level and plant level.

9)Reliability Guideline Power Plant Model Verification for Inverter-Based Resources, September 2018
https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/PPMV_for_Inverter-Based_Resources.pdf [nerc.com]

- NERC's own document with contributions from numerous folks and vendors showing in various examples throughout the document the efficacy of the generic models.

10) Example for Verification of the proposed IBFFR model, Memo Issued to WECC REMTF, DATE: 7/1/19 (REVISED 7/11/19; 7/16/19; 7/17/19)
https://www.wecc.org/_layouts/15/WopiFrame.aspx?sourcedoc=/Administrative/Pouyan%20-%20Memo%20IBFFR%20Model.pdf&action=default&DefaultItemOpen=1 [wecc.org] (EPRI Funded R&D)

- This memo illustrates, using actual field measured data, the efficacy of the newly proposed IBFFR model for emulating inertial-based fast-frequency response for WTGs, using the generic models.

11) D. Ramasubramanian, W. Wang, P. Pourbeik, E. Farantatos, A. Gaikwad, S. Soni and V. Chadliev, "A Positive Sequence Voltage Source Converter Mathematical Model for Use in Low Short Circuit Systems", IET Generation, Transmission & Distribution, January 2020.
https://ietresearch.onlinelibrary.wiley.com/doi/epdf/10.1049/iet-gtd.2019.0346 [ietresearch.onlinelibrary.wiley.com]

funded "PV-MOD" project milestone reports [2] being the dissemination of research result. IEEE 2800-2022 provides detailed description regarding testing and verification. The ongoing IEEE P2800.2 is working on establishing processes and criteria on how to perform model validation and conformity assessment. All of the above standards and guidelines could be referred in the final order to provide a potential solution for the above gaps.

22. Related to the modeling requirements, as a detailed and site-specific model may not be available at the time of interconnection studies, there might be a need for transmission providers to evaluate "material modification" and/or restudy the cluster once the model is updated (which will be likely shortly prior to or during the construction of the plant, or even during or after commissioning). This creates a potential loophole where the updated models may show reliability issues which had not been observed previously. In addition, the stringent timelines (and penalties for violating those timelines) in this NOPR may add some pressure on transmission providers to redo the studies. Ultimately, bulk power system reliability and speed of IBR plant interconnection to the grid should both be adequately considered. To this end, IEEE 2800-2022 establishes a consensus-based technical minimum requirements which may help simplify and expedite the process.

a. One approach to help ensure performance requirements and system reliability are met in an efficient and effective way would be to require models which generally

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- This paper clearly shows, through simulations compared with field measurements from a PV plant, the efficacy of the newly proposed REGC_C model to address some of the limitations with the current-source mathematical models that were hitherto used for modeling the generator/converter interface.

12) D. Ramasubramanian, P. Pourbeik, E. Farantatos and A. Gaikwad, "Simulation of 100% Inverter-Based Resource Grids With Positive Sequence Modeling", IEEE Electrification Magazine, June, 2021.
https://ieeexplore.ieee.org/document/9447546 [ieeexplore.ieee.org]

- Granted that this paper is simulations only, but it is starting to show the potential efficacy of the generic models and positive sequence modeling even for 100% IBR systems.

conform to the applicable capability and performance standards (e.g., IEEE 2800-2022 and IEEE 1547-2018) during the interconnection process and studies subject to further assessment once a detailed site-specific model is available. This concept is similar to provisional interconnection service, which was introduced in FERC Order 845. Interconnection customers with provisional agreements may proceed through the interconnection process based on an initial interconnection study with the available models at the time compliant with performance requirements and then continue to proceed with additional studies as necessary, and regularly updated studies. The provisional agreement may be in effect until the final results of the interconnection studies are available.

b. EPRI notes that there are risk and liabilities associated with any change to the plant design and models which result in changing the plant capability and performance compared to what was initially studied per the transmission provider assessment. However, this may encourage the interconnection customers to ensure the plant design conforms (and continues to conform throughout the design, commissioning, and operation) to the specified performance requirements set in the IEEE standards.

c. EPRI also notes that IEEE 2800-2022 conformity does not ensure reliability as this standard specifies minimum capability and performance requirements and a system impact study may result in additional performance requirements.

d. FERC Order 845 also proposed technological change procedure, which required transmission providers to assess and, if necessary, study whether they can accommodate a technological advancement by interconnection customers without the change being considered material. This concept can also be entertained in the new FERC order, as it provides flexibility to the interconnection customers while ensuring system reliability can be maintained through the assessment by the transmission provider. A transmission provider's assessment, however, may require models from an interconnection customer with sufficient model accuracy and fidelity.

23. The NOPR proposed to require the interconnection customer to provide a validated EMT model if the TS provider performs an EMT study. EPRI agrees that performing EMT studies should be at the discretion of TS provider considering multiple factors such as size and location of interconnecting generation facility and also type of nearby plants and transmission equipment [22],[29]. However, EPRI highly recommends collecting validated and appropriately parametrized EMT models during the interconnection process irrespective of the need to perform an EMT study for the interconnecting generation facility. While an EMT study may not be required at the time of interconnection studies, it may become necessary as the grid evolves in the future, which could result in changes in system strength, addition of nearby inverter-based resources, etc. Collecting an accurate and validated EMT model after the interconnection stage could be extremely challenging and the best time to obtain such models is during the interconnection stage, as there would be a close coordination among project developers, consultants, OEMs and plant designers to deliver a validated and appropriately parametrized model.

2. Paragraph 335, Question 2: Whether the inclusion of the table based on NERC Guidelines that cite WECC-approved models is appropriate? If not, we seek comment on how the Commission could require interconnection customers to submit models that are widely known in industry to be accurate without listing

specific models.

24. Both NERC and WECC publish approved models lists on their website that are updated whenever a new model becomes available [30], [31]. One alternative to FERC including Table 1 into the final order could be to include a reference and hyperlink to the NERC and WECC approved models lists.

25. If FERC decides to include Table 1 from the NOPR, it should consider revising the description of the DER_A model as noted in the following

GE PSLF	Siemens PSS/E*	PowerWorld Simulator	Description
der_a	*DERAU1*	*DER_A*	*Aggregated Distributed energy resources model*

and further consider adding columns with the model names from other applicable software tools.

C. Section I.C.2.c.i) Incorporating Alternative Transmission Technologies into the Generator Interconnection Process

1. Paragraph 300: Whether the list of alternative transmission technologies is sufficient; in particular, whether storage that performs a transmission function, synchronous condensers, and voltage source converters should be included in the list of alternative transmission technologies?

26. The NOPR requires transmission providers, upon request of the interconnection customer, to evaluate the requested alternative transmission solution(s) during the LGIP cluster study and the SGIP system impact study and facilities study within the generator interconnection process. The NOPR lists the following technologies to be considered:

a. advanced power flow control

b. transmission switching

c. dynamic line ratings

d. static synchronous compensators

e. static VAR compensators

27. In addition to the above technologies, FERC should consider including inverter-based resource-based technology solutions, which could provide advanced control capabilities and control parameter tuning. Both should be adequately considered and coordinated between Transmission Provider and Interconnection Customer to possibly reduce the need for traditional and alternative transmission technologies.

a. For example, EPRI has investigated the potential benefit of grid forming inverter technology to mitigate the risk of control interactions or instability in the presence of "weak grid" conditions and we have observed that an above-minimum performance requirement for grid forming technology with fast reactive power response could be a solution in certain grid regions [32],[33].

b. We note that advanced IBR plant control capabilities, including grid forming inverter capabilities, are commercially available today for battery storage facilities and have been deployed and demonstrated in a few jurisdictions mainly for blackstart/microgrid application[7].

D. Other comments (not directly responsive to FERC's request)

1. Application of new requirements to existing interconnection customers

28. The NOPR requires the proposed reforms to be applied to the newly interconnecting large facilities. The NOPR does not put forth a proposal how to treat the existing interconnection facilities or the interconnection facilities which are already progressing in the interconnection queues. Irrespective of whether FERC is involved or addresses the matter through revision of NERC reliability standards, there are a number of existing and in some case legacy facilities

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[7] Id.

which encounter ride-through issues during transmission faults per NERC disturbance reports following California and ERCOT events. Addressing how to apply grandfathering to the existing facilities is an important consideration that should be addressed through FERC/NERC requirements. One approach would be to add a procedure and criteria for a transmission system provider to waive the grandfathering rule and require retrofits of existing facilities at the time of plant changes or upgrades to meet the specified performance and modelling requirements or to meet specific capability and performance standard such as IEEE 2800-2022.

2. Data the Transmission Provider could provide to the Interconnection Customer

29. This NOPR does not specify information and data that the TS providers may need to provide to the interconnection customer during the design stage (e.g., acceptable voltage ranges, protection details, short circuit levels, etc.). The list of data included in the informative Annex H of IEEE 2800-2022 could be considered in the final FERC order.

30. Note that IEEE 2800-2022 includes definitions that can help define the combined generating and storage service level MW of a plant as referred in the NOPR. These are:

> <u>*IBR continuous rating (ICR):*</u> *The steady-state, continuous active power rating of an inverter-based resource (IBR) plant or hybrid IBR plant registered by the IBR owner at the transmission system (TS) operator's or authority governing interconnection requirements (AGIR)'s registry.*

> <u>*IBR continuous absorption rating (ICAR):*</u> *The steady-state, continuous active power absorption rating of an inverter-based resource (IBR) plant registered by the IBR owner at the TS operator's or AGIR's registry.*

IBR short-term rating (ISR): *The temporary, short-term active power rating of an inverter-based resource (IBR) plant or hybrid IBR plant registered by the IBR owner at the TS operator's or AGIR's registry.*

Source: IEEE 2800-2022, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems. https://standards.ieee.org/ieee/2800/10453/ (last accessed, October 3, 2022)

31. In addition, FERC could consider adopting the definitions of co-located and hybrid (IBR) plants from IEEE 2800-2022 to ensure alignment with the definitions and requirements in that standard:

co-located plant: *Two or more generation or storage resources that are operated and controlled as separate entities yet are connected behind a single point of interconnection (POI). Syn: co-located power plant; Contrast: hybrid plant.*

hybrid plant: *A generating or storage facility that is composed of multiple types of resources or energy storage systems controlled and operated as a single resource behind a single point of interconnection (POI). Syn: hybrid power plant; Contrast: co-located plant.*

hybrid IBR plant: A hybrid plant that is composed of only inverter-based resources (IBRs) and/or energy storage systems. Syn: mixed IBR plant.

Source: IEEE 2800-2022, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems. https://standards.ieee.org/ieee/2800/10453/ (last accessed, October 3, 2022)

IV.
RESPONSE TO NOPR WITH RECOMMENDATION TO UPDATE SMALL GENERATOR INTERCONNECTION PROCEDURES (PROPOSED CHANGES TO THE PRO FORMA SGIP)

32. In the year 2005, FERC adopted in its Order 2006 a first set of *pro forma* standard procedures (SGIP) and a *pro forma* standard agreement (SGIA) for interconnecting generating facilities no larger than 20 MW. FERC then revised the SGIA and SGIP in its Order 792 from 2013, among others, i) to increase the 2 megawatt (MW) threshold for participation in the Fast Track Process included in section 2 of the *pro forma* SGIP, and ii) to specifically include energy storage devices, for example by clarifying that the term "capacity" of the Small Generating Facility in the *pro-forma* SGIP refers to the maximum capacity that a device is capable of injecting into the grid while not precluding a Transmission Provider from studying the effect on its system of the absorption of energy by the storage device. In 2016, the Commission modified the *pro forma* SGIA to include performance requirements for newly interconnecting small generating facilities to ride through abnormal frequency and voltage events and not disconnect during such events, consistent with "Good Utility Practice" and any standards and guidelines applied by the transmission provider to other generating facilities on a comparable basis.

33. In addition to Section II of This Response with our general recommendation for adequate and timely consideration of technical interconnection capability and performance standards for small generating facilities, opportunities for additional changes to the language of the *pro forma* SGIP include (i) incorporating recent advancements in technology development and technical standards development, such as IEEE 1547-2018/IEEE 1547a-2020, as well as UL 1741 SB and PCS certification standards development and application for energy storage systems that may

have load following capability. And while most resources connected to electric distribution grids are outside FERC jurisdiction, (ii) many states use the FERC SGIP as a model for their distribution interconnection procedures. For these two reasons we recommend updating a range of areas within the FERC SGIP based on new standards and interconnection experience.

34. Significant experience in DER interconnections to distribution and sub-transmission grids has been acquired since previous updates to the SGIP. EPRI has published its experience, procedures, and learnings and those publications have helped in shaping our technical recommendations that we invite FERC to consider when reforming parts of SGIP and SGIA [34], [35]. Our recommendations are also informed by parts of a document published by the Interstate Renewable Energy Council (IREC) [36], that EPRI contributed to. In particular, that report proposes specific in-line language changes to the *pro forma* SGIP that FERC could consider.

35. EPRI's proposed changes to the *pro forma SGIP* are outlined below and are based on EPRI's independent experience and learnings from DER interconnection to distribution. We begin with a summary of potential changes and additions per SGIP section and attachment. Next, more detailed input offers a rationale and discussion by paragraph for each proposed modification to the SGIP. Finally, mark up of and additions to existing SGIP language is presented, where appropriate.

36. All instances where EPRI proposes to replace "Transmission Provider" with "Distribution Provider" in the SGIP are not directed at FERC, which has limited jurisdiction over distribution, but are intended to illustrate how states' regulatory bodies could consider a reformed FERC SGIP as a model for their own jurisdictional distribution interconnection procedures. In This Response, we put both terms into square brackets, i.e., "[Transmission

Provider | Distribution Provider]", and they could be used interchangeably subject to which jurisdiction the language is applied.

A. Summary of SGIP Recommended Changes

1. Summary of SGIP Changes by Section and Attachment

Section 1. **Application**

1.1.1 Revise Eligibility Criteria for Simplified/Expedited/Level 1 Screening Process for inverter-based Small Generating Facility (<10kW). Remove reference to attachment 5 and the attachment itself.

Section 2. **Fast Track Process**

2.1 **Applicability**, replace reference to "DER size" with "DER export capacity", when adopted by a state regulatory entity, replace "Transmission Provider" with "Distribution Provider".

2.2 **Initial Review**, add option to bypass this review level and go directly to supplemental or study process, update the grounding screen for inverter-based resources, and add credit for export limiting capability.

2.4 **Supplemental Review**, provide option to bypass this review level and go directly to study, update references to standard including IEEE 1547-2018, add criteria for each supplemental screen.

Section 3. **Study Process**

3.1 **Applicability**, remove failure to pass 10-kW inverter process.

3.3 **Feasibility Study**, provide criteria and option to skip.

3.4 **Impact Study**, provide criteria for typical distribution level.

3.5 **Facilities Study**, provided criteria to identify when Facility Study is needed.

Section 4. **Provisions that Apply to All Interconnection Requests**

4.10 **Capacity of the Small Generating Facility**, add acceptable methods to get credit for export limiting

Attachment 1. Glossary of Terms, consider adding definitions for ESS, DER, Non-Export, Limited Export, Inadvertent Export, Nameplate Rating, Export Capacity, Power Control System, Host Load, Operating Profile and Operating Schedule and RPA. Consider aligning definitions, to the extent possible, with IEEE 1547-2018 and its revised Application Guide, IEEE 1547.2, once published [37]. Consider further alignment and reconciliation of definitions with NERC SPIDERWG Terms and Definitions Working Document [38].

Attachment 5. Application, Procedures, and Terms and Conditions for Interconnecting a Certified Inverter-Based Small Generating Facility No Larger than 10 kW ("10kW Inverter Process"), delete

2. SGIP Changes by Paragraph with Rationale

Section 1. **Application**

1.1.1 – SGIP procedures for inverter-based DER <10kW is not necessary. Most jurisdictions provide for a simplified or expedited or Level 1 process with limited or no screening. The level allowed to be expedited varies. EPRI recommends up to 25kW in Nameplate Rating, and up to 50kW if the Small Generating Facility is export limited to 25kW or less. For the latter, that equates to a Nameplate Rating of up to 50 kW with an Export Capacity of up to 25 kW. Attachment 5 is not used.

Section 2. **Fast Track Process**

2.1 Applicability – Change "small generating facility" to "DER as defined by IEEE 1547-2018" and "size" to "Export Capacity". These terms are clearer and introduce the concept of export capacity to be used along with Nameplate Capacity.

2.2 Initial Review

2.2.1 Screens

2.2.1.2, 2.2.1.3, and 2.2.1.7 – Replace "small generating facility" with "DER as defined by IEEE 1547-2018". Replace "nameplate" with "export capacity" and "Transmission" with "Distribution or Sub-Transmission." This enables facilities using approved methods for export limiting to be connected without additional study. SGIP may consider listing these approved methods in Section 4.10.

2.2.1.X – Add a screen to check for excessive inadvertent export from a large export-limited system. Consider that screen 2.2.1.2 addresses an aggregate DER limit of 15% relative to peak feeder load. Peak load is used here because minimum load data are less readily available. DER nameplate capacity has been used to determine a worst case export scenario. However, there is an increasing number of DER systems, typically energy storage systems with load following capability, that are certified to limit export. Consequently, adding a screen to account for export limiting functions may be considered. Inadvertent export may be treated as an event lasting less than 30 seconds. The impact is to feeder root mean square (RMS) voltage (not steady state voltage). This new screen would serve as a backstop to individual plant inadvertent export. It would use the IEEE 1547 rapid voltage change limit as the test, $\Delta V \leq 3\%$.

2.2.1.6 – Update this screen to address inverter-based DER. Consider moving to supplemental screening.

This initial screen addresses grounding compatibility. It is a line configuration screen that acts as a proxy of effective grounding evaluation. As written in SGIP, and in most jurisdictions today, the screen does not consider differences in grounding needs between rotating machines and inverter-based DER. This can cause projects to fail the screen and/or be subject to unnecessary upgrades. EPRI has researched grounding practices for inverters, including guidelines to determine supplemental grounding needs [39]. Screening for grounding currently begins with initial review, however, the data and tools needed to evaluate inverter grounding are often not available at this review level. The main issue is ground fault overvoltage (GFOV). Updated wording is suggested below, however, there is also reason to move the grounding question to a supplemental review level.

2.4 Supplemental Review

2.4.4 Screens

2.4.4.1, 2.4.4.2. and 2.4.4.3 – Replace "small generating facility" with "DER as defined by IEEE 1547-2018", aggregate "nameplate" with aggregate "export capacity" and "Transmission" with "Distribution or Sub-Transmission." This enables facilities using approved methods for export limiting to be connected without additional study. SGIP may consider listing these approved methods in Section 4.10.

2.4.4.2 Voltage and Power Quality Screen – Update voltage and power quality standards reference to show IEEE 1547-2018 instead of IEEE 519 and IEEE 1453. There were substantial changes to power quality requirements, including additions, that came out with IEEE Std 1547-2018. These also carried through to DER testing requirements in IEEE 1547.1 and UL 1741 and are further elaborated in the P1547.2 draft application guide. FERC could consider bringing these new standards into the screen references. Language in the FERC 2.4.4.2 screen could be updated and expanded with guidance on how to address the point of connection influence on DER plant power quality measurements. Voltage variations, harmonic distortion, flicker, and rapid voltage change (RVC) are highly dependent on grid characteristics. The new ground fault and instantaneous overvoltage requirements in 1547 could be referenced. This also relates to grounding compatibility.

2.4.4.3 Safety and Reliability Screen – Inclusion of additional guidance in this screen could be considered to adequately address technological advancements that are consistent with established standards. If the DER limits export by an approved method (Section 4.10) then Export Capacity could be used for analysis including power flow simulations, except when assessing fault current contribution. To assess fault current contribution, DER fault current characterization as provided by manufacturer test data (pursuant to the fault current test described in IEEE 1547.1-2020 clause 5.18 fault current tests) could be used. Depending on the objective of the fault current screen, the type of faults considered therein, and the technology used in the DER, the fault current contribution from the DER could range from as low as zero current for Category III inverter-based DER that enter Momentary Cessation below 0.5 per unit voltage (a voltage condition that is often, but not always, related to close-in faults and faults on the distribution feeder), or as high as multiple times the DER rated current for synchronous DERs. One approach could be to use the rated fault current for any DER that limits export pursuant to Section 4.10 to avoid giving credit for such DERs in screens that relate to fault current.

Section 4. Provisions that Apply to All Interconnection Requests

4.10 Capacity of the Small Generating Facility – Capacity as used in this section refers to Nameplate capacity. To consider proven and certified technical innovations this section could be expanded to explicitly list export limiting capabilities and methods. Accepted standards and methods for export limiting capability are available and could be identified to facilitate more technology options, such as ESS, for each interconnection application in an effort to consider load following capability, increase grid asset utilization, and improve the efficiency of the interconnection process. There are several export control methods that are already widely accepted for use. While older methods employ relays, those that are newer, like power control systems (PCS) and the configured power rating in IEEE 1547-2018, can provide more grid-edge intelligence and configurability compared to relays and can offer more repeatable performance because they rely on equipment with certified functionality. To enable export controls to more types of technologies, SGIP Section 4.10 could be retitled Capacity of the DER (section 4.10.1 could remain).

Attachment 1. Glossary of Terms – Adding new terms as suggested here can improve clarity of the SGIP as well as better align it with the evolving standards set by IEEE and others. See suggested definitions further below in these comments.

B. Markup of SGIP by Section and Paragraph

The following markup proposes example in-line language changes to specific sections of the SGIP to provide a starting point for further discussion, clarification, and consideration by FERC and interested stakeholders.

1. Fast Track Process (Section 2);

2.1 Applicability

> *The Fast Track Process is available to an Interconnection Customer proposing to interconnect its DER ~~Small Generating Facility~~ with the [Transmission Provider | Distribution Provider]'s System if the DER ~~Small Generating Facility's~~ Export ~~c~~Capacity does not exceed the size limits identified in the table below. ~~Small Generating Facilities below these limits are eligible for Fast Track review.~~ However, Fast Track eligibility is distinct from the Fast Track Process itself, and eligibility does not imply or indicate that a ~~Small Generating Facility~~ DER will pass the Fast Track screens in section 2.2.1 below or the Supplemental Review screens in section 2.4.4 below.*
>
> *Fast Track eligibility is determined based upon the ~~generator~~ DER type, the Export Capacity ~~size~~ of the ~~generator~~ DER, voltage of the line and the location of and the type of line at the Point of Interconnection. All ~~Small Generating Facilities~~ DER connecting to lines greater than 69 kilovolts (kV) are ineligible for the Fast Track Process regardless of Export Capacity ~~size~~. All synchronous and induction machines must have an Export Capacity of ~~be no larger than~~ 2 MW or less to be eligible for the Fast Track Process, regardless of location. For certified inverter-based systems, the size limit varies according to the voltage of the line at the proposed Point of Interconnection. Certified inverter-based ~~Small Generating Facilities~~ DER located within 2.5 electrical circuit miles of a substation and on a mainline (as defined in the table below) are eligible for the Fast Track Process under the higher thresholds according to the table below. In*

addition ~~to the size threshold~~, the Interconnection Customer's proposed DER ~~Small Generating Facility~~ must meet the codes, standards, and certification requirements of Attachments 3 and 4 of these procedures, or the [Transmission Provider | Distribution Provider] has to have reviewed the design or tested the proposed DER ~~Small Generating Facility~~ and be ~~is~~ satisfied that it is safe to operate.

Fast Track Eligibility for Inverter-Based Systems		
Line Voltage	*Export Capacity of DER Eligible for Fast Track ~~Eligibility~~ Regardless of Location*	*Export Capacity of DER Eligible for Fast Track ~~Eligibility~~ on a Mainline and ≤ 2.5 Electrical Circuit Miles from Substation*
< 5 kV	*≤ 500 kW*	*≤ 500 kW*
≤ 5 kV and < 15 kV	*≤ 2 MW*	*≤ 3 MW*
≤ 15 kV and < 30 kV	*≤ 3 MW*	*≤ 4 MW*
≤ 30 kV and ≤ 69 kV	*≤ 4 MW*	*≤ 5 MW*

2.2 Initial Review

2.2.1 Screens

2.2.1.1 no change

2.2.1.2 For interconnection of a proposed DER ~~Small Generating Facility~~ to a radial distribution circuit, the aggregated Export Capacity ~~generation~~, including the proposed DER ~~Small Generating Facility~~, on the circuit shall not exceed 15 % of the line section annual peak load as most recently measured at the substation. A line section is that portion of a [Transmission Provider | Distribution Provider] 's electric system connected to a customer bounded by automatic sectionalizing devices or the end of the distribution line.

2.2.1.3 (new) For interconnection of a proposed DER that can introduce Inadvertent Export, where the Nameplate Rating minus the Export Capacity is greater than 250 kW, the following Inadvertent Export screen is required. With a power change equal to the Nameplate Rating minus the Export Capacity, the change in voltage at the point on the medium voltage (primary) level nearest the Point of Interconnection does not exceed 3%. Voltage change will be estimated applying the following formula:

Formula	$\frac{(R_{SOURCE} \times \Delta P) - (X_{SOURCE} \times \Delta Q)}{V^2}$

Where:

$$\Delta \boldsymbol{P} = \text{(DER apparent power Nameplate Rating – Export Capacity)} \times \text{PF},$$

$$\Delta \boldsymbol{Q} = \text{(DER apparent power Nameplate Rating – Export Capacity)} \times \sqrt{(\boldsymbol{1} - \boldsymbol{PF^2})},$$

R_{SOURCE} is the grid resistance, X_{SOURCE} is the grid reactance,

V is the grid voltage, PF is the power factor

2.2.1.~~3~~4 For interconnection of a proposed DER ~~Small Generating Facility~~ to the load side of spot network protectors, the proposed DER ~~Small Generating Facility~~ must utilize an inverter-based equipment package and the proposed DER's Nameplate Rating, together with the aggregated Nameplate Rating of other inverter-based generation, shall not exceed the smaller of 5 % of a spot network's maximum load or 50 kW.[8]

2.2.1.~~4~~5 The fault current of the proposed DER ~~Small Generating Facility~~, in aggregation with the fault current of other DER ~~generation~~ on the distribution circuit, shall not contribute more than 10 % to the distribution circuit's maximum fault current at the point on the high voltage (primary) level nearest the proposed point of change of ownership.

2.2.1.~~5~~6 The fault current of the proposed DER ~~Small Generating Facility~~, in aggregate with fault current of other ~~generation~~ DER on the distribution circuit, shall not cause any distribution protective devices and equipment (including, but not limited to, substation breakers, fuse cutouts, and line reclosers), or Interconnection Customer equipment on the system to exceed 87.5 % of the short circuit interrupting capability; nor shall the interconnection be proposed for a circuit that already exceeds 87.5 % of the short circuit interrupting capability.

2.2.1.~~7~~8 If the proposed DER ~~Small Generating Facility~~ is to be interconnected on a single-phase shared secondary, the aggregate Export Capacity ~~generation capacity~~ on the shared secondary, including the proposed DER ~~Small Generating Facility~~, shall not exceed:

-Some states use "20 kW"

-Some states use "65 % of the transformer nameplate power rating"

2.2.1.~~9~~10 The Nameplate Rating of the DER ~~Small Generating Facility~~, in aggregate with the Nameplate Rating of other ~~generation~~ DER interconnected to the transmission side of a substation transformer feeding the circuit where the ~~Small Generating Facility~~ DER proposes to interconnect shall not exceed 10 MW in an area where there are known, or posted, transient stability limitations to generating units located in the general electrical vicinity (e.g., three or four transmission busses from the Point of Interconnection).

2.4 Supplemental Review

2.4.1, .2, .3 No change

2.4.4 Supplemental Screens

2.4.4.1 Minimum Load Screen: Where 12 months of line section minimum load data (including onsite load but not station service load served by the proposed DER ~~Small Generating~~

[8] A spot network is a type of distribution system found within modern commercial buildings to provide high reliability of service to a single customer. *See* [40].

~~Facility)~~ are available, can be calculated, can be estimated from existing data, or determined from a power flow model, the aggregate Export Capacity ~~Generating Facility capacity~~ on the line section is less than 100% of the minimum load for all line sections bounded by automatic sectionalizing devices upstream of the proposed DER ~~Small Generating Facility~~. If minimum load data is not available, or cannot be calculated, estimated or determined, the [Transmission Provider | Distribution Provider] shall include the reason(s) that it is unable to calculate, estimate or determine minimum load in its supplemental review results notification under section 2.4.4.

2.4.4.1.1 The type of generation used by the proposed ~~Small Generating Facility~~ DER will be taken into account when calculating, estimating, or determining circuit or line section minimum load relevant for the application of screen 2.4.4.1. Solar photovoltaic (PV) generation systems with no battery storage use daytime minimum load (i.e. 10 a.m. to 4 p.m. for fixed panel systems and 8 a.m. to 6 p.m. for PV systems utilizing tracking systems), while all other generation uses absolute minimum load.

2.4.4.1.2 When this screen is being applied to a ~~Small Generating Facility~~ DER that serves some station service load, only the net injection into the [Transmission Provider | Distribution Provider]'s electric system will be considered as part of the aggregate generation.

2.4.4.1.3 [Transmission Provider | Distribution Provider] will not consider as part of the aggregate Export Capacity ~~generation~~ for purposes of this screen ~~generating facility capacity~~ DER Export Capacity known to be already reflected in the minimum load data.

2.4.4.2 Voltage and Power Quality Screen: In aggregate with existing generation on the line section: (1) the voltage regulation on the line section can be maintained in compliance with relevant requirements under all system conditions; (2) the voltage fluctuation is within acceptable limits as defined by Institute of Electrical and Electronics Engineers (IEEE) Standard 1547, section 7. If the DER limits export pursuant to Section [4.10], the Export Capacity must be included in any analysis including power flow simulations.

2.4.4.3 Safety and Reliability Screen: The location of the proposed ~~Small Generating Facility~~ DER and the aggregate Export Capacity ~~generation capacity~~ on the line section do not create impacts to safety or reliability that cannot be adequately addressed without application of the Study Process. If the DER limits export pursuant to Section 4.10, the Export Capacity must be included in any analysis including power flow simulations, except when assessing fault current contribution. To assess fault current contribution for DER that limit export, the analysis must use the rated fault current, unless the Customer provides manufacturer test data (pursuant to the fault current test described in IEEE 1547.1-2020 clause 5.18) showing that the fault current is independent of the Nameplate Rating. The [Transmission Provider | Distribution Provider] shall give due consideration to the following and other factors in determining potential impacts to safety and reliability in applying this screen.

2.4.4.3.1 Whether the line section has significant minimum loading levels dominated by a small number of customers (e.g., several large commercial customers).

2.4.4.3.2 Whether the loading along the line section is uniform or even.

2.4.4.3.3 Whether the proposed ~~Small Generating Facility~~ DER is located in close proximity to the substation (i.e., less than 2.5 electrical circuit miles), and whether the line section from the substation to the Point of

Interconnection is a Mainline rated for normal and emergency ampacity.

2.4.4.3.4 *Whether the proposed DER ~~Small Generating Facility~~ incorporates a time delay function to prevent reconnection of the ~~generator~~ DER to the system until system voltage and frequency are within normal limits for a prescribed time.*

2.4.4.3.5 *Whether operational flexibility is reduced by the proposed DER ~~Small Generating Facility~~, such that transfer of the line section(s) of the DER ~~Small Generating Facility~~ to a neighboring distribution circuit/substation may trigger overloads or voltage issues.*

2.4.4.3.6 *Whether the proposed DER ~~Small Generating Facility~~ employs equipment or systems certified by a recognized standards organization to address technical issues such as, but not limited to, islanding, reverse power flow, or voltage quality.*

2. Section 3. Study Process

3.1 **Applicability**, remove inverter based < 10kW

3.3 **Feasibility Study**, provide criteria and option to skip

3.4 **Impact Study**, provide criteria for typical distribution level

3.5 **Facilities Study**, provided criteria, identify when needed

3. Section 4. Provisions Applying to All Interconnection Requests

4.10 Capacity of the Small Generating Facility

4.10.1 no change

4.10.2 (replace with) If a DER uses any configuration or operating mode in subsection 4.10.4 to limit the export of electrical power across the Point of Interconnection, then the Export Capacity shall be only the amount capable of being exported (not including any Inadvertent Export). To prevent impacts on system safety and reliability, any Inadvertent Export from a DER must comply with the limits identified in this Section. The Export Capacity specified by the interconnection customer in the application will subsequently be included as a limitation in the interconnection agreement.

4.10.3 (replace with) An Application proposing to use a configuration or operating mode to limit the export of electrical power across the Point of Interconnection shall include proposed control and/or protection settings.

4.10.4 (add) Acceptable Export Control Methods

4.10.4.1 Export Control Methods for Non-Exporting DER

4.10.4.1.1 Reverse Power Protection (Device 32R)

To limit export of power across the Point of Interconnection, a reverse power protective function is implemented using a utility grade protective relay. The default setting for this protective function shall be 0.1% (export) of the service transformer's nominal base Nameplate Rating, with a maximum 2.0 second time delay to limit Inadvertent Export.

4.10.4.1.2 Minimum Power Protection (Device 32F)

To limit export of power across the Point of Interconnection, a minimum import protective function is implemented using a utility grade protective relay. The default setting for this protective function shall be 5% (import) of the DER's total Nameplate Rating, with a maximum 2.0 second time delay to limit Inadvertent Export.

4.10.4.1.3 Relative Distributed Energy Resource Rating

This option requires the DER's Nameplate Rating to be so small in comparison to its host facility's minimum load that the use of additional protective functions is not required to ensure that power will not be exported to the electric distribution system. This option requires the DER's Nameplate Rating to be no greater than 50% of the interconnection customer's verifiable minimum host load during relevant hours over the past 12 months. This option is not available for interconnections to area networks or spot networks.

4.10.4.2 Export Control Methods for Limited-Export DER

4.10.4.2.1 Directional Power Protection (Device 32)

To limit export of power across the Point of Interconnection, a directional power protective function is implemented using a utility grade protective relay. The default setting for this protective function shall be the Export Capacity value, with a maximum 2.0 second time delay to limit Inadvertent Export.

4.10.4.2.2 Configured Power Rating

A reduced output power rating utilizing the power rating configuration setting may be used to ensure the DER does not generate power beyond a certain value lower than the Nameplate Rating. The configuration setting corresponds to the active or apparent power ratings in Table 28 of IEEE Std 1547-2018, as described in subclause 10.4. A local DER communication interface is not required to utilize the configuration setting as long as it can be set by other means. The reduced power rating may be indicated by means of a Nameplate Rating replacement, a supplemental adhesive Nameplate Rating tag to indicate the reduced Nameplate Rating, or a signed attestation from the customer confirming the reduced capacity.

4.10.4.3 Export Control Methods for Non-Exporting DER or Limited- Export DER

4.10.4.3.1 Certified Power Control Systems

DER may use certified Power Control Systems to limit export. DER utilizing this option must use a Power Control System and inverter certified per UL 1741 by a nationally recognized testing laboratory (NRTL) with a maximum open loop response time of no more than 30 seconds to limit Inadvertent Export. NRTL testing to the UL Power Control System Certification Requirement Decision shall be accepted until similar test procedures for power control systems are included in a standard. This option is not available for interconnections to area networks or spot networks.

4.10.4.3.2 Agreed-Upon Means

DER may be designed with other control systems and/or protective functions to limit export and Inadvertent Export if mutual agreement is reached with the [Transmission Provider | Distribution Provider]. The limits may be based on technical limitations of the interconnection customer's equipment or the electric distribution system equipment. To ensure Inadvertent Export remains within mutually agreed-upon limits, the interconnection customer may use an uncertified Power Control System, an internal *transfer relay, energy management system, or other customer facility hardware or software if approved by the [Transmission Provider | Distribution Provider].*

4. **Attachment 1. Glossary**

These definitions are based on IEEE 1547-2018 and the IEEE SA Initial Ballot draft of its revised Application Guide, IEEE P1547.2, and offered to help improve consistency and clarity when discussing distribution interconnection processes today. EPRI used these definitions in the sections noted above. Most follow the syntax of the FERC SGIP format and apply to the same emerging issues.

I. Definition Section: EPRI has found the following definitions for terms have been useful for clearly communicating and supporting a common understanding of how to review export-controlled systems.	
Applicability and Definitions of DER, Generating Facility, and ESS	• ***Energy Storage System*** *or ESS means a mechanical, electrical, or electrochemical means to store and release electrical energy, and its associated interconnection and control equipment. For the purposes of these Interconnection Procedures, an Energy Storage System can be considered part of a DER or a DER in whole that operates in parallel with the distribution system.* • ***Distributed Energy Resource*** *or DER means the equipment used by an interconnection customer to generate and/or store electricity that operates in parallel with the electric distribution system. A DER may include but is not limited to an electric generator and/or Energy Storage System, a prime mover, or combination of technologies with the capability of injecting power and energy into the electric distribution system, which also includes the interconnection equipment required to safely interconnect the facility with the distribution system.* • ***Reference Point of Applicability*** *or RPA means the location, either the Point of Common Coupling or the Point of DER Connection, where the interconnection and interoperability performance requirements specified in IEEE 1547 apply.*
Definition of PCS and Related Terms	• ***Non-Export*** *or* ***Non-Exporting*** *means when the DER is sized and designed, and operated using any of the methods in Section 4.10, such that the output is used for Host Load only and no electrical energy (except for any Inadvertent Export) is transferred from the DER to the Distribution System.* • ***Limited Export*** *means the exporting capability of a DER whose Generating Capacity is limited by the use of any configuration or operating mode* • *described in Section 4.10.* • ***Power Control System*** *or PCS means systems or devices which electronically limit or control steady state currents to a programmable limit.*

	• ***Host Load*** *means electrical power, less the DER auxiliary load, consumed by the Customer at the location where the DER is connected.* • ***Inadvertent Export*** *means the unscheduled export of active power from a DER, exceeding*[9] *a specified magnitude and for a limited duration, generally due to fluctuations in load-following behavior.*
Definition of Nameplate Rating and Export Capacity	• ***Export Capacity*** *means the amount of power that can be transferred from the DER to the Distribution System. Export Capacity is either the Nameplate Rating, or a lower amount if limited using an acceptable means identified in Section 4.10.* • ***Nameplate Rating*** *means the sum total of maximum rated power output of all of a DER's constituent generating units and/or ESS as identified on the manufacturer nameplate, regardless of whether it is limited by any approved means.*
Definitions of Operating Profile and Operating Schedule	• ***Operating Profile*** *means the manner in which the distributed energy resource is designed to be operated, based on the generating prime mover and operational characteristics. The Operating Profile includes any limitations set on power imported or exported at the Point of Interconnection and the resource characteristics, e.g., solar output profile.* • ***Operating Schedule*** *means the time of year, time of month, and hours of the day designated in the Interconnection Application for the import or export of power*

5. **Attachment 5. 10kW Inverter Process –** Delete this section

[9] IEEE P1547.9 uses "beyond" rather than "exceeding."

V. CONCLUSION

37. EPRI appreciates the opportunity to provide FERC with its technical recommendations and comments on these important topics related to Improvements to Generator Interconnection Procedures and Agreements. EPRI looks forward to working with its members, FERC, and other stakeholders on providing further independent technical information on these important questions.

VI.
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3002025703

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