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BPS Reliability Perspectives

Reliability Starts during the Interconnection Process

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Director, Engineering and Security Integration, NERC

Generator Interconnection Workshop

August 10, 2022

RELIABILITY | RESILIENCE | SECURITY



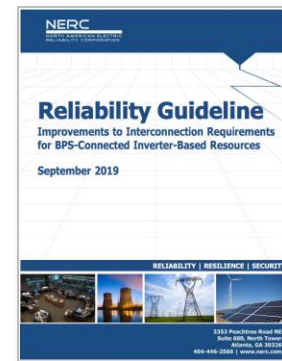
- Blue Cut Fire (2017)
- Canyon 2 Fire (2018)
- Palmdale Roost and Angeles Forest (2019)
- San Fernando (2020)
- Odessa (2021)
- CA 2021 Disturbances (2022)
- Texas Panhandle Wind Event (2022)
- **CATEGORY 3: Odessa II (2022)**



<https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx>

1. Industry Adopt NERC Reliability Guidelines

- Industry Engagement, Outreach, Education, and Collaboration
- Best Practices and Education



2. Improvements to FERC Generator Interconnection Procedures and Agreements

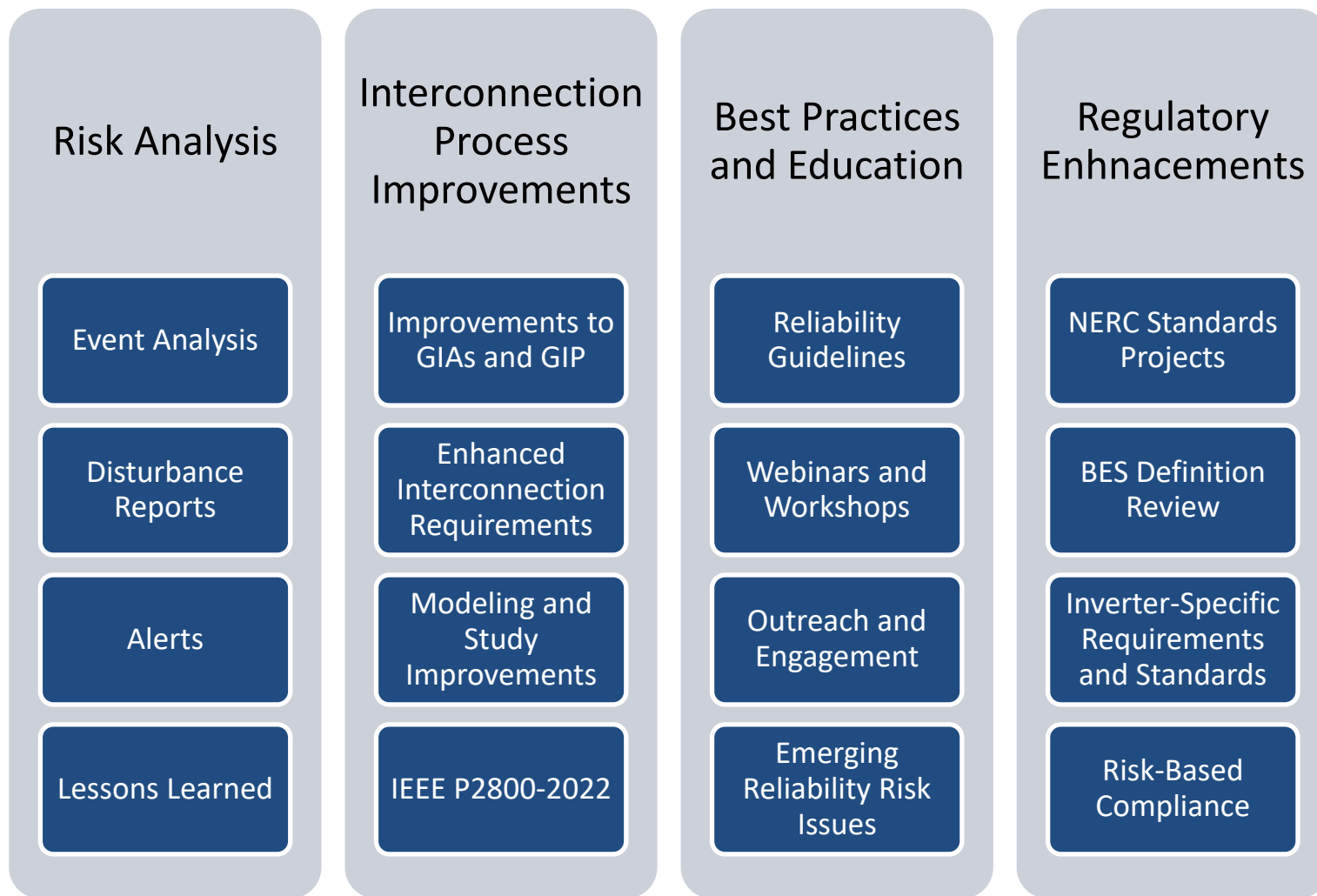
- Focused Improvements to Commissioning Processes
- IEEE P2800-2022



3. Enhancements to NERC Reliability Standards

- Addressing Model Quality Issues and Inadequate Reliability Studies
- Post-Event Performance Validation and Addressing Abnormal Performance Issues





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Technical Report

BPS-Connected Inverter-Based Resource Modeling and Studies

May 2020

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Reliability Guideline

BPS-Connected Inverter-Based Resource Performance

September 2018

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Utilizing the Excess Capability of BPS-Connected Inverter-Based Resources for Frequency Support

NERC Inverter-Based Resource Performance Working Group (IRPWG)
White Paper
September 2021

The Federal Energy Regulatory Commission (FERC) issued Order No. 842 in 2018, amending the pro forma Large Generator Interconnection Agreement (LGIA) and Small Generator Interconnection Agreement (SGIA) to require all "newly interconnecting large and small generating facilities, both synchronous and non-synchronous, to install, maintain, and operate equipment capable of providing primary frequency response (PFR) as a condition of interconnection."¹ On the same subject, NERC recently published a white paper, "Fast Frequency Response Concepts and Bulk Power System Reliability Needs," in March 2020 describing the interrelationship between primary frequency response (PFR) and fast frequency response (FFR). This work extends on the FERC Order No. 842 and the NERC white paper and recommends leveraging PFR and FFR capabilities from inverter-based resources to the extent possible to support BPS Frequency as an essential reliability service.

Specifically, inverter-based resources operating at their maximum contractual agreement, also referred to as the steady-state interconnection limit (SSIL), may be able to support the grid during underfrequency events beyond their SSIL. This situation is most likely to occur in air-cooled hybrid plants (i.e., the combination of battery energy storage and wind or solar PV) or in standalone wind, solar PV, and battery energy storage plants where additional capacity is available but not presently utilized due to the SSIL constraints imposed by interconnection agreements. It should be noted that this paper only focuses on the excess capability of inverter-based resources that is limited by the SSIL; it does not consider the short-term overload capability of individual inverters.

By establishing a short-term interconnection limit (STIL)² in interconnection agreements, inverter-based resources with excess active power capability beyond SSIL can use this capability to better support the grid frequency. However, once the system frequency recovers to nominal, the MW output of the plant should

<https://www.nerc.org/~/media/2021/09/01/2021-09-01-Utilizing-the-Excess-Capability-of-BPS-Connected-Inverter-Based-Resources-for-Frequency-Support-White-Paper.pdf>
White Paper: Fast Frequency Response Concepts and Bulk Power System Reliability Needs, March 2020
¹ https://www.nerc.org/~/media/2020/03/2020-03-20-Fast-Frequency-Response-Concepts-and-Bulk-Power-System-Reliability-Needs-White-Paper.pdf
² An air-cooled hybrid plant can be deemed similar to the standalone MW facilities for the topic of this paper.
This document is also referenced in IEEE 2020 document. However, there are some differences. A detailed reader is encouraged to refer to the IEEE 2020 standard to fully understand the similarities and differences.
<https://www.nerc.org/~/media/2020/03/2020-03-20-Fast-Frequency-Response-Concepts-and-Bulk-Power-System-Reliability-Needs-White-Paper.pdf>

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Reliability Guideline

Performance, Modeling, and Simulations of BPS-Connected Battery Energy Storage Systems and Hybrid Power Plants

March 2021

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Reliability Guideline

Improvements to Interconnection for BPS-Connected Inverter-Based Resources

September 2019

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Key Takeaways

Inverter Manufacturer and Relay Manufacturer

April 2019

NERC facilitated an in-depth technical discussion between inverter manufacturers and relay manufacturers, and industry experts related to how inverters during fault conditions and potential impacts on the grid. The discussion resulted in the following key takeaways, recommendations, and next steps were an outcome of this discussion.

General Takeaways

- Industry needs to collectively speak in terms of phase unbalance rather than sequence components, to better understand the underlying issues regarding current injection during faults. Sequence components are a tool for analyzing unbalanced three-phase power systems, and are derived from phase quantities.
- Protection engineers setting protective relay settings do not generally use electromagnetic transient (EMT) simulation programs. Short-circuit programs typically used by protection engineers do not accurately represent the dynamic response of inverter-based resources during the first few cycles after fault inception as the phase and sequence components may not stabilize.
- The injection of negative sequence current (I2) from generating resources during unbalanced fault events is beneficial for existing protection schemes and BPS reliability. All resources, where possible, and in the future, should maintain the correct phase relationship between the unfaulted phases and faulted phase both in voltage and current. This ensures predictable phase relationship between sequence voltages and currents, and consequently operation and protection behavior that is consistent with conventional power system operation.
- Inverter-based resources respond to faults based on the controls programmed into the inverter. Controlled inverter response generally does not start to occur earlier than one electrical cycle (pre-detection and processing) to the delay from fault inception. During the first couple of electrical cycles of a severe fault, the response from inverter may not be controlled in a way that can ensure necessary sequence setting primary goal.
- The concept of critical inverter-based resource.

<https://www.nerc.org/~/media/2019/04/2019-04-01-Key-Takeaways-Inverter-Manufacturer-and-Relay-Manufacturer-April-2019.pdf>

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San Fernando Disturbance Follow-Up

NERC Inverter-Based Resource Performance Working Group (IRPWG)

White Paper – June 2021

This brief white paper was developed by the NERC Inverter-Based Resource Performance Working Group (IRPWG) as a follow-up to the July 2020 San Fernando Disturbance Report published by NERC. This report contained a set of key findings and recommendations. The IRPWG discussed each of the key findings and recommendations in detail, provided a brief technical discussion and basis for each item, and where appropriate recommended how to address them. Table 1 shows the key findings and recommendations from the NERC Disturbance report on the left hand column and the IRPWG follow-up and recommendations for each item on the right hand column.

The following are the recommended actions from the IRPWG review:

1. IEEE should integrate the recommendations from the San Fernando report and the IRPWG guidelines into the pro forma LGIA for all newly interconnecting inverter-based resources. The future IEEE 2020 Standard Drafting Team should consider IEEE 2020 Clause 11.4 efforts, and ensure that the modifications require disturbance monitoring equipment at inverter-based resource facilities.
2. IRPWG will continue summarizing lessons learned from the events with systematic causes of inverter tripping. IRPWG will future publications include papers, guidelines, SSI, etc. NERC and IEEE, in coordination with industry, should develop a coordinated strategy to ensure the effective and widespread adoption of IEEE 2020 once it is approved.
3. IRPWG should draft a SAM to address the outstanding recommendation by NERC to address the issue identified in EOP 004 regarding the generation loss criteria to that it is applicable to inverter-based resources as well as synchronous generation.
4. Modeling and study standards (e.g., MWD and TPL) should be reviewed by IRPWG to consider the inclusion of EMT models for study purposes by the TP and PC. Currently these studies that would be used to identify possible tripping or abnormal performance from inverter-based resources are not required and are performed only in certain instances where the TP or PC has identified issues with other modeling tools. However, the issues identified in these disturbances have not been identified or highlighted by the TP or PC in their

<https://www.nerc.org/~/media/2021/06/2021-06-01-San-Fernando-Disturbance-Follow-Up-White-Paper.pdf>

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Grid Forming Technology

Bulk Power System Reliability Considerations

December 2021

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Fast Frequency Response Concepts and Bulk Power System Reliability Needs

NERC Inverter-Based Resource Performance Task Force (IRPTF)
White Paper

IEEE Power & Energy Society
July 2018

TECHNICAL REPORT
PES-TR68

Impact of Inverter Based Generation on Bulk Power System Dynamics and Short-Circuit Performance

PREPARED BY THE
IEEE/NERC Task Force on Short-Circuit and System Performance
Impact of Inverter Based Generation

<https://www.nerc.org/~/media/2018/07/2018-07-01-Impact-of-Inverter-Based-Generation-on-Bulk-Power-System-Dynamics-and-Short-Circuit-Performance-Technical-Report.pdf>

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Integrating Inverter-Based Resources into Low Short Circuit Strength Systems

Reliability Guideline

December 2017

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Odessa Disturbance Follow-Up

NERC Inverter-Based Resource Performance Working Group (IRPWG)

White Paper – October 2021

This brief white paper was developed by the NERC Inverter-Based Resource Performance Working Group (IRPWG) as a follow-up to the Odessa Disturbance Report published by NERC in October 2021. This report contained a set of key findings and recommendations. The IRPWG discussed each of the key findings and recommendations in detail and providing a brief technical discussion and basis for each item. Where appropriate, follow-up and/or items are identified. Table 1 shows the key findings and recommendations from Chapter 3 of the NERC Disturbance report on the left hand column and the IRPWG follow-up and recommendations for each item on the right hand column.

The following are the recommended actions from the IRPWG review:

1. IEEE and NERC should collaboratively modernize the interconnection study process and applicable NERC Reliability Standards to ensure that the recommendations outlined in the reliability guidelines are effective, and consistently conducted performance requirements for inverter-based resources. These requirements should be based on the performance of inverter-based resources as they are currently used in the field. The requirements should be based on the performance of inverter-based resources as they are currently used in the field. The requirements should be based on the performance of inverter-based resources as they are currently used in the field.
2. IRPWG will develop standard authorization requests (SARs) related to a number of existing standards and possibly the addition of new standards to address the issues described below.
3. IRPWG will conduct a comprehensive assessment, taking into consideration the guidelines and reference documents developed in this file, to determine any performance gaps not addressed by the NERC Reliability Standards and provide recommendations for additional SARs, where applicable. This assessment will also specifically evaluate the need for any inverter-specific performance requirements language.

<https://www.nerc.org/~/media/2021/10/2021-10-01-Odessa-Disturbance-Follow-Up-White-Paper.pdf>

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Fast Frequency Response Concepts and Bulk Power System Reliability Needs

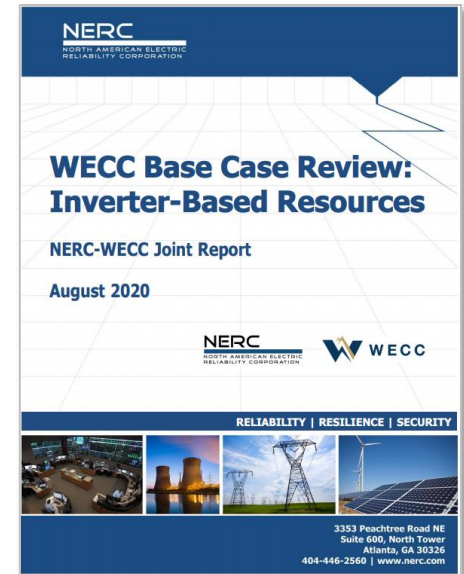
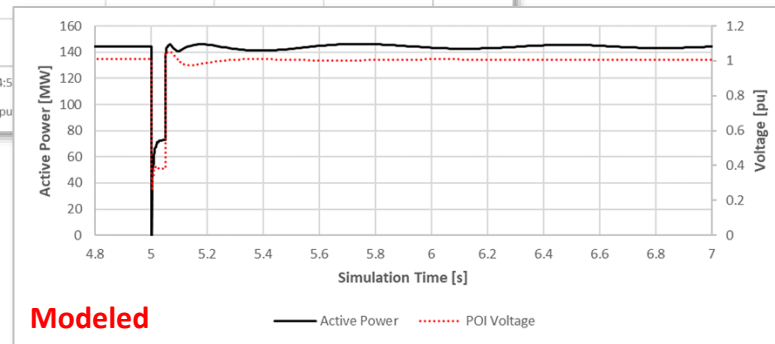
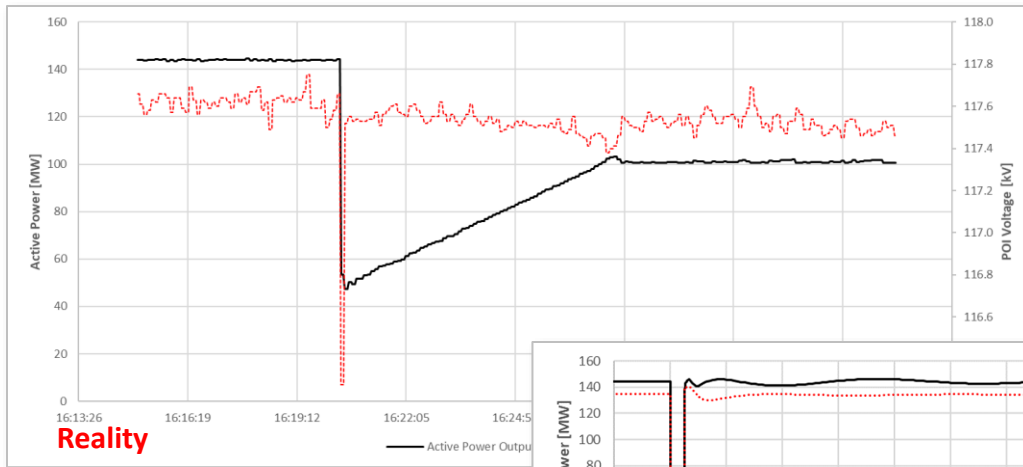
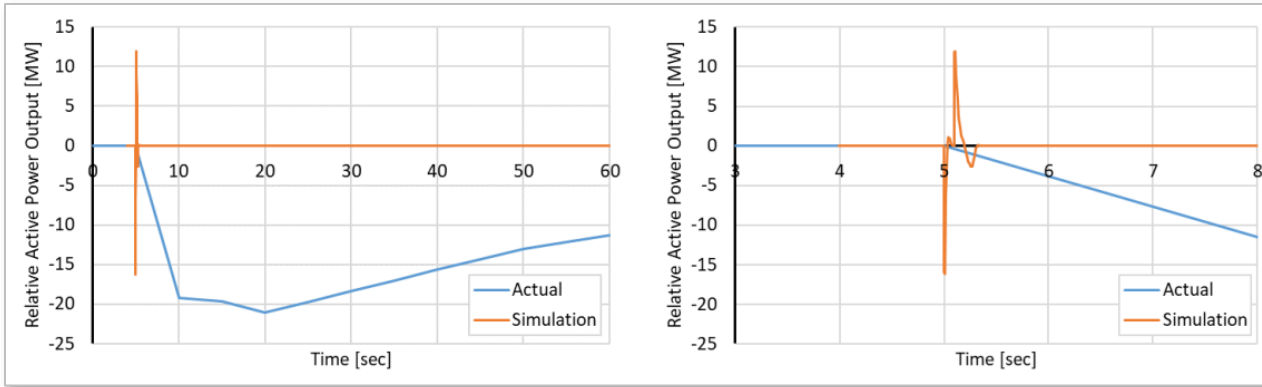
NERC Inverter-Based Resource Performance Task Force (IRPTF)
White Paper

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WECC Base Case Review: Inverter-Based Resources

NERC-WECC Joint Report
August 2020

<https://www.nerc.org/~/media/2020/08/2020-08-01-WECC-Base-Case-Review-Inverter-Based-Resources-Report.pdf>



329. Specifically, we propose to revise Attachment A to Appendix 1 of the *pro forma* LGIP, and Attachment 2 of the *pro forma* SGIP to require each interconnection customer requesting to interconnect a non-synchronous generating facility to submit to the transmission provider: (1) a validated user-defined root mean square (RMS) positive sequence dynamics model; (2) an appropriately parameterized, generic library RMS positive sequence dynamics model, including a model block diagram of the inverter control system and plant control system, that corresponds to a model listed in a new table of acceptable models or a model otherwise approved by WECC; and (3) a validated EMT model, if the transmission provider performs an EMT study as part of the interconnection study process.

- ✓ Suite of ***accurate*** models is critical to conducting adequate BPS reliability studies moving forward
- ✓ Each model type plays a ***unique*** role in different types of reliability studies

330. First, regarding the validated user-defined model, we propose to define a “user-defined model” as any set of programming code created by equipment manufacturers or developers that captures the latest features of controllers that are mainly software based and represents the entities’ control strategies but does not necessarily correspond to any particular generic library model. In order for this model to be “validated,” it must be confirmed that the equipment behavior is consistent with the model behavior. This can involve, for example, an attestation from the interconnection customer that the model accurately represents the entire generating facility, attestations from each equipment manufacturer that the user defined model accurately represents the component of the generating facilities, or test data.

- ✓ User-defined models reflective of actual installed (planned) equipment, controls, settings, modes, and protection is ***critical***
- ✓ Models must ***match*** actual equipment behavior; otherwise, reliability studies are useless

331. Second, regarding the table of acceptable generic library models, this table is based on the current WECC list of approved dynamic models for renewable energy generating facilities.⁴⁶⁸ WECC's list of approved dynamic models has also been integrated into NERC Guidelines.⁴⁶⁹ These models represent the current state of the art with regard to dynamic modeling requirements for non-synchronous generating facilities.

- ✓ Standard library model, parameterized with appropriate plant-specific settings; ***not*** generic parameters

- ✓ Modeling accuracy is ***critical*** to reliability studies; inaccurate models lead to inaccurate studies, which lead to poor interconnection decision making and unreliable operation
- ✓ Models need to include controls, modes of operation, settings, and protections that could affect ***ability to ride through and provide essential reliability services***

332. We believe that these models represent the full spectrum of modeling data that transmission providers need to perform accurate interconnection studies for non-synchronous generating facilities. We recognize that the modeling data we propose to require from non-synchronous generating facilities may be more voluminous than that required of synchronous generating facilities; however, this data submission requirement is intended to result in a comparable level of modeling accuracy among all generating facilities.

333. An interconnection customer’s failure to provide the above information within the deadlines established in the *pro forma* LGIP and *pro forma* SGIP would make the interconnection request incomplete and will be considered invalid in accordance with section 3.4.3 of the *pro forma* LGIP and section 1.3 of the *pro forma* SGIP. Pursuant to those provisions, if the interconnection customer does not cure the deficiency within the 10-day cure period, the interconnection request will be considered withdrawn pursuant to section 3.7 of the *pro forma* LGIP and section 1.3 of the *pro forma* SGIP.

✓ **Necessary modeling linkage to “first-ready”** – interconnecting customers need to be able to provide accurate modeling information at time of interconnection...

✓ ...and process can accommodate changes or modifications along the way, but these **must be re-studied** from a reliability perspective – new models are necessary to reflect those changes.

334. We also propose to modify subsection 4.4.4 of the *pro forma* LGIP and section 1.4 of the *pro forma* SGIP to require that any proposed modification of the interconnection request be accompanied by updated models of the proposed generating facility. This will ensure that the transmission provider will be able to accurately model the impact of the interconnection request throughout the interconnection process.

A stylized map of North America, including the United States, Canada, and Mexico. The map is rendered in shades of blue and grey, with the United States and Canada in a darker blue and Mexico in a lighter grey. The map is positioned in the background, partially obscured by a horizontal blue band that contains the title.

Questions and Answers

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