NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Recap of Inverter-Based Resource Panel

NERC MRC/BOT Meeting Technical Session – February 2023

The rapid integration of bulk power system (BPS)-connected inverter based resources (IBRs) is the most significant driver of grid transformation across North America. These resources present unique operational benefits; however, they can also present significant risks to the BPS if not integrated in a reliable and secure manner. The pace of change of the resource mix continues to challenge grid planners, operators, protection engineers, and other facets of the electricity sector. For instance, the 2022 NERC Long-Term Reliability Assessment[1] projects a rapid growth of IBRs—mostly solar photovoltaic (PV), wind, battery energy storage systems (BESS), and hybrid plants—representing over 70% of new generation in development connecting to the BPS.[2]

NERC launched a technical session at its February 2023 Member Representatives Committee/Board of Trustees meetings, with a panel dedicated to the challenges faced by BPS-connected inverter-based resources. The discussion noted that essential reliability services must be provided and future grid conditions studied if reliability is to be maintained. Key takeaways from the panel discussion included:

- **Paradigm Shift for Inverter Technology:** As inverter-based resources comprised a relatively minimal share of the generation mix, the philosophy was that those resources should simply generate energy during normal operation and "get out of the way" during grid disturbances. However, this strategy is not acceptable under rapidly increasing penetrations of IBRs on the BPS across North America. BPS-connected inverter-based resources must provide essential reliability services, support the BPS during normal and disturbance conditions, and provide sufficient information and data to ensure transmission entities can reliably and effectively operate the grid. The inverter and plant controller at these facilities dictate how the resource responds to grid conditions, and it is imperative that these controls be configured in a way that supports grid reliability.
- **ERO Enterprise Forensics and Technical Leadership:** NERC disturbance reports and reliability guidelines have paved the way for uncovering and better understanding BPS reliability issues with increasing levels of inverter-based technology.[3,4] Developing mitigating measures, working with asset owner/operators and equipment manufacturers, and sharing lessons learned widely with industry stakeholders has been paramount to BPS reliability to-date. However, reliance on recommendations and guidance has proved insufficient for mitigating these risks moving forward.
- **Interconnection Requirements:** Some Transmission Owners have developed more stringent interconnection requirements in an effort to keep up with the changing resource mix; however, this has been an evolution as industry understanding and technology have evolved rapidly. Requirements have been left at the functional level without specifying performance clearly and with

[1] https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf
[2] Over 88+ GW of fossil-fueled synchronous generation is slated for retirement over the same assessment period.
[3] https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx
[4] https://www.nerc.com/comm/Pages/Reliability-and-Security-Guidelines.aspx

sufficient detail, which has led to ambiguous requirements that are difficult to enforce as well as inconsistencies across different areas and misinterpretations by owner/operators, developers, and equipment manufacturers. The lack of uniformity, clarity, consistency, enforcement, and detail in the interconnection requirements and processes has led to unreliable operation of BPS-connected inverter-based resources and the widespread abnormal performance of resources during grid disturbances.[5] These unexpected grid disturbances have grown in likelihood and magnitude for more than seven years.

- **Reliance On and Challenges with the FERC Interconnection Agreements and Procedures:** Many other entities in the US may still have fairly rudimentary interconnection requirements, relying heavily on the FERC *pro forma* interconnection agreements which do not provide adequate specificity regarding detailed performance of IBRs. Furthermore, the FERC interconnection agreements and procedures are the focal point of the interconnection process. However, the facilitation of the interconnection queue needs to be differentiated (and possibly bifurcated) from the establishment of performance requirements that define BPS reliability. With the effective NERC registration date for facilities being upon commercial operation,[6] NERC's jurisdiction for assuring BPS reliability is met by all applicable parties is fairly limited but can be expanded through a bifurcation of performance requirements and facilitation of the interconnection queue. Focus to-date has been on the Transmission Owner having interconnection requirements (FAC-001) and the Transmission Planner and Planning Coordinator conducting reliability studies (FAC-002) during that process; however, all entities will have those requirements and conduct those studies per the FERC interconnection process. Focus must turn on the quality and sufficiency of the requirements established, the models used, and the studies conducted. Lastly, the requirements must be updated to ensure that the "interconnection customer"[7] *actually* comply with the established performance and modeling requirements throughout the process, otherwise face explicit corrective actions to address any shortcomings prior to the interconnecting customer's planned commercial operation date. Currently, this is inferred in the requirements based on past experience with synchronous generation; however, current practice shows that significant gaps exist.
- **Reliability Due Diligence during the Interconnection Process:** BPS reliability must be given due diligence during the interconnection process; however, those activities may conflict with legal and financial pressure during the interconnection process as well as political pressure related to renewable energy targets. Ensuring an effective and efficient interconnection process that gives credence to adequately studying and mitigating possible BPS reliability issues is paramount to a sustainable electricity delivery system of the future.
- **Equipment Standardization:** Lack of equipment standards have challenged the interconnection of inverter-based resources. IEEE 2800-2022 outlines minimum performance specifications and is based on state-of-the-art IBR capabilities.[8] Development and implementation[9] of this standard is necessary but not sufficient to address ongoing reliability risk issues in this area. Implementation of

[5] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_2022_Odessa_Disturbance_Report%20(1).pdf
[6] https://www.nerc.com/pa/comp/RegistrationReferenceDocsDL/ERO%20Enterprise%20Registration%20Procedure.pdf
[7] Term used by FERC to refer to the developer or Generator Owner seeking interconnection to the grid.
[8] https://standards.ieee.org/ieee/2800/10453/
[9] IEEE standards are voluntary in nature; this standard requires an authority governing interconnection requirements to enforce the standard requirements.

this standard solely for newly interconnecting resources ("grandfathering" existing facilities) will not address systemic risks posed to BPS reliability today. Furthermore, many of the procedural challenges that occur during the interconnection and commissioning processes cannot be addressed solely by reliance on IEEE 2800-2022 adoption.

- **Changing Needs for Modeling and Reliability Studies:** The need for more detailed and accurate modeling while performing reliability studies during interconnection studies and annual planning assessments are challenging Transmission Planners and Planning Coordinators. Namely, the necessity for conducting detailed electromagnetic transient (EMT) studies in many areas is problematic for many entities as there is limited expertise in this area and significant computational requirements. Industry will need to quickly upskill existing resources and/or hire additional expertise in this area to ensure reliable operation of the BPS under increasingly higher penetration of inverter-based resources.
- **Enhanced Commissioning Practices Needed:** There are currently no commissioning requirements within the NERC reliability standards for newly interconnection resources. However, the ERO Enterprise has observed numerous situations in which the facility commissioned does not match the model provided and used for studies throughout the interconnection process (i.e., what was built does not match what was studied). This discrepancy leaves the system being operated in an unknown operating state subject to unexpected or abnormal performance issues, which have been illustrated numerous times in the NERC disturbance reports. Requirements are needed to ensure that the commissioned facility matches what was studied during the interconnection process, and all discrepancies should be addressed *prior to* commercial operation. Gaps in interconnection studies cause last-minute changes to settings during commissioning without a proper feedback loop to study their impact on prior study results. Current industry practices fail to identify possible configuration, settings, or other design issues and leave the system prone to unexpected behavior from poorly commissioned inverter-based resources. Non-compliance with interconnection requirements or NERC standards are generally only identified after a major reportable event occurs rather than proactively through auditing and study practices.
- **Agile Modernization of NERC Reliability Standards:** There are numerous existing NERC standards projects underway to modernize the NERC reliability standards to ensure applicability, clarity, and consistency for inverter-based technologies. FERC has also issued a Notice of Proposed Rulemaking[10] regarding NERC standards enhancements to address inverter-based resource risk issues raised by the ERO. International experience has proved that open-ended process-oriented requirements are insufficient and that more stringent functional specifications and performance requirements are needed for systems with increasing levels of inverter-based resources. Enhancements to the NERC standards must be fast-tracked, to the extent possible, recognizing the criticality and urgency of risks posed to BPS reliability.
- **Risk-Based Compliance Enhancements:** ERO Enterprise Compliance Monitoring and Enforcement Program (CMEP) activities will need to account for the significantly elevated risk that IBRs pose to BPS reliability and take necessary actions to assure entities are adequately complying with all

[10] https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20221117-3114&optimized=false

associated NERC standards. NERC has issued and will continue to refine CMEP Practice Guides[11] in this area to support Regional auditing teams.

- **Registration Focus:** Industry is increasingly challenged with addressing reliability issues for unregistered[12] inverter-based resources, and those resources are reaching critical mass in some parts of the country. The lack of requirements currently imposed on those resources creates local and regional reliability risks to the BPS in aggregate. This issue compounds in many areas with the growing presence of distributed energy resources (DERs) connected to the distribution system. NERC will strengthen its advocacy, particularly with State regulators and the National Association of Regulatory Utility Commissioners (NARUC). Furthermore, NERC has submitted a work plan to FERC to address registration of inverter-based resources more comprehensively.[13] They are subject to appropriate standards to ensure adequate levels of reliability of the BES moving forward. NERC can collaboratively work with industry to identify applicable owners and associated requirements.
- **Cyber Security Concerns:** Cyber security continues to be a top concern for industry, particularly with an increasing amount of generation that is not subject to the NERC Critical Infrastructure Protection (CIP) standards. Concerns include the growing level of DERs often connected directly to the Internet as well as unregistered inverter-based resources on the BPS that are also not subject to the NERC CIP Standards; the introduction of DER Aggregators, their control of many DERs across a large footprint, and their lack of applicability to the NERC CIP Standards; the prevalence of vendor/manufacturer remote access and potential cross-border control center operations; and securing the overall electricity ecosystem for this vastly changing resource mix. As part of the Security Integration Strategy,[14] NERC is supporting industry with advances in DER cyber security and recommended security practices for unregistered inverter-based resources on the BPS.
- **Looking to the Future:** It is imperative that industry not let the challenges of today (e.g., fundamental and reliable provision of essential reliability services from inverter-based resources) deter from the focus of system integration and interoperability issues ahead. Example topics include the need for system strength and stability measures (e.g., identifying the need for "grid forming" inverter technology, synchronous condensers, etc.), impacts to BPS protection systems, rapid growth of offshore wind, and resourcing large-scale EMT studies. Beyond the engineering, design, planning, and operation of these resources, changes to resource and energy adequacy due the variable nature of these resources (mostly renewable energy resources) also pose BPS reliability risks that must be adequately addressed moving forward.

It is important to recognize that the challenges industry faces regarding BPS-connected inverter-based resources are not due to shortcomings of the technology, but rather the shortcomings of processes and the lack of harmonized comprehensive standards applicable as early as the interconnection process and throughout the life cycle of an inverter-based resource project. NERC continues to execute its *Inverter-Based Resource Strategy*[15] to assure the effective and efficient reduction of risks posed to the BPS in this area.

[11] https://www.nerc.com/pa/comp/guidance/Pages/default.aspx
[12] Those resources connected to the BPS yet do not meet the BES definition.
[13] https://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/IBR%20Registration%20Work%20Plan_final.pdf
[14] https://www.nerc.com/comm/Documents/NERC_Security_Integration_Strategy_2022.pdf
[15] https://www.nerc.com/comm/Documents/NERC_IBR_Strategy.pdf