141 FERC ¶ 61,045
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part 40

[Docket No. RM12-22-000]

Reliability Standards for Geomagnetic Disturbances

(Issued October 18, 2012)

AGENCY: Federal Energy Regulatory Commission.

ACTION: Notice of Proposed Rulemaking.

SUMMARY: Under section 215 of the Federal Power Act, the Federal Energy Regulatory Commission (Commission) proposes to direct the North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization, to submit for approval Reliability Standards that address the impact of geomagnetic disturbances (GMD) on the reliable operation of the Bulk-Power System. The Commission proposes to do this in two stages. In the first stage, the Commission proposes to direct NERC to file, within 90 days of the effective date of a final rule in this proceeding, one or more Reliability Standards that require owners and operators of the Bulk-Power System to develop and implement operational procedures to mitigate the effects of GMDs consistent with the reliable operation of the Bulk-Power System. In the second stage, the Commission proposes to direct NERC to file, within six months of the effective date of a final rule in this proceeding, one or more Reliability Standards that require owners and operators of the Bulk-Power System to conduct initial and on-going

assessments of the potential impact of GMDs on Bulk-Power System equipment and the Bulk-Power System as a whole. Based on those assessments, the Reliability Standards would require owners and operators to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. This plan cannot be limited to operational procedures or enhanced training alone, but should, subject to the needs indentified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, or location of specific equipment. These strategies could include automatically blocking geomagnetically induced currents from entering the Bulk-Power System, instituting specification requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to retrofit. This second stage would be implemented in phases, focusing first on the most critical Bulk-Power System assets.

DATES: Comments are due **[INSERT DATE 60 days after publication in the FEDERAL REGISTER].**

ADDRESSES: Comments, identified by docket number, may be filed in the following ways:

- Electronic Filing through http://www.ferc.gov. Documents created electronically using word processing software should be filed in native applications or print-to-PDF format and not in a scanned format.

- Mail/Hand Delivery: Those unable to file electronically may mail or hand-deliver comments to: Federal Energy Regulatory Commission, Secretary of the Commission, 888 First Street, NE, Washington, DC 20426.

Instructions: For detailed instructions on submitting comments and additional information on the rulemaking process, see the Comment Procedures Section of this document.

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SUPPLEMENTARY INFORMATION:

141 FERC ¶ 61,045
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Reliability Standards for Geomagnetic Disturbances Docket No. RM12-22-000

NOTICE OF PROPOSED RULEMAKING

(Issued October 18, 2012)

1. Pursuant to section 215(d)(5) of the Federal Power Act (FPA),[1] the Federal Energy Regulatory Commission (Commission) proposes to direct the North American Electric Reliability Corporation (NERC), the Commission-certified Electric Reliability Organization (ERO), to file for approval with the Commission Reliability Standards (GMD Reliability Standards) that address the risks posed by geomagnetic disturbances (GMD) to the reliable operation of the Bulk-Power System.[2] The Commission proposes to direct NERC to develop the GMD Reliability Standards in two stages. In the first stage, within 90 days of the effective date of a final rule in this proceeding, NERC would file one or more proposed Reliability Standards that require owners and operators of the Bulk-Power System to develop and implement operational procedures to mitigate the

[1] 16 U.S.C. 824o(d)(5) (2006).

[2] "A geomagnetic disturbance occurs when the magnetic field embedded in the solar wind is opposite that of the earth. This disturbance, which results in distortions to the earth's magnetic field, can be of varying intensity and has in the past impacted the operation of pipelines, communications systems, and electric power systems." Oak Ridge National Laboratory, *Electric Utility Industry Experience with Geomagnetic Disturbances* at xiii (1991), *available at* http://www.ornl.gov/~webworks/cpr/v823/rpt/51089.pdf.

effects of GMDs consistent with the reliable operation of the Bulk-Power System. In the second stage, within six months of the effective date of a final rule in this proceeding, NERC would file one or more proposed Reliability Standards that require owners and operators of the Bulk-Power System to conduct initial and on-going assessments of the potential impact of GMDs on Bulk-Power System equipment and the Bulk-Power System as a whole. Based on those assessments, the Reliability Standards would require owners and operators to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD.[3] This plan cannot be limited to operational procedures or enhanced training alone, but should, subject to the needs indentified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, or location of specific equipment. These strategies could include automatically blocking geomagnetically induced currents (GICs) from entering the Bulk-Power System, instituting specification requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to retrofit.[4] This second stage would be implemented in phases, focusing first on the most critical Bulk-Power System assets.

[3] 16 U.S.C. 824o(a)(4) (2006).

[4] Some examples of automatic blocking include series line capacitors, transformer neutral GIC blocking and/or reduction devices, and selective tripping of vulnerable

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2. We take this action based on government-sponsored studies and NERC studies that conclude that GMD events can have an adverse, wide-area impact on the reliable operation of the Bulk-Power System.[5] In a 2010 study prepared for the Commission, Department of Energy, and Department of Homeland Security, the Oak Ridge National Laboratory reported that GMD events can develop quickly over large geographic footprints, having the capability to produce geographically-large outages and significant damage to Bulk-Power System equipment.[6]

3. The seriousness of the risk posed by GMDs to the reliable operation of the Bulk-Power System was expressed at a Technical Conference held on April 30, 2012.[7] At the Technical Conference, several panelists indicated that severe GMD events could potentially compromise the reliable operation of the Bulk-Power System, with some

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assets. Automatic blocking measures can also include the use of relays that can be set so that they are activated only when needed.

[5] *See*, *e.g.,* The Oak Ridge National Laboratory prepared a study consisting of six technical reports (collectively, "Oak Ridge Study") on the effects of electromagnetic pulses on the Bulk-Power System. *Available at* http://www.ornl.gov/sci/ees/etsd/pes/ferc_emp_gic.shtml; North American Electric Reliability Corp., 2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbances on the Bulk Power System at 85 (February 2012) (*NERC Interim GMD Report*), *available at* http://www.nerc.com/files/2012GMD.pdf; North American Electric Reliability Corp., *High-Impact, Low-Frequency Event Risk to the North American Bulk Power System* at 68 (June 2010) (*HILF Report)*, *available at* http://www.nerc.com/files/ HILF.pdf.

[6] Oak Ridge National Laboratory, *Electromagnetic Pulse: Effects on the U.S. Power Grid:Meta-R-319* at pages 1-30, 1-31, 4-1 (January 2010) (*Oak Ridge Study 319 Report*), *available at* http://www.ornl.gov/sci/ees/etsd/pes/pubs/ferc_Meta-R-319.pdf.

[7] Written statements presented at the Technical Conference, post-Technical Conference comments, and Technical Conference transcript are accessible through the Commission's eLibrary document retrieval system in Docket No. AD12-13-000.

noting as an example the GMD-induced disruption of the Hydro-Québec grid in 1989.[8] At the Technical Conference, panelists stated that the current 11-year solar activity cycle is expected to hit its maximum activity in 2013 and large solar events often occur within four years of such a cycle maximum.[9] While strong GMDs are infrequent events, their potential impact on the reliable operation of the Bulk-Power System (e.g., widespread blackouts) requires Commission action under section 215(d)(5) of the FPA.[10]

[8] *See*, *e.g.*, Statement of Scott Pugh, U.S. Department of Homeland Security at 2 (citing 1989 Hydro-Québec blackout); Statement of Frank Koza, PJM Interconnection, L.L.C. at 1 ("The combination of half-cycle transformer saturation and increased reactive power consumption can lead to voltage collapse and blackouts if not properly managed."); Statement of John Kappenman at 8 ("The bulk power system is the nation's most important critical infrastructure and unlike other threats, a severe geomagnetic storms [sic] can impose a near simultaneous nationwide crippling threat to this vital infrastructure."); Statement of Gerry Cauley, NERC at 1 ("Previous examples, such as the 1989 event in Hydro Québec demonstrate that severe solar storms represent a serious risk that can challenge the reliability of the bulk power system.").

[9] April 30, 2012 Technical Conference Tr. 84:14-19 (Pugh); 106:9-15, 169:1-19 (Murtagh).

[10] 16 U.S.C. 824o(d)(5); *see also Transmission Relay Loadability Reliability Standard*, 134 FERC ¶ 61,127, at P 25 (2011) (explaining that under section 215(d)(5) "the Commission, and not just the ERO, has the responsibility and authority to identify 'specific matters' that it considers appropriate to carry out section 215. Section 215 establishes a paradigm by which both the Commission and the ERO are responsible for identifying reliability gaps—the ERO through its Reliability Standards development process, where it can independently identify areas of concern and develop Standards to address them; and the Commission through its review of proposed Reliability Standards and authority to direct modifications or new Standards that address specific issues necessary to effectuate the purposes of section 215.").

4. Currently, GMD vulnerabilities are not adequately addressed in the Reliability Standards.[11] This constitutes a reliability gap because, as discussed below, GMD events can cause the Bulk-Power System to collapse suddenly and can potentially damage the Bulk-Power System.

5. GMD events affect the Bulk-Power System by introducing geomagnetically-induced currents[12] that can cause "half-cycle saturation" of certain high-voltage Bulk-Power System transformers.[13] Half-cycle saturation of transformers can lead to increased consumption of reactive power and creation of disruptive harmonics that can cause the sudden collapse of the Bulk-Power System.[14] Further, half-cycle saturation from GICs can potentially damage Bulk-Power System transformers because of overheating.[15]

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[11] NERC Reliability Standard IRO-005-3a (Reliability Coordination — Current Day Operations), Requirement R3, is the only existing requirement that discusses GMDs. Requirement R3 requires reliability coordinators to make transmission operators and balancing authorities aware of GMD forecast information and assist as needed in the development of response plans, but it does not require steps for mitigating the effects of GMD events.

[12] GIC is an electrical current created by a solar event that appears as direct current to the bulk electric system. North American Electric Reliability Council, *March 13, 1989 Geomagnetic Disturbance* at 36 (1989), *available at* http://www.nerc.com/files/1989-Quebec-Disturbance.pdf. Automatic blocking prevents or reduces GICs flows into protected Bulk-Power System components without operator intervention. *NERC Interim GMD Report* at 73.

[13] NERC Interim GMD Report at iii-iv. Half-cycle saturation is an abnormal operating condition whereby a transformer operates outside nominal voltage design values, saturating the transformer core with magnetic flux and forcing magnetic flux into other parts of the transformer. *Id.* at 25.

[14] *Id.* at 3 ("GMD can have … a wide range of impacts on power apparatus and power system operations. The effects on apparatus range from nuisance events, such as tripping of electrical equipment, radio interference, and control malfunctions, to large-

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Permanent damage to large transformers due to GICs can lead to restoration delays for the power grid.[16] For example, the Oak Ridge Study assessed the effects of a "1-in-100 year" geomagnetic storm on the modern Bulk-Power System.[17] The Oak Ridge Study simulation concluded that such an event could put a significant number of Bulk-Power System transformers at risk for failure or permanent damage.[18] The Oak Ridge Study simulation also found that the effects of a GMD event may be substantially larger if it

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scale events, such as voltage and reactive power fluctuations, local disruption of service, limited equipment failure, and potential voltage instability resulting in uncontrolled cascading of the bulk power system.").

[15] While disagreements exist as to the likely severity of transformer damage from GMDs compared with the likelihood of voltage collapse due to increased reactive power absorption arising from GMDs, there appears to be a consensus that GMDs can cause at least some damage to Bulk-Power System transformers. *See*, *e.g.*, Comments of the North American Electric Reliability Corporation, Docket No. AD12-13-000, at 5 (filed May 21, 2012) ("Though the most likely result is voltage collapse, the GMD Task Force members agreed that, depending on the transformer health, design, geology and geomagnetic latitude, geomagnetic induced current flows can result in transformer loss-of-life, and may ultimately result in the failure of some transformers.").

[16] *Oak Ridge Study 319 Report* at pages 4-1, 4-3 ("The recovery could plausibly extend into months in many parts of the impacted regions … These multi-ton apparatus [transformers] generally cannot be repaired in the field, and if damaged in this manner, they need to be replaced with new units, which have manufacture lead times of 12 months or more in the world market."); NERC Interim GMD Report at iv ("[R]estoration times for system collapse due to voltage instability would be a matter of hours to days, while replacing transformers requires long-lead times (a number of months) to replace or move spares into place, unless they are in a nearby location. Therefore, the failure of a large numbers [sic] of transformers would have considerable impacts on portions of the system.").

[17] *Oak Ridge Study 319 Report* at page 3-22.

[18] *Id*. at page 1-14, Tables 4-1, 4-2, 4-3 (listing numbers of at-risk transformer).

occurred at lower latitudes.[19] Estimates prepared by the National Research Council of the National Academies concluded that these events have the potential to cause wide-spread, long-term losses with economic costs to the United States estimated at $1-2 trillion and a recovery time of four to ten years.[20] The NERC Interim GMD Report concluded, on the other hand, that the worst-case scenario is "voltage instability and subsequent voltage collapse," and cites as an example the 1989 Hydro-Québec blackout.[21] While the conclusions of these reports differ significantly, our proposed action is warranted by even the lesser consequence of a projected widespread blackout without long-term, significant damage to the Bulk-Power System. Taking steps to prevent such blackouts is consistent with maintaining the reliable operation of the Bulk-Power System.[22]

6. Given the potentially severe, wide-spread impact to the reliable operation of the Bulk-Power System from GMD events and the absence of existing Reliability Standards to address it, the Commission proposes to direct the ERO to file with the Commission for

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[19] *Id.* at pages 3-25, 3-26.

[20] National Research Council of the National Academies, *Severe Space Weather Events—Understanding Societal and Economic Impacts: A Workshop Report* at 4 (2008) (*NAS Workshop Report*), *available at* http://www.nap.edu/catalog/12507.html.

[21] NERC Interim GMD Report at 69.

[22] 16 U.S.C. 824o(a)(4) ("The term 'reliable operation' means operating the elements of the bulk-power system within equipment and electric system thermal, voltage, and stability limits so that instability, uncontrolled separation, or cascading failures of such system will not occur as a result of a sudden disturbance, including a cybersecurity incident, or unanticipated failure of system elements.").

approval Reliability Standards that address this reliability gap. In proposing to address the risks posed by GMDs in two stages, the Commission finds that there are Reliability Standards that the ERO can develop and file quickly (i.e., requiring GMD operational procedures) to mitigate the effects of GMDs while it develops other Reliability Standards that require owners and operators of the Bulk-Power System to assess the potential impact of GMDs on Bulk-Power System equipment and the Bulk-Power System as a whole. Based on those assessments, the Reliability Standards would require owners and operators to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. This plan cannot be limited to operational procedures or enhanced training alone, but should, subject to the needs indentified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, or location of specific equipment. These strategies could include automatically blocking geomagnetically induced currents from entering the Bulk-Power System, instituting specification requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to retrofit.[23]

7. We recognize that, depending on the results of the initial and on-going assessments that would be required under this proposed rule, there could be substantial costs associated with some measures to protect against damage to the Bulk-Power System

[23] *See infra* PP 34-36.

from GMDs.[24] In determining that it is appropriate to issue this proposed rule, however, we have compared such costs against the societal harms, including the potential costs of equipment damage or prolonged blackouts, that could result from taking no action.[25]

I. Background

A. Section 215 and Mandatory Reliability Standards

8. Section 215 of the FPA requires the Commission to certify an ERO to develop mandatory and enforceable Reliability Standards, subject to Commission review and approval.[26] Once approved, the Reliability Standards may be enforced in the United States by the ERO, subject to Commission oversight, or by the Commission independently.

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[24] For example, estimates for installing blocking devices on transformers range from $100,000 to $500,000 for each affected transformer. *See* Foundation for Resilient Societies, Comments on Advance Notice of Proposed Rulemaking (ANPR) of the Nuclear Regulatory Commission Relating to the Prevention and Mitigation of Station Blackout, filed in Docket No. AD12-13-000, at 13 (May 4, 2012) (citing $500,000 installed costs per transformer); MITRE Corp., Impacts of Severe Space Weather on the Electric Grid, at 66 (November 2011) (citing $100,000 cost for neutral-current-blocking-capacitors per transformer), *available at* http://www.fas.org/irp/agency/dod/jason/spaceweather.pdf.

[25] For example the estimated total cost of the August 2003 four-day blackout in the United States is between $4 billion and $10 billion, with the Department of Energy calculating the total cost to be $6 billion. Electricity Consumers Resource Council, The Economic Impacts of the August 2003 Blackout, *available at* http://www.elcon.org/Documents/EconomicImpactsOfAugust2003Blackout.pdf. *See also supra* P 5 (citing estimates by the National Research Council of the National Academies of potentially $1-2 trillion in economic costs from a severe GMD event).

[26] 16 U.S.C. § 824o (2006).

9. Pursuant to section 215(d)(5) of the FPA, the Commission has the authority, upon its own motion or upon complaint, to order the ERO to submit to the Commission a proposed Reliability Standard or a modification to a Reliability Standard that addresses a specific matter if the Commission considers such a new or modified Reliability Standard appropriate to carry out section 215 of the FPA.[27]

B. Studies of GMD Events on the Bulk-Power System

10. The impact of GMDs on the Bulk-Power System has been evaluated in several government-sponsored studies and NERC reports. The EMP Commission issued reports assessing the threat to the United States from Electromagnetic Pulse (EMP) attack in 2004 and 2008, which also addressed the effects of geomagnetic storms on the electric power infrastructure.[28] The NAS Workshop Report addressing the impact of severe space weather events was released in 2008. The Oak Ridge National Laboratory issued the Oak Ridge Study on the effects of electromagnetic pulses on the Bulk-Power System in January 2010. The NERC HILF Report on high-impact, low-frequency risks to the Bulk-Power System was issued in June 2010.[29] In February 2012, NERC issued the NERC Interim GMD Report evaluating the effects of GMDs on the Bulk-Power System.

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[27] 16 U.S.C. 824o(d)(5); 18 CFR 39.6(f) (2012).

[28] These reports are accessible at the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack website at http://www.empcommission.org/.

[29] The HILF Report was prepared by NERC, Department of Energy, and a steering committee comprised of industry and risk experts and was approved by the NERC Board of Trustees on May 17, 2010. *HILF Report* at 2.

11. The Commission conducted a staff-led Technical Conference on April 30, 2012 to discuss the effects of GMDs on the reliable operation of the Bulk-Power System. NERC, government agencies, industry stakeholders, and other interested entities attended the Technical Conference and submitted post-Technical Conference comments.

C. Effects of GMD Events on the Bulk-Power System

12. The interaction of the Earth's magnetic field and solar events can cause low frequency GICs to flow along the surface of the Earth and in the oceans. Reliability issues arise when GICs enter the Bulk-Power System from the Earth. Since many Bulk-Power System transformers are grounded, the GIC appears as electrical current to the Bulk-Power System and flows through the ground connection and conductors, such as transformers and transmission lines.[30]

13. GICs can cause transformer cores to become "saturated," resulting in loss of reactive power (VARs), the introduction of harmonic distortions, and possible physical damage to the transformer.[31] GICs enter the Bulk-Power System through the grounded neutrals of transformers and are responsible for forcing their metal cores into saturation.[32]

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[30] Oak Ridge National Laboratory, *Electromagnetic Pulse: Effects on the U.S. Power Grid (Meta-R-322)* at page 1-1 (January 2010) (*Oak Ridge Study 322 Report*), *available at* http://www.ornl.gov/sci/ees/etsd/pes/pubs/ferc_Meta-R-322.pdf.

[31] *HILF Report* 70-71. Harmonics are currents or voltages with frequencies that are integer multiples of the fundamental power frequency (i.e., 60 Hz in the United States). *See* Northeast Power Coordinating Council, Inc. Glossary of Terms, *available at* https://www.npcc.org/Standards/Directories/Glossary%20of%20Terms.pdf. They can cause overcurrent relays to automatically trip components (e.g., capacitor banks and static VAR compensators) from service. *HILF Report* at 71. Automatic removal of such components can further exacerbate system voltages already reduced by the GIC-related

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A primary effect of saturation is the potential for transformer damage through the overheating of internal components.[33] Saturation is also responsible for secondary effects, such as the production of harmonics that are not present during normal Bulk-Power System operation and for substantially increasing the transformer's absorption of reactive power from the system, thus requiring significant amounts of additional voltage support to compensate for reactive power absorption. Harmonic production and reactive power absorption may interfere with normal system operations creating secondary effects on other Bulk-Power System facilities. These primary and secondary effects can occur almost simultaneously over a large geographic area, resulting in a multiple contingency outage that has the potential to cascade across the Bulk-Power System.[34]

14. The Oak Ridge Study identified factors that determine the severity of GMD events, including: (1) location and strength of the underlying solar event; (2) ground conductivity in the affected locations (i.e., the geology of the location); (3) orientation of

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absorption of reactive power.

[32] *Oak Ridge Study 322 Report* at pages 1-1, 7-11.

[33] *HILF Report* at 70 ("Transformers experience excessive levels of internal heating brought on by stray flux when GICs cause the transformer's magnetic core to saturate and spill flux outside the normal core steel magnetic circuit. Previous well-documented cases have noted heating failures that caused melting and burn-through of large-amperage copper windings and leads in these transformers (Figure 9)."); *Oak Ridge Study 319 Report* at page 2-29 ("Also of note from this particular [March 1989] storm is strong evidence that GIC-induced half-cycle saturation of transformers can indeed produce enough heat to severely damage or even destroy exposed large power transformers.").

[34] *HILF Report* at 71-72.

the transmission lines; (4) length of transmission lines; and (5) grid construction.[35] A solar disturbance can cause near-simultaneous, multi-point failures that can trigger collapse of the Bulk-Power System.[36]

II. Discussion

15. As discussed below, the Commission finds that there is a gap in the Reliability Standards regarding GMDs. Therefore, in order to carry out section 215 of the FPA, the Commission proposes to direct the ERO to develop and file for approval Reliability Standards that address the potentially severe, wide-spread impact of GMD events on the reliable operation of the Bulk-Power System.

16. We propose that the ERO develop and file the GMD Reliability Standards in two stages. In the first stage, within 90 days of the effective date of a final rule in this proceeding, the Commission proposes to direct NERC to file one or more Reliability Standards that require owners and operators of the Bulk-Power System to develop and implement operational procedures to mitigate the effects of GMDs consistent with the reliable operation of the Bulk-Power System. In the second stage, the Commission proposes to direct NERC to file one or more Reliability Standards, within six months of the effective date of a final rule in this proceeding, that require owners and operators of the Bulk-Power System to assess the impact of GMDs on Bulk-Power System equipment

[35] *Oak Ridge Study 319 Report* at page 2-5.

[36] *Id.* at pages 4-1, 4-2. One example cited in the Oak Ridge Study is the March 13, 1989 solar disturbance that triggered the collapse of the Hydro-Québec power grid, which went from normal to a situation where it sustained seven contingencies in an elapsed time of 57 seconds. *Id.*

and the Bulk-Power System as a whole. Based on those assessments, the Reliability Standards would require owners and operators to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. This plan cannot be limited to operational procedures or enhanced training alone, but should, subject to the needs indentified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, or location of specific equipment. These strategies could include automatically blocking geomagnetically induced currents from entering the Bulk-Power System, instituting specification requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to retrofit.[37]

17. In proposing to direct the ERO to submit Reliability Standards that address the impact of GMD events on the reliable operation of the Bulk-Power System, we are not proposing specific requirements or otherwise pre-judging what the ERO may eventually submit. Instead, we identify concerns that we believe should be addressed in any GMD Reliability Standards. We expect the ERO to support its proposed Reliability Standards and explain how they address the Commission's concerns.

[37] The second stage Reliability Standards would not require owners and operators of the Bulk-Power System to protect the Bulk-Power System beyond what is found to be required based on the initial and ongoing assessments.

A. Reliability Standards Requiring Operational Procedures

18. Requiring operational procedures, while not a complete solution, constitutes a first step to addressing the GMD reliability gap because they can be implemented relatively quickly.[38] The Commission does not propose to require the ERO or owners and operators of the Bulk-Power System to adopt any particular operational procedures. Owners and operators of the Bulk-Power System are the most familiar with the equipment and system configurations. Accordingly, we propose that the ERO file one or more Reliability Standards requiring owners and operators of the Bulk-Power System to develop and implement operational procedures to mitigate the effects of GMDs consistent with the reliable operation of the Bulk-Power System based on the following guidance.

19. Operational procedures may help alleviate abnormal system conditions due to transformer absorption of reactive power during GMD events, helping to stabilize system voltage swings, and may potentially isolate some equipment from being damaged or misoperated. The NERC Interim GMD Report identifies examples of operational procedures to mitigate GMD events (i.e., the effects of GICs), including: reduction of equipment loading (e.g., by starting off-line generation), unloading the reactive load of operating generation, reductions of system voltage, and system and/or equipment

[38] NERC Interim GMD Report at 79 ("Operating procedures are the quickest way to put in place actions that can mitigate the adverse effects of GIC on system reliability … Both system operating and transmission owner organizations need to have appropriate procedures and training in place.").

isolation through reconfiguration of the transmission system.[39] Some entities already have operational procedures to mitigate the effect of GICs on the Bulk-Power System utilizing system resources.[40] The Commission expects that the ERO and owners and operators of the Bulk-Power System will draw on industry's experience in developing and implementing existing operational procedures. Given that experience, we propose to direct NERC to file, within 90 days of the effective date of a final rule in this proceeding, proposed Reliability Standards that require the development and implementation of operational procedures. While this deadline is aggressive, mandatory and enforceable Reliability Standards requiring owners and operators to implement operational procedures should be established quickly to afford some level of uniform protection to the Bulk-Power System against GMD events. As discussed above, the impact of GMDs on the Bulk-Power System has been studied extensively for many years, laying the foundation for the prompt development of these first stage Reliability Standards. Moreover, the fact that operational procedures are already in place in some areas should allow for faster development and implementation of these Reliability Standards.

20. While the proposed Reliability Standards should not necessarily specify what operational procedures must be adopted, the ERO should give owners and operators of

[39] NERC Interim GMD Report at 80-81.

[40] *See*, *e.g.*, PJM Interconnection, L.L.C., Manual 13: Emergency Operations at 47, *available at* http://www.pjm.com/~/media/documents/manuals/m13.ashx; Northeast Power Coordinating Council, Inc., Procedures for Solar Magnetic Disturbances Which Affect Electric Power Systems, *available at* https://www.npcc.org/Standards/Procedures/c-15.pdf.

the Bulk-Power System guidance as to what procedures have been or are expected to be effective in mitigating the effects of GMDs consistent with the reliable operation of the Bulk-Power System. Moreover, the proposed Reliability Standards should address the coordination of operational procedures among responsible entities across regions.[41] Since there could be potential equipment damage resulting from a GMD event, the proposed Reliability Standards should also address operational procedures for restoring GMD-impacted portions of the Bulk-Power System that take into account the potential for equipment that is damaged or out-of-service for an extended period of time.

21. We do not propose to direct a specific implementation schedule for the proposed Reliability Standards, but the Commission encourages the ERO to require owners and operators of the Bulk-Power System to implement the required operational procedures 90 days after Commission approval of the Reliability Standards. Following implementation, the Commission proposes to require NERC to provide periodic reports assessing the effectiveness of the operational procedures in mitigating the effects of GMD events. In addition, NERC should periodically review the required operational procedures and recommend to owners and operators that they incorporate lessons-learned and new research findings.

22. In addition to developing Reliability Standards that require operational procedures during the first stage, the Commission also proposes to accept aspects of the "Initial

[41] NERC Interim GMD Report at 79 ("The [operating] procedures of these organizations need to be coordinated with each other and with their neighboring organizations.").

Actions" proposal set forth in NERC's May 21, 2012 post-Technical Conference comments. Specifically, NERC proposed to "identify facilities most at-risk from severe geomagnetic disturbance" and to "conduct wide-area geomagnetic disturbance vulnerability assessment."[42] As noted in NERC's comments regarding the vulnerability assessments, special attention would be given to evaluating critical transformers (e.g., step-up transformers at large generating facilities). We agree with NERC that critical Bulk-Power System facilities should be evaluated for GMD vulnerability as an initial action. In addition, as part of the initial action, special attention should be given to those Bulk-Power System facilities that provide service to critical and priority loads.[43] The Commission, therefore, proposes to direct NERC to conduct this "initial action" simultaneously with the development and implementation of the first stage GMD Reliability Standards. The Commission seeks comment from NERC and other interested entities on all aspects of this proposal.

[42] NERC Comments at 8-9 ("As the first step in identifying the risk of geomagnetic disturbance to the bulk power system, NERC intends to complete a system-wide vulnerability assessment … special attention will be given to the evaluation of critical transformers, such as generator step-up units at large generating facilities … a high level review will be conducted to identify and classify the at-risk population based on existing peer-reviewed research. This assessment will be based on a high level screening approach that will include transformer design, condition, geology and geomagnetic location.").

[43] The NERC Severe Impact Resilience Task Force identified critical and priority loads in a report. *See* Severe Impact Resilience: Considerations and Recommendations at 26 (Accepted by NERC Board of Trustees on May 9, 2012), *available at* http://www.nerc.com/docs/oc/sirtf/SIRTF_Final_May_9_2012-Board_Accepted.pdf.

B. Second Stage Reliability Standards

23. To address GMDs comprehensively, the Commission proposes to direct NERC to develop, in a second stage, Reliability Standards that require owners and operators of the Bulk-Power System to conduct initial and on-going assessments of the potential impact of GMDs on Bulk-Power System equipment and on the Bulk-Power System as a whole. Based on those assessments, the Reliability Standards would require owners and operators to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. This plan cannot be limited to operational procedures or enhanced training alone, but should, subject to the needs indentified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, or location of specific equipment. These strategies could include automatically blocking geomagnetically induced currents from entering the Bulk-Power System, instituting specification requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to retrofit. While the Commission proposes to direct the ERO to submit the proposed second stage Reliability Standards within six months of the effective date of a final rule in this proceeding, the Commission seeks comment on the feasibility of a six-month deadline.

24. We propose to direct the filing of these second stage GMD Reliability Standards because of two concerns with relying on operational procedures alone: (1) owners and operators of the Bulk-Power System may not have enough time to initiate effective

operating procedures after being warned of a GMD event; and (2) operational procedures may not prevent permanent damage to Bulk-Power System equipment.[44] Current GMD forecasting methods provide limited time for operators to react once a GMD warning is issued.[45] Even with enough time to react, the Oak Ridge Study found that, given a large enough GMD event, operational procedures are unlikely to provide the substantial levels of GIC reduction needed to limit the potential for permanent damage to transformers.[46] The Oak Ridge Study and the HILF Report also found that widespread damage to Bulk-Power System transformers could result in prolonged outages.[47]

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[44] NERC Interim GMD Report at 10 ("These warning can be received as short as 30 minutes before the onset of an impending geomagnetic storm."). At the April 30, 2012 Technical Conference, Mr. Murtagh, Program Coordinator at the National Oceanic and Atmospheric Administration's Space Weather Prediction Center, stated that a warning is issued when a GMD event reaches the NASA Advanced Composition Explorer (ACE) satellite and at that point, in some cases, it could be 20 or 30 minutes before the event reaches the Earth's magnetic field. April 30, 2012 Technical Conference Tr. 170:5-22 (Murtagh).

[45] Mr. Pugh, from the U.S. Department of Homeland Security's Interagency Programs Office Science & Technology Directorate, stated that the operators in the 1989 Hydro-Québec blackout only had 90 seconds to react, which was insufficient to "prevent a massive blackout and significant equipment damage." April 30, 2012 Technical Conference Tr. 12:4-7 (Pugh).

[46] *Oak Ridge Study 322 Report* at pages ix and 1-1.

[47] *HILF Report* at 12 ("The physical damage of certain system components (e.g. extra-high-voltage transformers) on a large scale, as could be effected by any of these threats, could result in prolonged outages as procurement cycles for these components range from months to years."); *Oak Ridge Study 319 Report* at pages 2-33, 2-34 ("An especially large storm or GIC event could plausibly create the potential for widespread failure of many exposed transformers and hamper rapid restoration capabilities. In extreme cases, where replacements may take months, a situation may exist where the demand for electric service can only be partially supplied, raising the prospect of rationing and rotating blackouts to regions that are unable to be fully served.").

25. We recognize that the NERC Interim GMD Report concludes that a prolonged blackout due to extensive damage to Bulk-Power System transformers is less likely than voltage instability due to increased reactive power consumption and loss of reactive power support, which can lead to blackouts like the 1989 Hydro-Québec event.[48] The Commission's proposed two-stage approach recognizes this difference by focusing first on the development of Reliability Standards requiring operational procedures in a relatively short time frame. The Commission proposes to give NERC and owners and operators of the Bulk-Power System more time to perform, in the second stage, initial and on-going assessments. Based on those assessments, the Reliability Standards would require owners and operators to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. This plan cannot be limited to operational procedures or enhanced training alone, but should, subject to the needs indentified in the assessments, contain strategies for protecting against the potential impact of GMDs based on factors such as the age, condition, technical specifications, or location of specific equipment. These strategies could include automatically blocking geomagnetically induced currents from entering the Bulk-Power System, instituting specification requirements for new equipment, inventory management, and isolating certain equipment that is not cost effective to retrofit. Moreover, although the NOPR proposes that the second stage

[48] NERC Interim GMD Report at vi.

Reliability Standards be filed within six months of the effective date of the final rule, we seek comment on the feasibility of that deadline.

26. Below, we offer guidance on the assessments of Bulk-Power System vulnerability to GMDs and potential measures for automatically protecting critical or vulnerable components. In addition, recognizing the potential for substantial investments of time and resources to implement these Reliability Standards, we offer guidance on an implementation schedule, which will likely consist of an extended, multi-phase process. The Commission seeks comment from NERC and other interested entities on all aspects of this proposal.

1. GMD Vulnerability Assessments of the Bulk-Power System

27. The Commission proposes to direct the ERO to develop Reliability Standards that require owners and operators of the Bulk-Power System to conduct vulnerability assessments to determine how critical or vulnerable Bulk-Power System components react to simulated GICs of varying intensities.[49] The Commission proposes to direct the ERO to consider the following parameters as it develops the Reliability Standards.[50]

[49] To accurately simulate the impact of GMDs on the Bulk-Power System, the assessments should consider the impact of GICs that may enter the system through transformers that are not treated as part of the bulk electric system and any impact that the non-bulk electric system transformers may have on the reliability of the Bulk-Power System. We do not propose, however, that equipment falling outside of our jurisdiction would be required to be protected under the proposed Reliability Standard.

[50] The vulnerability assessments in the second phase Reliability Standards are distinct from the "initial action" evaluations, discussed above, which NERC proposed to do and we propose to have NERC conduct simultaneous with the development and implementation of the first phase Reliability Standards. We expect, however, that the

(continued…)

28. First, the Reliability Standards should contain uniform evaluation criteria for owners and operators to follow when conducting their assessments. As the Commission noted with respect to other reliability assessments, uniformity increases the accuracy of transmission system reliability assessments and consequently enhances overall reliability.[51]

29. Second, the assessments should, through studies and simulations, evaluate the primary and secondary effects of GICs on Bulk-Power System transformers, including the effects of GICs originating from and passing to other regions.

30. Third, the assessments should evaluate the effects of GICs on other Bulk-Power System equipment, system operations, and system stability, including the anticipated loss of critical or vulnerable devices or elements resulting from GIC-related issues.[52]

31. Fourth, in conjunction with assessments by owners and operators of their own Bulk-Power System components, wide-area or Regional assessments of GIC impacts should be performed. A severe GMD event can cause simultaneous stresses at multiple

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analyses performed in the "initial action" evaluations will be used to quickly identify and protect the most critical and vulnerable Bulk-Power System components once the second stage Reliability Standards become effective.

[51] *Mandatory Reliability Standards for the Bulk-Power System*, Order No. 693, FERC Stats. & Regs. ¶ 31,242, at P 1298, *order on reh'g*, Order No. 693-A, 120 FERC ¶ 61,053 (2007).

[52] The Oak Ridge Study assessment included GMD modeling, simulation and review of storm impacts, power grid GIC flows and reactive power demands, transformer heating and risk of potential damage to transformers. *See generally Oak Ridge Study 319 Report*.

locations on the Bulk-Power System, potentially resulting in a multiple-outage event.[53] In predicting GIC flows, it is necessary to take into consideration the network topology as an integrated whole (i.e., on a wide-area basis).[54]

32. Fifth, the assessments should be periodically updated, taking into account new facilities, modifications to existing facilities, and new information, including new research on GMDs, to determine whether there are resulting changes in GMD impacts that require modifications to Bulk-Power System mitigation schemes.

33. The Commission seeks comments from NERC and other interested entities on all aspects of this proposal.

2. Automatic GIC Blocking for Critical or Vulnerable Bulk-Power System Components

34. While we do not propose to require a particular solution in the second stage Reliability Standards to address GMDs, we expect that some assessments will demonstrate that automatic blocking is necessary in some instances. The Commission, above, proposes to direct the ERO to develop Reliability Standards that require owners and operators of the Bulk-Power System to develop and implement a plan so that instability, uncontrolled separation, or cascading failures of the Bulk-Power System, caused by damage to critical or vulnerable Bulk-Power System equipment, or otherwise, will not occur as a result of a GMD. Automatic blocking measures address the major concerns with relying exclusively on operational procedures to mitigate GMDs (i.e., the

[53] *Oak Ridge Study 319 Report* at pages A1-1, A1-2.

[54] *Id.* at page 1-17.

short period of time to react to a GMD event and the potential consequences of not reacting fast enough). Blocking can prevent the flow of GICs through power transformers and the Bulk-Power System.[55] Eliminating GICs in transformers prevents transformer core saturation and, thus, mitigates or prevents the effects of GMDs on the Bulk-Power System (i.e., transformer overheating, reactive power absorption, and harmonic generation).

35. The Commission does not propose to direct the ERO to require a particular automatic blocking technology, where blocking is necessary. Instead, the Commission proposes to direct the ERO to identify in the proposed Reliability Standards what would constitute appropriate automatic blocking measures. In defining what is an appropriate blocking measure, the ERO should address: (1) its feasibility and effectiveness; and (2) its ability to operate without adversely impacting the reliable operation of the Bulk-Power System. The Commission proposes that the Reliability Standards should include a means by which the ERO can verify that selected blocking measures are appropriate.

36. The use of automatic blocking devices, such as transmission line series capacitors and transformer neutral blocking, are possible measures.[56] These devices block or reduce the flow of GIC in a power grid.[57] Although not a means for blocking GICs, another possible option is to improve the "withstand" capability of Bulk-Power System

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[55] NERC Interim GMD Report at 73.

[56] *Oak Ridge Study 322 Report* at ix-x.

[57] *Id.*

components. The "withstand" capability, in this context, refers to a component's ability to withstand stresses imposed by GICs before suffering damage, but it does not prevent GICs from affecting the rest of the Bulk-Power System (e.g., it does not prevent the secondary effects of harmonics or increased reactive power consumption).[58] The ERO should consider whether the reliability goals of the proposed Reliability Standards can be achieved by a combination of automatic protection measures, including, for example, some combination of automatic blocking and improved "withstand" capability. In any event, the measures must be adequate to protect the reliability of the Bulk-Power System against the risks identified in the assessments.

37. The Commission seeks comments from NERC and other interested entities on all aspects of this proposal.

3. Implementation Schedule

38. The second stage Reliability Standards will likely require an extended, multi-phase implementation period given the time needed to conduct the required assessments and the time and cost of installing any required automatic protection measures. Although the Commission does not propose to direct the ERO to develop a specific implementation plan, we believe it would be appropriate for the proposed Reliability Standard to include an implementation schedule that requires owners and operators of the Bulk-Power System to prioritize implementation so that components considered vital to the reliable

[58] NERC Interim GMD Report at 67.

operation of the Bulk-Power System are provided with any necessary automatic protection measures in the earliest phase of the plan.[59]

39. The Commission seeks comments from NERC and other interested entities on an implementation plan.

III. Information Collection Statement

40. The Office of Management and Budget (OMB) regulations require approval of certain information collection requirements imposed by agency rules. Upon approval of a collection(s) of information, OMB will assign an OMB control number and an expiration date. Respondents subject to the filing requirements of an agency rule will not be penalized for failing to respond to these collections of information unless the collections of information display a valid OMB control number. The Paperwork Reduction Act (PRA) requires each federal agency to seek and obtain OMB approval before undertaking a collection of information directed to ten or more persons, or contained in a rule of general applicability.

41. The Commission is submitting these reporting requirements to OMB for its review and approval under section 3507(d) of the PRA. Comments are solicited on the Commission's need for this information, whether the information will have practical utility, ways to enhance the quality, utility, and clarity of the information to be collected,

[59] For example, critical Bulk-Power System equipment identified by NERC in the first stage "initial actions" assessments, discussed previously, should be protected in the earliest phase of the implementation plan.

and any suggested methods for minimizing the respondent's burden, including the use of automated information techniques.

42. The Public Reporting Burden and cost related to the proposed rule in Docket No. RM12-22-000 are covered by, and already included in, the existing FERC-725, Certification of Electric Reliability Organization; Procedures for Electric Reliability (OMB Control No. 1902-0225). FERC-725 includes the ERO's overall responsibility for developing Reliability Standards, such as the Reliability Standards for Geomagnetic Disturbances.

43. Internal review: The Commission has reviewed the proposed changes and has determined that the changes are necessary to ensure the reliability and integrity of the Nation's Bulk-Power System.

44. Interested persons may obtain information on the reporting requirements by contacting: Federal Energy Regulatory Commission, 888 First Street, NE, Washington, DC 20426 [Attention: Ellen Brown, Office of the Executive Director, e-mail: DataClearance@ferc.gov, Phone: (202) 502-8663, fax: (202) 273-0873]. Comments on the requirements of this rule may also be sent to the Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, DC 20503 [Attention: Desk Officer for the Federal Energy Regulatory Commission]. For security reasons, comments should be sent by e-mail to OMB at oira_submission@omb.eop.gov. Please reference OMB Control No. 1902-0225, FERC-725 and the docket number of this proposed rulemaking in your submission.

IV. Environmental Analysis

45. The Commission is required to prepare an Environmental Assessment or an Environmental Impact Statement for any action that may have a significant adverse effect on the human environment.[60] The Commission has categorically excluded certain actions from this requirement as not having a significant effect on the human environment. Included in the exclusion are rules that are clarifying, corrective, or procedural or that do not substantially change the effect of the regulations being amended.[61] The actions proposed here fall within this categorical exclusion in the Commission's regulations.

V. Regulatory Flexibility Act

46. The Regulatory Flexibility Act of 1980 (RFA)[62] generally requires a description and analysis of proposed rules that will have significant economic impact on a substantial number of small entities.

47. By only proposing to direct NERC, the Commission-certified ERO, to develop GMD Reliability Standards, this Notice of Proposed Rulemaking will not have a significant or substantial impact on entities other than NERC. The ERO develops and files with the Commission for approval Reliability Standards affecting the Bulk-Power System, which represents: (a) a total electricity demand of 830 gigawatts (830,000

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[60] *Regulations Implementing the National Environmental Policy Act of 1969*, Order No. 486, 52 FR 47897 (Dec. 17, 1987), FERC Stats. & Regs., Regulations Preambles 1986-1990 ¶ 30,783 (1987).

[61] 18 CFR 380.4(a)(2)(ii).

[62] 5 U.S.C. 601-612.

megawatts) and (b) more than $1 trillion worth of assets. Therefore, the Commission certifies that this Notice of Proposed Rulemaking will not have a significant economic impact on a substantial number of small entities.

48. Any Reliability Standards proposed by NERC in compliance with this rulemaking will be considered by the Commission in future proceedings. As part of any future proceedings, the Commission will make determinations pertaining to the Regulatory Flexibility Act based on the content of the Reliability Standards proposed by NERC.

VI. Comment Procedures

49. The Commission invites interested persons to submit comments on the matters and issues proposed in this notice to be adopted, including any related matters or alternative proposals that commenters may wish to discuss. Comments are due [**INSERT DATE 60 days after publication in the FEDERAL REGISTER**]. Comments must refer to Docket No. RM12-22-000, and must include the commenter's name, the organization they represent, if applicable, and their address in their comments.

50. The Commission encourages comments to be filed electronically via the eFiling link on the Commission's web site at http://www.ferc.gov. The Commission accepts most standard word processing formats. Documents created electronically using word processing software should be filed in native applications or print-to-PDF format and not in a scanned format. Commenters filing electronically do not need to make a paper filing.

51. Commenters that are not able to file comments electronically must send an original of their comments to: Federal Energy Regulatory Commission, Secretary of the Commission, 888 First Street NE, Washington, DC 20426.

52. All comments will be placed in the Commission's public files and may be viewed, printed, or downloaded remotely as described in the Document Availability section below. Commenters on this proposal are not required to serve copies of their comments on other commenters.

VII. Document Availability

53. In addition to publishing the full text of this document in the Federal Register, the Commission provides all interested persons an opportunity to view and/or print the contents of this document via the Internet through the Commission's Home Page (http://www.ferc.gov) and in the Commission's Public Reference Room during normal business hours (8:30 a.m. to 5:00 p.m. Eastern time) at 888 First Street, NE, Room 2A, Washington, DC 20426.

54. From the Commission's Home Page on the Internet, this information is available on eLibrary. The full text of this document is available on eLibrary in PDF and Microsoft Word format for viewing, printing, and/or downloading. To access this document in eLibrary, type the docket number excluding the last three digits of this document in the docket number field.

55. User assistance is available for eLibrary and the Commission's website during normal business hours from the Commission's Online Support at 202-502-6652 (toll free at 1-866-208-3676) or email at ferconlinesupport@ferc.gov, or the Public Reference

Room at (202) 502-8371, TTY (202) 502-8659. E-mail the Public Reference Room at public.referenceroom@ferc.gov.

By direction of the Commission.

Kimberly D. Bose,
Secretary.