FERC Reliability Technical Conference

Panel III: The Potential for Long-term and Large-Scale Disruptions to the Bulk-Power System

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On behalf of the North American Electric Reliability Corporation (NERC), I appreciate the Commission's focus on the potential for long-term and large-scale disruptions to the bulk-power system. As the Electric Reliability Organization (ERO), avoiding such disruptions is at the heart of our mission and the very foundation of the ERO Enterprise. NERC, and the Regional Entities which make up the ERO Enterprise, work with industry every day to identify risks to reliability, prioritize actions and implement mitigation strategies. This panel is an opportunity to review NERC's leadership concerning known and emerging threats posing the greatest risk to reliability.

At no point in modern history has the electricity sector experienced a period of such revolutionary change. The generation resource mix is undergoing a rapid transformation from large, remotely-located central station coal-fired and nuclear power plants, towards gas-fired, renewable variable energy, distributed energy, demand response, and distribution-centric resources. This transformation has implications for power delivery and is altering the operating characteristics of the BPS.

Risk Identification and Mitigation

To start, I will briefly describe NERC's risk identification process, and the role of industry. Two timeframes are used: Current and emerging risks.

Current risks are those that are either measured directly from experience of system performance, or lacking data or information, from other systems that use similar technology. Analysis of system performance captured in a number of system component availability data systems, along with independent performance analysis of security, enables NERC to examine trends and identify potential risks to reliability, establish priorities, and develop effective mitigation strategies to control reliability risks. The mitigations promote further risk assessment and mitigation efforts as well as help focus the work and resources of the ERO and the industry. NERC annually produces the State of Reliability Report, which has already been summarized in Panel I, so I will not go into much more detail here on the results.[1]

[1] *State of Reliability 2017*.

To identify emerging risks, in 2013, based on recommendations of the Reliability Issues Steering Committee, NERC's Board of Trustees requested that the Committee provide insights of high priority and medium priority risks to bulk power system reliability. These insights are used by the Board of Trustees, ERO Enterprise, and Technical Committees as input into strategic plans, work plans, and business plan and budget. Risks are identified and prioritized, and mitigation plans developed to ensure that, with industry's commitment, their residual risks are well managed.

The Reliability Issues Steering Committee is made up of participants from the Members Representative Committee, senior at-large industry members, and technical committee representatives. The Committee obtains insights into emerging risks to the reliable operation of the bulk power system through a number of ways: discussions with representatives from technical and standards committees, industry dialogue through a series of focused executive leadership interviews, the annual FERC Reliability Technical Conference, technical reports, assessments, and subject matter expertise of the committee members. Additionally, on a biennial basis, the Reliability Issues Steering Committee holds the Reliability Leadership Summit to bring together industry, regulators and academics to discuss the changing industry scenarios and potential risks to reliability.

Recently, the Reliability Issues Steering Committee reevaluated the issues of strategic importance to bulk power system reliability through industry input and the expertise of its members. The evaluation, which included the results from the March 2017 Reliability Leadership Summit, reaffirmed the risks identified in its previous Reliability Risk Priorities Report accepted by NERC's Board of Trustees in November of 2016:

- Cybersecurity Vulnerabilities
- Changing Resource Mix
- Bulk Power System Planning
- Resource Adequacy
- Loss of Situational Awareness
- Physical Security Vulnerabilities
- Extreme Natural Events
- Asset Management and Maintenance
- Human Performance and Skilled Workforce

The key observations from the Reliability Leadership Summit include 1) the pace of change of the resource mix is accelerating, 2) interdependencies between the energy and communication sectors is increasing, 3) increased complexity of system design, 4) maintenance and operations, and 5) the changing workforce skills required to maintain bulk power system reliability. Many of these share the same underlying drivers that further complicate the landscape and result in challenges in the identification of distinct mitigating actions.

I will review each of these observations at a high level.

Public policy, economic, and environmental factors continue to accelerate the pace of the changing resource mix. The speed of change differs across North America, and between market and non-market areas. The changing resource mix includes existing resources switching fuels to natural gas, as well as new combined-cycle gas turbine power plants and renewable energy resources replacing retiring coal, oil and, in some areas, nuclear resources. This reduces the diversity of fuels and increases the risk from the interdependencies between the electric and natural gas energy sectors.

The design and management the bulk power system becomes more complex as the resource mix changes:

- Power electronics and faster digital protective relays add complexity to all phases of the business that focus on the reliable operation of the bulk power system; modeling load and resources, planning, designing, operating and maintenance:
  - When asynchronous resources with inverter technology replace the synchronous generators which have large rotating masses, the system may be less capable to dampen the impacts from routine system disturbances (e.g., lightning strikes), increasing the potential for instability. Namely, the remaining synchronous resources may not be able to respond quick enough to offset the immediate imbalance between power supply and demand during these events. While the addition of batteries and high speed protection systems may mitigate this risk, they increase system complexity and the potential risk from equipment failures, routine system faults from the environment or implementation of ineffective control strategies.
  - The shift of resources to distributed renewable energy resources has added further complexity and uncertainty. These resources are generally interconnected to the power system through power inverters needed to convert energy characteristics from the sun or wind, for in-feed into bulk power system. The devices may need additional power electronics and faster digital protective relays to provide the essential reliability services required to stabilize the power system. NERC recently published a report identifying an issue concerning the settings on some inverters connected to utility-scale solar facilities.[2] Following analysis of an event involving the loss of approximately 1,200 MW of photovoltaic generation, NERC found that certain inverters are susceptible to erroneous tripping during a momentary system

[2] *Solar Loss Disturbance Report Uncovers Reliability Gap in Frequency Measurement Errors*.

disturbance. NERC's report discusses the reliability implications of this finding and making recommendations.

- Data access to maintain situational awareness, evaluate system performance, and plan for future needs must also be taken into account. For example, the design of the power system is becoming more reliant on communication networks that have the ability to transfer large amounts of data across local as well as wide area networks. This affects control centers and protection systems within a substation, while increasing their dependency on internal and external communication networks needed to maintain bulk power system reliability.

- The potential for common mode failures (e.g., loss of a major pipeline supply for generation, equipment failures from common system conditions, or concurrent cyber-attack on the electric grid) increases the potential for outages beyond current contingency planning.

- Human performance errors may also increase as system complexity with challenges in coordination between distribution and the BPS, and loss of operator situational awareness of locally controlled resources and load.

Each of these complexities affects the skills required by the workforce. For instance, the networking of substation equipment both changes and expands the skills required by field technicians interfacing with this equipment. Further, engineers need to understand each of the control systems interconnected to the power system, how they function and what settings must be adjusted to provide the dynamic and steady state response required under multiple system configurations to ensure reliability. System Operators will be provided additional power system data to evaluate the state of the power system and more options than traditional alternatives such as ramping resources or dispatching static reactive devices. The industry needs to be proactive in recognizing and developing the skills of the workforce to ensure continued reliability.

As you will hear in the next panel, grid security is inextricably linked to reliability. In other words, only with security may reliability be assured. There has not been any loss of load in North America that can be attributed to a cyber-attack. At the same time, the security landscape is dynamic and ever evolving, requiring constant vigilance and agility. NERC addresses cyber threats through a comprehensive range of diverse activities using robust CIP standards, situational awareness, sharing of information with industry and government, and strong public/private partnerships. These topics will be thoroughly discussed in the following panel.

Regarding the hazards from man-made electromagnetic pulse, some of these issues are covered through NERC's physical Security Reliability Standards, though understanding and mitigating the potential impacts on both the system and demand requires the continued research efforts. Fundamentally, the threat of nuclear warfare necessitates the intelligence and national defense capabilities of the U.S. government.

Aliso Canyon

The integration of large amounts of natural gas-fired generation amplifies the jurisdictional integration between natural gas and electric industries. Until recently, challenges with natural gas deliverability were mostly visible during extreme winter conditions focused almost exclusively on gas supply through pipelines. We saw this a few years ago with the polar vortex.

However, suspended supply of natural gas from the Aliso Canyon storage facility directed a spot-light on vulnerabilities at the intersection of the electric and natural gas industries. Aliso played an important role in supporting bulk power system operations, yet its sudden shut down and continuing compromised status provides both an important warning and case study for reliability.

For example, prior to Aliso Canyon, power system operations and planning did not consider the role of a storage facility to support reliability and the potential for a single point of disruption of many resources at once. Clearly, these common mode failures at the interface of gas pipelines, compressor stations and storage facilities need to figure prominently in planning and operating protocols. Further, to include these characteristics, industry needs to thoroughly understand how gas facilities are operated and interface with the reliable operation of the bulk power system. For instance, the increasing operational strains resulting from high penetrations of renewable variable energy resources and the increasing need for system flexibility are placing reliability stress on both the electric and natural gas systems. Further, from a day-to-day and hour-to-hour timeframe, increased coordination and communication between electric and gas operating is critical. This cooperation includes coordination of maintenance outages in both systems and across the electric and gas systems to support overall bulk power system reliability.

NERC is completing its study of single points of disruption developed in partnership with the Department of Energy's efforts with Argonne National Labs. At a high level, our recommendations include:

- Endorse firm transportation, rather than spot, as a more reliable supply mechanism for gas-fired generators
- Periodically verify dual fuel capability and availability of on-site fuel
- If circumstances warrant, provide a mechanism for air permit waivers for dual fuel plants when their capability is needed
- Increase planning, operational communication, coordination between the natural gas and electric sectors

- Planners should develop contingency plans for fuel disruption and gas-electric interface challenges. Similarly, operators should develop operational plans that account for possible fuel disruptions.

As industry increasingly incorporates lessons learned from Aliso Canyon and system events such as the Polar Vortex, NERC will continue to shine a light on these issues through its assessment, events analysis and situation awareness activities.

Resiliency

System resiliency is becoming an enhanced yardstick of reliability. Planning and operating a resilient grid will require more data to measure system performance, and forecast system characteristics. NERC is developing analytical methods to identify interdependencies between events and resiliency performance. This includes integrating cyber and physical security into the planning and operations of the bulk electric system to be more robust to attacks, and less of a target. The number of constituencies at federal, state, and local levels that are focusing on resiliency and reliability is also growing. This increases the need and importance of accurate, coordinated, and timely information sharing between the electricity industry and government.

Although there is no clear and universally accepted definition of resiliency, the term refers to three related factors: how severe an impact the bulk power system can withstand without complete failure, the time and resources required to restore load and an adequate amount of transmission and generation, and the time and resources required to return the bulk power system to its pre-event condition in all regards.

State of Reliability 2017 shows that the BPS is highly resilient and continues to become even more so. Among the key findings, BPS resiliency to severe weather has improved. Despite days with extreme weather conditions across North America, during no day in 2016 or 2015 did the daily Severity Risk Index make the top-10 most severe list of days between 2008 and 2015. Over the last five years, there have been at least 25 instances of extreme weather causing adverse impacts to the bulk power system. The primary characteristic of these events is that the overall impacts have been driven by terrestrial weather conditions – extreme heat or cold, winter storms, tornadoes, hurricanes, flooding, or strong winds and thunderstorms – as opposed to electrical system conditions and other contributing causes such as were seen in the August 2003 Northeast Blackout or the September 2011 Southwest Blackout. NERC continues to monitor severe weather trends and will continue to expand outreach with industry to improve grid resilience before, during, and after high impact weather events.

NERC believes that a consistent analytical framework is needed that can be used to record data and analyze extreme weather events and the corresponding resiliency performance of the bulk power system. A consistent approach is important as it enables comparative analyses on similar events which then may be used to identify effective strategies and practices for broader socialization across the industry.

Industry constantly readies itself to address emerging hazards that could have lasting impacts on the bulk power system. In January 2016, NERC, Regional Entities, and FERC issued a joint report documenting their review of restoration and recovery plans. The objective of the review was to assess and verify the electric utility industry's bulk power system recovery and restoration planning, and to test the effectiveness of related reliability standards in maintaining and advancing reliability. The report concluded that overall, surveyed industry participants have system restoration plans that, for the most part, are thorough and highly-detailed. The reviewed plans included the identification and testing of black-start resources, identification of primary and alternate cranking paths, and periodic training and drilling on the restoration process under a variety of outage scenarios. In addition, participants had extensive cyber security incident response and recovery plans for critical cyber assets covering the majority of the response and recovery stages. Further, each participant has full time personnel dedicated to the roles and responsibilities defined in their respective response and recovery plans.

Based on the recommendation in the Restoration and Recovery Plan Report, FERC, NERC and the Regional Entities have published an additional joint study. This report focuses on the potential impact of the loss of Supervisory Control and Data Acquisition (SCADA) systems, Energy Management System (EMS), or Inter-Control Center Communications Protocol (ICCP) functionality on system restoration, and the manner in which such impact could be mitigated.[3] The study assesses steps in applicable entities' system restoration plans that may be difficult in the absence of SCADA, ICCP data, and/or EMS, and identifies viable resources, methods or practices that would expedite system restoration despite the loss of such systems, including identifying where such methods and practices could be incorporated into system restoration training.

In addition to terrestrial weather, resiliency requires an understanding of space weather and mitigation of space weather effects. Impacts of a major geomagnetic disturbance (GMD) could cause large-scale voltage stability disruptions to the BPS. Protecting the BPS from GMD is a priority for assuring grid resilience. In response to Commission directive, NERC has developed two standards to address reliability risks caused by GMDs. The first stage standard (EOP-010-1 – Geomagnetic Disturbance Operations) took effect in April 2015. This standard requires entities throughout North America to have GMD operating procedures that can mitigate the potential impacts of GMD on the grid. The second stage standard (TPL-007-1 – Transmission System Planned Performance for Geomagnetic Disturbance Events) was filed by NERC in January 2015 and approved by FERC in September 2016. This new standard requires entities throughout North America to perform state-of-the-art vulnerability assessments of their systems and equipment for potential impacts from a severe 1-in-100 year benchmark GMD event and mitigate against identified impacts. When needed, mitigation could include changes in system or equipment design, or the installation of hardware to monitor or reduce the flow of geomagnetically-induced currents (GIC). Entities will begin implementing the new requirements in 2017 and must meet several steps leading to completion of the

[3] *Planning Restoration Absent SCADA or EMS (PRASE).*

vulnerability assessments and mitigation plans by 2022. In approving TPL-007-1, FERC has also directed certain revisions to the standard that must be completed by May 2018. NERC has begun developing these revisions, which are aimed at enhancing the benchmark GMD event used in vulnerability assessments, establishing deadlines for entities to complete mitigation actions, and expanding the collection of GMD data. Pursuant to Commission directive, NERC recently submitted a preliminary work plan to conduct research on topics related to GMD events and their impacts on the BPS.[4] This preliminary research plan will require an extensive, multi-year effort requiring scientific and technical expertise from a variety of disciplines.

Conclusion

As the ERO, NERC has a responsibility, working with industry experts and other stakeholders, to identify new and emerging risks to reliability. One of our paramount goals is to avoid the potential for large-scale disruptions to the bulk-power system. By leveraging industry expertise, informed by sound technical analysis, NERC's activities support a learning environment to identify risks and mitigate them in pursuit of improved reliability performance. NERC's leadership role is essential to maintaining a focus on conventional risk, while anticipating emerging risks that are less understood during a period of revolutionary change in the electricity sector. By putting a spot-light on known and emerging risks, the ERO Enterprise, working with industry and all stakeholders, endeavors to ensure a highly reliable and secure bulk power system.

Thank you for the opportunity to address these important topics. I look forward to this discussion.

[4] *Geomagnetic Disturbance Research Work Plan of the North American Electric Reliability Corporation*, Docket No. RM15-11-002 (May 30, 2017).