RELIABILITY FIRST

ReliabilityFirst's Review of Winter Preparedness Following the Polar Vortex

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PREAMBLE AND LIMITATION OF PURPOSE

In early January 2014, the Midwest, South Central, and East Coast regions of North America experienced an extreme weather condition known as the "polar vortex." ReliabilityFirst Corporation ("RF") took a number of actions following the polar vortex to understand the issues that occurred during the polar vortex and the extent to which those issues have been resolved. In conducting this work, RF identified positive observations and best practices indicating improvements in cold-weather preparedness, along with areas where Registered Entities could still improve. RF also took a broader look at the polar vortex and identified four themes that emerged in terms of actions to take to prepare for future similar weather conditions, and identified management practices, that, if implemented, could assist in the preparation. The purpose of this report is to communicate these observations, best practices, areas for improvement, and themes and management practices so that we can all learn from the events during the polar vortex and improve system reliability and resiliency during extreme weather events. RF thanks Midcontinent Independent System Operator and PJM Interconnection LLC for their valuable input in preparing this report.

The discussions in this report are not, and should in no way be construed as, directives to industry to undertake any actions. Rather, these discussions are meant merely as suggestions or to facilitate conversations to help industry craft approaches to address issues identified during the polar vortex.

I. RELIABILITYFIRST'S WINTERIZATION SURVEY AND ONSITE VISITS

The extreme cold weather during the polar vortex, where temperatures dropped 20 to 35 degrees below average, had a major impact on generator equipment. Of the approximately 19,500 megawatts ("MW") of capacity lost due to cold weather conditions (which excludes outages due to lack of natural gas) during the polar vortex, over 17,700 MW was directly due to frozen equipment.[1]

As part of its effort to understand the issues that caused generator unavailability during the polar vortex and the extent to which those issues have been resolved, RF developed and issued a 2014-2015 Plant Winterization Survey ("RF Survey") to generating facilities in the RF region. The RF Survey focused on winterization issues and the actions Registered Entities have taken to resolve those issues and prevent recurrence. RF analyzed the responses to the RF Survey, then conducted three onsite visits to generating facilities in December 2014 to discuss their responses to the RF Survey and inspect areas of the generating facilities that may be exposed to extreme weather conditions. These three generating facilities each experienced cold-weather related outages or de-rates in January 2014. Some of the specific issues they experienced during January 2014 include frozen equipment and systems, line breaks, and piping damage due to freezing; ice buildup on equipment and piping; and limestone freezing on the conveying and transfer system.

Section II of this report discusses positive observations and best practices that RF identified during the onsite visits and through its review of the RF Survey, along with areas where Registered Entities could still improve with respect to winter preparedness.

II. POSITIVE OBSERVATIONS, BEST PRACTICES, AND AREAS FOR IMPROVEMENT

A. Positive Observations and Best Practices Overview

Registered Entities provided thorough responses to the RF survey and were open and transparent during RF's targeted onsite visits. These interactions allowed RF to identify numerous positive observations and best practices relating to cold weather preparedness. These positive observations and best practices can be grouped into four categories:

(1) Protecting equipment;
(2) Improving operations;
(3) Ensuring adequate supplies and parts; and
(4) Crafting comprehensive procedures and winterization plans.

B. Positive Observations and Best Practices

While some of the positive observations and best practices that RF identified are unique to certain Registered Entities, following is a list of those that can apply more generally to industry:

[1] NERC, Polar Vortex Review, September 2014, page 13.

1. Protecting Equipment

a. Install additional freeze protection, including heat tracing circuits, wind and cold barriers or windbreakers, enclosures, double insulation, and portable heaters.

b. Install heat tracing cabinets to monitor heat tracing circuits.

c. Replace equipment damaged by freezing conditions with a more reliable design.

d. Change mode of operation for coal and/or limestone conveying systems so as to reduce cold weather effects. As an example, to prevent freezing, one entity continuously ran its limestone conveying system during cold weather conditions.

e. Add kerosene to fuel oil system to minimize gelling.

f. Treat the coal and limestone systems with an anti-freezing solution.

g. Improve and change equipment design or system design to reduce cold weather effects.

2. Improving Operations

a. Preparation for Cold Weather

i. Conduct meetings with staff to discuss lessons learned from prior events.

ii. Complete winterization walk downs of the entire generating facility.

iii. Utilize a work order system to ensure all winter preparedness preventative work is completed prior to the winter season.

iv. Generate and distribute a checklist of duties to operators 72 hours prior to an expected storm or cold weather event.

v. Pre-schedule operation of the generating facility prior to an expected storm or cold weather event.

vi. Require plant electricians to review with plant operators the design, operation, and troubleshooting instructions for the plant heat trace panels.

b. During Cold Weather

i. Double the frequency of operator rounds to increase equipment monitoring.

ii. Schedule an extra operator who is dedicated to monitoring any potential or realized adverse effects of cold weather conditions.

iii. Maintain necessary standby personnel close to the facility in case a need arises.

iv. Assign the task of monitoring and maintaining the fuel levels of all portable heaters to contractors to allow the generating plant staff to focus on operation and maintenance of the generating facility.

3. Ensuring Adequate Supplies and Parts

a. Prior to the winter season, enter into contracts to rent high output, portable heaters for additional freeze protection.

b. Include as part of the generating facility's winterization plan and associated checklists adequate inventories for supplies and parts needed for winter.

4. Crafting Comprehensive Procedures and Winterization Plans.

a. Modify the winterization program to incorporate lessons learned from previous cold weather events.

b. Conduct an annual review of the winterization program and associated checklists to ensure that adequate annual preventative work orders exist for freeze protection and winter weather readiness.

c. Include in the winterization plan and associated checklists inspections and repairs for at least the following items: critical equipment; insulation; heat trace circuits; and portable and permanent heaters.

d. Require complete building inspections to ensure that there are no openings that could allow cold air to penetrate.

e. Work with other utilities to identify winter readiness gaps in procedures and share lessons learned.

C. Areas For Improvement

The Registered Entities in the RF region have done a lot of work to improve their preparedness for extreme cold weather conditions through, for example, increased equipment monitoring, installing weather barriers, and drafting comprehensive winterization plans. Because of this, RF has identified only three areas where the entities could further improve their winter preparedness. RF's suggestions to further improve winter preparedness are as follows:

1. In addition to reviewing fuel quality and quantity for emergency generators, entities should run emergency generators immediately prior to severe weather to help ensure availability.

2. Entities should ensure heat trace or freeze protection is associated with all equipment that has the potential to freeze.

3. Entities should upgrade their plants' instrument air drying systems as appropriate. Duct burners are often used to supplement a facility's power output beyond the continuous rating by producing additional steam for delivery to the steam turbines. The control valves and actuators associated with the duct burner system can be affected by cold weather and freezing conditions as moisture in the instrument air system can cause improper operation of the duct burner equipment. Entities should consider upgrading these plant instrument air drying systems to ones that are designed to avoid this issue.

III. MANAGEMENT PRACTICES IMPLICATED BY THE POLAR VORTEX

A. Overview of Themes and Management Practices

While the positive observations, best practices, and areas for improvement discussed in Section II relate to specific actions observed by RF, RF also took a broader look at the polar vortex and identified four themes that emerged in terms of actions to take to prepare for future similar weather conditions. RF recognized the emergence of these themes in doing its own work following the polar vortex and in reviewing reports issued by the North American Electric Reliability Corporation ("NERC"), Registered Entities, and others. The themes are as follows:

1. *Equipment on hand: protect equipment from direct effects of cold weather;*

2. *External factors: secure natural gas supply and alternate fuels;*

3. *Limit planned outages during cold weather; and*

4. *Improve situational awareness.*

RF has identified certain management practices that, if implemented, could assist in addressing these four themes. These management practices are natural groupings of common, functional activities that Registered Entities can perform to efficiently run their businesses and ultimately, to contribute to reliability.[2] They do not necessarily involve "management," but are simply categories of behaviors, practices, and programs that together allow a Registered Entity to ensure reliability.

[2] RF, through analysis of Reliability Standard violations, events and outages (including the 2011 Arizona-Southern California Outage), and other occurrences has identified 16 such management practices that contribute to the reliability, security, and resiliency of the electrical grid.

The table below indicates which management practices RF has mapped to each theme.

Theme	Management Practices
1: *Equipment on Hand: Protect Equipment From Direct Effects of Cold Weather*	Grid Maintenance Verification and Validation
2: *External Factors: Secure Natural Gas Supply and Alternate Fuels*	External Interdependencies
3: *Limit Planned Outages During Cold Weather*	Planning
4: *Improve Situational Awareness*	Grid Operations

Following is a discussion of how the management practices could address each theme as outlined in the table above.

B. Management Practices Mapped to Each Theme

1. Equipment on Hand: Protect Equipment From Direct Effects of Cold Weather

Protecting equipment from the effects of cold weather conditions is essential to preventing the type of issues that occurred during the polar vortex. As previously mentioned, of the approximately 19,500 MW of capacity lost due to cold weather conditions during the polar vortex, over 17,700 MW was due to frozen equipment. To help resolve this issue, entities should review the cold weather design basis for their generating units and make improvements as necessary. Two management practices, grid maintenance and validation, could assist entities in this effort.

Grid maintenance processes and activities, the purpose of which are to proactively maintain equipment, are a necessary component of an effective weatherization program. For example, grid maintenance should include defining maintenance procedures required to proactively maintain equipment in light of cold weather conditions, taking into account historical equipment failures due to cold weather. Additionally, entities should identify and have readily available spare parts that it may need in case of a cold weather event. Once the entity defines maintenance procedures and equipment necessary to carry out those procedures, the entity must perform grid maintenance, including proactively monitoring equipment.

Verification and validation processes can also assist in the effort to protect equipment on hand as they ensure that the Bulk Electric System continues to be updated, operated, and maintained correctly. The purpose of verification is to confirm that any changes to the systems are conducted in accordance with requirements, plans, or specifications, while the purpose of validation is to confirm that changes to the systems function as designed in the intended environment and conditions. As demonstrated by the polar vortex, the conditions include severe cold weather. Thus, entities must review the design basis of their equipment to determine if the

design can withstand these severe cold weather conditions and also ensure that any changes they make to improve winter preparedness are conducted and completed as intended.

An entity's requirements, plans, or specifications relating to verification should take into account lessons learned throughout winter preparedness activities and in reviewing prior winter events and preparedness. Regarding validation, given that validation is the act of ensuring that an item operates correctly in its environment, an organization needs to first establish the validation environment. An organization can recreate or build the validation environment itself, or it can purchase it in certain instances, depending upon the item to be validated. The validation environment may include tools, models, simulation software, testers, facilities, lab tests, and may even include supplier validation of components. An organization should establish a validation procedure and criteria to help ensure that the equipment will operate as intended during validation. The validation procedure should set forth the method for conducting the validation, and the validation criteria should set forth the goals for the validation (e.g., the equipment performs under extreme cold conditions). The entity should then conduct the validation activities according to the procedures and analyze the results against the validation criteria.

2. External Factors: Secure Natural Gas Supply and Alternate Fuels

Increased reliance on natural gas to fuel generators caused significant issues during the polar vortex when increased demand for natural gas resulted in a significant amount of gas-fired generation being unavailable due to curtailments of gas. More specifically, natural gas suppliers had to serve their firm contracts first, and because this demand increased during the polar vortex, less gas was available to serve the generators that generally obtain gas on a non-firm, interruptible basis. This highlighted the importance of securing firm contracts during potential cold weather events. Additionally, the increased demand for natural gas, and thus less available gas for gas-fueled generators, increases the importance of protecting alternate fuels, such as oil. Thus, entities need to also ensure that the oil they order is protected from the effects of cold weather.

For gas-fired generators, gas supply is an external interdependency in that it can be affected by the actions or inactions of an outside entity. To manage this external interdependency, entities should implement strong external interdependency processes. These processes require entities to first identify reliability related external interdependencies (i.e. fuel supply), then to prioritize those external interdependencies and identify, assess, and mitigate the risks associated with external interdependencies based on priority. Because supply of natural gas is essential to running a gas-fired generator, entities should develop plans that considers facts such as the likelihood that natural gas may be curtailed to due increased demand in a given areas during cold weather.

Entities also need to manage external risks relating to alternate fuel supplies. To do this, entities should implement external interdependency management practices to ensure that the fuel is protected from cold weather despite not being under the entity's direct control. When depending upon external entities to accomplish business objectives (i.e. generating power), it is important to have the external interdependency processes in place to ensure that the reliability and resilience is not negatively impacted. The entity must first identify what risks are associated with the ordered fuel and then identify how it can mitigate these risks.

To do this, entities could work with fuel providers to define specifications to help ensure consistent and reliable service. Even if the fuel provider cannot meet all specifications, identifying the specifications is an important step for the entity to manage risk as it highlights gaps that need to be mitigated and to potentially help the entity manage its relationship with the fuel provider. If the fuel provider is not performing as required or desired, the entity could potentially take corrective actions. Entities should not simply assume that their external entities are performing adequately, but instead actively manage the relationship by monitoring performance and implementing corrections if necessary.

3. Limit Planned Outages During Cold Weather

The extreme cold weather during the polar vortex resulted in record high electrical demand associated with increased electric heating requirements. Thus, to help ensure the system has enough generating capacity, entities should limit planned outages during possible cold weather events to the extent possible.

To do this, entities can use planning management practices to create generation and transmission outage schedules to meet that goal. Planning involves steps to estimate and plan for performing work, and to monitor, control, and measure work performed against plans. The first step in planning is to estimate the impact of the project, such as the negative impact an outage could have during winter peaks. Next, an entity has to identify the project risks and project resources and balance these concepts to establish a plan. The entity should then review the plan and reconcile other work and resources to support the plan and its other plans.

4. Improve Situational Awareness

In anticipation of extreme cold weather, entities should work to proactively improve situational awareness relating to conditions or issues such as generation unavailability, system conditions, loss of fuel, and analysis capabilities.

Grid operations management processes include maintaining situational awareness of operations, including for example, operational awareness of fuel status of all generators. Entities can maintain this awareness through daily fuel inventory solicitation and increased communication channels with electric and gas industries during extreme events. Additionally, operations planning staff should consider participating with gas industry planning groups and invite the gas industry to participate in their long range assessments so that both industries understand the needs and capabilities of the other and work toward a collaborative solution to issues with natural gas supply to the power sector.

In addition, entities should review their power plant weatherization programs, which should include operating procedures that help increase situational awareness during extreme weather events. Grid operations processes are aimed at establishing thorough, repeatable, and systematic processes that are well defined and integrated across an organization. Achieving operational proficiency and awareness, especially during a cold weather event, requires well defined and executable processes and procedures that are integrated across an organization, and personnel responsible for implementing those procedures and processes must be aware of their

responsibilities and trained on them. Combining the appropriately skilled staff with the appropriate work tools is also part of grid operations and is required to effectively implement an entity's procedures.

IV. TAKING A PROACTIVE APPROACH TO RELIABILITY

It is important for entities to learn from their own good practices and from others' good practices. Additionally, although it is also important for entities to learn from past failures and issues and correct those realized failure modes, it is equally important, if we are to achieve a robust reliable system, that entities contemplate possible future, yet unrealized, failure modes so as not to have to endure actual failures and issues before taking the appropriate mitigating actions.

RF thus encourages entities to:

1. *Proactively identify future possible failure modes;*
2. *Contemplate likely root causes that might precipitate those failure modes;*
3. *Perform a reliability risk assessment and prioritize the high risk/high impact root causes and failure modes;*
4. *Design and implement controls to mitigate those risks; and*
5. *Periodically verify and validate the effectiveness of those controls.*

V. CONCLUSION

Although Balancing Authorities and Load-Serving Entities across the Regions were mostly able to maintain their operating reserve margins and serve firm load during the polar vortex, we should always strive for continuous improvement to help us better prepare for future extreme weather conditions. Entities should continue to learn from other entities' actions and best practices, and, more broadly, focus on protecting equipment on hand, managing external factors such as securing natural gas supply, limiting planned outages during possible cold weather conditions, and improving situational awareness.

If you have any questions regarding this report or other questions regarding future winter preparedness activities, please contact Tim Fryfogle, Engineer in RF's Reliability Assessment and Performance Analysis group.