



RELIABILITY **FIRST**

COLD WEATHER WINTERIZATION

BEST PRACTICE GUIDE

2026

TABLE OF CONTENTS



03 ABOUT THE PROGRAM

- 3 ...*Voluntary Program vs. Mandatory Compliance*
- 3 ...*Applicable Region*
- 4 ...*Site Visit Process*
- 5 ...*Program Creation*
- 5 ...*Performance Trends*

06 BEST PRACTICES

- 6 GENERAL
- 6 ...*Training*
- 7 COMBUSTION AND STEAM TURBINE POWER PLANTS
- 7 ...*Heat Tracing*
- 12 ...*Critical Component Housing*
- 15 ...*Insulation*
- 16 ...*Transmitter/Instrument Enclosures*
- 17 ...*Air Intake Filter and Cooling Tower Freezing*
- 18 ...*Compressed Air*
- 18 ...*Pre-Staging/Winterization Supplies*
- 18 ...*Pre-Winter and Daily Checklists*
- 19 INVERTER-BASED RESOURCES (IBRs)
- 19 ...*Solar Power*
- 22 ...*Battery Energy Storage Systems (BESS)*

24 ADDITIONAL RESOURCES

ABOUT THE PROGRAM

30

CWW site visits
during 2025-26
winter season

ReliabilityFirst (RF) has led a Cold Weather Winterization (CWW) outreach program dedicated to promoting generator preparedness and enhancing grid reliability during extreme cold weather events since 2014.

For the 2025-2026 winter season, RF visited 30 power plants to evaluate their cold weather preparedness. RF partnered with Pennsylvania-New Jersey-Maryland Interconnection (PJM), Midcontinent Independent System Operator (MISO), and WECC to assemble a small team of experts. PJM provided significant support in these efforts, contributing significant resources, planning, and subject matter expertise.

The team aimed to observe best practices and provide feedback to the Generator Owners (GOs) on documented maintenance and cold weather preparedness activities. This guide outlines best practices identified during these visits, aiming to promote generator preparedness and ensure the reliability of the electric grid during future extreme cold weather events.

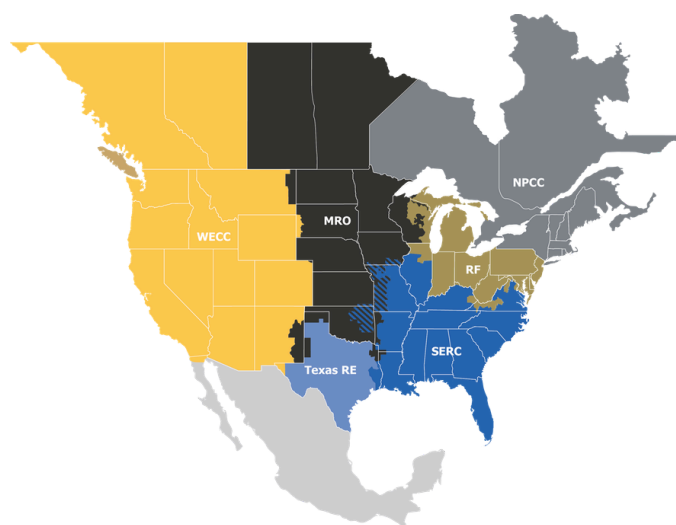
Thank you to the power plants for providing and agreeing to publicly share the example photos included within this report. Please note this report intends to maintain anonymity and avoid identifying specific plant locations.

VOLUNTARY PROGRAM VS. MANDATORY COMPLIANCE

RF conducts this program outside of mandatory compliance for EOP-012-3 (Extreme Cold Weather Preparedness and Operations) and other NERC Reliability Standards. The program focuses on identifying and sharing best practices. However, if the entity has questions related to mandatory compliance, the cold weather winterization team can connect the entity to the appropriate RF team to assist, including submitting written compliance approach questions to a panel of RF SMEs.

APPLICABLE REGION

RF's CWW on-site assist visit program is open to Generator Owners (GOs) in the RF Region. If the entity is part of the multi-region registered entity (MRRE) program, RF will coordinate its resources with other applicable region(s). If the plant is outside of the RF Region, RF may still be able to facilitate discussion to identify the lead region and how to start the process for a CWW on-site assist visit. In the 2025-2026 winter season, RF partnered with WECC in conducting plant visits.



SITE VISIT PROCESS

Plant Selection

Plant selection for the winterization walkdowns comes from several different categories, including:

- Requests received from registered entities through the RF [Assist Visit](#) program
- Results from the [NERC Generator Availability Data System \(GADS\)](#) from the previous two years of cold weather
- [PJM eDART Dispatcher Application and Reporting Tool](#)
- New registrations with 300 MW gross output power or greater and special emphasis on natural gas-powered generators

GADS and eDART data are analyzed for plants that experienced derates or starting issues during extreme cold weather. Plant selection is risk-based, focusing on plants with larger capacity; for example, an 800 MW plant would carry a higher risk and priority for assist visit attention compared to a 100 MW plant. Plants are also selected based on groups or clusters, enabling assembled teams to visit multiple plants in one geographic area in consecutive days where possible.

Plant Surveys

In advance of the site visits, prospective plants completed and returned an informational survey to provide RF staff with plant-specific information. The image below shows a sample of questions included in the fossil fuel-powered survey.

1.0	PLANT WINTERIZATION - OVERALL CONCERNS & ISSUES
1.1	How many boiler-turbine-generator enclosures are of the outdoor type, i.e., boiler room and turbine-generator room are not enclosed and directly exposed to weather conditions?
1.2	How many boiler-turbine-generator enclosures are of the semi-outdoor type, i.e., boiler room partially enclosed with portions directly exposed to weather conditions but turbine generator room fully enclosed?
1.3	How many boiler-turbine-generator enclosures are of the indoor type, i.e., boiler room and turbine-generator room are fully enclosed and not directly exposed to weather conditions?
1.4	Due to the applicable type of configuration, describe any past problems (trips, derates, fail-to-start, etc.) caused by extreme weather and list the amount of megawatts impacted.
1.5	Does your entity presently have a plant winterization plan for all generating facilities?
1.6	Briefly describe the training program or exercise which prepares plant personnel for extreme cold weather conditions.
1.7	What plant personnel are specifically assigned or responsible for the plant winterization plan related to directing key activities before, during and after severe winter weather events?
1.8	To what level of corporate management is the plant winterization plan communicated?
1.9	What is the status of the your plant winterization plan?
1.11	What is your facility(ies) minimum starting temperature(s)?
1.12	What is your facility(ies) minimum design/operating temperature(s) and how long can the facility operate at that temperature?

On-Site Visits

After receiving the written survey, and prior to the on-site

activity, the cold weather winterization team reviews documentation, including but not limited to the plant winterization procedure, checklists, and maintenance activities.

Visits usually take place between October and January, include between two to three subject matter experts (SMEs) and one or two observers, and generally take around four to six hours to conduct on-site. Following the on-site activity, the team writes a report noting any best practices and recommendations.

During the on-site activity, both RF and PJM (if applicable) present an overview of RF and PJM, respectively. These presentations help explain other resource available to the plants in the way of assist visits, outreach, or training.

PROGRAM CREATION

Over the past decade, extreme cold weather events have repeatedly tested the resilience of the electric grid in North America, particularly impacting the generation or "resource" side. Notable among these events are the Polar Vortex of 2014 and Winter Storms Elliott in 2022 and Uri in 2021. The Polar Vortex brought unprecedented cold temperatures, causing widespread generator failures and significant power outages. Similarly, Winter Storm Uri resulted in one of the largest controlled firm load shed events in U.S. history, with many generating units experiencing outages, derates, or failures to start. These events underscore the critical need for robust cold weather preparedness among power generators.

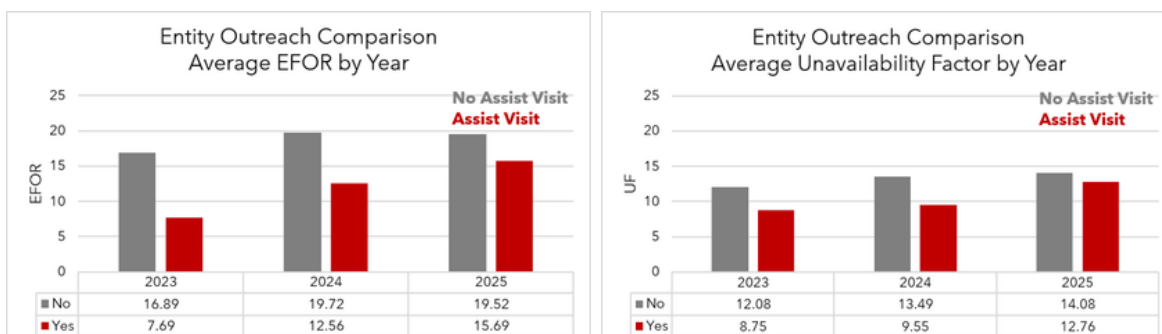
The North American Electric Reliability Corporation (NERC) conducted extensive analyses and published detailed reports on these and other winter storms. The [February 2021 Cold Weather Outages in Texas and the South Central United States Report](#) and [Federal Energy Regulatory Commission \(FERC\)'s Reliability Spotlight on Cold Weather Preparedness](#) provide valuable insights into the challenges faced and the measures needed to enhance grid reliability during extreme cold weather conditions. These reports highlight the importance of implementing comprehensive cold weather preparedness plans, including freeze protection measures, enhanced emergency response protocols, and improved coordination between electric and natural gas industries.

PERFORMANCE TRENDS

RF has seen a positive impact on generator performance from the CWW program. Between the winter months (e.g., November through March) of 2023 and 2025, a group of registered entity Generator Owners (GOs) that participated in the program showed significant improvement in three cold weather performance categories compared to a wider population of all registered GOs within the RF region, according to our statistical analysis. These metrics included:

- **Equivalent Forced Outage Rate (EFOR)**, which measures the probability that a generating unit will be unavailable due to a forced outage or derating.
- **Weighted Equivalent Forced Outage Rate (WEFOR)**, which measures the probability that a group of units will not meet their generating requirements because of forced outages or forced derates. The weighting gives larger units more impact to the metric than smaller units.
- **Unavailability Factor (UF)**, represents the percentage of time a generating unit is unavailable due to forced outages, maintenance outages, planned outages, or deratings resulting from a specified cause, such as cold weather.

The Electric Reliability Organization (ERO) desires lower average numbers for all three metrics to maximize plant utilization, efficiency, and uptime. This encouraging result indicates the positive impact of RF's CWW program in promoting and sharing cold weather winterization best practices throughout the region. Helping keep cold weather GO performance at the forefront of operations may help maximize GO outcomes during winter months.



Generator Availability Data System (GADS) shows support for improved plant performance in Equivalent Forced Outage Rate (EFOR) and Unavailability Factor (UF) among CWW program participants

BEST PRACTICES

GENERAL

RF built the CWW program on identifying best practices, which are then, in turn, shared with other program participants when and where applicable. The following summary highlights some examples of best practices. Any products shown throughout this document are intended for educational purposes. RF does not endorse or promote specific manufacturers' equipment.



TRAINING

There is a growing trend for companies to develop generic or common training programs for their generation fleet. However, entities must understand the NERC Reliability Standard EOP-012-3 (Extreme Cold Weather Preparedness and Operations) calls for "generating unit-specific training."

While the training deck may contain material common to the entity's fleet, it is recommended that training material for each plant also includes information unique to that specific plant. For example, the training material for the specific plant should include plant name, location, and plant specific procedures, including checklists.



As the arrow shows in the image above, one wind farm used a full-size wind turbine nacelle sitting at ground level (instead of several hundred feet in the air) to facilitate educational and training purposes for new staff.

COMBUSTION AND STEAM TURBINE POWER PLANTS

HEAT TRACING



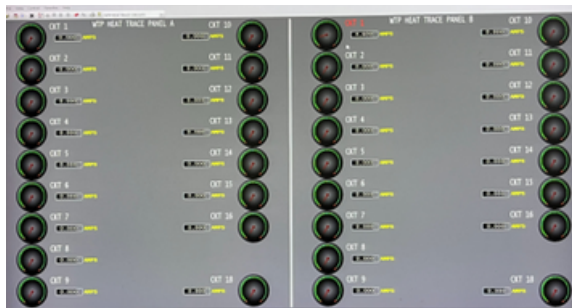
Heat tracing is vital to ensure sensing and other lines do not freeze during the winter. For example, a critical heat tracing application for boiler drum level involves level measurement, such as differential pressure transmitters or level sensing lines. These sensing lines are susceptible to freezing in cold weather, which can obstruct accurate readings of the boiler drum level. Without accurate boiler drum level indication, the plant would be forced to shut down.

Best practices associated with heat tracing are shown in images in the sections below:

- Heat Tracing Loss-of-Power Indication/Alarm
- Heat Tracing End-of-Line Indicators
- Heat Tracing Amperage Measurements
- Pre-Post Start-Up Testing

Heat Tracing Loss-of-Power Indication/Alarm

Most of the plants have panel lights to indicate power to the heat tracing circuits, with remote “loss-of-power” alarms. Operators can visually check power status when making their rounds. Operators may also receive remote alarms in the control room when a heat tracing power circuit trips off. If an alarm is received, an operator may be dispatched to the panel to identify the failed circuit, as shown the right below.

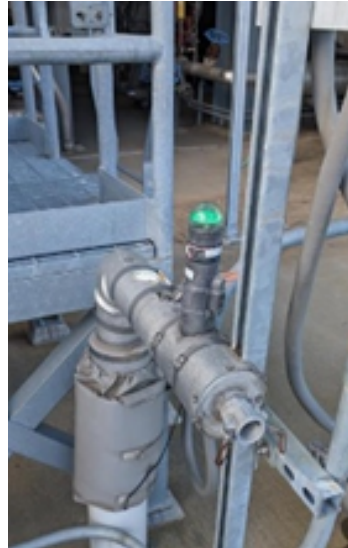


While older style field indication (below left) is still beneficial, digital local indication (below right) may allow for more detailed information on the health of heat trace circuits.



Heat Tracing End-of-Line Indicators

As noted above, while most plants have “loss of power” alarms for heat trace circuits, there is the possibility the heat tracing broke or has a failed connection along the path. Note heat tracing is not readily visible since it is covered with insulation. To help ensure the heat tracing has power and is intact (no breaks), some plants use end-of-line indicators. The lights are placed at the end of the heat tracing run which ensures two things: (1) power is “on”; and (2) no breaks in the heat tracing run. The direction and placement of the indicating lights are strategically located where operators can see the lights when making their daily rounds.



Heat Tracing Amperage Measurements

Another method installs ammeters for each heat tracing circuit. The operators benchmark or trend the current draw in cold temperatures for each circuit. Operators check the readings daily in cold weather. Any deviation from the normal ampere helps alert the operator to an abnormal operating condition, allowing the operators to investigate and make repairs to any damaged heat tracing circuit.



Pre-Post Start-Up Heat Trace Testing

Case studies have shown gaps in functionality of heat tracing circuits. Some plants pursue post-start-up (or periodic) outsourcing of testing of functionality of heat tracing circuits, including documenting megger testing and current draw for each circuit. Combining this circuit functionality testing approach with the heat tracing amperage method above has shown to be very effective.

Even without the real-time amperage reading, some utilities document their annual testing of functionality as shown in the following example. Both current draw and mega-ohm readings are recorded. Any anomalous readings are tracked by work order for corrective action.

PANEL #: U10 ACC/MCC EAST SIDE					
DATE:	10/1/2022				
CRKT #	DWG CUR OPER	ACT CUR OPER	MEGGER (M OHM)	Leakage Current	TYPE
1	10.3	6.4	550		MIQ
2	**	5.3	550		2 BOXES
3	13	13.7	550		HTSX
4	5.9*	12.7	550		HTSX&BOX
5	17.2	15.1	550		HTSX
6	*	4.1	550		BOX
7	6	15.4	550		HTSX
8	13.85	14.9	550		HTSX
9	10.4	13.8	6.4		HTSX
10	15.1	10.2	550		BSX
11	15.1	9.3	550		BSX
12	5.25	4.8	550		HTSX
13	10.8	13.4	550		BSX
14	11.1	6.3	550		BSX
15	1.3	1.3	550		HTSX
16	8.9	14.3	550		HTSX
17	13	11.7	550		HTSX
18	4.6	4.6	273		MIQ
19	*	8	550		BOX
20	0.6*	0.4	550		BOX&HTSX
21	*	4.6	550		BOX
22	1.9*	4.3	550		BOX&HTSX
23	14.8	18	550		HTSX
24	12.9	16.3	550		HTSX
25	*	0.8	550		BOX
26	5.1	8.4	550		HTSX
27	3.7	4.5	550		HTSX
28	*	15.1	0.7		BSX
29	SPARE				
30	SPARE				
31	SPARE				
32	SPARE				
33	*	3.3	550		BSX
34	SPARE				?
35	SPARE				
36	SPARE				
*= Inst Encl on crkt with no drawing of Encl					
51%-70% of Dwg Cur Oper value					
>50% of Dwg Cur Oper value					

One utility created a cross-reference spreadsheet that combines all the critical heat tracing information into one easy document that can save valuable repair/maintenance response time when needed. Information is often buried in Piping and Instrumentation (P&ID) diagrams, so researching this information in advance takes time, but also saves time during critical repair times.

Unit #/BOP	Location	Device	Description	What is the Freeze Protection?					Date Insp
				Insulation	Heat Trace	Temporary Heaters	Wind Breaks	Other	
Other	Date of Inspection	Maintenance Required?	Date Completed	Corrective Work Order	Comments	Obrien box and tubing associated panel	Obrien box and tubing associated Breaker	Root valves associated panel	Root valves associated Breaker

Unit #/BOP	Location	Device	Description	What is the Freeze Protection?					Date of Inspection	Maintenance Required?	Date Completed	Corrective Work Order	Comments	Obrien box and tubing associated panel	Obrien box and tubing associated Breaker	Root valves associated panel	Root valves associated Breaker
				Insulation	Heat Trace	Temporary Heaters	Wind Breaks	Other									
UNIT 10	WEST OF STACK	10LAMB00001	HP FLOW WATER FLOW	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	10	14	
UNIT 10	WEST OF STACK	10LCA000001	COND FW PRESSURE	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ006	10	15	
UNIT 10	WEST OF STACK	10LCA000001	COND FW FLOW	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ006	10	22	
UNIT 10	NORTH BY STACK	10BLJ005	MAIN HEAT TRACE PANEL	NA	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX				
UNIT 10	NORTH BY STACK	10BLJ006	MAIN HEAT TRACE PANEL	NA	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX				
UNIT 10	NORTH HP FW INLET	10LAB000001	HP FW PRESSURE	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ006	21	11	
UNIT 10	NORTH HP FW INLET	10LAB000001	HP SPRAY WTR FLOW	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ006	21	8	
UNIT 10	NORTH HP FW INLET	10LAB000001	HP FW PRESSURE	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ006	21	8	
UNIT 10	EAST OF BFP ROOM	10LAB1000001	BFP SUCT HOR FLOW	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ006	20	+	
UNIT 10	EAST OF BFP ROOM	10LAB1000001	COND PREHEAT PRESS	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ006	20	+	
UNIT 10	EAST OBR BOX #9	10LAB000001	LP STEAM PRESSURE	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ004	24	27	
UNIT 10	EAST OBR BOX #9	10LAB000001	LP STEAM FLOW	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ004	24	27	
UNIT 10	WEST HRSG STEPS	10BLJ008	MAIN HEAT TRACE PANEL	NA	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX				
UNIT 10	FUEL GAS HTR CV	10LBA100001	HP STEAM FLOW	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ004	17	17	
UNIT 10	FUEL GAS HTR CV	10LBA000004	CRN STEAM HO PRESS	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ004	34	22	
UNIT 10	EAST HRSG STEPS	10HAB000001	REHEAT INT ATT PRESS	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ004	16	11	
UNIT 10	HRSG STEPS E 16W	10LBA000001	HP STEAM FLOW	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ004	35	22	
UNIT 10	HRSG STEPS E 16W	10LBA000001	HP STEAM PRESSURE	Yes	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ004	35	+	
UNIT 10	TOP HRSG SW	10BLJ005	MAIN HEAT TRACE PANEL	NA	Yes	No	No	NA	9/19/2024	No	9/19/2024		OBRIEN BOX				
UNIT 10	TOP OF U10 HRSG- SW CRNR (THEN GO DOWN LADDER)	10LBA100001	HP Steam Pressure	Yes	Yes	No	Yes	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	12	26	
UNIT 10	TOP OF U10 HRSG- SW CRNR (THEN GO DOWN LADDER)	10LBA000001	Reheater Steam Outlet Pressure	Yes	Yes	No	Yes	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	12	3	
UNIT 10	TOP OF U10 HRSG- SW CRNR (THEN GO DOWN LADDER)	10HAB000001	4HP FW Outlet Pressure	Yes	Yes	No	Yes	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	18	8	
UNIT 10	TOP OF U10 HRSG- EAST	10HAD1000001	4HP Drum Pressures	Yes	Yes	No	Yes	NA	9/19/2024	Yes	9/19/2024	14191	OBRIEN BOX	10BLJ005	20	4	
UNIT 10	TOP OF U10 HRSG- EAST	10HAD1000002	4HP Drum Pressures	Yes	Yes	No	Yes	NA	9/19/2024	Yes	9/19/2024	14191	OBRIEN BOX	10BLJ005	20	4	
UNIT 10	TOP OF U10 HRSG- EAST	10HAD1000003	4HP Drum Pressures	Yes	Yes	No	Yes	NA	9/19/2024	Yes	9/19/2024	14191	OBRIEN BOX	10BLJ005	20	4	
UNIT 10	TOP OF U10 HRSG- EAST	10HAD1000001	4P Drum Pressures	Yes	Yes	No	Yes	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	21	8	
UNIT 10	TOP OF U10 HRSG- EAST	10HAD1000002	4P Drum Pressures	Yes	Yes	No	Yes	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	21	8	
UNIT 10	TOP OF U10 HRSG- EAST	10HAD1000003	4P Drum Pressures	Yes	Yes	No	Yes	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	21	8	
UNIT 10	TOP OF U10 HRSG- EAST	10HAD1000001	4P Drum Pressures	Yes	Yes	No	Yes	NA	9/19/2024	No	9/19/2024		OBRIEN BOX	10BLJ005	22	16	

A	B	C	D	E	F	G	H	I	J	K
Thermon Heater Number	P&ID	Instrument Enclosure if Applicable	Description	Panel Number	Circuit Breaker #	Panel Location	Power Connection Location	Replaced/ Repaired info	DWG Current	Actual Current
2	1	00MD0140-SH2 00MD0155-SH1	Raw water supply line 00SGX01BR001 from raw water tank connection N16, on 00MD0140-SH2, to electric pump suction line 00SGX01BR011 and diesel pump suction line 00SGX01BR001, on 00MD0155-SH1	00BLA06	1	Water Treatment Building MCC	South of Water Treatment Building 4' Elevation WT-3		16.5	10.4
16	16	00MD0142-SH1	Demineralized water tank outlet line 00GHC10BR001 from tank connection N50 to demin forwarding pump inlet line 00GHC10BR002, in water treatment building	00BLA06	8	Water Treatment Building MCC	On demin water tank box WF-20 3' elevation.	water in cable. Baked out and siliconed end of cable. 2024 w014333 closed	3.7	2.1
17	17	00MD0140-SH2	Raw water / freewater tank line 00LCA25BR004 from tank connection N11 to underground connection on line 00LCA25BR003 from unit 10 and 20 condensate reject lines.	00BLA06	6	Water Treatment Building MCC	South of H2O treatment building box WF-1 3' elevation - Fuel gas filter separator yard box WF-7A 3' elevation		1.8	2.4
18	18	10MD0151-SH2	HRSG blowdown sump pumps discharge line 10GMA15BR001 from enclosure outlet lines 10GMA15BR001 and 10GMA16BR001, on 10MD0151-SH2, to underground connection line 00GMA16BR001, on 10MD0151-SH2, in North East corner of HRSG	10BLJ06	29	North West Corner of HRSG Ground Level	No Access or no tag			
19	19	10MD0151-SH2	GT inlet evaporative cooler blowdown/drain line 10GMA16BR001 from connection on evaporative cooler to underground connection on line 10GMA16BR002 to HRSG blowdown sump	10BLJ04	29	West Side of HRSG by Stairs Ground Level	CCW skid under intake box 10B-171 10' elevation		2	3.4

CRITICAL COMPONENT HOUSING

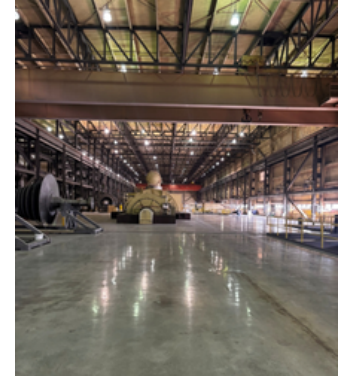
Generating units that have equipment located outdoors are at greater risk of experiencing a Generator Cold Weather Reliability Event because critical process instruments can freeze, fault, and trip the plant offline. In recent years, economics influenced more plants to be built with equipment located outdoors (e.g., wind, solar, and modern natural gas plants) compared to plants built in past years (e.g., traditional coal and nuclear plants).

While the focus of this CWW After Action Report is not compliance, it is noted under EOP-012, the definition of a Generator Cold Weather Critical Component excludes any component or system located inside a permanent building with a heating source that regularly maintains the space at a temperature above 32 degrees Fahrenheit. To mitigate this risk to Critical Components located outdoors, it is fundamental that GOs identify all Generator Cold Weather Critical Components and implement freeze protection measures to provide the capability to operate at the unit's Extreme Cold Weather Temperature per EOP-012-2/3.

Best practices associated with critical component housing are shown in the images below for:

- Permanent heated buildings
- Temporary wind breaks
- Temporary/seasonal enclosures

Permanent Heated Buildings



Main turbine building protects most critical components from freezing



Temporary Wind Breaks

Windbreaks enable staff to work without wind and without wind-driven precipitation, eliminating the windchill effect on staff. The windbreaks may also prevent excessive buildup of snow or ice on equipment.

Heavy curtains may be drawn closed to protect air compressor and control oil skid from inclement weather, to serve as a wind break, and to maintain residual heat.



Temporary/Seasonal Enclosures

Temporary shelters also enable staff to work without wind and without wind-driven precipitation, eliminating the windchill effect on staff. They also prevent excessive buildup of snow or ice on equipment.

The teams noted that most new plants have extensive components outdoors, such as modular platforms with piping, racks, pumps, compressors, or skids that require using temporary coverings in cold weather to prevent freezing. In some examples, the scaffolding structural framework remains installed and in place the entire year and the plant removes the membrane covering in the spring and reinstalls the covering in the fall, saving time and resources in the process.

These examples show structures wrapped in fire-retardant material to protect susceptible components against freezing during winter months.



Above right-side photo shows the interior of structure shown on the left



Portable "hot boxes", powered by 110 VAC, used to address freezing issues for instrumentation not permanently protected



Portable industrial heater to warm temporary enclosure



Thermometer mounted inside a temporary enclosure

INSULATION

While insulation for a pipe is fairly routine, insulation for non-standard shapes, such as valves and piping transitions can be complex. Custom insulation is required for these instances.



Valve stem without insulation



Valve stem with insulation



Insulation of structural support between piping to reduce heat transfer



Custom-fit insulation covers to protect irregular shaped and hard-to-reach components



Insulation covers for transmitters and sensing lines indoors but located near an external wall/door



Removable insulation covers overbuilding louvers

TRANSMITTER/INSTRUMENT ENCLOSURES

Power plants rely on functioning transmitters to operate. Transmitters are crucial for monitoring and controlling various aspects of the plant, such as temperature, pressure, and flow rates. Without reliable transmitters, the plant cannot accurately manage its processes, leading to potential safety hazards and operational inefficiencies, resulting in plant shutdown. A common theme across plants with outdoor equipment is protection from the elements for transmitters. While these are insulated and heated, it is still important for staff to periodically check or monitor the temperature inside the enclosure to ensure the heater is properly functioning. Checking transmitter enclosures is usually included in the daily operator rounds/checklist.



Left: Transmitter manifold assembly enclosed by a protective clamshell using an internal heater.



Above: This entity uses an indicating light and a small thermometer in the transmitter enclosure box to assist operators during inspection rounds helping to demonstrate proper heater functioning.

Above: Local visual temperature indication on transmitter enclosures.

AIR INTAKE FILTER AND COOLING TOWER FREEZING

Forced air movement at air inlets and cooling towers can present challenges. Moving air with freezing precipitation makes a good recipe for icing. In some cases, the “plume” of mist from the cooling tower can float over to the air intake to cause air intake freezing issues.



A best practice is to monitor the delta pressure across the filters. A drop in pressure could indicate freezing filters. Some plants use air inlet filter heating or “puffers” to prevent freezing of air intake. In some examples, plants use waste heat to heat inlet air.



To mitigate the effects of a frozen cooling tower, one plant switched over to a standby pond as an alternate condensate cooling method.



Remote temperature sensors on pumps/piping provide continuous temperature indication. (A wireless signal is sent back to the control room).

COMPRESSED AIR

Compressed air dryer controls maintain a very low dewpoint (~ 50° F) and combine with an automatic blowdown (i.e., method to remove accumulated water) inside the receiver tank to operate with less risk in cold weather.



Compressed air supply system

PRE-STAGING/WINTERIZATION SUPPLIES

Pre-staging temporary heaters, portable generators, and other winter supplies ensures that equipment will be accessible during extreme cold weather.



PRE-WINTER AND DAILY CHECKLISTS

An eLogger checklist reminds an operator to perform specific tasks and records the results, dates, and times of the activities:

INSTRUCTIONS

- CHECK ITEMS **TWICE** A SHIFT WHEN AMBIENT TEMPERATURES ARE BELOW **32°F**. HIGHLIGHTED ITEMS ARE TO BE CHECKED **EVERY 3 HOURS** WHEN AMBIENT TEMPERATURES ARE BELOW **20°F**.
- ENSURE ALL HEAT TRACE CIRCUITS ARE ENERGIZED AND FREE OF ALARMS.
- VERIFY THAT INSULATION IS IN SERVICEABLE CONDITION WITH NO DAMAGE OR WEAR.
- CONFIRM THAT ALL O'BRIEN BOX HEATERS ARE FUNCTIONING PROPERLY.

COLD WEATHER CHECKLIST

Add	BOX NO.	LOCATION	XMTR KKS	DESCRIPTION	HTR CKT NO.	NOTES	RESULT	
1		East Side BFW Pump House	10LAB10CF001 10LAB10CP002	-BFP Suction Header Flow -Condensate Preheater Press.			☒ SAT ☐ UNSAT	Delete
2		HRSG East & West Heat Trace Panel	10LAB30CP001 10LAE01CF001 10LAB60CP001	-HP Feedwater Pressure -HP Spray Water Flow -IP FW Pressure			☒ SAT ☐ UNSAT	Delete
3		Fuel Gas Heater Control Valve Area	10LBA10CF001 10LBC40CP004	-HP Steam Flow -CRH Steam Header Pressure			☒ SAT ☐ UNSAT	Delete
4		Turbine Exhaust Duct Drain Pot	10MAG05CL001 10MAG05CL002 10MAG05CL003	-Duct Drain Pot Levels			☒ SAT ☐ UNSAT	Delete

Add

INVERTER-BASED RESOURCES (IBRs) - SOLAR, BATTERY, WIND



Most winterization site visits conducted by RF focus on traditional generation facilities—particularly gas combustion turbines and coal plants — where freeze protection challenges are commonly associated with sensing lines and instrumentation. However, RF also makes a deliberate effort to visit a select number of renewable energy facilities each year to broaden understanding of evolving operating practices. These visits to wind, solar, and battery storage sites provide valuable insights into how winterization risks differ across technologies and highlight emerging best practices tailored to renewable plant configurations.

SOLAR POWER

Solar power continues to be the backbone of renewable energy development in the RF Region with 23 new plants – or approximately 3,500 MW – of new development in the past year.

Dust Monitoring System for Solar Panels

Soiling rates can vary across a PV plant, so sensors are used to monitor the loss of light transmission caused by dust or other environmental factors. Installed at the same angle and using materials similar to standard silicon PV modules, they measure how much light is being blocked at the panel surface, providing real-time remote indication of performance loss from contamination. Because they operate continuously without moving parts or reliance on sunlight, they enable reliable, low-maintenance monitoring.

The resulting data allows operators to trigger cleaning only when needed and identify where losses are greatest across a site, supporting more efficient, condition-based maintenance. The model shown communicates directly with a SCADA remote terminal unit (RTU).



Dust monitoring system



Bifacial solar panels, which draw power from both front and rear

Weather Station

A local plant weather station measures multiple environmental parameters, including wind speed and direction, ambient temperature, humidity, and snow conditions. Together, these measurements provide a complete picture of site conditions, helping operators understand how weather is affecting both energy production and structural loading.

Snow sensing systems at solar plants provide continuous, objective measurement of site conditions, including both accumulated snowpack and ongoing snowfall rates, giving operators critical context for performance and structural risk management.

Snow sensor systems typically use ultrasonic or laser distance measurements to track changing snowpack in real time, allowing operators to correlate snow depth with reduced generation and distinguish snow-related losses from other factors.

Snowfall and snowpack information become operationally actionable: heavy accumulation can increase structural loading on modules and trackers. Snow accumulation can also alter optical performance—particularly for bifacial systems where ground snowpack affects reflected irradiance (albedo).

By integrating snow depth data with plant controls and performance monitoring, operators can proactively adjust tracker positions (for example, tilting or stowing arrays) to shed snow, prevent excessive loads, and restore production more quickly once conditions improve.



Solar Panel Tracker Control and Single-Axis Controllable PV Panels

Modern tracker control systems allow photovoltaic (PV) arrays to operate in multiple modes depending on operating conditions and site needs. In normal operation, trackers automatically follow the sun to maximize energy production, but they can also be commanded—either manually or automatically—to move into alternate positions for maintenance activities or in response to weather conditions. These include modes such as snow shedding, hail or storm stow, and fixed-angle positioning for field work (for example, mowing or inspections).

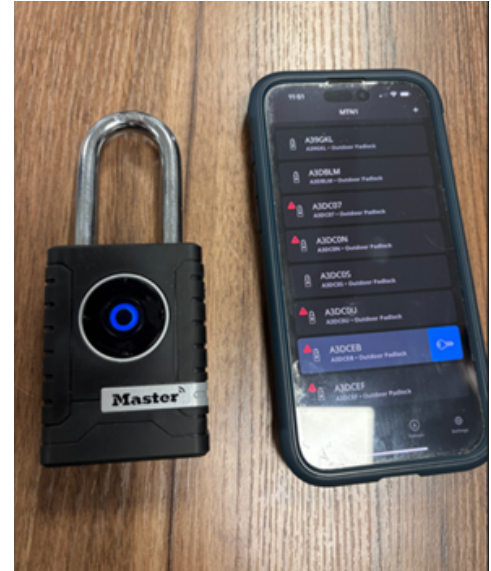
In winter applications, this flexibility is particularly important. Operators can intentionally adjust tracker angles to shed snow accumulation and reduce loading on the structure, then return the system to normal tracking once conditions improve. This ability to transition between automated tracking and protective or operational positions allows solar plants to balance energy production with asset protection and site accessibility throughout changing conditions.



Bluetooth Lock Control System

Solar plants may have hundreds of locks due to PV panels being spread across hundreds of acres with multiple access points, as well as the need to lock access to electrical equipment, such as inverters, breakers, controllers, and transformers. The high number of locks can present challenges for key control, especially with personnel changes.

In this example, a solar plant uses a Bluetooth lock control system, which allows for centralized management of access permissions, enabling operators to quickly grant or revoke access without the need to physically collect keys or re-key locks. This approach improves security and operational efficiency by reducing the risk of unauthorized access and simplifying access control as personnel change over time.



As a reminder, for applicable Low Impact BES Cyber Systems, NERC CIP does not prescribe specific physical lock technologies. Instead, it requires utilities to implement documented, reasonable physical and electronic access controls (primarily under CIP-003 and CIP-006). While this type of lock system may be permissible in a Low Impact environment, its use must be considered in the context of an overall defense-in-depth strategy of physical and electronic controls.



Solar panels secured behind fenced area

BATTERY ENERGY STORAGE SYSTEMS (BESS)

Utility-scale battery energy storage systems (BESS) are expanding rapidly as energy policies evolve to meet the reliability and flexibility needs of a growing bulk power system. As more wind and solar generation is added to the grid, the variability of these resources has increased the importance of dispatchable support, driving widespread adoption of battery storage.

BESS technologies provide critical benefits, including the ability to store excess energy during periods of high renewable output and deliver it when wind or solar production is low, helping to balance supply and demand in real time. In addition, battery storage enhances grid resilience, improves frequency regulation, and can defer costly infrastructure upgrades by reducing peak load stress. As a result, utilities and grid operators are increasingly integrating utility-scale storage into their planning strategies, making battery storage one of the fastest-growing segments of the modern energy landscape.



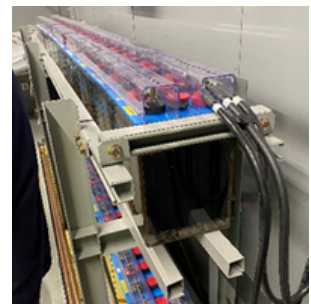
Battery storage



Battery storage pods with inverter in front



Inverter with indication lights



A line of batteries within an electrical control building, where it is important to maintain proper battery temperature

SF6 Breakers and Station Batteries

While IBRs don't have issues related to freezing water lines, valves, or pressure sensors, renewable plants still have manufacturer specifications for space heating equipment. And, like traditional spinning resources such as coal or nuclear-powered Bulk Electric System (BES) generators, renewable plants also must focus on heating battery rooms and monitoring gas pressure in sulfur hexafluoride (SF6) breakers.

SF6 breakers rely on gas pressure to operate. When the SF6 gas pressure gets too low because of extreme cold weather, the breaker will either (1) trip, or (2) disable the breaker trip. It is important to monitor SF6 gas pressure through periodic operator rounds and/or remote alarming.



SF6 instrument gauge



Typical SF6 breakers installed at an IBR

ADDITIONAL RESOURCES



If your company owns power generation, we hope you find value in this best practice guide and continue to enhance your reliability and resiliency during extreme cold weather. We thank those Generator Owners (GOs) that contributed to best practices outlined in this document. If your company would like a winterization on-site assist visit, if you have a best practice not yet illustrated, or if you have any questions, please reach out to us through the RF [Assist Visit](#) program.

FURTHER READING

Event reports:

[January 2025 Arctic Events Report](#)

[January 2024 Arctic Storm Report](#)

[December 2022 Winter Storm Elliott Report](#)

[February 2021 Event Texas and South Central US](#)

[January 2018 South Central Cold Weather Report](#)

[January 2014 Polar Vortex Report](#)

Other resources:

[NERC Reliability Guideline: Generating Unit Winter Readiness](#)

[2025 NERC Small Groups Advisory Session \(SGAS\) FAQ](#)

[FERC Cold Weather Preparedness Spotlight](#)

[RF Assist Visit Program](#)

[RF Generator Winter Preparedness](#)

[RF CWW Preparedness and EOP-012-2 Article](#)