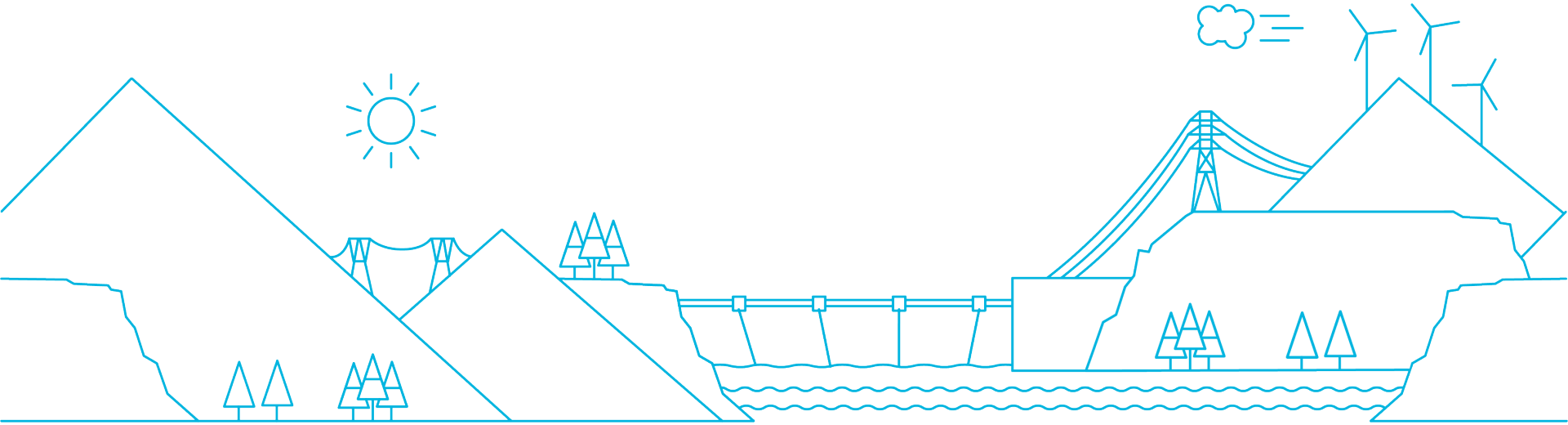
BC Hydro Generating Facilities Cold Weather Preparedness according to NERC EOP-012-1 Standard



Date: June 2024

Christian Bonilla, Specialist Engineer, BC Hydro, Canada

BC Hydro
Power smart

Content

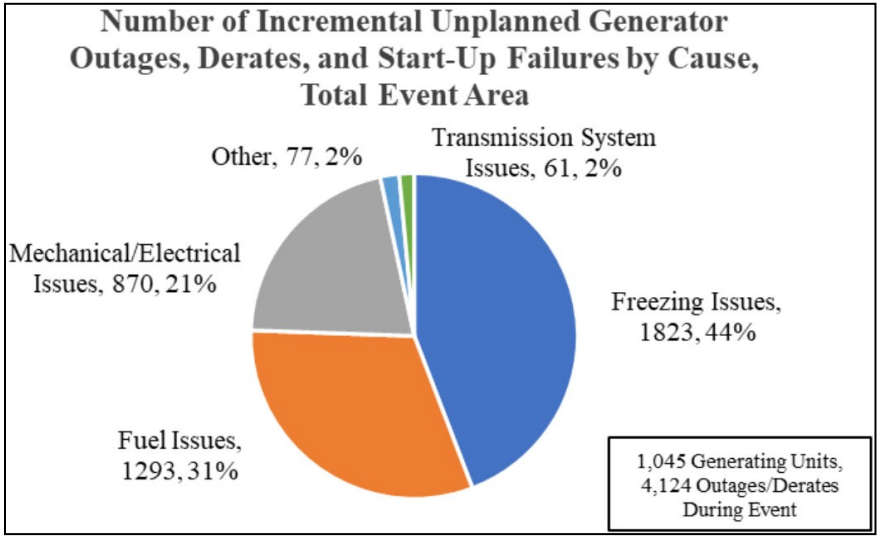
EOP-012-1 Standard Requirement No. 3 (R3):

1. Extreme Cold Weather Definition and 0.2 Percentile Methodology
2. Historical Operating Temperatures
3. Minimum Design Temperatures (MDT)

Extreme Cold Weather Definition and 0.2 Percentile Methodology

2021 Texas and South-Central United States Cold Weather Outages

- February 2021 cold weather outages in Texas and the South-Central United States
- Outages were 4x larger than the next largest event
- Electric Reliability Council of Texas (ERCOT) averaged nearly 50% of its all-time winter peak load unavailable for over two days
- 4.5 million people without power, 210 fatalities [1]



[1] https://www.naesb.org/pdf4/ferc_nerc_regional_entity_staff_report_Feb2021_cold_weather_outages_111621.pdf

NERC Cold Weather Reliability Standards

- The 2021 Texas Cold Weather Event prompted NERC to develop:
  - Cold Weather Reliability Standards
  - Emergency preparations for extreme cold weather events
- NERC Standards:
  - EOP-011-2 Emergency Preparedness and Operations
  - EOP-012-1 Extreme Cold Weather Preparedness and Operations
  - Note that EOP-012-1 will eventually replace EOP-011-2 Standard

NERC EOP-011-2 R7 & R8

- EOP-011-2 is Subject to Enforcement (as of June 2024)
- Requirement 7 (R7) and R8 in EOP-011-2 are applicable to the Generator Owner/Generator Operator (GO/GOP) functions
- R7. Each GO shall implement and maintain cold weather preparedness plans:
  - Generating units:
    - Freeze protection measures
    - Annual inspection and maintenance of freeze protection measures
    - Operating limitations: Capability and availability, fuel supply, …

NERC EOP-011-2 R7 & R8 (Cont.)

- R7. Generating units:
  - Current cold weather performance temperature determined by an *engineering analysis* (***NERC 0.2 Percentile Methodology***)
  - ***Minimum design temperature***
  - ***Historical operating temperature***
- R8. Each GO/GOP shall provide training to its personnel responsible for implementing cold weather preparedness plan [2]

[2] https://www.nerc.com/pa/Stand/Reliability Standards/EOP-011-2.pdf

NERC EOP-012-1 R7 & R8 (Cont.)

- EOP-012-1:
  - is Subject to Future Enforcement (as of June 2024) [3]
  - goes into effect on Oct. 1, 2024
  - is applicable to the GO/GOP functions and includes the content of R7 and R8 from the EOP-011-2 Standard (R3 and R5 respectively with wording to include extreme weather) [4]
- The Extreme Cold Weather Temperature definition is used in EOP-012-1

[3] https://www.nerc.com/pa/Stand/Reliability Standards/EOP-012-1.pdf
[4] https://www.provencompliance.com/news/key-points-of-fercs-recent-order-for-reliability-standards-addressing-emergency-operations-and-extreme-cold-weather/

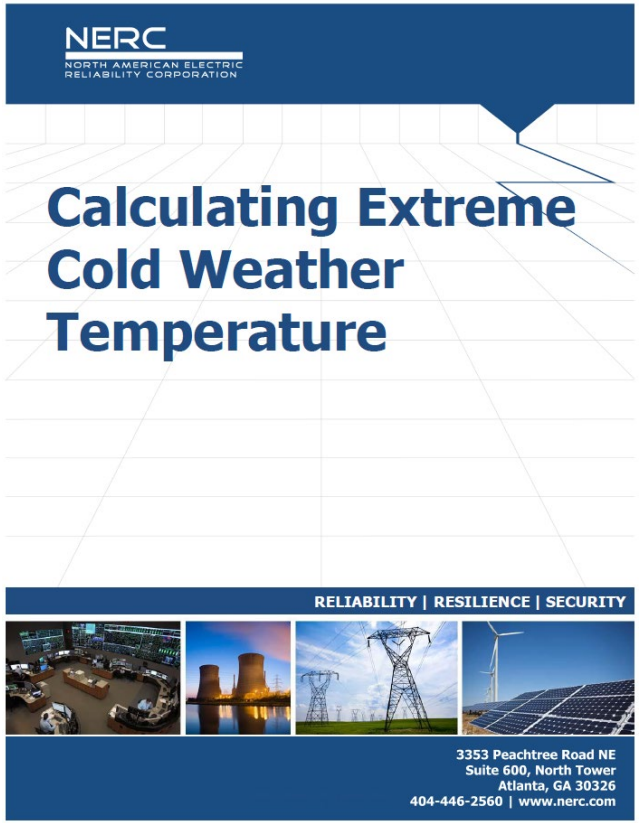
NERC Extreme Cold Weather Temperature Definition

- *The temperature equal to the lowest 0.2 percentile of the hourly temperatures measured in December, January, and February from 1/1/2000 through the date the temperature is calculated. [5]*
- NERC has selected the 0.2 percentile of the winter month temperatures since 1/1/2000 to identify a temperature which has been rarely surpassed but allows margin to demonstrate successful operation of generating unit. [6]
- Lowest ambient temperature considered, but dismissed for statistical approach [6]

[5] https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf
[6] https://www.nerc.com/pa/Stand/Project202107ExtremeColdWeatherDL/2021-07%20Technical%20Rationale%20for%20EOP-012-1_final%20ballot_clean.pdf

Calculating Extreme Cold Weather Temperature

- Demonstrates one method for acquiring the necessary data for a given location and a method of performing the statistical analysis of the data to determine the Extreme Cold Weather Temperature for a given location.
- Uses data obtained from a climate data database and perform the statistical analysis with Microsoft Excel (built-in function “PERCENTILE.INC” used to calculate the 0.2 percentile value of the data)



[6] https://www.nerc.com/pa/Stand/Project202107ExtremeColdWeatherDL/2021-07%20Calculating%20Extreme%20Cold%20Weather%20Temperature_082022.pdf

Applying the 0.2 Percentile Methodology to BC Hydro

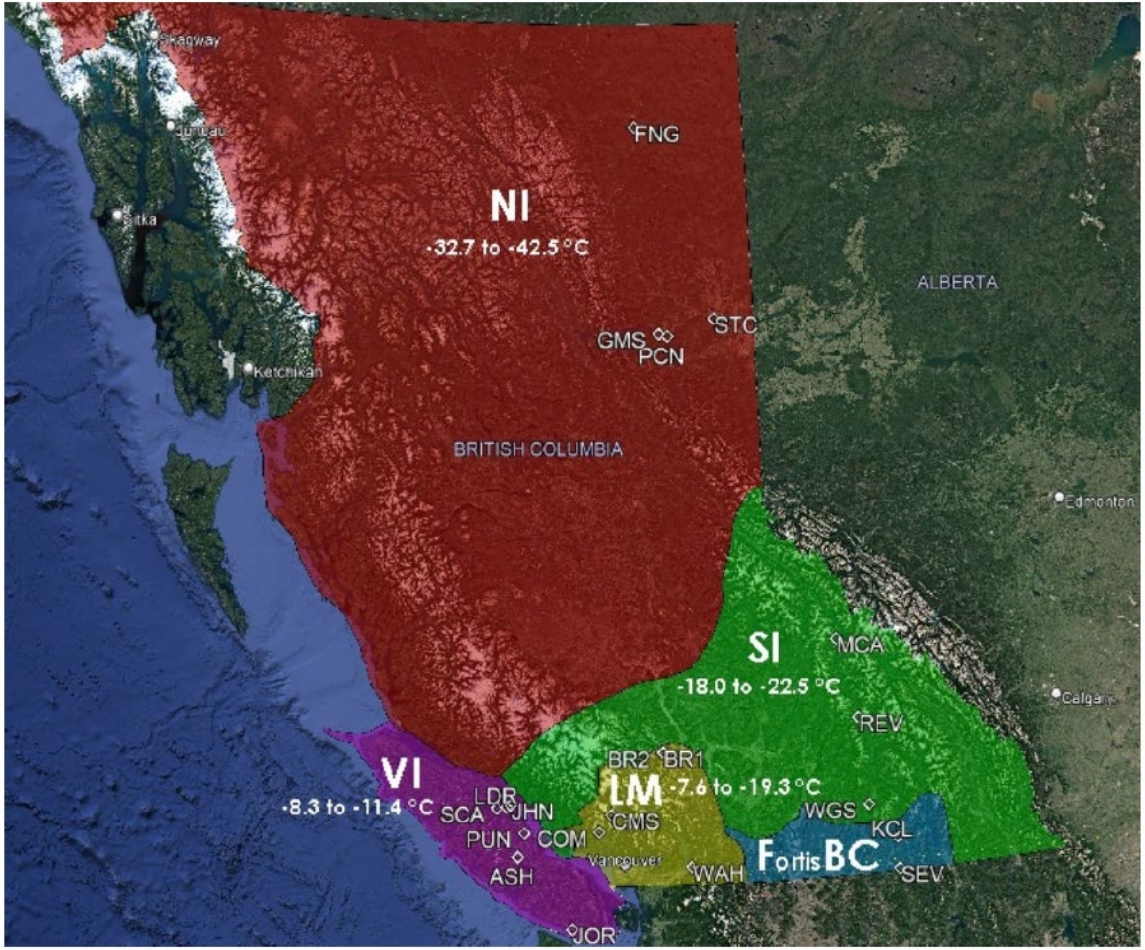
1. Climate database was searched for weather stations near 20 Bulk Electric System (BES) BC Hydro generating facilities with:
    - hourly temperatures available for the period of 2000/01/01 to the date the temperature was calculated (Feb 2023) and are climatologically similar
2. If no station was available, the Pacific Climate Impacts Consortium (PCIC) station database was searched using same criteria
3. If no appropriate weather station with hourly data could be found, daily max and mins were used. Missing information was interpolated.
4. Hourly data was filtered to include only Dec, Jan, Feb for Jan 2000 to Feb 2023
5. Microsoft Excel's function "PERCENTILE.INC" was used to calculate the 0.2 percentile value of the data

BC Hydro Extreme Cold Weather Temperatures

Region	Generating Station	Proxy Weather Station	% Missing	Dec-Jan-Feb 0.2 Percentile (0.002) Temperature
Lower Mainland (LM)	Station 1**	Weather Station 1	10.6%	-19.3 °C
	Station 2**	Weather Station 1	10.6%	-19.3 °C
	Station 3	Weather Station 2	1.6%	-15.6 °C
	Station 4	Weather Station 3	0.6%	-7.6 °C
	Station 5	Weather Station 4	3.3%	-17.5 °C
Northern Interior (NI)	Station 6	Weather Station 5	9.9%	-42.5 °C
	Station 7	Weather Station 6	1.9%	-32.7 °C
	Station 8	Weather Station 6	1.9%	-32.7 °C
	Station 9	Weather Station 7	5.8%	-36.0 °C
Southern Interior (SI)	Station 10 *	Weather Station 8	0.0%	-18.3 °C
	Station 11 *	Weather Station 9	0.0%	-22.5 °C
	Station 12 *	Weather Station 10	0.0%	-20.8 °C
	Station 13 *	Weather Station 11	0.0%	-18.3 °C
	Station 14 *	Weather Station 12	0.3%	-18.0 °C
Vancouver Island (VI)	Station 15	Weather Station 13	2.3%	-11.4 °C
	Station 16	Weather Station 14	1.0%	-8.3 °C
	Station 17**	Weather Station 15	14.7%	-10.9 °C
	Station 18	Weather Station 14	1.0%	-8.3 °C
	Station 19 **	Weather Station 16	27.6%	-10.0 °C
	Station 20	Weather Station 17	3.9%	-10.7 °C

* No sufficient hourly dataset available. Interpolated to hourly from daily maximum/minimum.

** Significant missing climate data for Station 19 (27.6%), Station 17 (14.7%), and Station 1 and Station 2 (10.6%)



BC Hydro
Power smart

Historical Operating Temperature

20 BES BC Hydro Historical Operating Temperatures

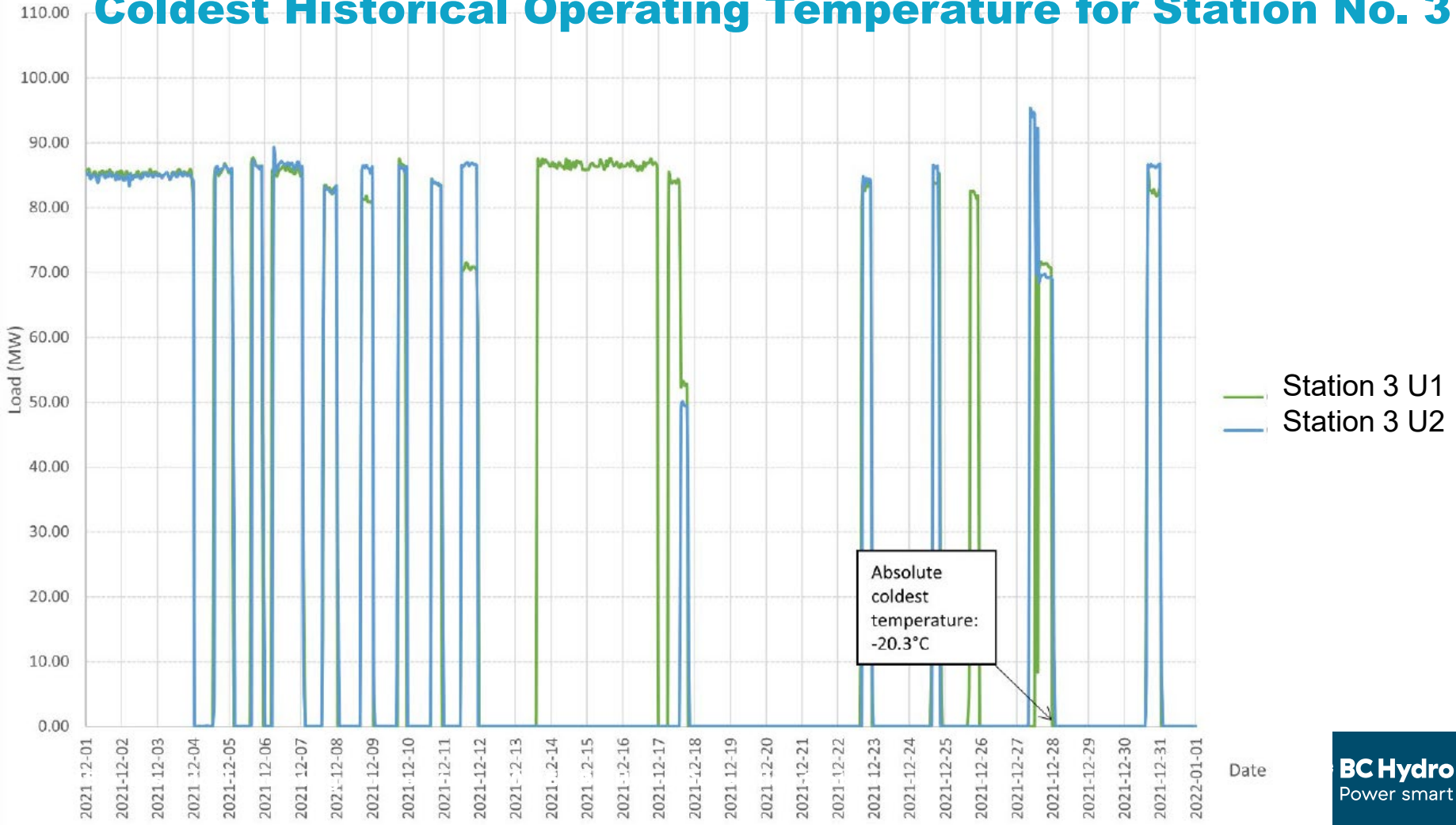
- The lowest historical cold weather ambient temperatures were acquired from climate database for the months of December, January, and February from 2000 to 2023
- The historical operating temperatures were derived from generating unit operational data and the lowest historical cold weather ambient temperatures
  - Generating unit's hourly real power output in megawatts [MW]
  - Lowest historical temperatures in degrees centigrade [°C]
  - The operational status of each generating unit during the coldest event date indicated whether the generating units were out of service due to planned maintenance or forced outage or operational

20 BES BC Hydro Historical Operating Temperatures

- The selection criteria for the coldest historical temperatures are:
- All generating units of a station were operational and ready to be dispatched during the absolute coldest temperature event date, then this absolute coldest ambient temperature can be used for that event date
- If any of the generating units of a station were not operational due to a planned or forced outage during the coldest temperature, then find the next coldest temperature from the climatic dataset. If all generating units of a station were operational during the next coldest temperature, that coldest ambient temperature can be used for that event date

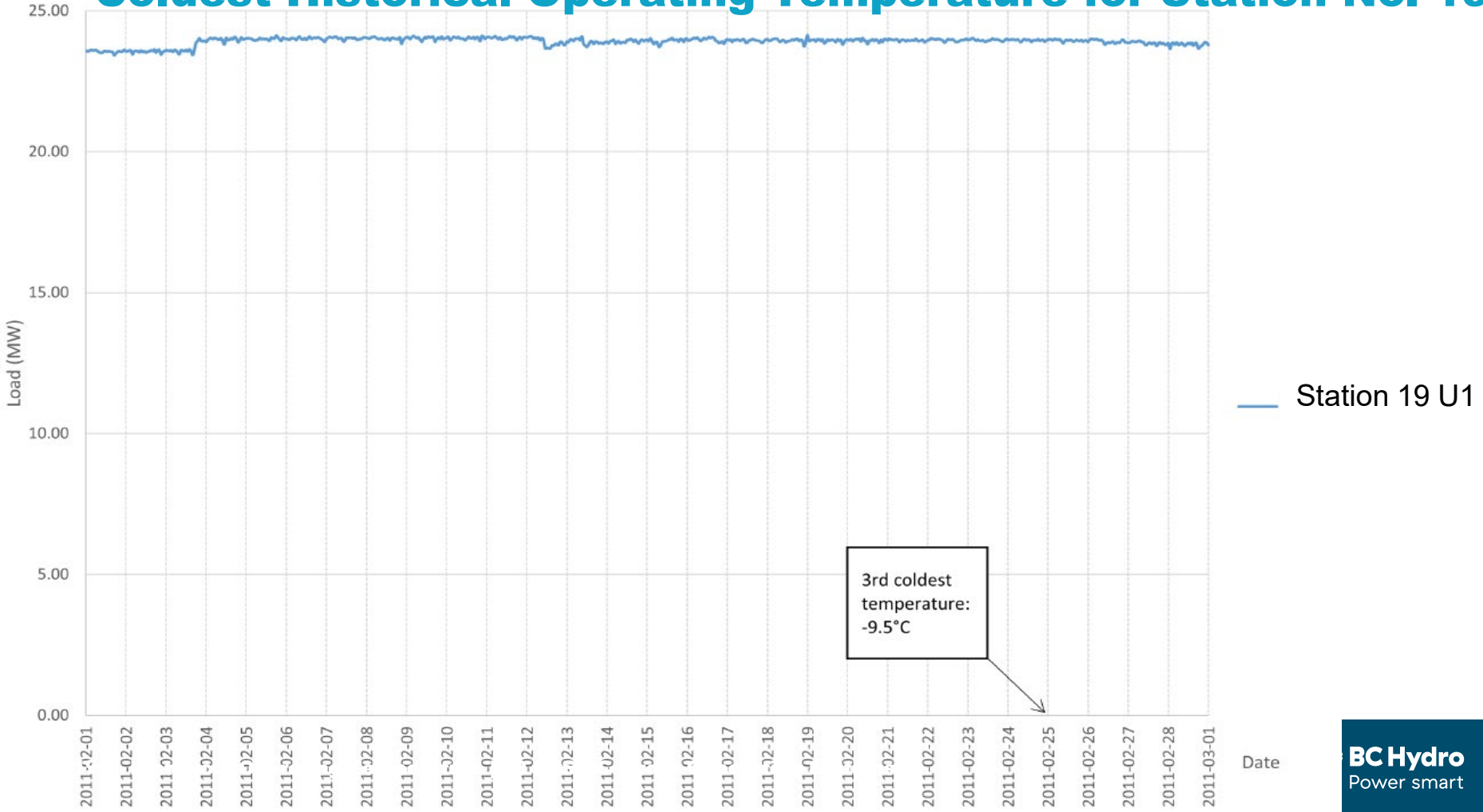
Region	Generating Station	Proxy Weather Station	Coldest Operational Event	Coldest Operational Date	Coldest Operational Ambient Temperature (°C)	Coldest Operational Generating Units	Coldest Operational Dispatched Generating Units	Coldest Operational Day Peak Generating Station MW Output
LM	Station 1**	Weather Station 1	**absolute coldest**	2021-12-27	**-24.1**	U1 to U4	U1 to U4	183.44
	Station 2**	Weather Station 1	**absolute coldest**	2021-12-27	**-24.1**	U5 to U8	U5 to U8	236.98
	Station 3	Weather Station 2	**absolute coldest**	2021-12-28	**-20.3**	U1, U2	U1	68.81
	Station 4	Weather Station 3	**absolute coldest**	2008-12-20	**-11.1**	U1	N/A	0.10
	Station 5	Weather Station 4	**absolute coldest**	2021-12-27	**-22.5**	U1	U1	59.77
NI	Station 6	Weather Station 5	**absolute coldest**	2004-01-27	**-49.0**	U1	U1	40.10
	Station 7	Weather Station 6	**2nd**	2008-02-09	**-35.9**	U1 to U10	U1 to U10	2618.67
	Station 8	Weather Station 6	**absolute coldest**	2004-01-26	**-36.2**	U1 to U4	U1 to U4	640.76
	Station 9	Weather Station 7	**absolute coldest**	2009-01-02	**-40.0**	Under construction		
SI	Station 10 *	Weather Station 8	**4th**	2004-01-06	**-20.7**	U1 to U4	U1 to U4	568.87
	Station 11 *	Weather Station 9	**absolute coldest**	2008-01-29	**-27.9**	U1 to U4	U1 to U4	1563.46
	Station 12 *	Weather Station 10	**absolute coldest**	2004-01-06	**-26.2**	U01 to U04	U01 to U04	1847.63
	Station 13 *	Weather Station 11	**absolute coldest**	2008-12-21	**-21.5**	U1 to U4	U2 to U4	645.50
	Station 14 *	Weather Station 12	**absolute coldest**	2004-01-05	**-22.0**	U1	U1	49.13
VI	Station 15	Weather Station 13	**2nd**	2008-01-28	**-15.1**	U1	U1	26.50
	Station 16	Weather Station 14	**absolute coldest**	2021-12-27	**-13.1**	U1 to U3	U1 to U3	132.52
	Station 17**	Weather Station 15	**absolute coldest**	2008-12-23	**-13.9**	U1	U1	52.59
	Station 18	Weather Station 14	**absolute coldest**	2021-12-27	**-13.1**	U1, U2	U1,U2	35.86
	Station 19 **	Weather Station 16	**3rd**	2011-02-25	**-9.5**	U1	U1	24.01
	Station 20	Weather Station 17	**absolute coldest**	2021-12-27	**-15.6**	U1, U2	U1	49.33

Coldest Historical Operating Temperature for Station No. 3



BC Hydro
Power smart

Coldest Historical Operating Temperature for Station No. 19



BC Hydro
Power smart

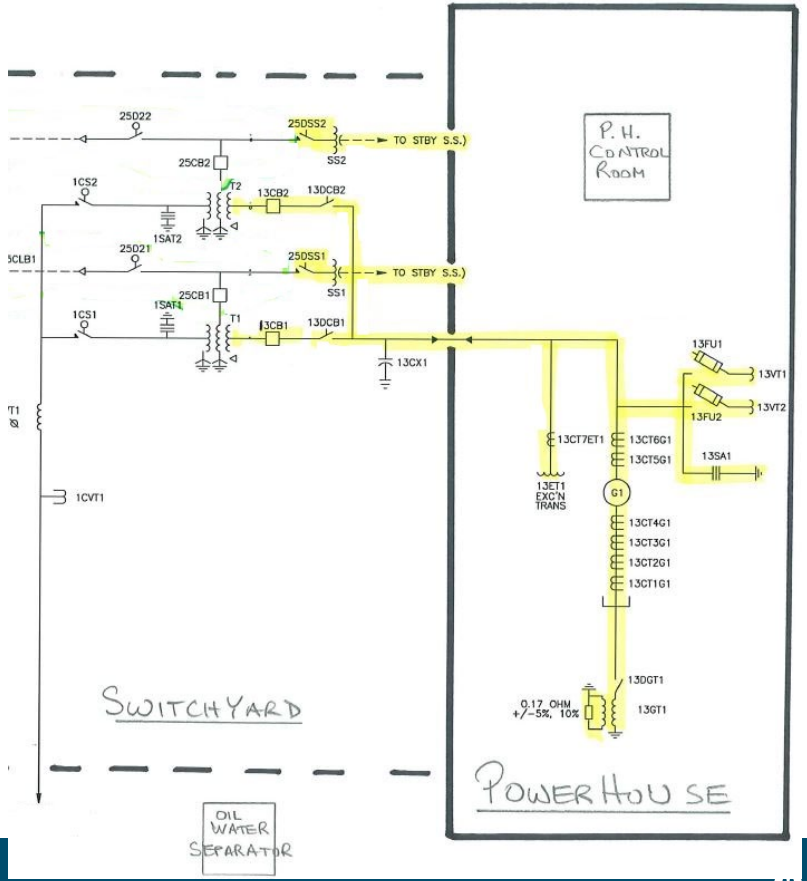
Temperature Variance for 2nd, 3rd, 4th Coldest Temperature

Region	Generating Station	Selected Coldest Temperature		Absolute Coldest Temperature	Temperature Difference
NI	Station 7	2nd coldest temperature	-35.9 °C	-36.2 °C	**0.3 °C**
VI	Station 15	2nd coldest temperature	-15.1 °C	-15.7 °C	**0.6 °C**
VI	Station 19	3rd coldest temperature	-9.5 °C	-12.4 °C	**2.9 °C**
SI	Station 10	4th coldest temperature	-20.7 °C	-21.5 °C	**0.8 °C**

Minimum Design Temperature

Minimum Design Temperature of Outdoor Equipment

- Researched the minimum design temperatures (MDT) of outdoor electrical equipment that is categorized as Generation cold weather critical components of 20 BES stations
- Indoor electrical equipment was out of scope because of controlled ambient temperature (HVAC)



Minimum Design Temperature of Outdoor Equipment

- Selected outdoor equipment included: GSU transformer, LV&HV circuit breaker and disconnects, IPB, cables, O/H buses, arrestors, stations services, etc.
- Researched component design temperature of major outdoor equipment (e.g., bushing MDT of GSU power transformer
- Collected MDT data from equipment manuals, specifications, project records, etc.
- Interviewed knowledgeable crew members of 20 BES generating stations and documented past cold weather-related issues such as mis-operation or forced outages of electrical equipment

Sample Station 15 GSU Transformer MDT Data

Equipment Designation	Component	0.2 Percentile T (°C)	Historical Operating T (°C)	Minimum Design T (°C)	Traceability	Built to Standard
T1	Main asset	-11.4	-15.1	**-50.0**	Various Stations 64.5 and 138 kV Power Transformers Contract No. XYZ Documents	BC Hydro Standard Technical Specification XYZ
	Bushing	-11.4	-15.1	**-50.0**	Various Stations 64.5 and 138 kV Power Transformers Contract No. XYZ Documents	BC Hydro Standard Technical Specification XYZ; CAN/CSA-C88.1 (1996)
	Control	-11.4	-15.1	**-50.0**	Various Stations 64.5 and 138 kV Power Transformers Contract No. XYZ Documents	BC Hydro Standard Technical Specification XYZ
	Tap changer	-11.4	-15.1	**-50.0**	Various Stations 64.5 and 138 kV Power Transformers Contract No. XYZ Documents	BC Hydro Standard Technical Specification XYZ

Note:
MDT of some transformer components were not obtained: Cooling system, core, oil, oil preservation system, surge arrestors, tank, winding. Used main set MDT (T1) temperature for those components.

Minimum Design Temperature of Outdoor Equipment

- Researched data for 900 outdoor electrical equipment MDT in 20 BES stations
- Compared the found MDT with:
  - The calculated 0.2 percentile temperature (T)
  - The obtained historical operating T
- ***MDT < Historical operating T < 0.2 percentile T***

Conclusions

- The 2021 Texas Cold Weather Event prompted NERC to develop cold weather reliability standards
- Adapted NERC Extreme Cold Weather Temperature methodology from NERC EOP-011-2 to define and calculate the 0.2 percentile temperatures for 20 BC Hydro BES generating stations.
- NERC EOP-012-1 standard provides justification for selecting 0.2 percentile

Conclusions

- 0.2 percentile temperatures were calculated using the excel “PERCENTILE.INC” function for the winter months, using data obtained from the BC Hydro Climate and PCIC databases that had:
    - Hourly temperatures available between 2000/01/01 and 2023/02/28
    - Similar climate to generating station
- BC Hydro Hydrology team used best judgement to interpolate or estimate missing data
- Calculated the 0.2 percentile temperatures for the 20 BC Hydro BES generating stations and 4 regions using data supplied by BC Hydro Hydrology team

Conclusions

- The historical operating temperatures analysis shows that 15 out of the 20 in scope generating stations and all their generating units were operational during their coldest weather event dates and temperatures. The analysis also shows that it was necessary to select a 2nd, 3rd, and 4th coldest temperatures for four stations. This is because a generating unit for those four stations was not operational for the absolute coldest, 2nd, and 3rd cold temperature events
- One out of the 20 stations is under construction (Site C)

Conclusions

- Using the subsequent coldest temperature approach (2nd, 3rd, 4th coldest temperature) is reliable because the historical coldest temperature variance for Stations 7, 10 and 15 is less than 1.0 °C
- The temperature variance for Station 19 is 2.9 °C. It is possible this is due to the significant (27.6%) missing climate data for this station

Conclusions

- Stations Maintenance invested significant efforts to collect MDT of in scope outdoor electrical equipment (900+ units). Approximately, less than 50% of the temperature data was collected
- For the MDT data that was not found, the historical operating temperature has been suggested to be used for NERC compliance purposes because it demonstrates that the 20 BC Hydro BES stations have been operating at ambient temperatures lower than the NERC 0.2 percentile temperatures

Conclusions

- The lowest ambient temperatures and obtained MDTs align with BC Hydro Stations two zones classification for substations: a -30 ˚C zone and a -50 ˚C zone

Acknowledgement

The author would like to thank BC Hydro Mandatory Reliability Standards and Generation Stations Asset Planning for funding and initiating the work, and BC Hydro Generation Stations Electrical, Mechanical, Protection & Control for checking and reviewing the work.

BC Hydro

Power smart