newfoundland labrador hydro

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December 22, 2021

Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, NL A1A 5B2

Attention: Ms. Cheryl Blundon
Director of Corporate Services & Board Secretary

Dear Ms. Blundon:

Re: *Reliability and Resource Adequacy Study Review* – Additional Considerations of the Labrador-Island Link Reliability Assessment and Outcomes of the Failure Investigation Findings

Enclosed please find Newfoundland and Labrador Hydro's "Additional Considerations of the Labrador-Island Link Reliability Assessment and Outcomes of the Failure Investigation Findings."

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

Shirley A. Walsh
Senior Legal Counsel, Regulatory
SAW/sk

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Reliability and Resource Adequacy Study

Additional Considerations of the Labrador-Island Link Reliability Assessment and Outcomes of the Failure Investigation Findings

December 22, 2021

A report to the Board of Commissioners of Public Utilities

Contents

List of Attachments

1.0 Introduction

Newfoundland and Labrador Hydro ("Hydro") committed to providing an update in the fourth quarter of 2021 which would provide the findings related to additional considerations associated with the reliability of the Labrador-Island Link ("LIL"), information related to the findings of the failure investigation reports,[1] and updates to the LIL emergency response plan.

This report provides a high-level summary of the findings related to the "Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads – Phase II," ("Phase II LIL Reliability Report")[2] included as Attachment 1 to this report, updates to the "Emergency Response & Restoration Plan – Labrador-Island Link Overland Transmission" ("Emergency Response and Restoration Plan"),[3] included as Attachment 2 to this report, as well as further information related to the failure investigation related to the 2021 ice storm, provided in Section 4.0 herein.

2.0 Assessment of LIL Reliability in Consideration of Climatological Loads

The "Assessment of Labrador Transmission Link (LIL) Reliability in Consideration of Climatological Loads" ("Original LIL Reliability Report")[4] included a number of recommendations made by Haldar & Associates Inc. ("Haldar & Associates") with respect to future work that should be undertaken to better understand the as-built reliability of the LIL. In its correspondence of April 30, 2021,[5] Hydro committed to completing additional work with respect to unbalanced ice loading, wind speed-up factors, and combined wind and ice loading and engaged Haldar & Associates to complete the analysis.

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[1] "Failure Investigation Report – L3501/2 Tower and Conductor Damage Icing Event January 2021 in Labrador," Nalcor Energy, May 28, 2021 and "Failure Investigation Report – L3501/2 Pole Assembly Turnbuckle Failure Failure Event February 2021 in Labrador," Nalcor Energy, May 28, 2021.
[2] "Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads – Phase II," Haldar & Associates Inc., December 12, 2021.
[3] "Emergency Response & Restoration Plan – Labrador-Island Link Overland Transmission," Newfoundland and Labrador Hydro, December 15, 2021.
[4] "Assessment of Labrador Transmission Link (LIL) Reliability in Consideration of Climatological Loads," Haldar & Associates Inc., rev. April 11, 2021 (original March 10, 2021).
[5] "Reliability and Resource Adequacy Study Review – Assessment of Labrador-Island Link Reliability – Further Information," Newfoundland and Labrador Hydro, April 30, 2021.

Attachment 1, the Phase II LIL Reliability Report, provides the findings of the noted work. The following presents a brief summary of the report's findings.[6]

2.1 Use of Return Period Associated with Ultimate Limit States Rather Than Damage Limit States

The prior analysis conducted by Haldar & Associates in the Original LIL Reliability Report determined that the optical ground wire was the governing component with respect to structural reliability. The resulting damage limit state had a return period of 1:73 years. Analysis also indicated that an extended bipole outage under an ultimate limit state scenario would have a return period of 1:160 years with an associated annual failure rate of 0.48%.

The additional analysis undertaken by Haldar & Associates in the Phase II LIL Reliability Report considered more extreme loading scenarios where support structures would become the governing system component due to considerations associated with combined wind and ice loads as well as wind speed-up effects. These considerations are further discussed in the sections that follow. Findings are summarized as follows:

- Under the more extreme loading conditions, structures were found to be the governing component for transmission line reliability. As a result, there would no longer be a differentiation between damage limit state and ultimate limit state failure modes. Rather, there would be an interruption of power delivery in either event due to structural failure.
- When more extreme loading conditions are considered, there is a material decrease in the return period of the line to 1:10 years with a 10% probability of failure.
- Progressive failure analysis is not required in such a case as critical towers would be governed by main leg members.

[6] No work was completed on the Event Tree Analysis during the Phase II LIL Reliability Report assessment as this occurrence is not suspected to result in a bipole outage and is considered to be a lower priority for the purpose of evaluating the overall reliability of the LIL. Hydro will continue to monitor operational performance of the LIL and assess any conditions as experienced with respect to this subject on an as-required basis.

2.2 Unbalanced Ice Loading

The Original LIL Reliability Report discussed the design of the LIL in consideration of unbalanced loading conditions. It was recommended that further studies be completed to investigate the impact of loads and loading combinations in accordance with CSA standards and criteria developed previously by Hydro.

The updated analysis presented in the Phase II LIL Reliability Report confirmed that the towers meet the 50-year criteria with respect to unbalanced loads as specified in CSA 22.3 No. 60826-10: Design criteria of overhead transmission lines. The analysis identified two critical towers in the Labrador section (Zones 1 and 3A) that exceeded 100% utilization when considering Hydro's internal unbalanced ice loading criteria. It was noted that given the lower ice accretion associated with the LIL's large pole conductor size, this utilization could be decreased by 10% to 15% on average.

2.3 Wind Speed-Up Factors and Combined Wind and Ice Loading

The Original LIL Reliability Report identified that the effect of wind speed-up as a result of sloping terrain has the potential to increase loading on the lower portion of existing support structures by approximately 35%. It was recommended that specific areas be reviewed to ensure an appropriate understanding of loading and potential structural impacts.

Haldar & Associates also recommended that additional investigation be undertaken with special consideration of more extreme combined wind and ice criteria ranges presented in CSA recommendations for areas (such as in Labrador) where operational experience is limited.

The updated analysis within the Phase II Reliability Report identified 17 structures that would be subject to wind speed-up effects. Of these structures, 7 could be subject to conditions that exceed 100% utilization for a 50-year return period based on the extreme load combination of wind and ice (85/40) and wind speed-up.

The cumulative effect of combined wind and ice at the more extreme 85/40 level and wind speed-up results in a probability of failure of 10%. This probability of failure is directly based on the fact that there are several towers in Labrador (in Zone 3A) that are vulnerable due to local topography effects coupled with CSA 22.3 No. 60826-10 increased combined wind and ice load events.

As noted in the Phase II LIL Reliability Report, however, the loading associated with the 85/40 are extreme values that appear to be in exceedance of local historical data. Further, this report cautions that

CSA 22.3 No. 60826-10 provides a range between 0.6–0.85 for the upper limit of wind and ice loading but does not provide clear direction on when the upper or lower limits should be utilized. As such, the Phase II LIL Reliability Report indicated that it may be overly conservative to accept the extreme impact on the resultant probability of failure. If a lower wind and ice combination (70/40 or 60/40) is utilized, the number of structures exceeding 100% utilization would be reduced to four structures and the probability of failure will decrease thereby providing a higher return period ranging from 21 to 53 years.

2.4 Impact due to Pole Conductor Size

As noted in the analysis from the Original LIL Reliability Report, icing values identified within CSA 22.3 No. 60826-10 are based on a standard 30 mm rod diameter compared to the 50 mm pole conductor utilized on the LIL. The current analysis indicates that the annual probability of failure could reduce by 7% to 10% as a result of the impact of reduced ice thickness due to large size of the pole conductor on the LIL.

2.5 Extreme Event Correlation

The Original LIL Reliability Report identified an alternative means of determining the overall line reliability based on the line length and correlation of extreme events between varying line segments. Reliability was assessed on the basis of four climatological regions established by past operational experience. This methodology is outside of CSA 22.3 No. 60826-10 as the standard does not account for the impact of line length. The Original LIL Reliability Report work suggested that a correlation study for extreme events should be completed to validate the criteria used in the analysis.

The Phase II Reliability Report involves consideration of regional independence due to line length when assessing LIL reliability. By considering this concept, the as-built design of the LIL would have a return period of 1:6 years with an associated annual failure rate of 16%. Given such considerations, the reliability of the LIL would be materially lower under certain climatological conditions than previously contemplated.

However, CSA 22.3 No. 60826-10 does not include allocations for the consideration of line length or regional correlation with respect to transmission lines. Further, such concepts have not been widely validated or utilized within the utility industry.

3.0 Emergency Response and Restoration Plan

The purpose of the Emergency Response and Restoration Plan, provided as Attachment 2 to this report, is to provide an overview of Hydro's current program to support the LIL's ability to avoid sustained outages during high-risk conditions, including Hydro's plans for incident preparedness, response, and restoration.

3.1 Incident Preparedness

3.1.1 Asset Analysis and Engineering Tools

To enable effective and timely response to an emergency on the LIL, a number of engineering considerations contemplating the LIL's physical characteristics and design must be taken into account. The following tools are applied to aid in design and analysis of areas of exposure and structural performance:

- LIL zone classification based on accessibility and general meteorological loading. This assists with identification of areas which require more focus and planning from an emergency response perspective;
- As-built LiDAR[7] and orthophotography for the LIL, including as-built condition of the line, conductor sag, tower clearances, access road network, and right-of-way information;
- ArcGIS geospatial database to track maintenance records, historical damage and trends, and inspection reports; and
- Real-time monitoring stations to record certain conditions on the LIL such as ice loading, wind loading, galloping, and Aeolian vibrations.

Further information on each of these asset analyses and engineering tools is located in Section 4 of Attachment 2.

3.1.2 Interim Engineering Solutions

Hydro has developed detailed engineering solutions which could potentially be used to expedite re-energization of the LIL following a bipole failure. This upfront engineering is intended to reduce response time by making a variety of solutions available for the operations team to choose from

[7] Light detection and ranging ("LiDAR").

depending on the failure scenario. Further information regarding the engineering design alternatives considered is provided in Section 6 of Attachment 2.

3.2 Emergency Response

3.2.1 Mock Exercises

Since 2018, Hydro has undertaken a series of increasingly complex mock exercises to obtain experience in responding to potential types of failures to reflect actual restoration conditions. Doing such work in a controlled environment highlights gaps in coordination, documentation, processes, procedures, and logistics which can then be addressed in advance of a true emergency situation. This experience helps with the definition of roles and responsibilities and reduces response time in an emergency response scenario. Further information regarding the engineering design alternatives considered is provided in Section 9 of Attachment 2.

3.2.2 Emergency Response Plan

The "Labrador-Island Link Overhead Transmission Line Emergency Response Plan" ("Emergency Response Plan")[8] provided in Appendix A of Attachment 2 outlines pertinent information related to personnel, roles and responsibilities, equipment, emergency response and restoration protocols, and logistical plans to be followed in the event of a line failure. As Hydro obtains additional operational experience with the LIL, its Emergency Response Plan will also evolve. For example, the previous version of the Emergency Response Plan[9] was modified in May 2021 to reflect the learnings obtained through the process of investigating and repairing the LIL following the January/February 2021 ice storm incidents.

3.3 Restoration Timeframe

In 2019, Hydro undertook an exercise to determine the estimated time to restore power based on the location of the failure. At the time, it was determined that restoration could take up to seven weeks, depending on the circumstances of the failure.[10] An additional analysis was undertaken in 2021 by

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[8] "Labrador-Island Link Overhead Transmission Line Emergency Response Plan," Newfoundland and Labrador Hydro, December 1, 2021

[9] Originally filed with the Board as Attachment 1 to the "Near-Term Reliability Report," Newfoundland and Labrador Hydro, May 15, 2020.

[10] Hydro's analysis reflected a number of assumptions regarding weather, accessibility, resource availability, etc. which are further outlined in Section 5.1 of Attachment 2.

Locke's Electrical Limited to assess the timelines for power restoration for seven discrete scenarios. This analysis resulted in a similar estimated restoration time frame of three to six weeks, depending on the scenario including logistics and line location.[11]

4.0 Failure Events Investigation – Further Information

A significant ice storm passed through Labrador from January 6 to 8, 2021. On January 11, 2021, line workers out of Happy Valley-Goose Bay observed an abnormality with the electrode line near a structure close to the Trans-Labrador Highway.[12]

On May 31, 2021, Hydro filed LIL failure investigation reports for the January 2021 icing event[13] and the February 2021 failure event.[14] The submission also included a third-party engineering review of the root-cause analysis related to the L3501/2 tower and conductor damage resulting from the January 2021 icing event, completed by Maskwa High Voltage Ltd.[15]

In its LIL monthly update for July 2021,[16] Hydro advised that remedial work related to the 2021 ice storm on the Labrador portion of the LIL was planned for the summer of 2021. The work was completed as scheduled at an approximate cost of $3.85 million dollars. The scope of the work included a drone inspection of the Labrador section of the line to identify any non-critical damage caused by the ice storm and included repairs to optical ground wire assemblies and conductors as well as damper replacements.

Further work is ongoing with respect to regular line patrols, weather monitoring, and emergency restoration and response planning. This work includes the installation of a weather station and real-time ice load monitoring on a test span along the transmission line route. Additionally, line patrols will occur

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[11] Locke's Electrical Limited's analysis reflected a number of assumptions regarding weather, resource availability, etc. which are further outlined in Attachment 2, Section 5.2.
[12] "Reliability and Resource Adequacy Study Review – Labrador-Island Link Monthly Update – March 2021 – Board Questions – Hydro's Response
[13] "Failure Investigation Report – L3501/2 Tower and Conductor Damage Icing Event January 2021 in Labrador," Nalcor Energy, May 28, 2021.
[14] "Failure Investigation Report – L3501/2 Pole Assembly Turnbuckle Failure Failure Event February 2021 in Labrador," Nalcor Energy, May 28, 2021.
[15] "Cold Eyes Review – Failure Investigation Report; L3501/2 Tower and Conductor Damage," Maskwa High Voltage Ltd., May 26, 2021.
[16] "Reliability and Resource Adequacy Study Review – Labrador-Island Link Monthly Update – July 2021," Newfoundland and Labrador Hydro, August 13, 2021.

when severe weather is forecasted. This work will aid in Hydro's understanding of the ice load exposure for the LIL and will allow for proper planning of mitigating interventions during an icing event.

As discussed in the Emergency Response Plan (Appendix A to Attachment 2) and the "Emergency Response Timeline Report - Labrador Island Link"[17] (Appendix B to Attachment 2, the timeline for repair will be reduced somewhat by the various solutions that have been acquired, but are still in the range of three to six weeks depending on the failure and location.

During the failure investigation, galloping and vibration issues were identified as contributing factors of failure, but not the primary root cause. These galloping and vibration issues continue to be investigated as part of regular maintenance operations, including monitoring of suspension clamps and damper performance under operation. Testing of the suspension clamps confirmed that vibration will affect the slip strength. Vibration monitors have been installed on the line to determine if the dampers are performing correctly. The monitoring period has concluded and the results will be analyzed when the monitors can be safely removed. To address the issue of galloping, a galloping study was completed to determine areas where galloping could occur and air spoilers are being installed at locations of known galloping. This information can be used to plan further monitoring of these locations and installation of additional air spoilers, as required.

In addition, a second set of testing was completed on the failed conductor from the ice storms. The testing supported original findings that the primary cause of the failure was overloading due to icing but also noted that vibration may have been a contributing factor.

As previously noted, weather modeling completed as a result of the January 2021 icing event suggests that higher ice loads could occur more frequently than originally contemplated. Further operational experience and increased monitoring are required to validate this concern, including the installation of weather and ice load monitoring along the line route and the completion of line patrols after a severe weather event. Furthermore, an aerial ice removal procedure is under development for the removal of ice from the line before design loads are exceeded.

[17] "Emergency Response Timeline Report – Labrador Island Link," Locke's Electrical Limited, November 25, 2021.

5.0 Next Steps/Recommendations

Hydro is using the output of the assessments completed by Haldar & Associates in combination with the information provided in the Emergency Response and Restoration Plan to further inform its next filing of Volume I and Volume III of the Reliability and Resource Adequacy Study, which will be submitted in the summer of 2022. These components will serve as the basis for the modeling of the unavailability of the LIL in consideration of the potential ranges for the frequency and duration of outages.

As previously summarized, repairs to the LIL could range from three to six weeks. LIL return periods were previously defined to be in the range of 1:73 to 1:160 years. A revised reliability analysis, based on more extreme loading consideration, indicates a probability of failure of 10% and a return period of 1:10 years. Other outcomes include consideration of regional correlation and line length where the return period could be as low as 1:6 years with an associated annual failure rate of 16%.

As stated previously, the extreme combined wind and ice load scenarios are not supported by historical data. Further, concepts relating to line length and regional correlation have not been widely validated or utilized within the utility industry. On this basis, Hydro does not have a basis to definitively accept such considerations. Rather, Hydro will consider the sensitivity impact of this wide range of reliability considerations as part of the detailed reliability analysis of the system, which will be performed as part of the next stage of the Reliability and Resource Adequacy Study. Sensitivity analyses will be performed to assess the impact of LIL reliability on customers and determine the associated costs for system additions to ensure acceptable levels of reliability.

Hydro will evaluate the range of proposed solutions and develop recommendations. Such solutions could include the addition of generation to the Island Interconnected System. The analyses will also consider the cost of structural enhancements of the LIL. While comprehensive structural upgrades to increase the reliability of the full transmission line on the basis of extreme meteorological conditions would almost certainly be cost prohibitive, consideration will be given to the targeted upgrades to specific structures identified in the analysis performed by Haldar & Associates in the Phase II LIL Reliability Report. As discussed, upgrades to address local combined wind and ice and wind speed-up effects could be performed to appreciably impact the reliability of the transmission line.

Hydro's Reliability and Resource Adequacy Study will also include consideration of the outcomes of the ongoing condition assessment of the Holyrood Thermal Generating Station ("Holyrood TGS"), scheduled for completion in the first quarter of 2022. The condition assessment will help inform whether the Holyrood TGS can economically provide support to the system in the near term while incremental resources are constructed, should they be required, or play a larger role in economically satisfying system requirements in the future.

As an additional consideration, Hydro intends to begin system impact study work associated with implementation of its Network Additions Policy in the first quarter of 2022. As part of this process, more detailed information relating to load requests in Labrador will be received. Such load growth could drive an increase in provincial capacity requirements. The resulting solutions to meet incremental demand could also resolve concerns presented in Hydro's Reliability and Resource Adequacy Study.

Table 1 summarizes the anticipated timing of each of the next pieces of work that will aid in informing future provincial reliability decisions.

Table 1: Anticipated Timing of Filings

Report/Analysis	Scope	Anticipated Time Frame for Completion
"Assessment to Determine the Potential Long-Term Viability of the Holyrood Thermal Generating Station"	Assessment to determine (i) the requirements of extending the Holyrood TGS on an interim basis in the short term (e.g., additional 2, 4, or 6 years), should it be required and (ii) whether the Holyrood TGS can economically provide support to the system on a longer term basis as a backup generation facility.	First Quarter of 2022
"Network Additions Policy Incremental Load Requirements and System Impact Studies"	Findings related to load requirements assessment and system impact studies for Labrador and associated estimated supply requirements.	Third Quarter of 2022[18]
"Reliability and Resource Adequacy Study" Volume I and III Updates	Update to Volumes I and III to reflect findings of the additional matters considered under the *Reliability and Resource Adequacy Study Review* proceeding including the LIL Reliability Assessment, Network Additions Policy System Impact Studies, and Holyrood TGS Assessment.	Summer 2022

[18] Hydro intends to begin system impact study work associated with implementation of its Network Additions Policy in the first quarter of 2022. This work is anticipated to be completed within 24 weeks.

Attachment 1

Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads – Phase II

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Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads - Phase II

Follow Up Work by Newfoundland and Labrador Hydro (NLH) With Respect to Key Recommendations-Analysis Results

Final Report

Prepared by
Haldar & Associates, Inc.
St. John's, NL, Canada

Principal Investigator
Asim Haldar, Ph. D, P.Eng.

Report Prepared
for
Newfoundland and Labrador Hydro
Original: December 12, 2021

REPORT DISCLAIMER

This report contains information about the Labrador Island Link ("**LIL**") reliability study (the "**Report**"). The Report uses data specifically related to the structural analysis of the LIL, which was provided by Newfoundland and Labrador Hydro and Nalcor Energy. While every effort was made to ensure the accuracy and completeness of the information contained in the Report, in no event shall the author be liable for any damages whatsoever resulting from the use of this Report, or any information obtained from this Report. The Report and this exclusion of liability have been drafted in contemplation of the Report being made public once submitted to the Public Utility Board.

Executive Summary

This report is an extension of the earlier study report that addressed the baseline assessment of the structural reliability of Labrador-Island Link (LIL) by exposing the HVdc transmission line to two types of icing in various scenarios. The two types of icing considered were (a) glaze icing due to freezing precipitation and (b) rime icing due to in-cloud precipitation. This reliability assessment was conducted to validate the LIL design with respect to CSA 60826 -2010 reliability class of loads and to determine the overall likelihood of failure of the LIL with respect to extreme icing events.

In the March 2021 report (Haldar Report), all the annual probability of failure (POF) values were reported as baseline values. They were primarily determined for reliability class of loads: extreme ice, extreme wind, and combined wind and ice loads following CSA 60826-10. Baseline values referred in Haldar Report were determined using the lower limit of the reference wind speed and ice load combination values for glaze icing following CSA 60826-10. For rime icing, these load combination values were determined based on an actual meteorological study conducted using a numerical weather prediction (NWP) model. The values were close to the upper limit values of reference wind speed and ice load for combined loads in CSA 60826-10. Unbalanced ice loads and load combinations were excluded from the reliability analysis and treated as deterministic loads after a careful review of the CSA standard's clauses. The influence of topography and its impact on LIL structural reliability was excluded from the calculation of baseline annual POF values.

The Haldar Report (2021) concluded that the annual POF of LIL can range from little over 1% for Scenario #1 (a simple series model with full correlation along the entire line length) to 5% for Scenario #4D (considering two different types of icing exposures, correlation among the key elements, and regional independence of the various weather zones). All these analyses were done under CSA 60826-10 damage limit state (DLS) criterion. In terms of return period values, it was concluded that the LIL structural reliability (baseline values) could be anywhere between 20 years to 73 years.

The Haldar Report made several recommendations. One of the important recommendations was to study the impacts of terrain (turbulence) and topography (local wind speed up) effects on the reported baseline LIL reliability. This needs to be done with or without the upper limit of the reference wind speed value following CSA 60826-10 combined loads. A recommendation was also made to ensure that the towers in the Labrador region meet the NLH load combinations for unbalanced ice loads (UBI). Two other recommendations were made: the first one was on the validation of the assumption of regional independence of the extreme climatic load events (load correlation issue) in assessing the impact of line length on LIL reliability and the second one, was on the reduction of pole conductor loads due to lesser ice accretion (large diameter effect) and their impact on the baseline reliability values.

Based on our present analysis, LIL reliability decreases (POF increases) significantly when one considers the impact of topography exposure (local wind speed up effect, WSU) and the upper limit value (0.85) of the reference wind speed (V_R) for wind plus ice and (0.5 of V_R) for ice plus wind loads following CSA 60826-10 combined loads exposure. Under the combined effects of these two exposures, the annual POF increases significantly – almost tenfold (10% vs. 1.1%) – compared to baseline value (1.1%) reported earlier (Haldar,2021). The failure sequence is also reversed: in this case, the "structure support system" will fail before the failure of the "wire support system". In terms of annual POF, this would be approximately 10% and the return period would be 10 years, compared to

73 years reported earlier. In the earlier study, OPGW system was identified to be the weakest element and the assessment was that the "wire support system" is likely to fail first before an element within the "structure support system (tower, foundation etc.)" fails. If one only considers the upper limit of the reference wind speed value in CSA 60826-10 increased combined loads (using Type C terrain and excluding the topography effect), the annual POF still increases approximately fourfold (4.1% vs. 1.1%); in terms of the return period, this would be 24 years instead of 73 years that was reported earlier. It appears that several towers, in Section 3a (Labrador Region) are vulnerable and are likely to fail before the "wire support system" failure happens (OPGW failure), leading to a bi-pole outage.

It is shown in Section 3.3 that the design combined wind and ice load is below the 50-year load criterion stipulated in CSA 60826-10. It has been also noted in this study that there are some challenges and inconsistencies in implementing CSA 60826-10 based combined wind and ice loads in line design. CSA based wind speed range (0.6-0.85Vr) with ice load is based on one single global reduction factor of 0.4 applied on conductor vertical load (0.4gl) and this single factor may not be suitable for the entire NLH service area in representing the extreme combined wind plus ice loads. In CSA 60826-10, it is stipulated that this (0.6-0.85Vr) reference wind speed range reflects the relatively high extreme wind speed during icing accretion periods. The combined load for a T-year return period is not only the function of ice thickness, concurrent wind speed and duration of the event but also the COV's of these parameters and the conductor diameter. Therefore, one global reduction factor for ice load for the entire CSA map based wind and ice loads may not provide a consistent and conservative load combination for wind and ice loads. A specific recommendation is made how to address this in the future.

Western University's study on the influence of topography on the wind speed up (WSU) effect identified five sections that included seventeen critical tower locations. Three of these seventeen towers located in Section 3a are significantly vulnerable and most likely will not survive under CSA 60826-10 increased load conditions. It appears that although the line Section 3a is 1.1% of the total LIL line length of 1100km, several towers in this zone are vulnerable due to influence of topography coupled with CSA 60826-10 increased combined load effects. Several towers in this section that are not subjected to WSU effects are still significantly exposed to CSA increased combined load events (wind plus ice), and the annual POFs of all these towers are high and these towers show significant overloads on the mast members (tower leg members under buckling mode of failure). The annual POFs of the three specific suspension towers that are exposed to topography effect coupled with increased load effect vary between 8% to 10%. However, several towers in Section 3a including these three suspension towers have also high annual POF ranging 3.3 % to 4.1% when influence of topography is not considered. Under Scenario #2, where the mutual exclusivity of two icing exposures is considered, the annual POF of LIL is estimated to be 12.3% under increased combined loads with topography effect.

The unbalanced ice (UBI) load analysis considering NLH load combinations was done based on LIL design ice load and the load combination criteria and the analysis revealed that the use factors for several members of S1-318 tower in Zone 1 and S2-541 tower in Zone 3 in Labrador region exceeded the members' strength limit significantly under two specific load combinations. These are: (1) all five cables shedding simultaneously and (2) four cables shedding simultaneously. However, these use factors decreased by 10-15% on average for several key members when one considers the expected reduction of ice accretion due to large pole conductor size. Even with this reduction, these two critical towers are still exposed to significant overloading issue (buckling of leg members) should these load combinations do occur. Two other towers located on the island part of the line have also some overloading that is within acceptable limit. In the earlier report (Haldar, 2021), these towers were checked for CSA 60826-10 combined load criteria for UBI analysis and results were reported that they did meet the minimum 50-year load combination criteria. It is to be noted here that CSA 60826-10 load combination criteria are very different than NLH load combination criteria. All analyses reported here are deterministic analysis.

A high level load correlation study using simulated extreme event load data reveals that, in general, the regions identified in the Haldar Report (2021) are independent with respect to extreme wind and ice events: correlation only exits within the region for line length not exceeding fifty-kilometer length spatially (Hong, 2021). This validates the assumption made under Scenario #4D in the earlier report in assessing the impact of line length on LIL reliability (Haldar, 2021). If one considers the impact of line length on the expected annual POF under Scenario #1 in this study, LIL reliability decreases further significantly. Under Scenario # 4D, the POF of LIL is 15.5%. In this, the critical tower S2-539 in Section 3a and OPGW cable in Section 7a controls 80% of the total POF while all other sections only contribute to 20% of the total POF of 15.5%. In terms of return period this is 6.5 years.

For structural reliability analysis, a correction factor can be made to adjust for the reduced pole conductor load and the return period can be increased by 10% on average for increased CSA 60826-10 combined loads with WSU effects. For baseline loads without WSU effect, this realization could be higher. This increase should only be applied where one of the key elements (tower) of "structure support system" controls. For the increased combined loads coupled with WSU effect, this gain in return period is marginal (10 year vs. 11 year).

The figure below presents the risk level of exceedance for these three scenarios for asset life of 5, 10, and 50 years. Under all these Scenarios, LIL annual failure probability is very high (well above the 1-2% of industry standard) and the failure of LIL is very likely leading to a bi-pole outage when one considers the 50-year service life of the asset (Figure A).

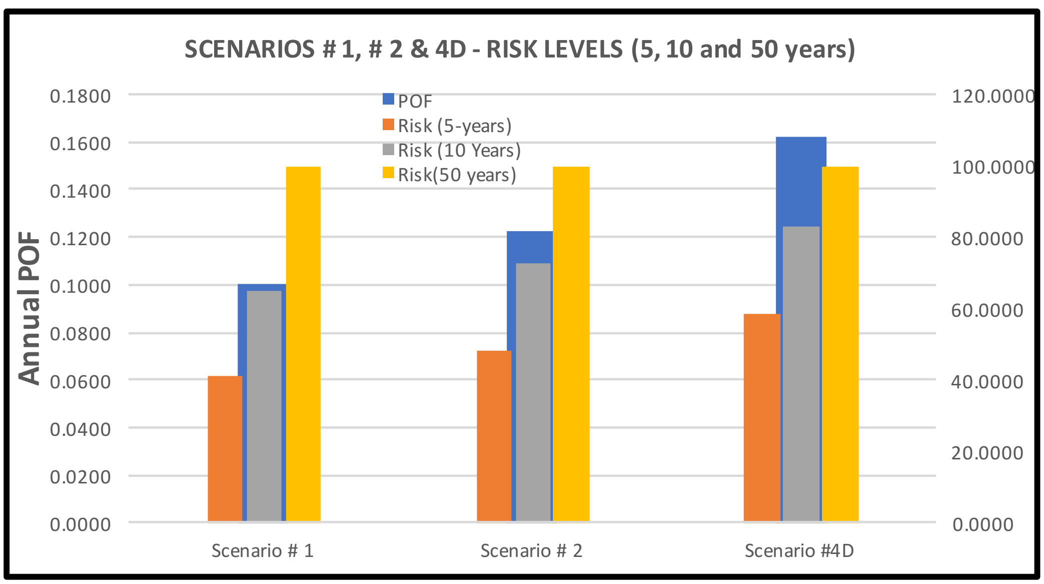

Figure A - Comparison of Risk Levels for Various Scenarios

This report includes several recommendations. NLH may want to further study Section 3a, and few other sections where A1 suspension tower is predominantly used, to determine how the structural reliability of LIL sections can be improved by adding mid-span towers. Alternatively, NLH might also consider redesigning the A1-type tower to withstand not only the CSA 60826-10 required load criteria for combined load events and to make sure they also withstand the NLH load combination for UBI and develop a plan to strengthen these towers over the next five (5) years so the POF for this section 3a and in other zones will be reduced considerably and fall within the acceptable range of the industry's best practices. Before a CSA 60826-10 combined load for wind and ice is used for a mitigation option, the last recommendation should be completed to ensure that combined loads selected for subsequent re-design and upgrading of the selected sections and key elements be based on a consistent statistical approach that is sound and practical and provides reliable design load envelope data validated by observed ice loads from past failure events in these regions.

Key Words: Labrador Transmission Link, HVdc, Reliability Based Design (RBD), Probability of Failure (POF), Topography effect, Terrain Effect, Overhead Transmission Line Reliability, Structural Reliability

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List of Abbreviations

1R – Symbol Used to Compare Results in Zone 1 for UBI Analysis Considering Reduced Pole Load

NWP – Numerical Weather Prediction Model

NWSU – No Wind Speed Up

NWSUR – No Wind Speed Up with Reduced Pole Load

POF – Probability of Failure

RBD – Reliability Based Design

UBI – Unbalanced Ice

WSU – Wind Speed Up

WSUR – Wind Speed Up with Reduced Pole Conductor Ice Load

1.0 Introduction

The Haldar Report (March 2021) made recommendations to close several "gaps" that were identified during the previous study. The earlier report presented the baseline annual probability of failure (POF) of the Labrador-Island Link (LIL) following the minimum combined load requirement of CSA 60826-10, particularly with respect to combined loads for wind and ice. Five recommendations that Newfoundland and Labrador Hydro (NLH) have pursued are summarized here:

1. Checking of LIL for unbalanced ice loads (UBI) with NLH's load combination criteria to assess the tower vulnerability, particularly in the Labrador Section of the LIL line where the suspension tower carries five cables and the tower weight is lighter compared to that on the Avalon Peninsula. In the earlier study, the "gaps" were identified in the LIL design with respect to complete omission of load combinations under UBI loads and the exposure that this poses for LIL. The specific recommendation was to reanalyze the critical towers for NLH's load combinations, assess members' use factors, and identify those towers that exceeded the capacity limit, particularly for the line section in Labrador.
2. The Haldar Report found that the lower limit of the CSA combined loads due to extreme wind and ice events might provide inadequate reliability. The original LIL design considered only wind plus ice load combination but did not consider the ice plus wind load combination. An analysis that considered the upper limit of the higher reference wind speed factor ($0.85V_R$) in combination with annual ice load was conducted on a few critical towers, and the result showed that the annual POF was significantly higher than what was reported for baseline values. Therefore, it was recommended that the "structure support system" and the "wire support system" be checked for these higher CSA combined loads.
3. The Haldar Report recognized that the original LIL design and EFLA report (2020) did not consider the impact of topography when determining the local wind speed up (WSU) effects on wind and ice loads and the as-built structural capacity. Based on the results of one topographic analysis for a tower located on the top of the Hawke Hill, this impact was shown to be significant. The author recommended a full topography analysis of the LIL route to identify all remaining "hot spots" along the LIL line route and to assess the site-specific wind loading and combined loads on the structure and wire support systems.
4. A full correlation study of the line route to past extreme storm events to establishing the correlation among various regions; if a strong correlation among various regions can be established, it may be possible to further improve the POF under Scenarios #4B and #4D, reduce the LIL POF (hence, increase the reliability, Haldar Report, 2021), and ultimately reduce the failure rate.
5. The earlier report (Haldar, 2021) also identified an opportunity to revise the current design loads considering the effect of large diameter of pole conductors on the design ice thickness. Although this recommendation was based on the limited data that was available based on an Environment Canada model run for St. John's airport, the author thought that a decrease in the expected loads on pole conductors would improve the baseline POF values for existing LIL design and might compensate for some of the expected increases from combined wind and ice loads considering topography effects. This improvement will only affect the POF (or reliability) under glaze ice exposure because in the rime sections, actual pole conductor size was included in predicting the ice loads. Therefore, reduction of pole conductor load does not apply in the rime ice sections.

1.1 Scope of the Present Work

The primary focus of this work is to assess the impacts of the above recommendations and determine the revised structural reliability of LIL under three scenarios (referred as Scenarios 1, 2 and 4D in Table 6.2 of the Haldar Report, March 2021). The specific tasks for the present work are:

- Complete the reanalysis of a few critical towers in the Labrador Region under UBI loads and load combinations following NLH's load combination criteria. Previous study did analyze the LIL for CSA 60826-10 UBI load combination criteria. NLH load combination will be based on LIL design ice thickness.

- Complete the reanalysis of critical towers in the Labrador region and some selected regions of the Island section of LIL to address the CSA 60826-10 load combination issue, particularly with respect to increased values of reference wind speed for combined wind and ice loads. Terrain type is considered as Type C.

- Complete the study to identify all "hot spots" along the LIL route where topography effects are significant and to determine its impact on the LIL's baseline reliability. This part of the work was subcontracted to Western University and was conducted by Prof. Grima Bitsuamlak, an expert in this area. Once the towers were identified, NLH conducted a structural analysis and Haldar and Associates conducted the reliability analysis and assessed the impact on the baseline values reported earlier.

- Conduct a separate "high level" study to determine the load correlation along the LIL route during extreme storm events. This part was conducted at a "high level" by Dr. Han-Ping Hong of Western University, who is an expert in this area.

- Reanalyze the line with a reduction in pole conductor loads due to a decrease in the expected ice accretion for freezing precipitation. This will require the addition of new load cases as well as an assessment of the reduction in the overall use factors for the support systems and its impact on the overall LIL reliability. No attempt is made here to do this structural reliability reanalysis for every element of the support systems for each location, rather for those elements only where the expectation is that this reduction will have significant impact with respect to load cases considered. An "order of magnitude" guidance will be provided to adjust the UF and POF values and return period for the increased load cases.

- Summarize the results with respect to baseline reliability, outlined in Table 6.2 in the Haldar Report (2021), and show the impacts on LIL POF for full CSA60826-10 load combination criteria with or without the topography effects (wind speed up effect). This revision is only done for Scenarios 1 and 2 in the Haldar Report (2021).

- Once all the above assessments are completed and the LIL POF's are revised for the above two scenarios, the impact of line length and correlation issue among various components will be qualitatively analyzed (Scenario #4D in Haldar Report, Table 6.2) based on the knowledge gained from the earlier study.

The reassessment of the LIL structural reliability analysis is conducted based on sample critical components that were identified in the earlier study. The primary focus of this study is on understanding the effects of topography, with or without the CSA increased combined load effects, on the LIL reliability and the validation of NLH load combination for UBI loads for sample critical towers in the Labrador section of the line. In addition, a high-level load correlation study will be done to understand the impact of line length on LIL reliability.

2.0 Analysis Results Under Each Recommendation

2.1 Unbalanced Ice Shedding and Load Combination Issues

The first recommendation in the Haldar Report was that the LIL line should be checked for UBI loads with NLH load combinations (Hydro's design criteria) to assess tower vulnerability, particularly in the Labrador region. The report noted that the suspension towers were designed for single-phase loads applied individually without any load combination under UBI analysis. Since the towers in the Labrador region carry five cables (one OPGW, two electrode conductors, and two pole conductors) and the tower weight is significantly lighter compared to the tower type used on the Avalon Peninsula, it was noted that these factors may make these towers more vulnerable to NLH UBI load combinations. NLH load combinations load cases are developed based on LIL design ice thickness and the criteria were discussed in the earlier report (Haldar, 2021).

Two critical towers identified in the Labrador section (Zones 1 and 3a) and two critical towers outside of the Labrador region, one in the central region (Zone 10-1) and the other in the Avalon region (Zone 11-3), were selected to validate Hydro's UBI load combination criteria with LIL design ice thickness. Analysis results are summarized in Figures 2.1a and 2.1b for S1-318 tower. Figure 2.1a presents the use factors for NLH design load combinations while Figure 2.1b presents the use factors for key members for LIL design criteria. For LIL design criteria (not considering the load combination), the use factors vary between 88% to 98%. However, these members are in different locations of the tower, some are in the cross- arm area. So, a direct one to one comparison is not done but according to deterministic design principle, this tower meets the original LIL design criterion, which is based on one phase shedding at a time and the load case consists of longitudinal unbalance load in one direction with reduced vertical load in that phase. All other cables have only vertical loads.

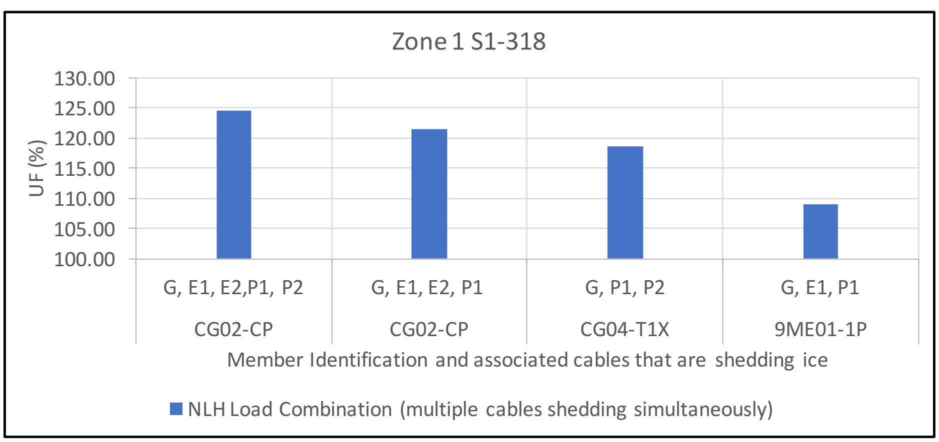


Figure 2.1 (a) - S1-318 (Members Identification and UF Exceeding 100%)

Figure 2.1c shows the screenshot of this tower for NLH load combination and the locations of those members that exceed the nominal capacity significantly (>105%). Most of these members are mast members (leg members) and are in compression (buckling mode). The left side screenshot presents the load combination for ground wire, two electrodes and one pole conductor while the right screenshot shows the shedding of all phases (cables). Both load combination will produce significant longitudinal load and bending of the tower and hence increased compressive loads on the mast causing a buckling mode of failure.

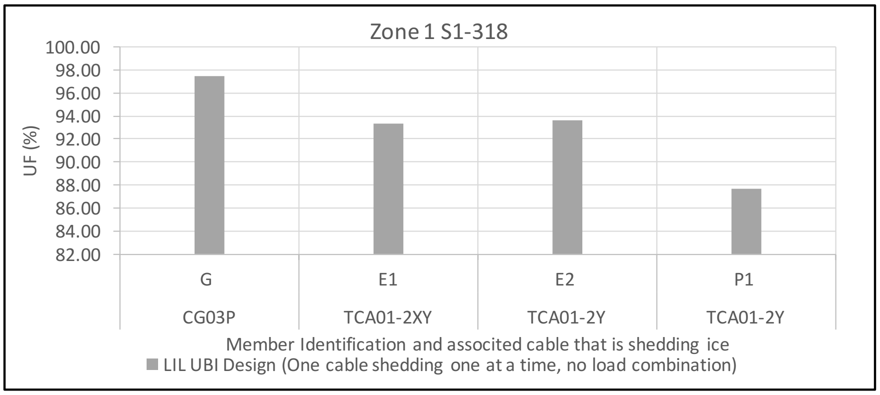


Figure 2.1 (b) - S1-318 (Members Identification and UF) For LIL Design UBI (No Load Combination)

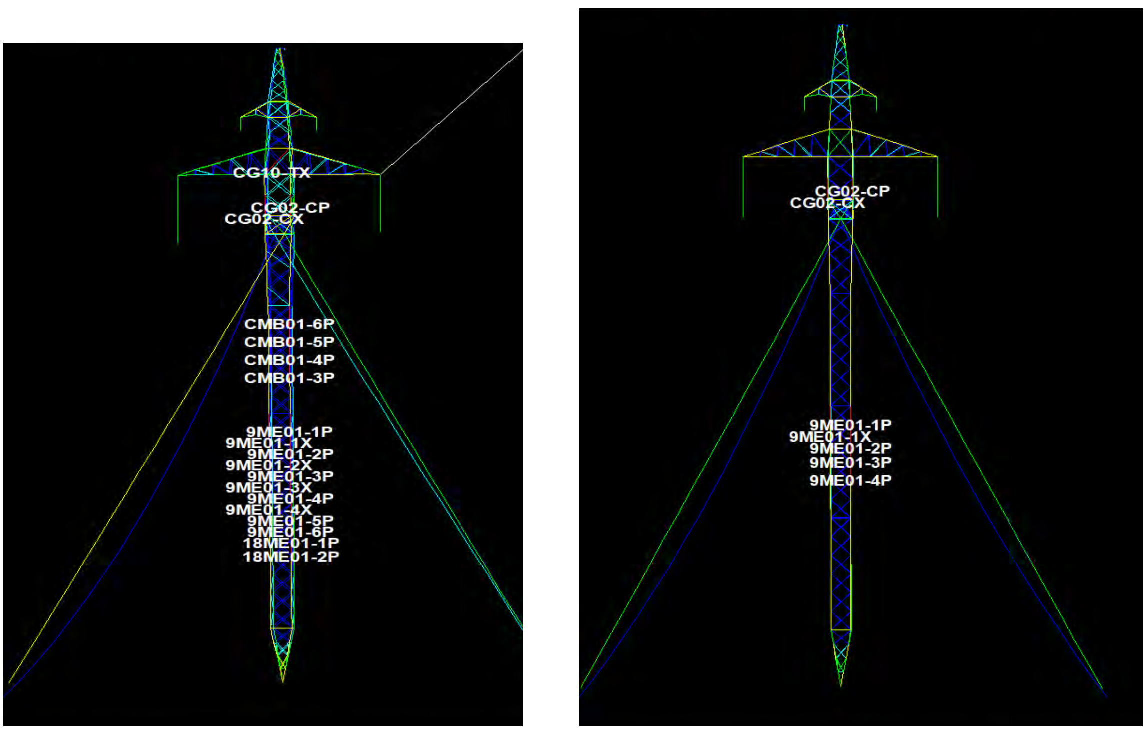


Figure 2.1(c) - Screenshot of S1-318 Tower in Labrador Zone 1 for two Load Combination Cases: Left (Longitudinal G, E1, E2, P1 - Design, C NA+) and Right (Longitudinal G, E1, E2, P1, P2 - Design, C NA+)

Figures 2.2a and 2.2b summarize the analysis results for S2-541 in Zone 3a. In this case two critical members are overloaded and the use factors for these two members are between 100%-115%. Again, critical load combinations are the same as it were for S1-318 tower (Figure 2.1c). Figure 2.b presents the same for LIL design criteria and the tower analysis results show it meets the criteria well and the members use factors are well below 100%.

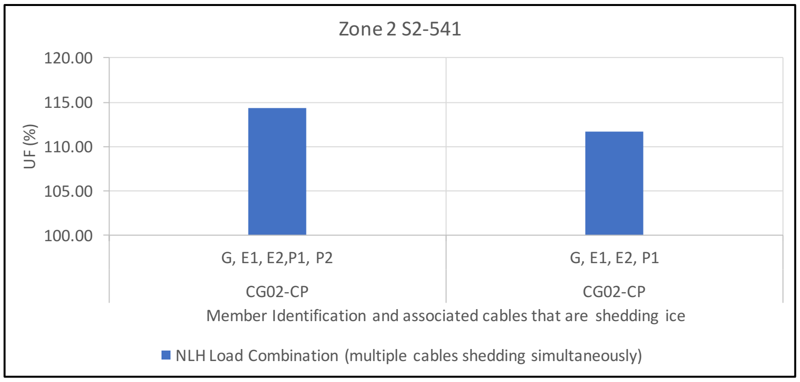


Figure 2.2 (a) - S2-541 (Members Identification and UF Exceeding 100%) For NLH Load Combination

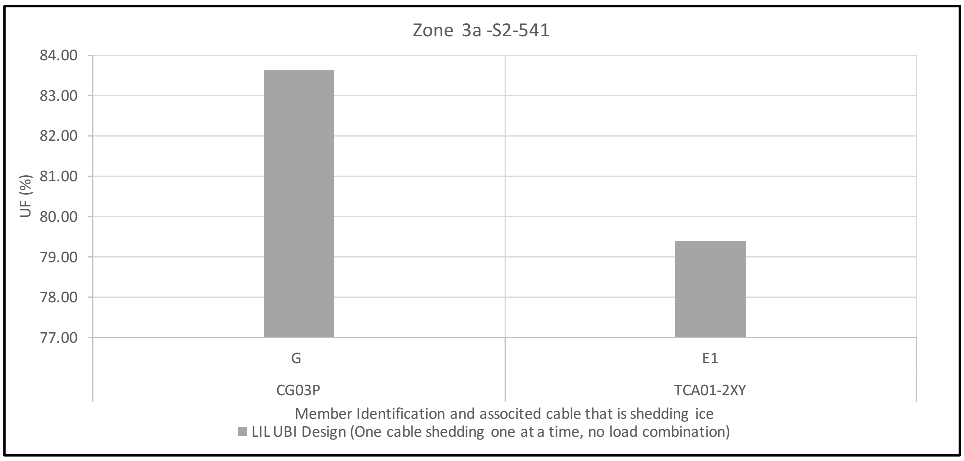


Figure 2.2 (b) - S2-541 (Members Identification and UF) For LIL Design UBI (No Load Combination)

Figure 2.3 presents the members for all four zones with UF that have exceeded the design capacity and are above 100%. Members UF that are greater than 105% indicate that these towers (S1-318 and S2-541) require additional action plan for mitigation. There may be others in the Labrador region that may not have been identified for UF exceedance above 100%. It is recommended those towers be also identified and NLH to develop a mitigation plan. Based on our earlier analysis for unbalanced ice following CSA 60826-10, it was determined that S1-318 and S2-541, both meet the 50 year criteria and the other critical towers that were checked have much lower POF values and do meet CSA 60826-10 criteria. The vulnerability assessment conducted in this report is only for NLH load combinations.

It is emphasized here that these two towers are exposed to severe damage (or likely failure) should this NLH load combinations are realized. Since our analysis is based on deterministic principle, no attempt is made here to quantify this probabilistically. It also shows that NLH load combination is onerous and overloads the tower much more compared to LIL design condition without load combination criteria. The author rejected the acceptance of UBI loads as reliability class of loads and therefore, it was excluded from the reliability analysis conducted in the earlier study (Haldar, 2021). However, if this would have been considered as reliability class of loads, the LIL annual POF would have been 0.018 (1.8% not 1.1% as reported earlier) and this would have provided a return period of

55 years (not a 73-year return period in Haldar report, 2021). In this case, structure support system would have controlled not the OPGW system.

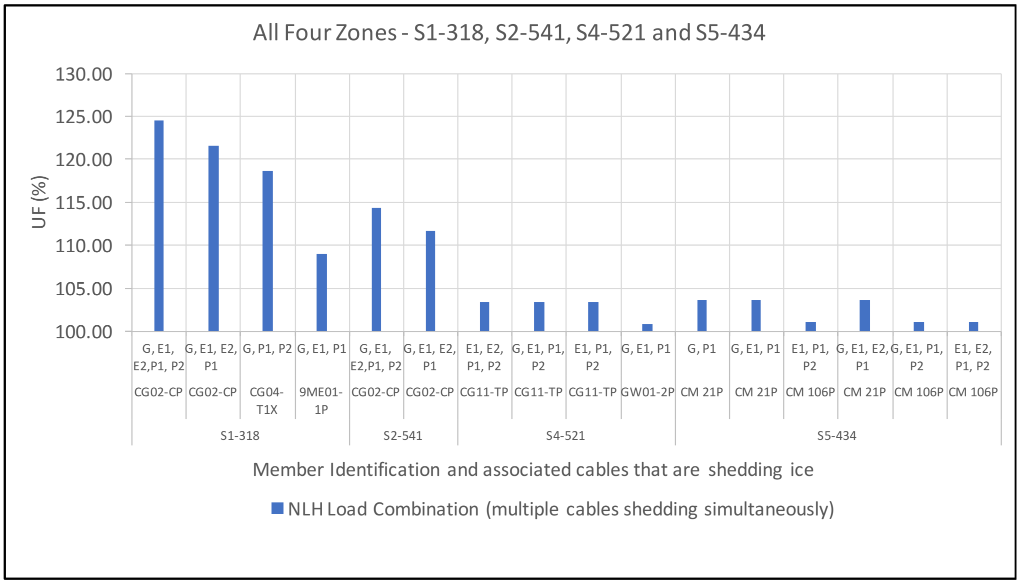


Figure 2.3 - Summary Plot for Four Critical Towers in Zones 1, 3a, 10-1 and 11-3

2.2 Load Combination Issues for Combined Wind and Ice and Ice Plus Wind Loads

Clause 6.4.1 of CSA 60826-10 requires that *"two loading combinations will be considered in this standard: Low ice probability (return period T) associated with the average of yearly maximum winds during icing presence, and low probability wind during icing (return period T) associated with the average of the maximum yearly icing."* The underlying assumption is that the two events are independent and there is no correlation between extreme ice and wind events. This is not totally correct and therefore, an estimate from combined probability method can produce loads which could be higher than the loads determined using the historical storm method (Goodwin et al, 1982). Correction factors are often required to reduce this overestimation by validating against the historical storm method, which is often based on field measured values after the actual storm events or based on model runs. The historical storm method is known to be more accurate. It is unclear why CSA/Environment Canada does not produce this combined wind and ice load map directly from the model run by stipulating maximum ice with concurrent wind and maximum days that the ice stayed on the cable by regions (residence time). In the US, ASCE 74 (2021) standard provides an extreme ice with concurrent wind speed map and only one load case is considered for combined loads.

Table 2.1 presents the CSA 60826 requirement for combined loading with wind and ice. The Haldar Report (March 2021) provided baseline POF (Table 6.2) based on the following criteria: full ice load on cables (100% g_l) with partial wind (40% V_R) and moderate wind on cables (60% V_R) with partial ice load on cables (40%g_l). However, CSA 60826-10 also recommends higher values for these amplification factors and, on the high side, there could be full ice load on cables (100% g_l) with partial wind (50% V_R) and high wind (85% V_R) with partial ice load on cable (40%g_l). The latter was not considered in the earlier study and a recommendation was made to include the higher range of these factors and its impact on the POF of the tower and LIL reliability.

- Baseline Load for Combined Wind and Ice – 100% of g_l + 40% of V_R and 40% of g_l + 60% of V_R (1A)
- Increased Load for Combined Wind and Ice – 100% of g_l + 50% of V_R and 40% of g_l + 85% of V_R (1B)

Table 2.1 - Definition of Combined Loading with Wind and Ice in the CSA60826 Standard (Reproduced from EFLA, 2020)

	Wind and Ice	Ice and Wind
Ice load	0.40 g_l	g_l
Wind speed	(0.60 to 0.85) V_R	(0.4 to 0.5) V_R
Description	Low probability wind during icing (return period T) associated with the average of the maximum yearly icing	Low ice probability (return period T) associated with the average of yearly maximum winds during icing presence

g_l is reference design glaze ice load (N/m) for the specified return period (*T*= 50, 150 or 500 years)

V_R is reference wind speed for the specified return period (*T*= 50, 150 or 500 years

Figure 2.4 presents the annual POF of three towers in Section 3a for two CSA combined loads and one intermediate load that was selected by NLH. This comparison is for CSA combined loads without topography consideration (no wind speed up, NWSU). The annual POF can vary between 0.4% to 4% for 60%/40%, 70%/40% and 85%/40% load combinations for wind plus ice loads. The factor 60% is applied to reference wind speed and 40% applied to vertical cable ice load. Figure 2.5 presents the screenshot for two load cases and shows the members (mostly leg members) where members' capacities have been exceeded significantly under CSA 60826-10 increased load combination (85/40). All these mast members are under severe compressive loads and significantly above the design capacity (very high use factors) that could lead to mast failure.

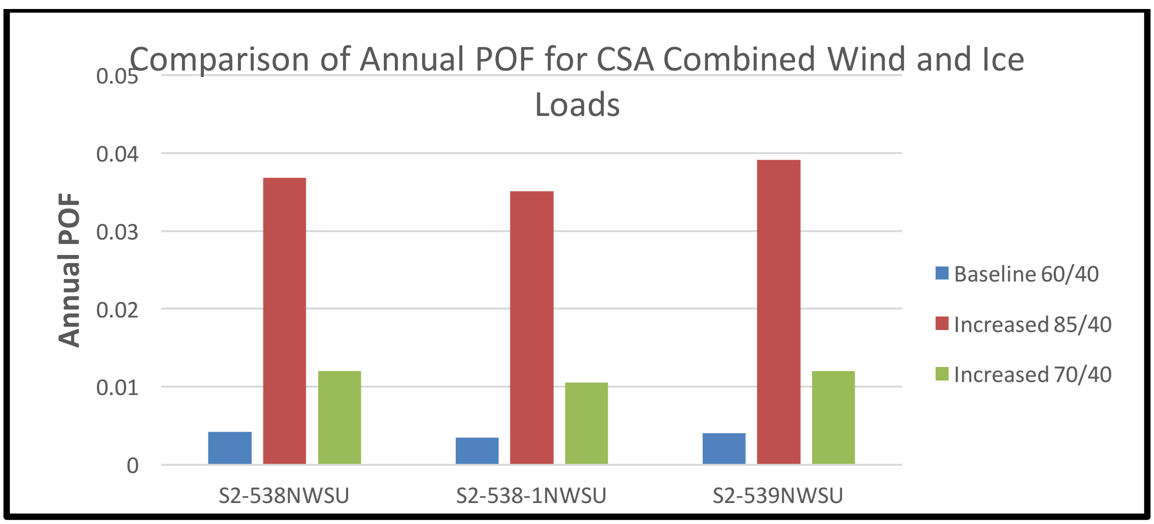
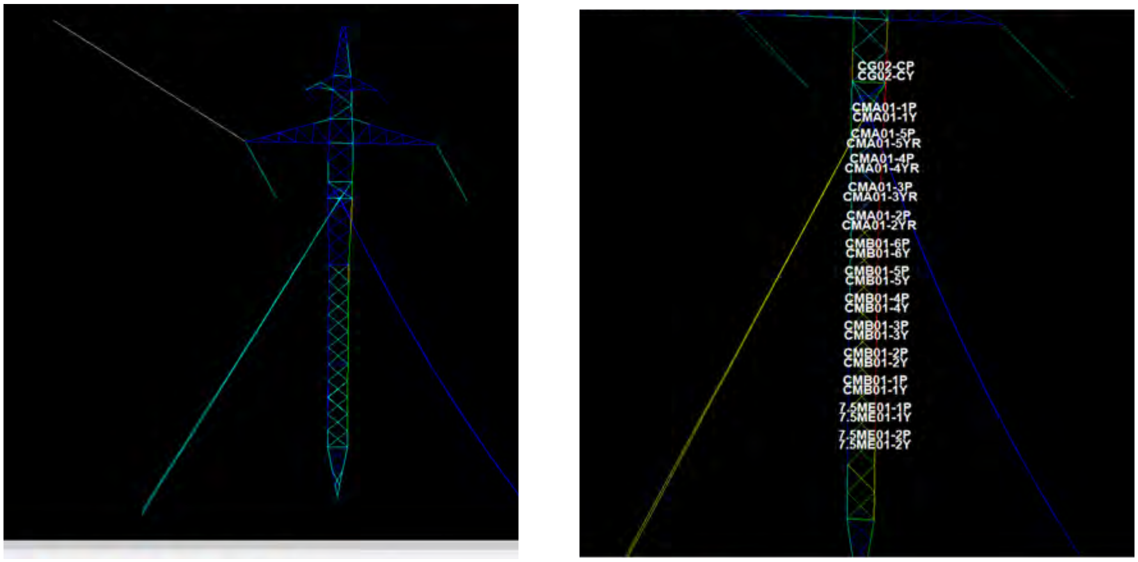


Figure 2.4 - Impact of CSA Load Combination on Annual Probability of Failures of Structures in Zones 3a (Glaze Ice Section)



Left Right

Figure 2.5 - Screenshots of S2-539 Tower in Section 3a (a) CSA Base Loads and (b) CSA Increased Combined Loads (NWSU – No Wind Speed Up Effect): Left (60/40), Right (85/40)

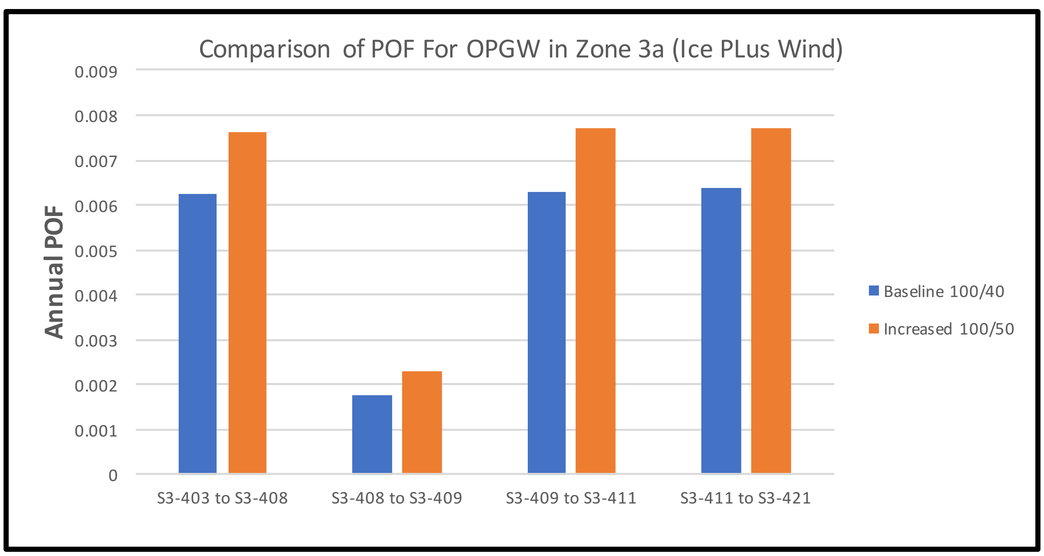


Figure 2.6 - Impact of CSA Load Combination on Annual Probability of Failure of OPGW in Zone 3a (Glaze Ice Section)

Figure 2.6 presents the annual POF comparison for "wire support system" in section 3a while Figures 2.7 and 2.8 presents the similar comparison for "structure support system" and "wire support system" in Section 7a (rime ice section) respectively. It is to be noted that all rime ice section it is only two load cases for combined loads: (A) 100% full ice load and 50% of reference wind speed and (B) 80% reference wind speed and 40% of full ice load. The load case A is like the increased load referred in CSA 60826-10 (upper limit of reference wind) but the Case B considers only 80% not 85%. The earlier study used these load cases and in this study, these load cases are considered with or without the topography effects. Also, ice loads on the cables are determined based on actual cable size and therefore, reduction of pole conductor load is not considered here.

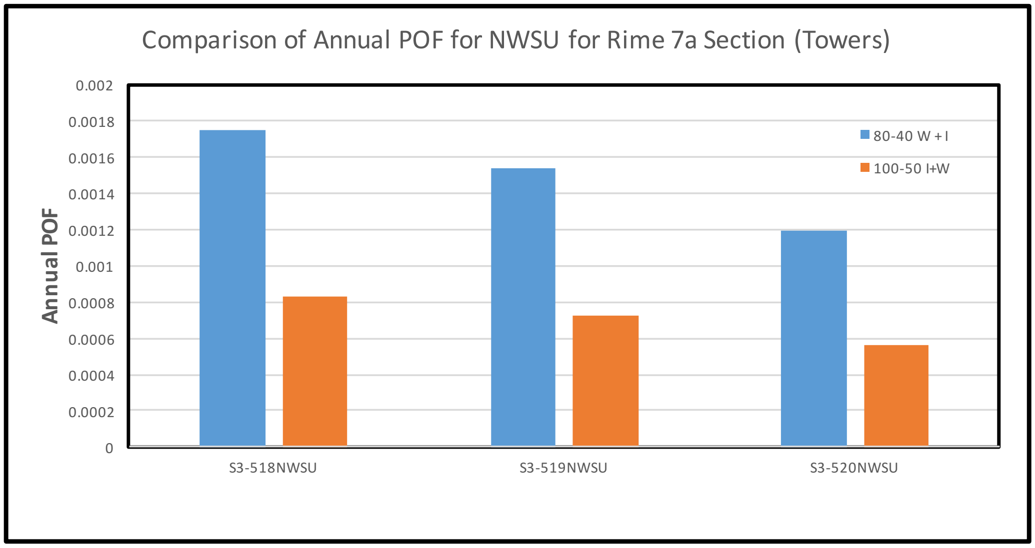


Figure 2.7 - Impact of CSA Load Combination on Annual Probability of Failure of Structures in Zone 7a (Rime Ice Section)

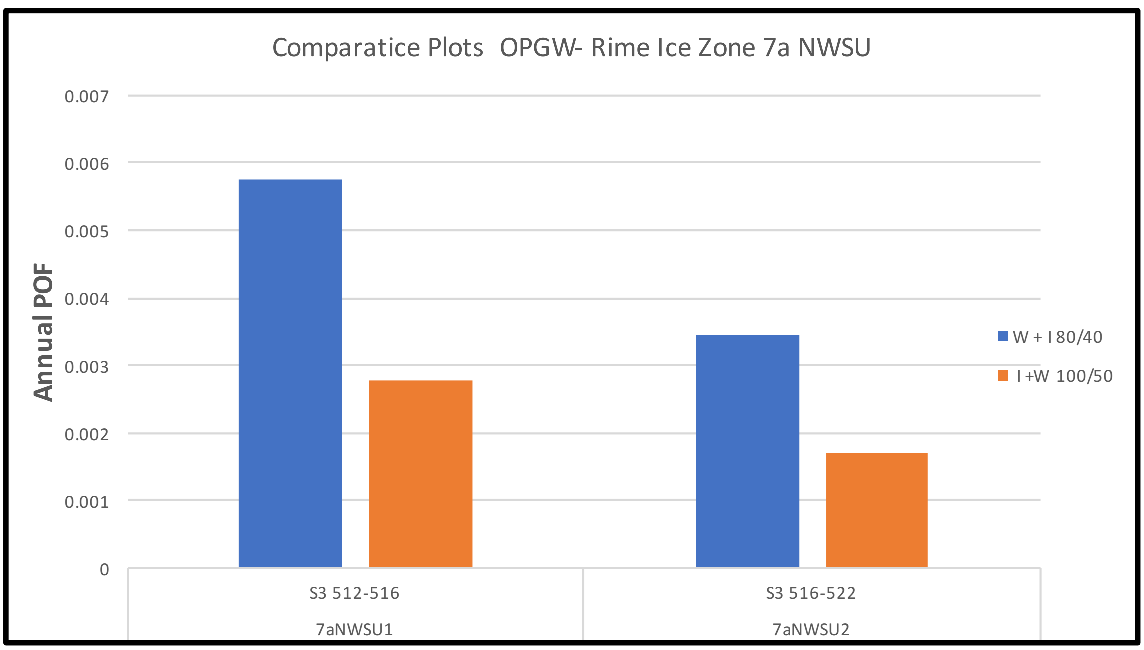


Figure 2.8 - Impact of CSA Load Combination on Annual Probability of Failure of OPGW/Electrode in Zone 7a (Rime Ice Section)

2.3 Influence of Topography and Terrain

The significant impact of topography and terrain effects has been well recognized in the reliable design of overhead high voltage transmission lines. Based on the topography analysis of a location on the top of Hawke Hill (near St. John's), Haldar and Associates identified that the topography influence could impact the LIL baseline reliability. Haldar (2021) recommended a full topography analysis of the LIL line to identify remaining "hot spots" and to assess the site-specific wind loading considering local terrain characteristics, topography, and environmental exposures/hazards. Accordingly, NLH undertook a follow up study to assess the uncertainties in the terrain data along the LIL line routing and to address topography and its impact on local WSU effects on LIL support systems.

The objective of this analysis is to assess the impact of the WSU effect on combined wind and ice loads and the effect on towers that are located either on the top of a 3D axisymmetric hill, a 2D ridge, or an escarpment. These elements were not explicitly considered in the LIL design, and the earlier report (Haldar, 2021) recommended that a plan be developed to identify these towers, assess the POF considering the WSU effects, and assess its impact on overall line POF (reliability, failure rate etc.) "Design wind loads on overhead transmission lines and towers depend, among other factors, on the velocity profile and turbulence characteristics of the upcoming wind. These, in turn, depend on the roughness and general configuration of the upstream topography. It has been reported that gust factors in the range of 1.8 to 1.9 (relative to 10-minute mean wind speed) may apply for wind speeds in hilly areas at 10 m height above ground, which could mean significant changes in design wind loads for transmission lines (Bitsuamlak, 2021)".

In this proposed work, Prof. Bitsuamlak from Western University, was retained to study the upstream topography's effect on design wind loads for transmission lines and towers and to identify the "hot spots" locations along the LIL line route. Detailed speed-up calculations were made at these "hot spots" by using advanced computational fluid dynamics (CFD) simulations at WindEEE's supercomputing facility. The primary objective was to:

(i) identify "hotspots" locations (points of considerable wind speed-up due to topographical changes) through approximate analytical speed-up calculations, and
(ii) carry out detailed CFD-based wind speed-up calculations for the identified "hot spots" that could be used to evaluate the local velocity pressure on the towers and the conductors.

The background and methodologies used in the WindEEE's study to determine the field contours of wind speed up effect (WSU) on select section of LIL (at the "hot spots" locations) and CFD wind speed-up plots for the "hot spots" and tabular wind-speed up values for transmission towers and conductors at these locations were provided by WEEE (2021). A brief summary of the methodology is included in the Appendix (Bitsumlak, 2021).

Based on this study, NLH and WindEEE identified five segments (2c, 3a, 6, 7a, and 8b) where seventeen (17) towers were identified at locations where the topographical issues are significant ("hot spots"}. Four of these towers are in Labrador and the remaining thirteen towers are located on the Island part of the line. Six of these seventeen towers are in the zones where rime icing is predominant (2c and 7a) and the remaining eleven towers are in zones where glaze icing is predominant (3a, 6, and 8b). Three of these ten towers in glaze icing zones are in Zone 3a in the Southern Labrador section. NLH conducted the structural analysis of all these "structure support systems" and "wire support systems" based on the wind profiles that were provided by WindEEE (Bitsumalak, 2021) for structures and the cables at these locations. Analysis was conducted for CSA 60826-10 load combinations for wind and ice and ice plus wind loads. These are: 100/40 and 100/50 for ice plus wind and 60/40 and 85/40 for wind plus ice load combinations for all three selected return periods.

Figure 2.9a presents the part of Section 3a that consists of the three towers (S2 538, 538A, and 539) that WEEE has identified as locations where the influence of topography cannot be ignored and are significant. Figures 2.9(b) and (c) present the relative use factors that theses towers are subjected for various load scenarios. Also, in these figures, LIL design ice and combined wind and ice loads are included for comparison. Figure 2.10 presents a typical CFD analysis field contour that shows the wind speed effect on towers located in Labrador.

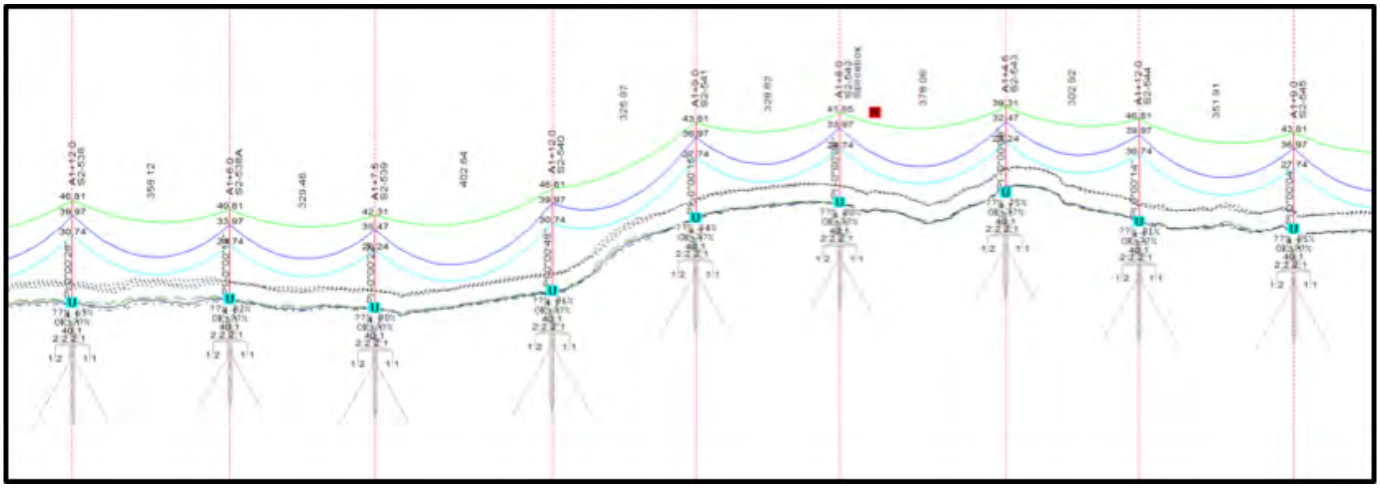


Figure 2.9 (a) - Locations of Three Towers on a Typical Plan and Profile of Section 3a

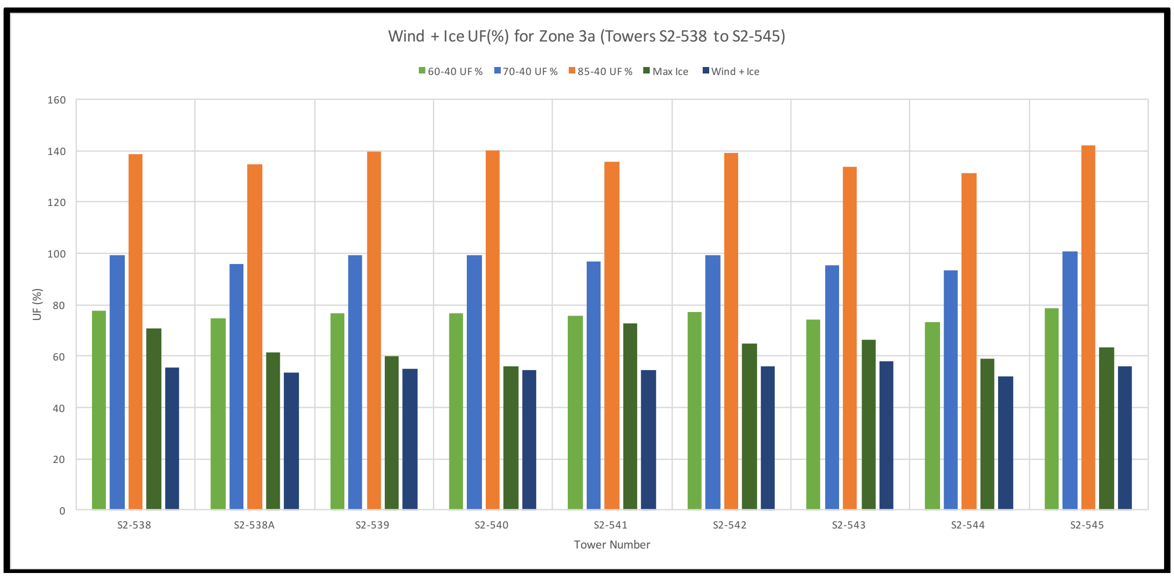


Figure 2.9 (b) - Use Factor Comparison for Wind Plus Ice Loads

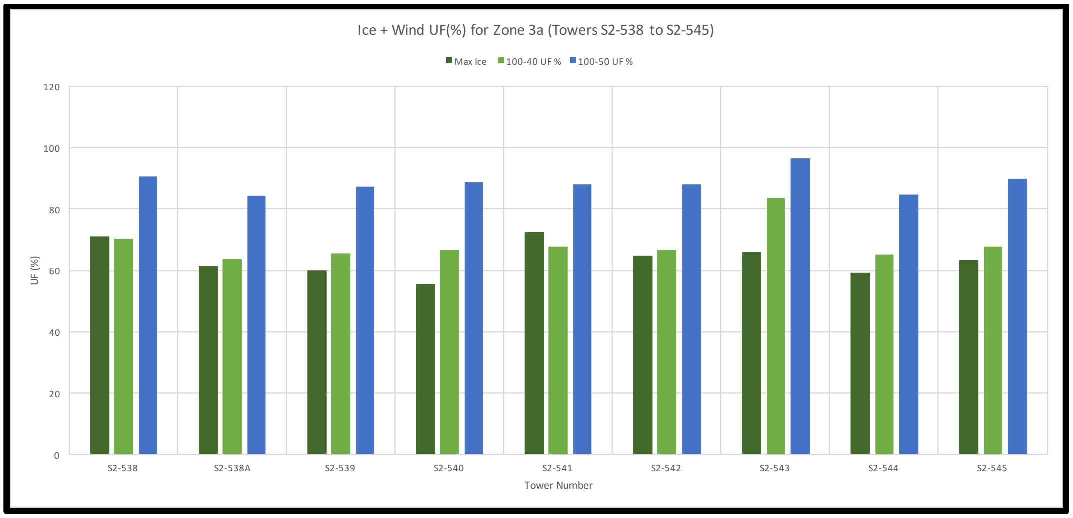


Figure 2.9 (c) - Use Factor Comparison for Ice Plus Wind Load

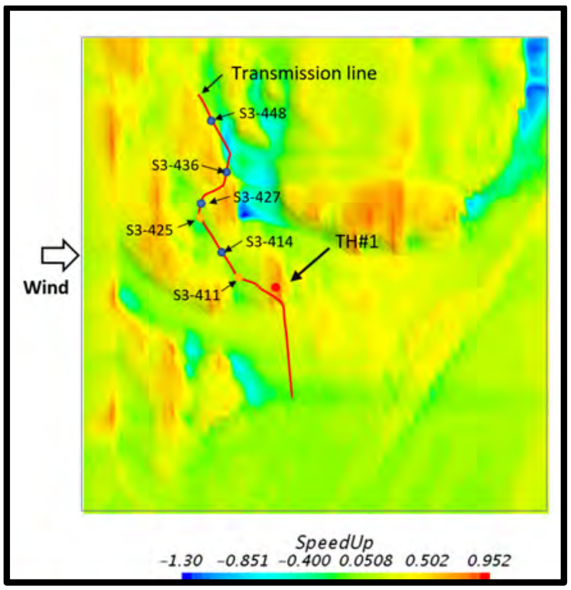


Figure 2.10 - Speedup Contour Example at a Height of 30m from the Ground (Kahsay and Bitsuamlak, 2021. See Appendix for Details)

Figures 2.11 presents the comparison of annual POF of three towers in section 3a where the effects of combined wind an ice loads are considered with or without the influence of topography. NWSU refers to no wind speed up effect while WSU indicates that local topography (wind speed up effect has been considered. All wind plus ice loads are based on CSA 60826-10. The Annual POF can vary between 0.4% to 10% depending on the specific criterion used.

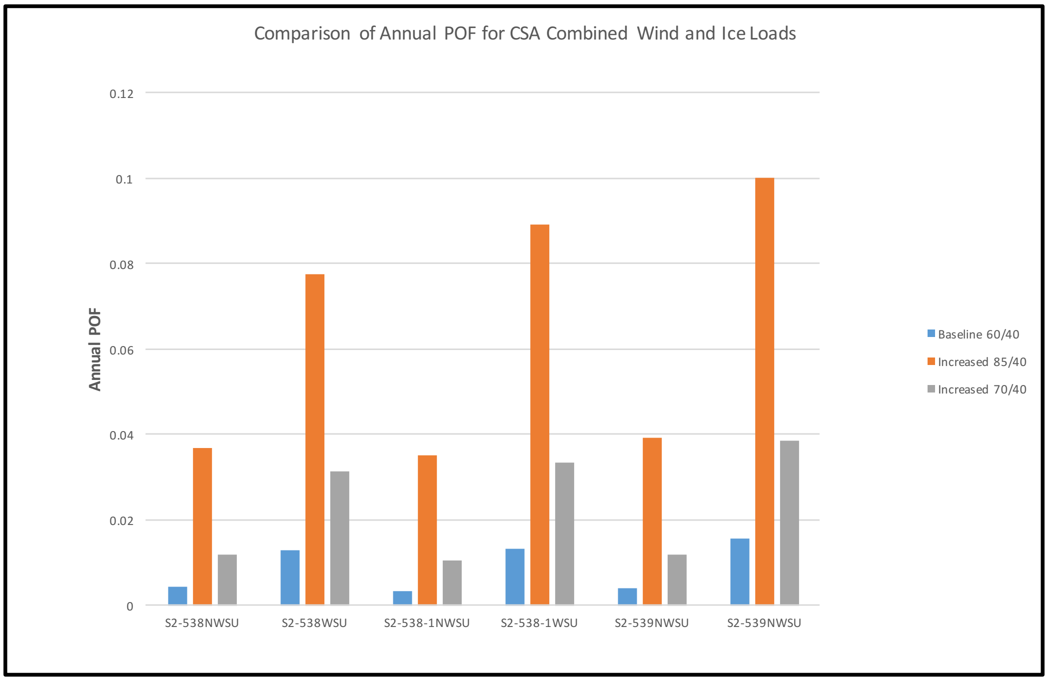


Figure 2.11 - Impact of Topography Effects (WSU) on Annual Probability of Failures of Structures in Zones 3a (Glaze Ice Section)

Figure 2.12a presents the comparison of annual POF of OPGW cable in section 3a with or without the influence of local topography of the "wire support" system. Figure 2.12b presents the same for sections 3a, 6 and 8b where the local topography effects were considered. Again, the comparison of annual POF is done with or without the influence of topography. Figure 2.13 presents the Screenshot of S2-539 tower under WSU effect with increased CSA 60826-10 combined loads.

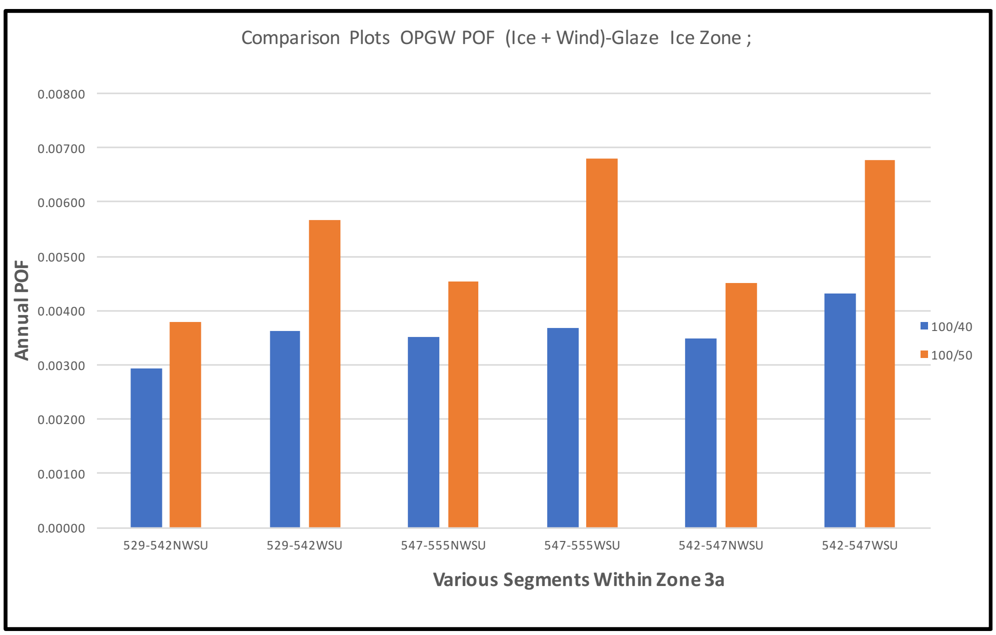


Figure 2.12 (a) - Impact of Topography Effects (WSU) on Annual Probability of Failure of OPGW in Zone 3a

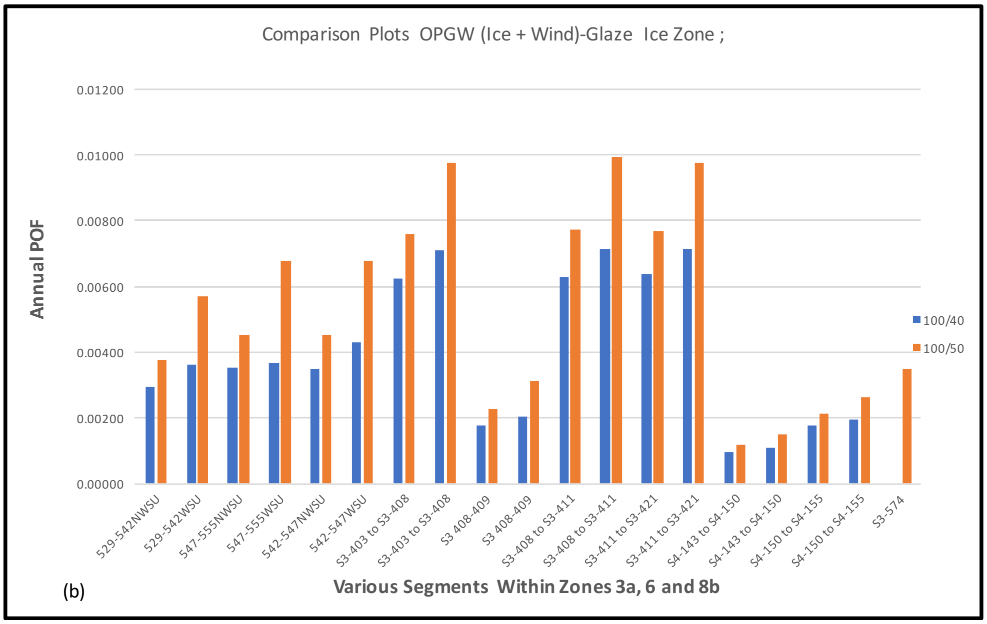
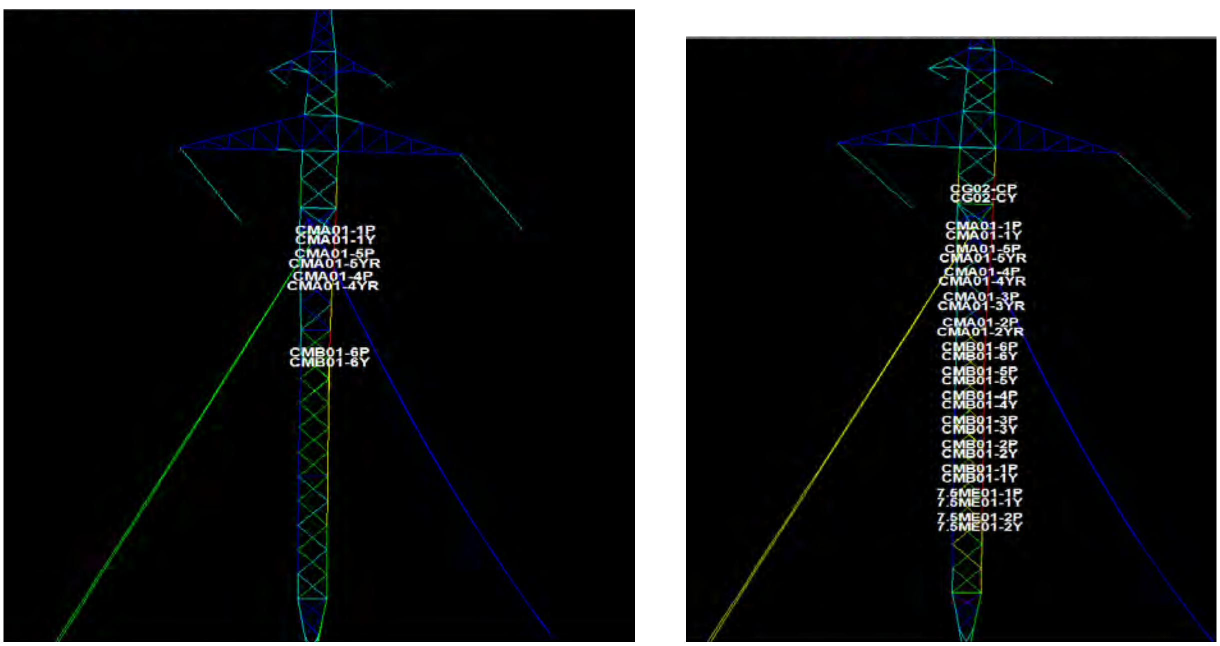


Figure 2.12 (b) - Impact of Topography Effects (WSU) on Annual Probability of Failure of OPGW in Sections 3a, 6 & 8b



(a) **(b)**

Figure 2.13 - Screenshots of S2-539 Tower in Section 3a (a) CSA Base Loads (left) and (b) CSA Increased Combined Loads (right, Available only for 70/40 combination)

Under increased CSA combined loads of 85/40 (wind plus ice), the analysis showed that the tower is unstable and will collapse. Therefore, Figure 2.13 presents the capacity exceedance of those members under 70/40 load combinations and locations. Almost all members are mast members and are under large compressive loads (very high use factors, see Figure 3.4 later) that makes the tower likely to fail even under 70/40 modest load combination of wind plus ice loads.

It appears that although the line Section 3a is less than 1.1% of the total LIL length of 1100km, several towers in this zone are vulnerable due to local topography effects coupled with CSA 60826-10 increased combined load events. Several towers in this section that are not subjected to WSU effect are also analyzed for CSA increased combined load effects (wind plus ice), and the annual POFs of all these towers are also high. Three of the suspension towers that are specifically exposed due to topography effects, the annual POF of these towers varies between 8% to 10% (Figure 2.12a). The POFs of these three towers, S2-538, S2-538A, and S2-539 in Section 3a, are very high. There are several other towers in this section that are not exposed to WSU effects but have high annual POF (3%-4%) and are outside the industry's best practices (S2-541, S2-545, etc.) under CSA 60826-10 increased loads. Figures 2.14 and 2.15 present the annual POFs for two support systems for rime icing in section 7a. It shows that for towers in this section have annual POF slightly less than 1% while for OPGW this is 2.3%. Two segments are analyzed and presented as 1 and 2 for NWSU and WSU respectively in Figure 2.15. Both POFs are under wind plus ice load combination (80/40). Section 5 was the controlling segment that was analyzed in the earlier study and under base load (80/40), the annual POF was 1.1%. It is concluded that the POF is increased twofold when WSU is considered. For rime ice sections, one wind plus load is considered (80/40) as per EFLA study (2020).

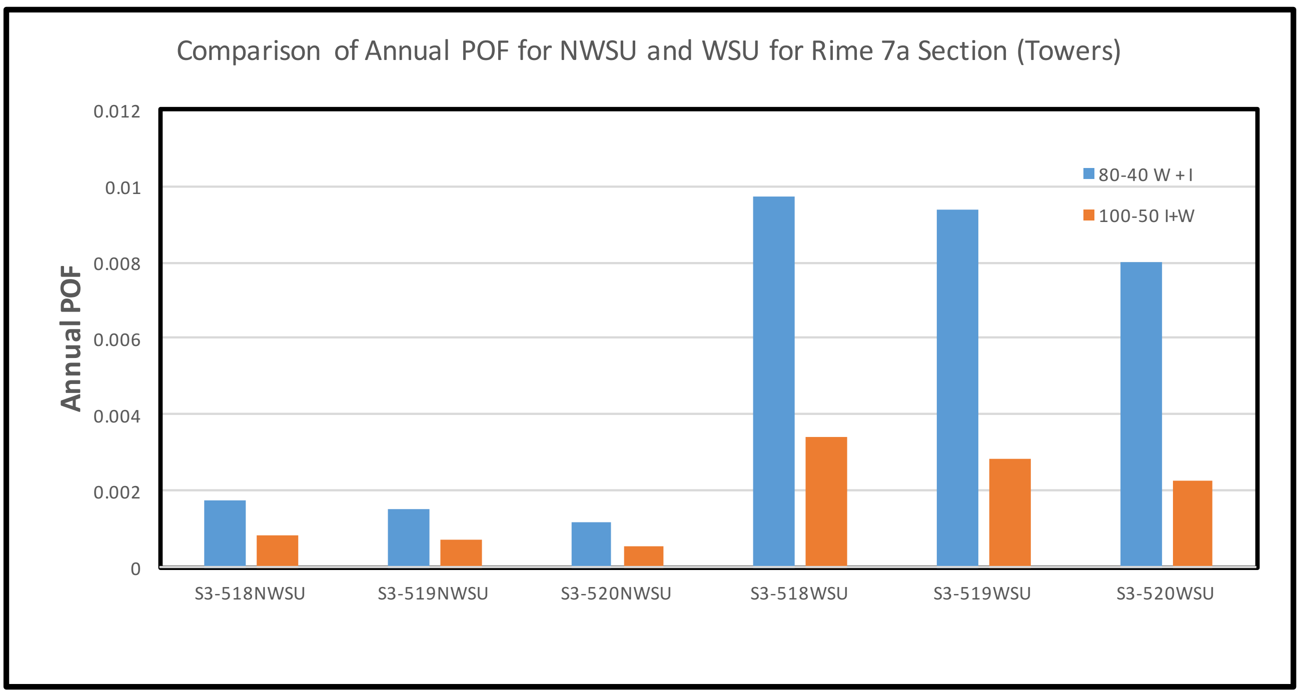


Figure 2.14 - Impact of Topographical Effects (WSU) on Annual Probability of Failures of Structures in Zones 7a (Rime Ice Section)

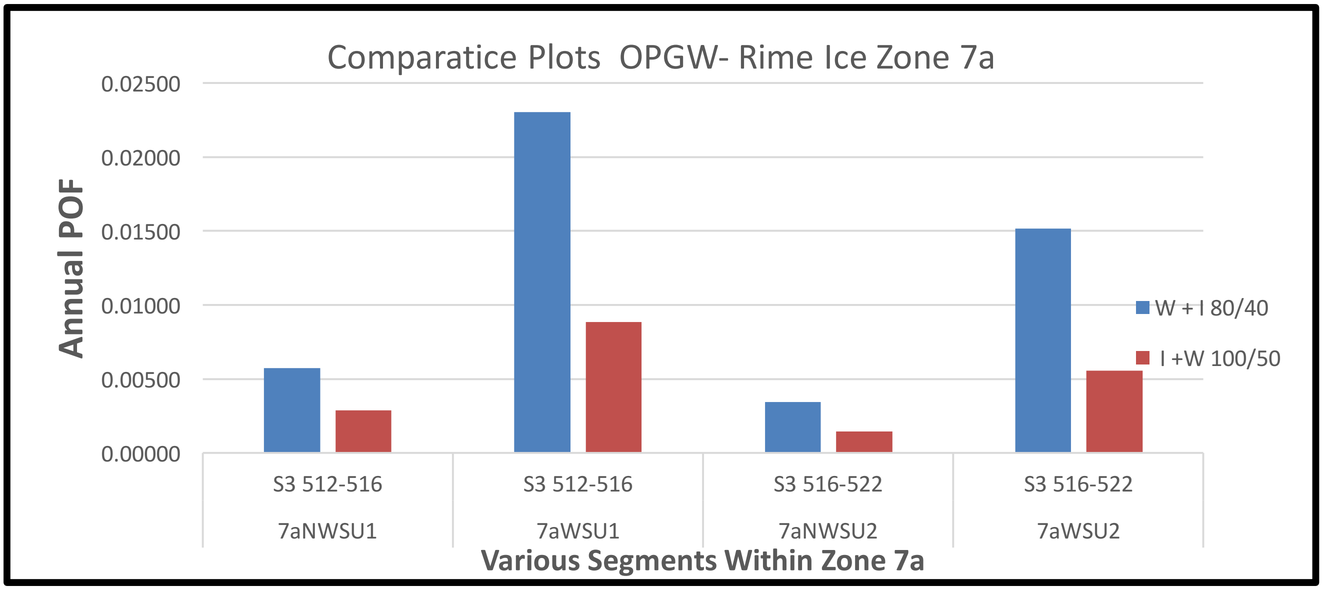


Figure 2.15 - Impact of Topographical Effects (WSU) on Annual Probability of Failure of OPGW in Zone 7a (Rime Ice Section

2.4 Correlation Issue

A high level correlation study of the past historical extreme storm events was conducted to assess whether there was a strong correlation among various regions. The idea was that it may be possible to further improve the POF under Scenario #4D, reduce the LIL POF (hence, increasing the reliability). This high level study was conducted by Dr. Han-PingHong of Western University. The following summarizes the conclusions that were drawn from this study:

1) The correlation coefficient between high winds at two sites is noticeable (if the site is close);
2) the correlation coefficient between the ice accretion thicknesses at two sites is noticeable (if the site is close);
3) the correlation coefficient between the high wind (ice accretion thickness) at one site and corresponding ice accretion thickness (wind) at another site is not significant, and
4) The correlation between a variable from one of the sites (tower # 1126, # 1217, or # 1273) to one of these sites (tower #3087, # 3140 or #3027) is small.

In view of the above, our original assumption of regional independence in Scenarios # 4B and #4D of Haldar Report (2021) appears to be correct and the POF reported considering the impact of line length is validated. It is in our opinion that Scenario #4D provides a more realistic assessment of baseline POF of LIL when the influences of topography effects is not considered (Refer to Table 6.2, Haldar Report, 2021). However, the present study will consider the increased combined loads of CSA 60826-10 with the upper limit of reference wind speed value (0.85 Vr) and the influence of topography and this analysis will provide a revised estimate of Scenario # 4D considering these two exposures and the impact of line length. In estimating this POF, the correlations among the key components within both support systems have not been considered and therefore, this estimate is a lower bound value. This is further discussed in Section 3.1.5.3.

2.5 Impact of Reduced Ice Thickness due to Large Pole Diameter Effect

The Haldar Report (March,2021) identified an opportunity to revise the current design loads by considering the effect of the large diameter of pole conductors on the accreted design ice thickness. This was not considered in the original LIL design or in the earlier study. Although this information is based on limited experimental results, it was supported by a sensitivity study conducted for St. John's data using the Chaine model run (Morris, 2020). This effect is considered in revising the pole conductor load in all glaze icing zones. The reduction factor was derived from St. John's data and is used for all regions. NLH has used the same reduction factor for all regions when computing the revised loads for pole conductors. A cautionary note is that this reduction amount may vary by region, especially in locations where icing data has been interpolated from the CSA weather map.

This analysis was not done for every structure location rather to get an understanding of the "order of magnitude" reduction that NLH can realize in UBI analysis with respect to use factor (UF) and the expected reduction of annual POF in the structural reliability analysis following CSA 60826-10. A guidance has been provided how to adjust the return period and annual POF for reliability analysis based on increased load combination and the use factors (UF) in UBI analysis using NLH load combinations.

2.5.1 Impact of Pole Conductor Size on UBI Analysis on Use Factors

The unbalanced ice (UBI) load analysis considering NLH load combinations was done based on LIL design ice load and the analysis revealed that the use factors for several members of S1-318 tower in Zone 1 and S2-541 tower in Zone 3 in Labrador region exceeded the members' strength limit significantly. However, these use factors decreased by 10-15% on average for several members when one considers the expected reduction of ice accretion due to large pole conductor size. Even with this reduction, these two critical towers are still exposed to overloading issue (mast buckling failures) should these load combinations occur. Two other towers located on the island part of the line have some overloading that is within acceptable limit (< 5%). It is to be noted that all these towers met the CSA 60826-10 load combination criteria which are very different than NLH load combination. It appears that NLH load combination criteria is more onerous compared to LIL design loads without load combinations. It is to be noted that all these towers met the CSA 60826-10 load combination criteria for a minimum 50-year return period which are very different than NLH load combination criteria (Haldar,2021). It appears that NLH load combination criteria are more onerous compared to LIL design load effects which does not consider load combination.

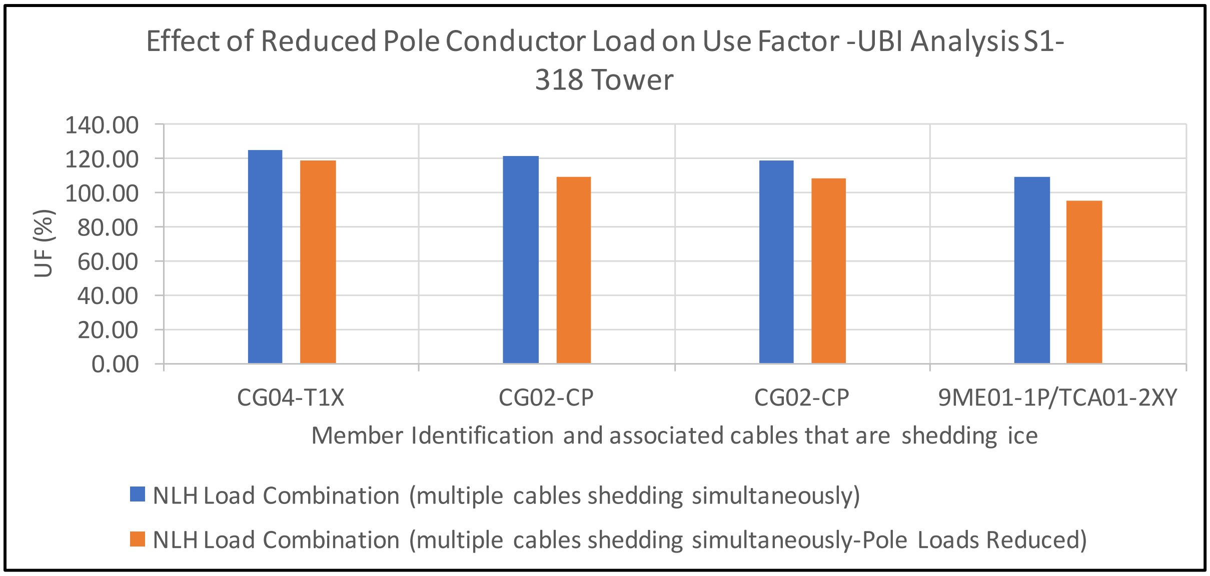


Figure 2.16 (a) - Impact of Reduced Ice Diameter Effect on UBI Load Combination (Deterministic Analysis – NLH Load Combinations)

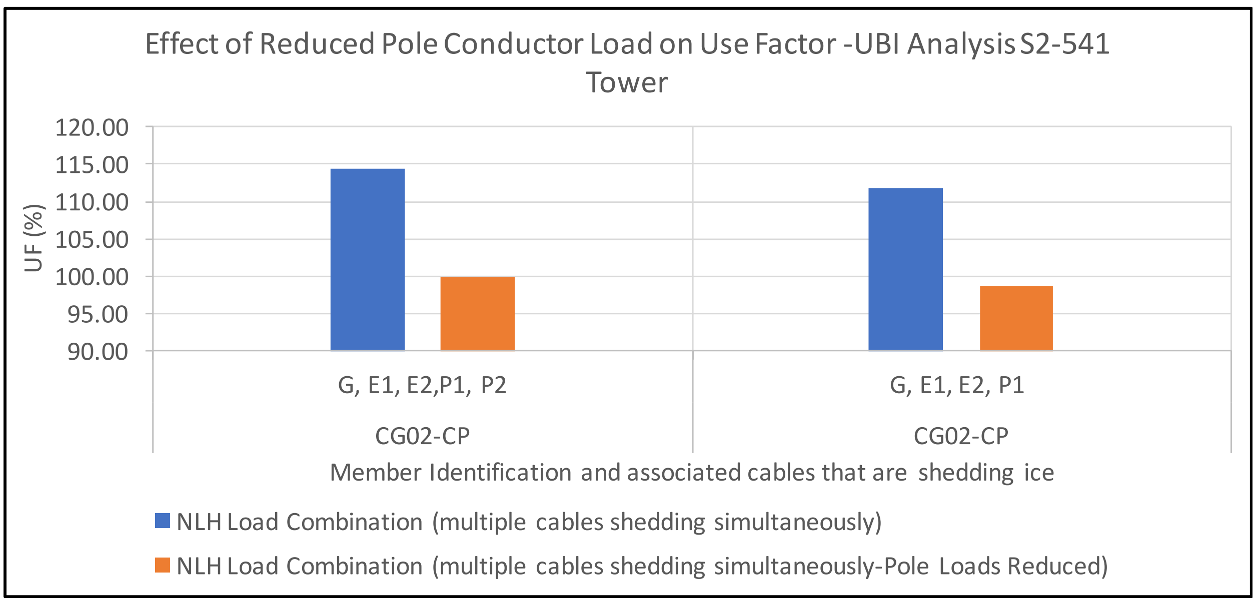


Figure 2.16 (b) - Impact of Reduced Ice Diameter Effect on UBI Load Combination (Deterministic Analysis – NLH Load Combinations)

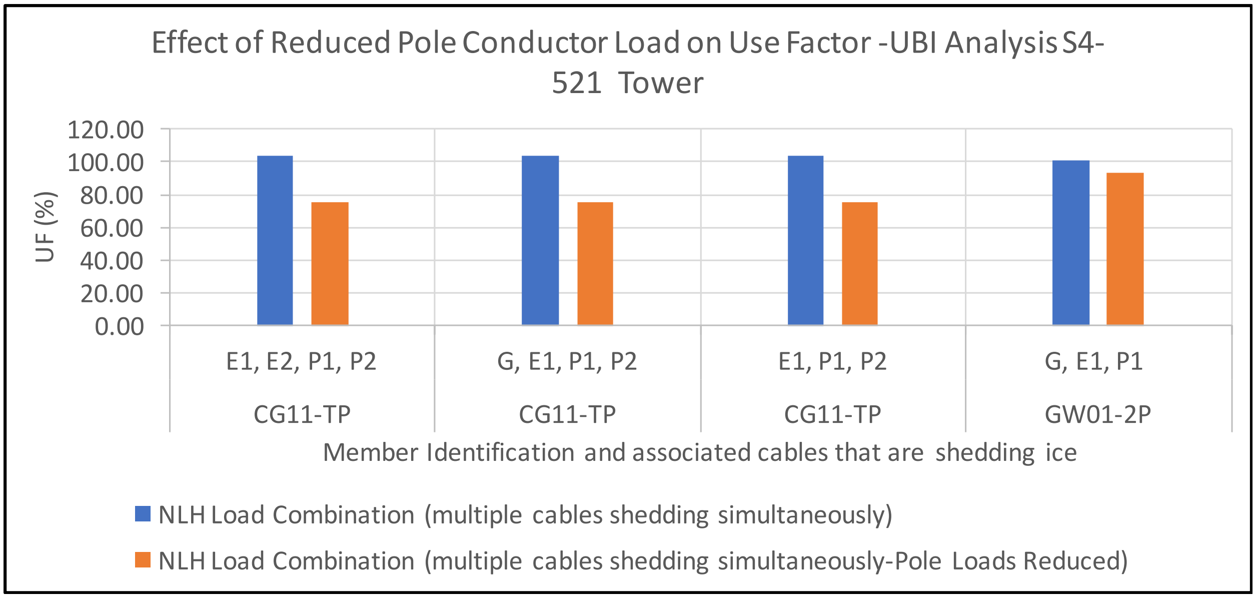


Figure 2.16 (c) - Impact of Reduced Ice Diameter Effect on UBI Load Combination (Deterministic Analysis – NLH Load Combinations)

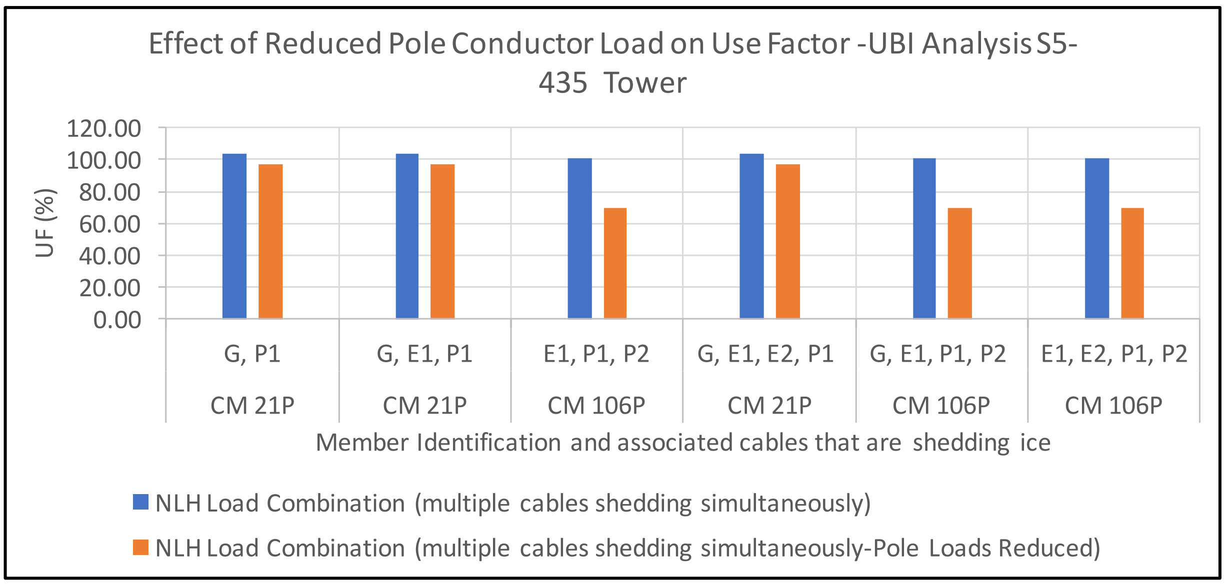


Figure 2.16 (d) - Impact of Reduced Ice Diameter Effect on UBI Load Combination (Deterministic Analysis – NLH Load Combinations)

2.5.2 Impact of Pole Conductor Size on Structural Reliability Analysis (on annual POF Values)

In this section two towers are selected from Section 3a and are studied to assess the POF reduction considering the increased CSA 60826-10 combined load effects with or without wind speed up effect (NWSU or WSU). Figure 2.17a presents the comparison for three combined load conditions (wind plus ice) for S2-545 where WSU condition does not apply. These analyses are done for no wind speed up effect (NWSU). NWSUR refers to the data with pole load reduced and its impact on annual POF. The annual POF could be reduced by 20% for baseline load (60/40) to 10% for increased load of

85/40. For example, the POFs for 85/40 are 4.1% and 3.7% while for 60/40, these values are 0.45% and 0.37% respectively.

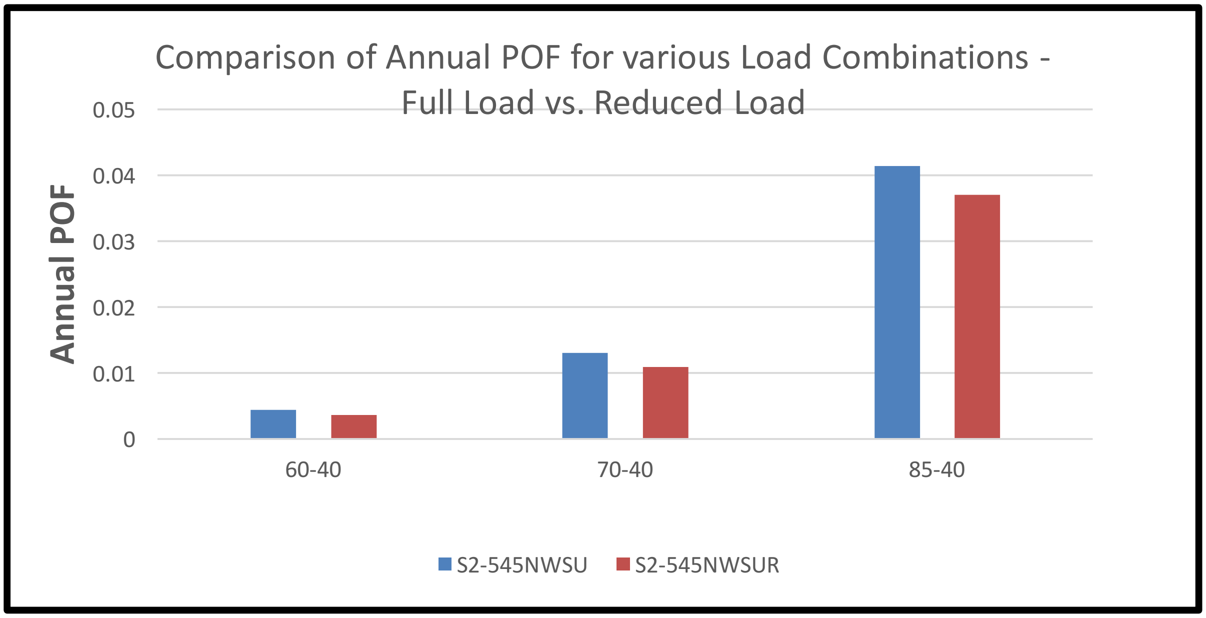


Figure 2.17 (a) - Impact of Reduced Ice Diameter Effect of Annual Probability of Failures of Structures in Zone 3a (Glaze Ice Section)

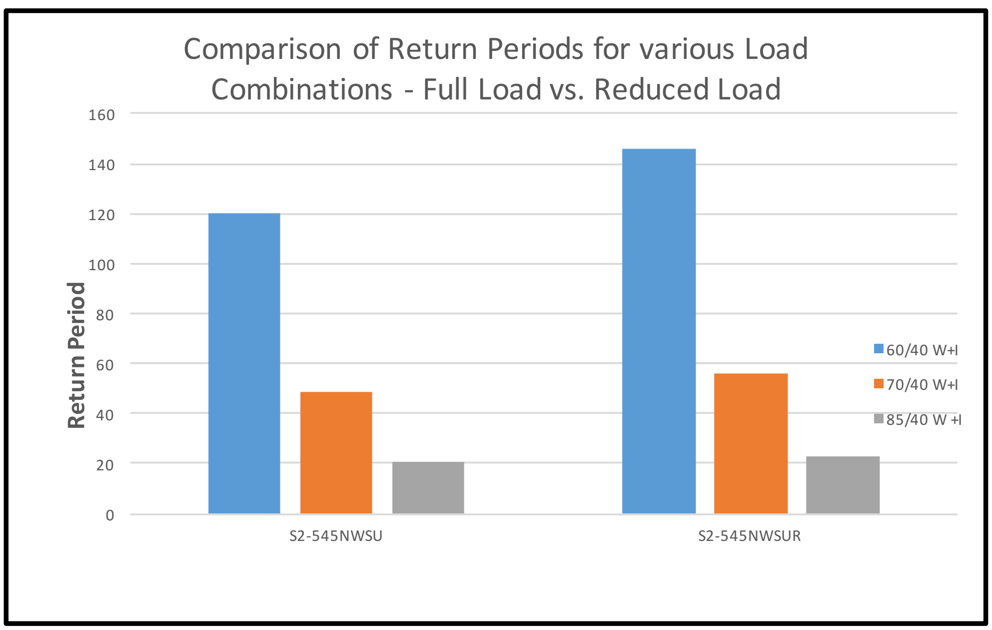


Figure 2.17 (b) - Impact of Reduced Ice Diameter Effect on Return Period of Structures in Zone 3a (Glaze Ice Section)

The increased realization in terms of return period is similar because the return period is inversely proportional to the annual POF (Figure 2.17b). Similar observation is also noticed for S2-539 tower where WSU condition is considered. The reduction in POF is 10-15% (Figure 2.17c) and the expected increase in return period is shown in Figure 2.17d. For increased combined load of 85/40, the increase is only 10% (11 years from 10 years) while for 60/40, this is 12% (47 years from 42 years).

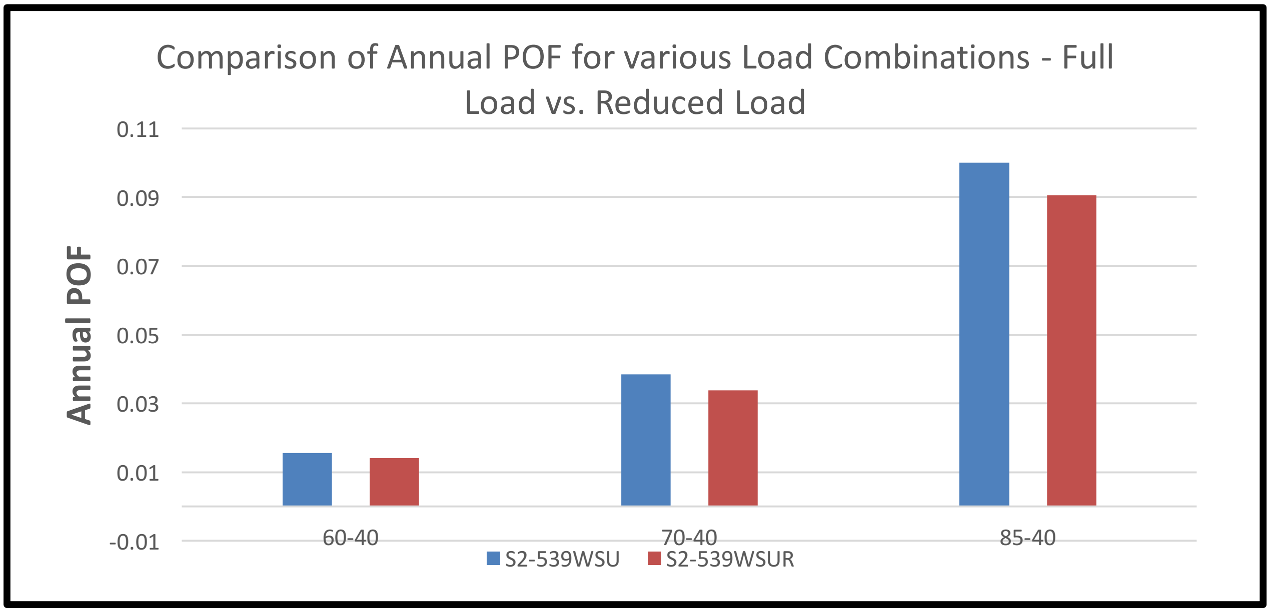


Figure 2.17 (c) - Impact of Reduced Ice Diameter Effect of Annual Probability of Failures of Structures in Zone 3a (Glaze Ice Section, WSU)

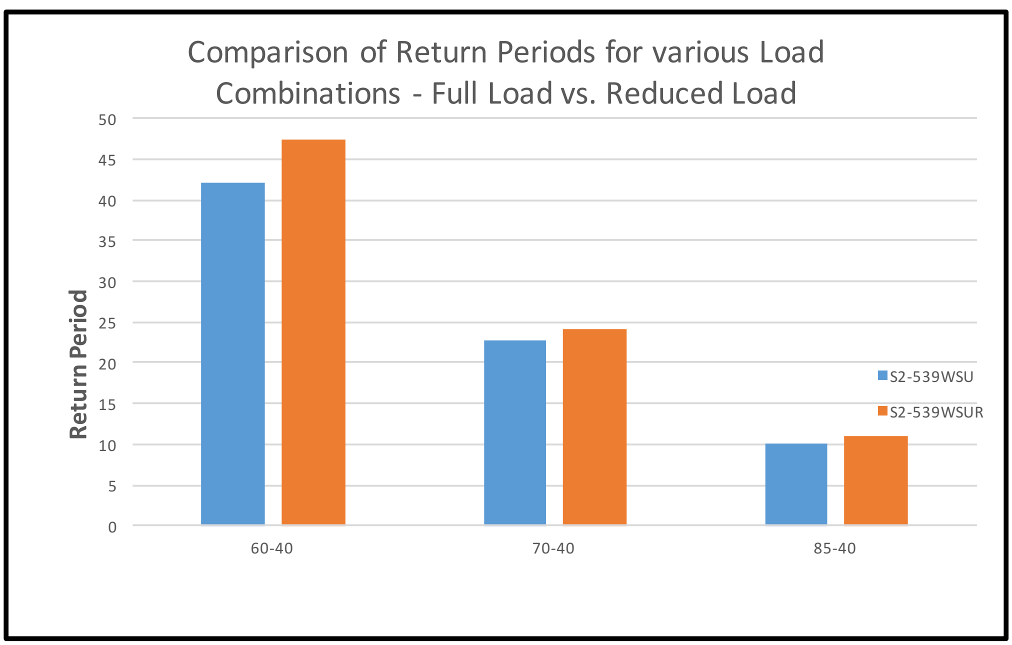


Figure 2.17 (d) - Impact of Reduced Ice Diameter Effect on Annual Probability of Failures of Structures in Zone 3a (Glaze Ice Section, WSU)

Based on limited analysis of NLH's data for some critical towers in Section 3a, it is observed that the annual probability of failure could be reduced by 10% on average for the increased combined loads following CSA 60826-10 (85/40), while the reduction of use factor (UF) for S1-318 and S2-541 is 10-

15% on average under NLH load combination. Figures 2.16 and 2.17 present the impact of load reduction on UF and POF for these load conditions.

3.0 Summary and Conclusions

This report assesses quantitatively the impact of several design parameters on LIL Reliability. Consideration of these design parameters and their impacts on LIL structural reliability were made in the five recommendations in the Haldar Report (2021). It was predicted in the earlier report that the impact of two specific recommendations (#2 on increased CSA 60826-10 loads and #3 on the influence of topography and terrain, see section 1.1 in this report) could increase the LIL POF further than what was predicted/reported in the Haldar Report (2021) as baseline values. The earlier report considered several scenarios (Refer to Table 6.2 in the report) but only three scenarios are only considered here and presented for further evaluation. These are Scenario #1, Scenario # 2 and Scenario # 4D.

The underlying assumption behind Scenario #1 is that extreme events are fully correlated along the entire length of the LIL route. This may not be totally correct for such a long line exposed to multiple hazards. Scenario #2 considers that the weather hazards are *mutually exclusive* and therefore, one should consider the upper bound of POF in determining the LIL structural reliability (POF) to these hazards. Scenario # 4D considers the impact of line length explicitly on assessing line reliability if the regions are independent with respect to extreme weather hazard events and recommended that the line reliability calculation should reflect this. Details were presented in the Haldar Report (2021).

3.1 Analysis and Summary Results

3.1.1 UBI Analysis

Unbalanced Ice load analyses using NLH load combinations have been completed on four selected critical towers. Two of these towers are in Labrador and the remaining two towers are in the Central and Avalon regions. All these analyses were performed based on deterministic design principle and the base design loads were those used in LIL design. NLH load combination criteria are explained in the Haldar Report (2021) and they are quite different from CSA 60826-10.

3.1.2 Impact of Increased CSA 60826-10 Combined Loads on LIL Reliability (with or without Topography and Terrain Effects)

The Haldar Report noted that the original LIL design considered only wind plus ice load combination but did not consider the ice plus wind load combination. The earlier report only considered the baseline loads (100/40 and 60/40 combinations). Therefore, it was recommended that the "structure support system" and the "wire support system" be checked for both these CSA combined loads for increased reference wind speed values. In addition, the report also recognized that the original LIL design and EFLA report (2020) did not consider the impact of topography (local wind speed up, WSU) effects on wind and ice loads and the as-built structural capacity. Based on the results of a limited analysis conducted in the earlier report, this impact was shown to be significant (Haldar, 2021). The author recommended a full topography analysis of the LIL route to identify all remaining "hot spots" locations along the LIL line route and to assess the site-specific wind loading and combined loads on the structure support and the wire support systems located at these locations.

Based on the Western University study on assessing the impact of topography and terrain effects on the LIL, seventeen critical tower locations in five segments (2c, 3a, 6, 7a, and 8b) along the LIL line route were identified as "hot spots" locations where further analysis of the "structural support system" and the "wire support system" was conducted. These support systems are described in the Haldar Report (2021). The analysis methodology is broken down in two parts.

3.1.2.1 Impact of Increased Combined Loads on LIL Reliability (No Wind Speed Up Effect, NWSU)

The first part of the analysis considers the impact of CSA 60826-10 combined loads, particularly the impact of *increased wind and ice loads* (Clause 6.4, increased factors on reference wind speed, V_R) on the two support systems and the impact on LIL reliability. The objective is to determine the response of various key line components within each system to these loads (member forces and redistribution of these forces etc.). This is referred to as Case B. Case A refers to CSA baseline combined loads that were used in the Haldar Report (2021).

3.1.2.2 Impact of Increased Combined Loads on LIL Reliability (with Wind Speed Up Effect, WSU)

The second part of the analysis considers the assessment of full topography and the limited terrain effects at these seventeen tower locations and its impact on LIL reliability. For each of these tower locations, WEEE, Western University provided the WSU profiles: one profile is along the tower height and the other profile is along the two adjacent cable spans. These profiles are based on simulation models that use CFD analysis. *These profiles were also checked against simple code given formulae*. The wind component in the CSA 60826-10 baseline combined loads (Case A) was amplified and applied along the tower height and cable length using the WSU factors. The force distribution in various key components of these two support systems at these "hot spots" locations was reassessed. This is referred here as the load group, Case C. Next, CSA combined loads were further amplified for increased wind load effects (Clause 6.4, particularly increasing the wind speed reference factor, V_R) and the analysis was repeated for both the "structural support system" and the "wire support system." This provided one more load case group which is referred to as Case D. These are summarized in the following section and are referred in Table 3.1

3.1.2.3 Summary of Load Cases Considered

- Case A - 100% of g_l + 40% of V_R and 40% of g_l + 60% of V_R (Haldar Report, 2021, topography influence not considered and terrain type C, NWSU)
- Case B-100% of g_l + 50% of V_R and 40% of g_l + 85% of V_R (Increased Combined Loads with topography influence not considered and terrain type C, NWSU)
- Case C –Case A with topography influence considered and terrain type C, WSU)
- Case D - Case B with topography influence considered and terrain type C WSU)

3.1.3 Correlation Study

One of the recommendations in our earlier report was to study the regional correlation or partially correlated natural loads of past storm exposures (extreme events) of such a long line route and its impact on reliability and annual POF of LIL. This needs to be understood with respect to correlation of extreme load events along the LIL route traversing various regions. This analysis for two regions has been completed. Data was provided by EFLA (2020) and analysis was conducted by Prof. Hong of Western University (2021)

3.1.4 Impact of Pole Conductor Size and LIL Reliability

NLH has rerun the line models to assess the impact of reduced pole conductor loads on LIL reliability. Additional load cases were introduced for both unbalance ice load analysis (UBI) and for the structural reliability analysis. No attempt has been made here to repeat the entire analysis using this reduced load scenario. It was decided to do few analysis on critical line components where the POF is large to see what the impact would be in terms of POF reduction and the increase in return period. Some guidance has been provided how the LIL reliability can be adjusted to assess this specific impact.

3.1.5 Summary of Results

3.1.5.1 UBI

For UBI Analysis with NLH load combinations, results show that the two critical towers on the Island section of the line do have few members that exceed the strength capacity and the use factors reported to be 100%-105%; however, the two critical towers in the Labrador region do not follow the same trend. The UBI analysis shows that the exceedance of use factors is quite large (up to 125%) and based on deterministic analysis, these towers are vulnerable under two specific load combinations and can suffer significant damage or even fail, should these load combinations occur. However, it is to be noted that these towers did meet the 50-year minimum criteria when they were analyzed under CSA 60826-10 in Haldar report (2021). However, Haldar Report rejected the principle of treating the UBI loads as reliability class of loads and therefore, excluded this UBI analysis from Scenario #1. If this was included as reliability class of loads, the return period of the line would have been less than 73 years and in this case, structure support system (tower) will control as opposed to wire support system (OPGW system). This shows that the analysis based on NLH load combinations of UBI is more onerous compared to CSA 60826-10 criteria (0.7 and 0.28 load factors on cables). All analyses conducted here using NLH combinations are based on LIL design ice thickness. This load combination has served NLH's 1300km steel transmission line assets well for the past 50 years and the author does not see the need for including unbalanced ice loads as return period based loads as suggested in CSA 60826-10 until an additional study can support the basis for these two deterministic numbers/factors cited in CSA 60826-10. Current standard CSA does not provide the basis for these two deterministic factors, which are invariant to return period based load values.

3.1.5.2 Impacts of Increased Loads with or without the influence of Topography

The results of the analysis reported in this section refer primarily to Scenarios #1 and #2 following Table 6.2 in Haldar Report (2021).

Table 3.1 - Annual POF Determined for Two Specific Scenarios (with or without the Influence of Topography)

Scenario #	Baseline CSA Combined Loads (Table 6.2 of Haldar Report) - A	Increased CSA Combined Loads – B	Baseline CSA Combined Loads with WSU-C	Increased CSA Combined Loads with WSU-D	Remarks
1	0.011[(a)]	0.041	0.023	0.10	Maximum of annual POF under two types of icing
2	0.020[(b)]	0.052	0.039	0.123	Mutual exclusivity considered for multiple hazards

(a) refers to Scenario # 1 in Table 6.2 in Haldar Report (2021); (b) refers to Scenario # 2 in Table 6.2 in Haldar Report (2021)

Table 3.2 - Estimated Return Period in Years-Approximate Range (DLS)

Scenario #	1A (Haldar Report, 2021)	1B	1C	1D	Remarks
1	73	24	39	10	

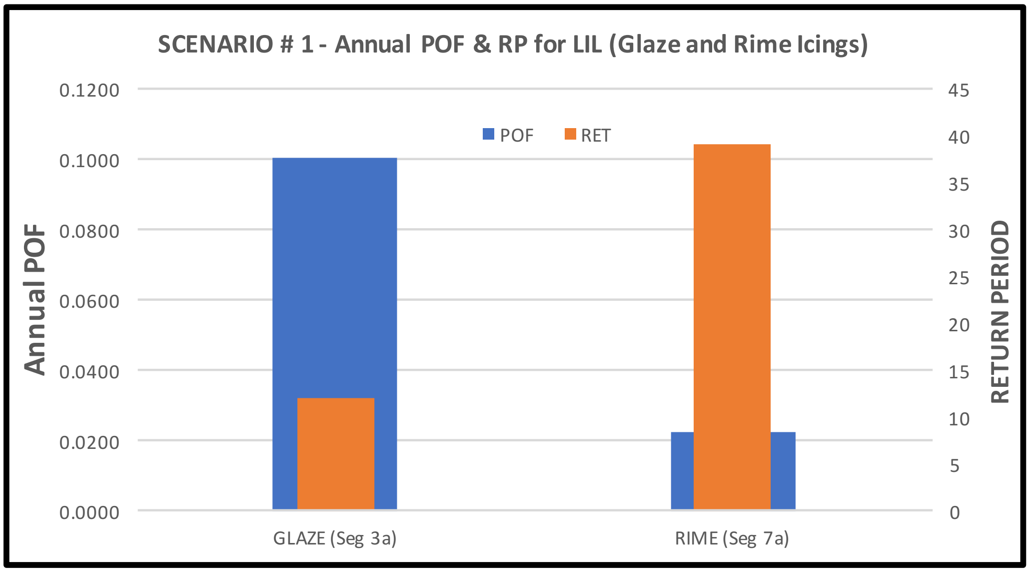


Figure 3.1 - Comparison POF for Scenario # 1

3.1.5.3 Correlation Issue and Impact of Line Length on LIL Reliability (including Topography Effects, Scenario # 4D)

The correlation study showed that the regions are independent with respect to extreme weather events and load correlation is "weak" among the regions (refer to Section 2.4). This validates our earlier independence assumption for Scenario#4D in the Haldar Report (2021) and this assumption is used here to determine the LIL POF. In this analysis, the increased loads and the influence of topography are also considered. However, this estimate is approximate and based on the knowledge gained during the previous study. Figure 3.1 presents the annual POF for glaze and rime icings and Figure 3.2 presents the annual POF for the three scenarios considered here.

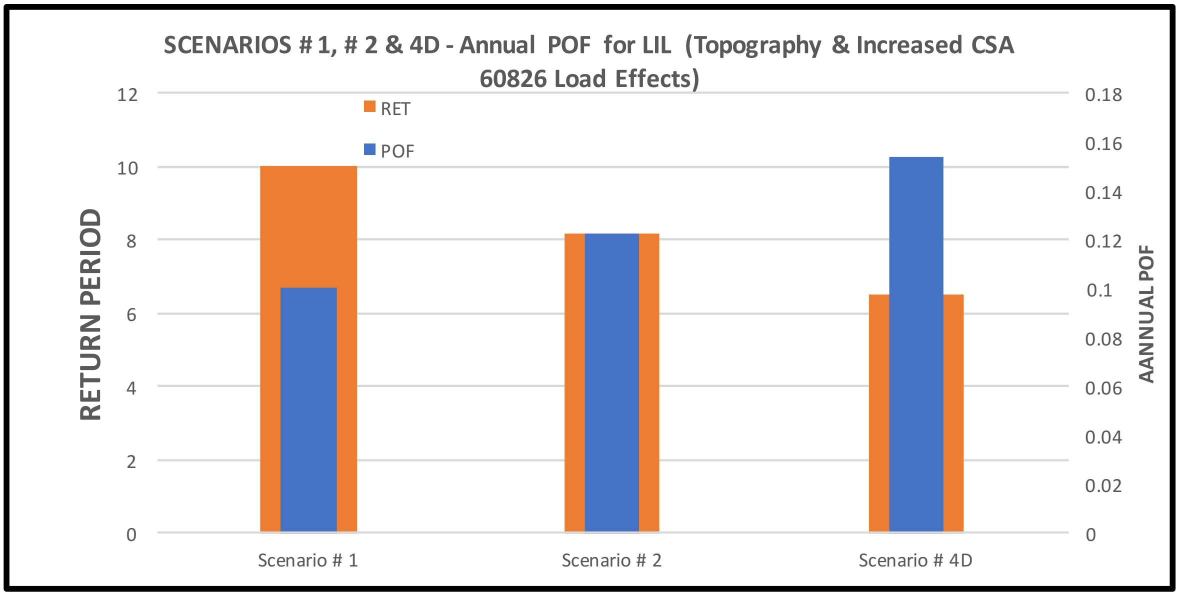


Figure 3.2 - Annual POF and Estimated Return Periods for Scenarios # 1, 2 & 4D

3.1.5.4 Impacts of Decreased Loads due to Pole Conductor Size on POF and UF

Based on the limited analysis, it is observed that the annual probability of failure could be reduced by 5-10% for increased load combinations with WSU effect, while the reductions in use factors for S1-318 and S2-541 towers for UBI analysis are less than 15% under NLH load combinations. Figures 2.16 and 2.17 present the impact of decreased load conductor loads on the reduction in UF and POF for two typical cases. This analysis was not done for every structure location rather to get an understanding of the "order of magnitude" reduction in POF (hence, increase in return period) in structural reliability analysis and in UF for UBI analysis. For baseline loads, this POF reduction could be higher. This reduction should be only considered when the structure support system controls. Therefore, the impact is relevant to the increased combined loads with or without the WSU effect where the tower probability is significantly high and controls the LIL reliability.

3.1.6 General Discussion on Revised LIL POF and Reasons for Significant Increase

Table 6.2 in Haldar Report (2021) provided the failure rates under Scenario#1 and #4D as 1.1% and 5% respectively. In terms of return periods, this was estimated to be 73 and 20 years respectively. Based on the present analysis, Scenario # 1 POF is governed by the "structure support system" that considers the influence of topography (WSU condition) and the increased load in CSA 60826-10. This is estimated to be 0.10, a 10 -year return period. Scenario #4D is estimated following Haldar Report (2021) and the POF in this case, is estimated to be 0.155 for LIL. This POF in Scenario #4D is determined without considering any correlation impact among key elements. This effect was considered in the earlier report and therefore, the present value reported as 0.155 is less conservative. This POF translates to approximately 6.5-year return period.

The reduction in the expected return period value for the increased combined load case with the influence of topography is significantly less in the present study (10 to 6.5 years) compared to the one that was presented in the earlier study for baseline loads without the topography effect (73 to 20 years, Haldar Report 2021) for Scenarios #1 and #4D respectively. The present analysis considers the influence of topography and the increased CSA 60826-10 loads in assessing POFs for Scenario# 1 and #4D respectively.

This can also be explained by the fact that in the previous study, "wire support system" was the critical element in calculating the LIL POF value and the POF values in various segments for "wire support system" were similar and were distributed evenly among the various regions for glaze and rime icing. However, in the present study, the "structure support system" in section 3a contributes most to the POF (almost 65% of the total POF) and the rime icing section 7a controls 15% of total POF while the remaining regions contribute only 20% to the overall POF of LIL (15.5%). Both Sections 3a and 7a are small sections of LIL. Therefore, 80% of LIL POF is heavily weighted by the two short sections of LIL (sections 3a and 7a) and this has skewed the reduction between Scenario# 1 and Scenario # 4D in this study compared to the one reported earlier.

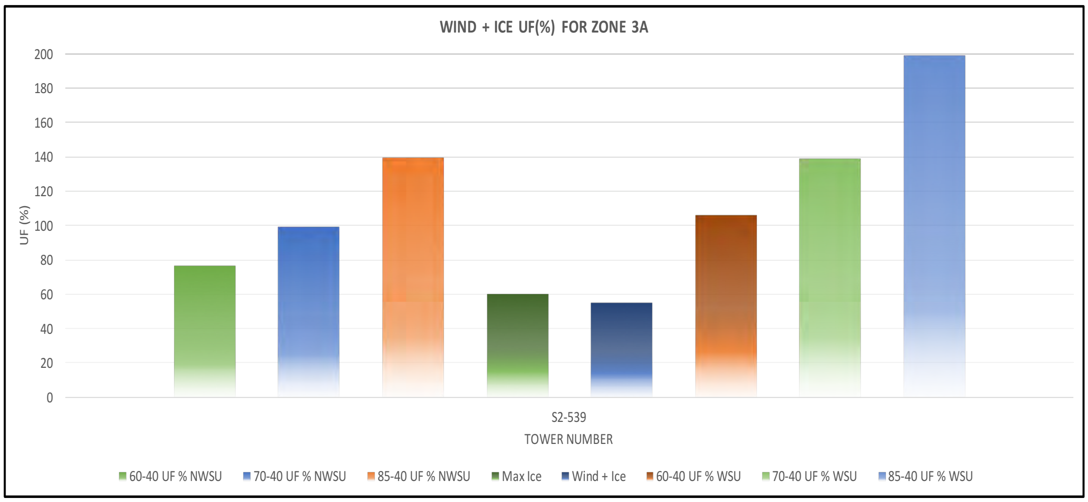


Figure 3.3 - Comparison of Use Factors (%) Under Various Load Combinations

The significant increase in the POF value due to increased combined loads considering the influence of topography (wind speed up effect, WSU) in this study can be explained in terms of the force magnitude and the distribution in the critical tower members. The total load effect on the tower has two components (1) load on the "wire support system" and (2) load on the "structure support system". A 40% increase in the reference wind speed factor due to increase combined loads coupled with the site-specific wind speed up factor for topography (1.2 to 1.4) can produce a large increase in the lateral loads on the tower body when one considers a significant increase in the wind pressure over a large surface area (ice covered tower members). The pressure is proportional to the square of the wind speed. On top of this, one still needs to consider the impact of increased loads on the "wire support system" compared to base line load case considered in Haldar report (2021). Figure 3.3 shows that an approximate fourfold increase in the increased wind load effect (baseline value in Haldar Report vs. the present value considering increased load effect and WSU effect) could increase the use factor of a critical member (force magnitude) by 275%. In view of this, a large increase in the POF for the towers located in Section 3a is fully aligned with the analysis data provided by NLH.

3.2 Sensitivity of Results for Section 3a (with or without Topography and Terrain Effects)

3.2.1 Influence of Topography

In this study, three towers, S2-538, S2-538A, and S2-539, in Section 3a have been identified as being in locations where influence of topography needs to be considered. Accordingly, structural analysis was conducted, and results show that the annual POF for these three towers would vary from 8% to 10% considering WSU effects coupled with CSA 60826-10 increased combined loads. The annual POF would be 3.8%-4.1% when WSU effects are not considered (NWSU). This significant increase should be understood in view of the explanation given in the previous section. Figure 3.4 presents a comparison of the POF for these towers located in Section 3a where the analysis results are compared for NWSU and WSU. Two towers, (S2-541, S2-545), which are near to the above three towers but are in locations where topography effects are not significant (NWSU) are also included in the analysis for reference. One tower from Zone 1 (S1-318) has also been added for increased load as a reference. It is to be noted that for an intermediate value of CSA 60826-10 load combination (70/40), the POFs for S2-539 are 1.2% and 3.84% for NWSU and WSU respectively. These values correspond to 51-year and 23-year return period respectively.

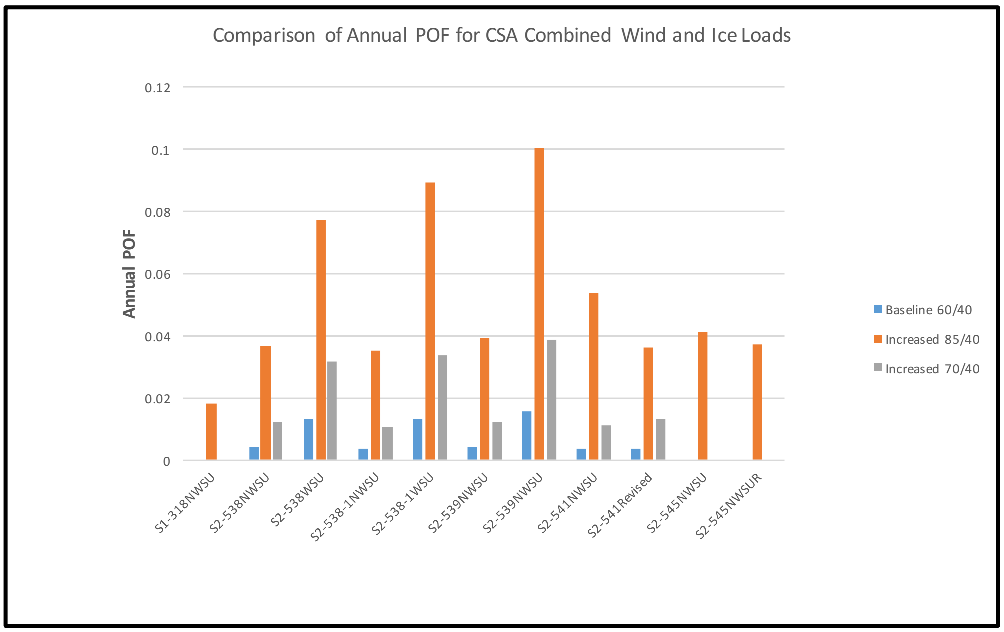


Figure 3.4 - Influence of Topography on Annual POF on LIL (part of Section 3a)

3.2.2 Influence of Terrain (Type B vs. Type C)

S2-541 (Section 3a, Southern Labrador) and S5-468 (Avalon Region) towers are also analyzed for two types of terrain categories (Type B vs. Type C). The analysis shows that the terrain effects could increase the annual POF by 30 to 50% (3.8% to 5.3% for S2-541 and 1.2% to 1.6% for S5-468), Figure 3.5. The influence is most significant on A1-towers (used in most part of the LIL line) than on A3 towers (used in Avalon region, Northern region and Southern Labrador region). A few other sections of the line were also analyzed for CSA 60826-10 increased combined loads for Terrain Type C. It appears that for comparable span range, with respect to towers in Labrador, the towers checked in Sections 6, 10 show that the annual POF of 1.2% which are significantly lower than the tower S2-541 in Labrador. For comparable span range and loads, the significant reduction in the annual POF is due to three cables used in Segment 6 versus five cables in Sections 1 and 3 in Labrador. This observation is in fully aligned with the explanation given in the previous section.

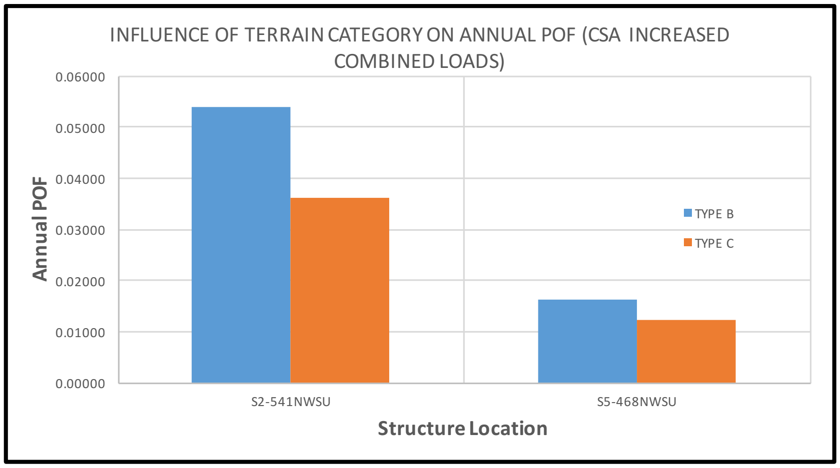


Figure 3.5 - Comparison Annual POF for Terrain Effects (Type B versus Type C)

3.3 Understanding Combined Wind Plus Ice Load Issue in LIL Design

Further analysis of the design wind and ice load combination revealed that the LIL design loads for Zone 3a were 50mm radial glaze ice for extreme ice load, 25mm radial glaze ice plus 60km/hour as wind plus ice load combination, and 120km/hour for extreme wind load (P-03188, 2018). The LIL design did not consider the combined load case for ice plus wind, which is a CSA 60826-10 requirement. CSA 60826-10 refers to 45mm radial glaze ice as a 50-year load along the line route in Section 3a (at structure location, reference NP-NLH-004, P-03188). The CSA factors for converting this 50-year ice thickness to 150- and 500-year return period values were used in determining the annual mean ice thickness and COV values in this section. Similarly, the 50-year extreme wind speed was converted for 150- and 500-year return period values; this also provided the annual mean wind speed with a COV of wind speed for this section.

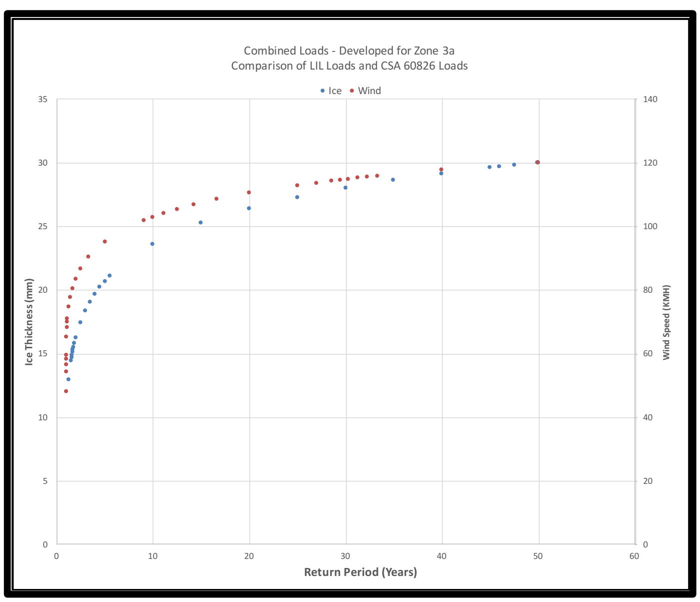


Figure 3.6 - Extreme Wind Speed and Ice Thickness Plots for Gumbel Distribution

Figure 3.5 presents the distribution of extreme wind and ice parameters with respect to various return periods following a Gumbel analysis. It is concluded that LIL design loads for Section 3a for extreme ice is a 92-year return period and for extreme wind, a 50-year return period following CSA 60826-10. However, the return period of the selected combined wind plus ice load is unknown, and a 50-year combined wind-and-ice load envelope was developed to assess the return period of this design load.

The combined wind-and-ice load envelope is developed based on the assumption that the wind speed and ice thickness act independently. Although this is not totally correct during ice accretion process, the assumption of independence may be valid to develop this T- year (e.g. 50-year) load envelope for the case when ice is staying on the cable after the storm has ended and a high wind is encountered during this time (residence time). This methodology may overestimate the load compared to the historical storm method, where each annual extreme event data point (model runs or measured ones) is analyzed and combined loads determined (Goodwin et al, 1982). The criterion used is the product of the two return periods (one for wind speed selected and one for ice thickness selected) must be 50 years to develop a 50-year combined wind and ice envelope. The respective return periods of the selected wind speed and ice thickness parameters are determined from Figure 3.6 for a finite sample size. Figure 3.7 shows the 50-year envelope of combined wind and ice loads. Two extremal points here are: (1) 50-year extreme ice thickness with 1-year wind and (2) 50-year extreme wind with 1-year ice thickness. Of course, there are many other load combinations that can be derived following the 50-year envelope data point that will also provide a 50-year combined loads for ice and wind loads when the ice is staying on the cable.

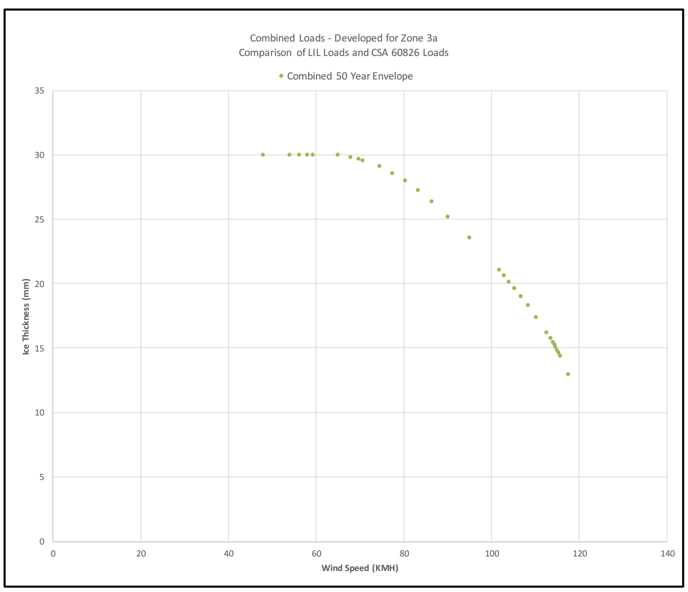


Figure 3.7 - Combined Loads Envelope for 50-year Return Period

The LIL combined load of 25mm radial ice and 60kmh of wind for Section 3a appears to be below the CSA minimum load because 60kmh wind is 50% of the reference wind speed for this section of the line. The 25mm ice thickness along the route (at structure location) is approximately 10% above (0.4gl) what is needed to meet the bare minimum of CSA fixed cable ice load. The overall return period for the LIL design combined wind and ice load appears to be below the 50-year return period criterion stipulated in CSA 60826-10. This is also reflected in the plot where a comparison is made among various use factors for a tower # S2-539 in Figure 2.9b and in Figure 3.4.

The use factor for LIL design wind and ice load for this tower S2-539 is 55% which is well below the use factor for extreme wind load of 80% (EFLA, 2021). The UF for extreme ice load is 60% (Figure 2.9b). It is interesting to note that under design wind plus ice and extreme wind loads, the leg members will be loaded in compression. Data shows that under extreme wind load, the mast member (leg member) is 80% loaded (in terms of capacity) in compression while this is loaded only 55% under design wind plus ice load. This appears to be low and many of our line failures that happened in the past are due to combined wind plus ice, not extreme wind.

A comparison of UF presented in Figure 3.4 shows that for tower S2-539 in Section 3a, the LIL UF for combined wind and ice load is 70% of the baseline CSA 60826-10 load value that was used in the earlier report (Haldar, 2021). CSA 60826-10 baseline wind plus ice UF is closer to the extreme design wind load effect reported (76% vs. 80%) but still slightly lower than the extreme wind load effect. For increased load without topography effect (NWSU), this design LIL UF is 40% of the use factor reported (Figure 3.4). For increased load with WSU effect, this design LIL UF is little over 25%. Accordingly, to satisfy the CSA 60826-10 increased load combination coupled with the influence of topography effect, the LIL line section in Zone 3a requires a design load envelope that needs to accommodate the significant increase in the combined wind and ice load effects than what was used in the original design of LIL.

Some problems are also encountered in interpreting the CSA 60826-10 combined load of (0.6-0.85 V_R) with $0.4g_l$. It is our understanding that the suggested ranges (factors) for key meteorological parameters for this load combination have been derived from many ice accretion model runs for stations across Canada. These aggregated factors for wind speed and ice load in CSA 60826-10 are functions of conductor diameter, COVs of ice thickness, concurrent wind speed and duration of the icing events. The COV of wind speed is well defined but the COV of ice thickness could vary significantly across Canada. Therefore, a map based wind speed factor ranges (0.6-0.85Vr) with one single ice load factor of 0.4 in determining reduced cable load 0.4gl may not be suitable not only for the entire country but even, for the NLH service area in representing the reference concurrent wind on conductors during the ice accretion process. The assumption that this concurrent wind will reflect the relative rarity of extreme wind (T-year concurrent wind) during icing periods may not provide a realistic load combination for the entire NLH service area unless the wire vertical load factor is adjusted to meet the 50-year criterion for a specific location. The CSA requirement of 0.4gl is stipulated for the entire country. Therefore, the author does not accept that one single global reduction factor for vertical cable ice load for the entire CSA map based wind and ice loads may not provide consistent reliable load combinations for combined wind and ice loads. The present study followed CSA 60826-10 criteria strictly but the author felt the need for pointing out this inconsistency in CSA 60826-10.

The other load combination of 100% full ice (gl) and yearly wind load (50% of reference wind speed, Vr) was not considered in the original LIL design. Again, CSA 60826-10 load combination 100% full ice load combined with 40%-50% of reference wind speed (60km/hour for Section 3a) conforms to a 50-year return period ice with approximately annual wind also satisfying a 50-year load combination (Figure 3.6). The author finds that CSA 60826-10 load combination 100% gl plus (0.4-0.5 Vr) is reasonable.

The ice storm event of January 2021 shows that ice remains on both support systems (towers and cables) for an extended period without shedding completely (long residence time). Therefore, the probability that a very high wind (extreme wind after the icing event) higher than 0.4-0.5 reference wind may be encountered during this period also increases significantly. Although, LIL design did not consider the ice plus wind load combination, analysis results show that under this load combination, the annual POF could vary between 1% to 2 % for NWSU condition and 2% to 2.5% for WSU condition. This POF may increase further if the factor used for increased loads (0.5) is underestimated for the various regions.

The specific value (range) for combined load event for a T-year return period is not only the function of wind speed and ice thickness values but also the COV's of these parameters, duration of the ice event, the conductor diameter and most importantly, the correlation between the ice thickness, concurrent wind speed and the duration (hours/days) during the icing event. A time series analysis is needed to adequately establish the joint densities of these three key parameters and the combined return period (T-year) of exceeding certain threshold values of wind speed, ice thickness and duration. While the LIL design loads for Section 3a have a ninety-two (92-year) return period for extreme ice thickness and a 50-year return period for extreme wind speed as per CSA 60826-10, the combined wind plus ice load appears to be well below the expected value that is required not only to meet CSA 60826-10 loads but also the expected combined loads for this region.

The expected load value refers to CSA 60826-10 upper range value and this is simply based on author's own experience and understanding in monitoring wind and ice loads on lines and associated uncertainties that one encounters in determining extreme meteorological parameters, its impacts on selecting site specific values for combined loads (Haldar, 2007). The design UF for wind plus ice load also indicates that the selection of this load in Section 3a may not have produced a conservative load because the impact on mast members (leg members) is not onerous when compared to the effect due to extreme wind or CSA 60826-10 baseline loads. In CSA 60826-10, it is understood that this reference concurrent wind speed range (0.6-0.85Vr) along with one fixed vertical cable load value reflects the relatively T-year extreme wind speed during icing accretion events. Although no attempt is made here to quantify the impact of the uncertainties of the above parameters on the values used in the reliability analysis for the entire section 3a, the author believes that this combined load for wind plus ice, (0.85Vr and 0.4 gl) is reasonable and could be higher, if there is a strong correlation between the ice thickness, concurrent wind speed and the event duration. This could change not only the T-year concurrent wind speed range but also the vertical cable load, rather a fixed specific value that has been stipulated. A specific recommendation is made on how to address this in the future.

It is also noted that most failures that NLH has experienced over the past fifty (50) years are related to combined wind and ice loads; these past failures rarely occurred due to extreme wind or extreme ice alone. Therefore, extreme combined loads need to be chosen carefully and must be validated before with field data before this is used in the future mitigation plan for LIL

3.4 Conclusions

Based on the revised analysis that addresses the CSA 60826-10 increased load combination issues and includes the influence of topography explicitly in assessing the LIL structural reliability, it appears that the annual POF of LIL is 10% under Scenario #1. In terms of the expected return period, this translates to 10 years. However, if one excludes the topography effect and considers only increased combined loads, the annual POF is 4.1% (24-year return period) under Scenario #1. If one considers the mutual exclusivity of multiple weather hazards to which the LIL is exposed (extreme glaze icing, rime icing events and extreme wind during non-icing seasons), the annual POF increases further and is calculated to be 5.2% to 12.3% in Scenario # 2. Since Scenario #2 is outside the CSA 60826-10 requirement and CSA does not address the line reliability under multiple weather hazards, a direct comparison is not made. However, the return period is estimated to be approximately 8 to 20 years for increased combined loads (with or without WSU effect). This implies that the decrease in the return period is small because the POF is primarily dominated by the tower POF in the glaze ice section with or without the effect of topography under increased combined loads. This was not the case when the earlier study (Haldar, 2021) was conducted where both OPGW POF values were very similar (closer) under both icing types and the POF reported had a two-fold increase in Scenario # 2. The impact of line length would reduce the structural reliability further and Scenario #4D indicates that this would be approximately 84.5% (POF of 15.5%). Figure 3.8 presents the risk levels for these three scenarios. The LIL failure probability is very high under these scenarios and the failure is very likely leading to a bi-pole outage when one considers a 50-year service life of the asset.

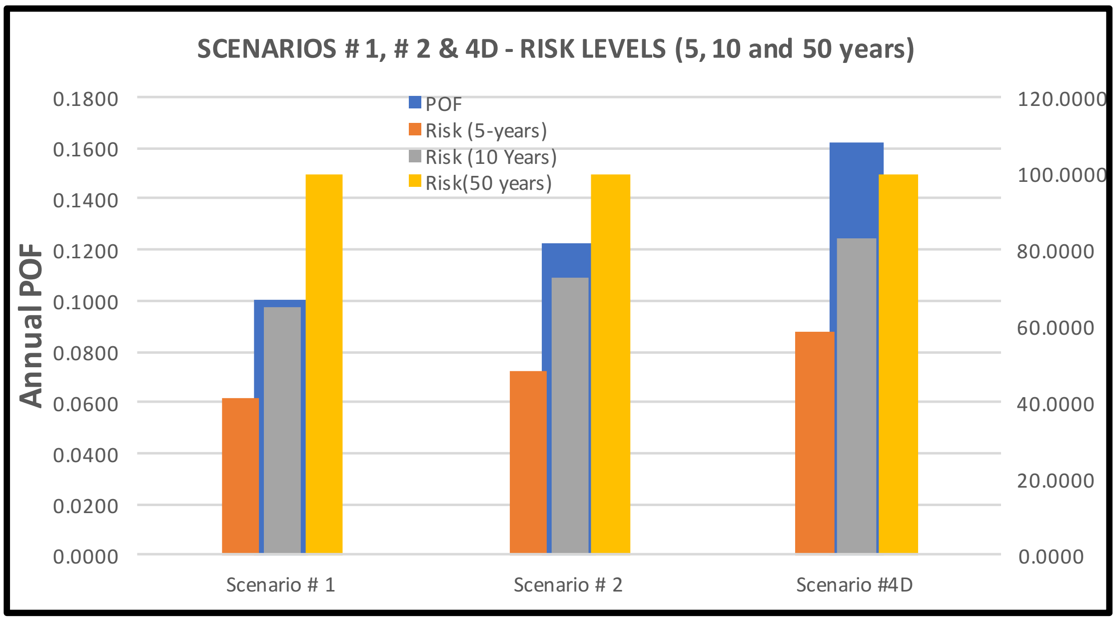


Figure 3.8 - Risk Levels Under Three Scenarios

A high-level load correlation study on extreme events revealed that there is very little load correlation among various regions thus validating the independence assumption that was used earlier in assessing the impact of line length on LIL reliability (Scenario # 4D). UBI analysis with NLH load combinations showed clearly the two critical towers in Labrador are vulnerable with respect to mast buckling because of significant overloading issue. The report also provides some guidance on the reduction of the use factor determined in UBI analysis considering the impact of large pole conductor size in ice accretion and shows that on average, a reduction of 10-15% can be realized for the two towers in Labrador. For structural reliability analysis, LIL annual POF can be reduced by 5-10% for increased CSA 60826-10 loads coupled with WSU effects. This reduction factor for increased pole conductor size should be applied when the structure support system controls and for increased loads with or without WSU effect. If the report did not explicitly provide return period value in every situation, a practical way to determine this would be to take a reciprocal of POF and then apply the adjustment factor for reduction due to increased pole conductor size.

3.5 Recommendations

- Measure wind speed after an ice storm and during line inspections in validating combined wind and ice load and ice plus wind loads for the critical sections of LIL, particularly the line sections in the Labrador Region where the reliable data is currently unavailable.

- Assess the mitigation option of upgrading the capacities of several towers in section 3a, either by redesigning the A1 tower or by installing mid span towers to upgrade the line in Section 3a and the other sections where similar problems may be encountered.

- Consider monitoring LIL remotely for ice and wind loads and validate this by occasional in-field measurements, particularly for loads on the "wire support system" (OPGW, electrode and pole conductor etc.); one objective should be to validate whether the pole conductor collects less ice compared to the other two cables during a storm. This may also provide data to clarify whether in the future, the OPGW should be designed for the conductor design ice loads as stipulated in CSA 60826-10.

- The author has checked a few critical A1 towers outside of the Labrador region. It is suggested that NLH check all the A1 towers in the Island Part of the line in addition to the ones in the Labrador region to ensure that all these A1 towers where UF are considerably higher (>100%) are fully identified.

- NLH may want to consider developing a better statistical procedure in determining the combined wind and ice loads that include the NLH's operational experiences for the past fifty (50) years supported by the icing that has been observed during past line failures. This requires further investigation and it is outside the scope of this study. It must also be understood that the combined ice and wind load prediction method (post storm event) often produces loads that are more conservative and higher than the loads based on the historical storm method. One of the reasons for this is that the correlation between the ice thickness and wind speed is totally ignored in the combined probability method and this is the reason, a factor or factors for various NLH service regions must be developed to correct these loads with respect to the historical storm method. This can only be done based on calibration with measured data during ice storm events or based online field monitoring (Haldar, 2007).

- With respect to wind plus ice load, correlation effect among the ice thickness, concurrent wind speed and the duration of the event needs to be understood. The data from Environment Canada for nearby weather stations coupled with field observation data and the data from NLH's operational experience should be used to develop this wind plus ice map for the regions identified in Haldar report (2021). This analysis can also be validated by NWP model along the line route and NLH has already used this numerical modelling technique in predicting combined rime loads. Once validated by measured data, this can be considered in the future possible upgrading of this LIL line.

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- Khasay, Meseret and Bitsuamlak, G. 2021Assessing the Influence of Topography on Wind Flow Over Transmission Line in Newfoundland and Labrador, a summary note prepared for Newfoundland and Labrador Hydro (NLH)

5.0 Appendix

Assessing the Influence of Topography on Wind Flow Over Transmission Line in NLH

Meseret Kahsay and Girma Bitsuamlak
WindEEE Research Institute, London, ON.

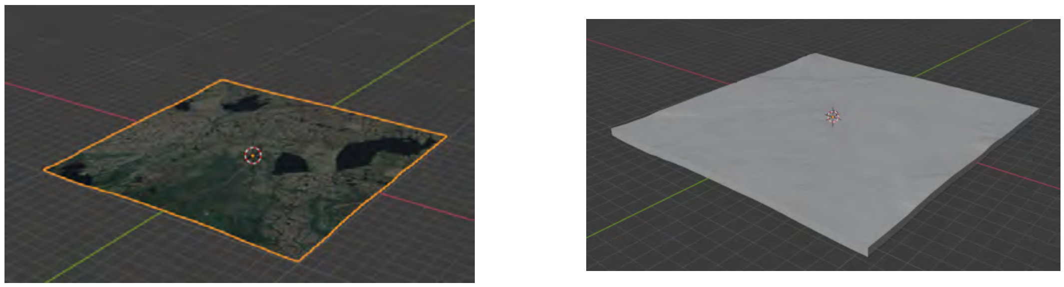
Overhead transmission lines and towers in NL passes through complex topography areas, that could see wind load amplified by topography effects usually referred as speed-up factors. Here a two-tier approach is presented. In the first step, approximate analytical speed up calculation methods are applied for two wind directions - along the line and across the line). The main objective of this exercise was to identify locations with high speed-up (hot spots). In the second phase, detail speed-up calculations were made at the hot spots identified in the first phase by using advanced Computational Fluid Dynamics (CFD) simulation at SHARCNET supercomputing facility. The terrain for the computational domain is extracted from satellite imagery and Shuttle Radar Topography Mission (SRTM) elevation data at 30-meter resolution (see Figure A.5.1)[1]. The computational domain is generated by aligning each hotspot at the center of the imagery and creating a region area of 20 km by 20 km.

The computational domain is divided into millions of polyhedral grids at which the flow equations are solved. In this study, a steady, three-dimensional, model is used with a Reynolds Averaged Navier-Stokes (RANS) formulation using the κ-ε turbulence closure model. Different grid refinement stages were used to maintain computational efficiency, while attaining acceptable numerical accuracy. To reduce the computational cost associated with the modelling of such a large domain, different control volumes were used. Around the target hill, fine grids were deployed. Overall, grid cells numbers ranging between 15 – 20 M cells are used with dense grids around the target terrains and in the wake region to resolve the air flow near the transmission lines. Figure A.5.2 shows the discretization and topography details.

In this study, the terrain upwind of the target terrain along with the wind direction, is categorized as open terrain. The incoming atmospheric boundary layer velocity and turbulence profile based on the ESDU (Engineering Standard Data Unit) is implemented at inlet. The two sides and the top surfaces of the computational domain are assigned symmetry conditions. The outlet zero static pressure boundary assigned.

Finally, speed up ratio values are provided in tabular forms and contours. Speed up is defined as $(U_t(z)-U_0(z))/U_0(z)$ where $U_t(z)$ is the velocity at the topography at z height above the local ground and $U_0(z)$ is the velocity at the inlet (open profile) at z height above the local ground. Figure A.5.3 shows an example speed-up contour at 30 m heights of the transmission tower.

[1] U.S. Geological Survey, 2021, Remote sensing and Landsat, accessed July 2021 at URL https://www.usgs.gov/products/data-and-tools/real-time-data/remote-land-sensing-and-landsat



(a) (b)

Figure A5.1 (a) - Satellite Imagery with the Hotspot Placed in the Center of the Extracted Computational Domain Region (b) the Terrain Generated

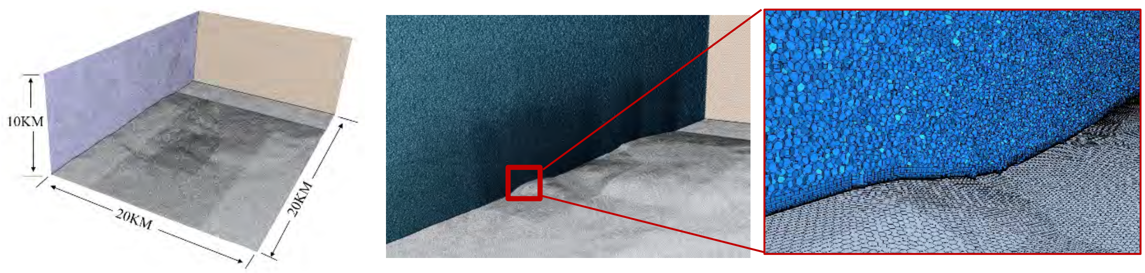


Figure A5.2 - Computational Domain and Grid Generated for Terrain Rank #1

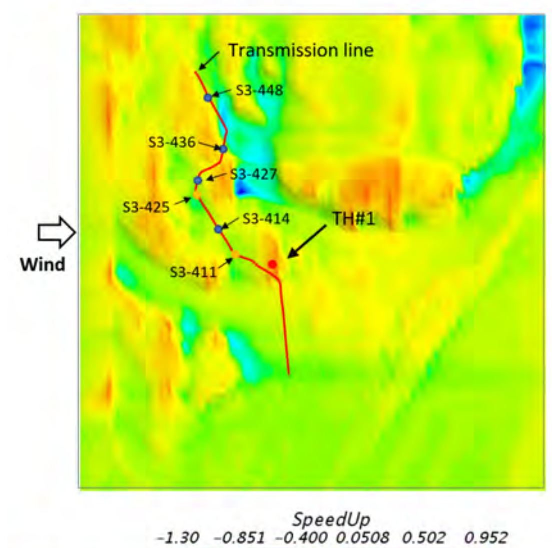


Figure A5.3 - Speedup Contour Example at a Height of 30m from the Ground

Attachment 2

Emergency Response & Restoration Planning
Labrador-Island Link – Overland Transmission

Emergency Response & Restoration Planning

Labrador-Island Link – Overland Transmission

December 15, 2021

Revision: R0

newfoundland labrador hydro	Emergency Response & Restoration Planning Labrador-Island Link – Overland Transmission	Revision R0	
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List of Appendices

1 PURPOSE

The purpose of this document is to provide an overview of Newfoundland and Labrador Hydro's ("Hydro") current program to support the Labrador-Island Link's ("LIL") ability to avoid sustained outages during high-risk conditions, including Hydro's plans for incident preparedness, response, and restoration.

The information contained within this report is reflective of Hydro's current emergency response and restoration plans based on studies, modelling, and Hydro's experience and lessons learned to date. Hydro's emergency response and restoration planning will continue to evolve as Hydro continues gain practical operational experience with the LIL.

2 BACKGROUND

The LIL is a 900 MW, +/- 350 kV HVdc bipole transmission line with a single conductor per pole and galvanized lattice steel towers. It runs between Muskrat Falls in Labrador and Soldiers Pond on the Island portion of the province. The LIL overhead HVdc transmission line traverses approximately 1,100 km from Muskrat Falls to Soldiers Pond. There are 11 different tower types on the LIL, consisting of both guyed and self-support structures. The elevation of the LIL varies from 0 m to approximately 630 m above sea level. The line passes through 11 different climatic loading zones with two types of icing conditions experienced along the line—rime ice (in-cloud icing) and glaze ice (from freezing rain).

Figure 1: Labrador-Island Link

3 SCOPE

The information contained within this document provides an update on Hydro's efforts to establish, test, and improve a sound working emergency response and restoration plan for the LIL from an engineering and operational perspective. Hydro's "Labrador-Island Link Overhead Transmission Line Emergency Response Plan"[1]

[1] Originally filed with the Board as Attachment 1 to the "Near-Term Reliability Report," Newfoundland and Labrador Hydro, May 15, 2020.

has been updated to reflect Hydro's learnings since the time of that submission. The revised document is provided as Appendix A to this report.

4 ONGOING ASSET ANALYSIS AND ENGINEERING

To enable effective and timely response to an emergency on the LIL, a number of engineering considerations contemplating the LIL's physical characteristics and design must be taken into account. The following sections describe ongoing engineering planning considerations that will help highlight the LIL's areas of exposure, performance, and tools which are available to aid in proper design and analysis.

4.1 LIL ZONE CLASSIFICATION

Table 1 summarizes an engineering study that: (i) identifies what can generally be considered areas of high exposure based on the degree of difficulty associated with access and (ii) comments on the zones general meteorological loading. This analysis outlines the areas which require more focus and planning from an emergency response perspective on a macro scale. For the purpose of ranking the accessibility, areas which are located within 20 minutes from paved government-serviced road are designated as "good," areas located between 20 and 60 minutes from paved government-serviced road are designated as "fair," and areas located more than 60 minutes from paved government-serviced roads are designated as "remote."

Table 1: Details on Conditions Based on LIL Section

Structures	Access	Comments
1 – 401	Good – Mainly Accessible off Route 510	Average Meteorological Loading Zone
402 – 1282	Remote – Interior of Labrador	Average and Alpine Meteorological Loading Zones
1283 – 1366	Remote – Island Northern Peninsula, Winter Access Zone	Average Meteorological Loading Zone. Construction in this section used winter access only.
1367 – 1685	Fair – Northern Peninsula, forestry trails and constructed access	Average and Alpine Meteorological Loading Zones
1685 – 2014	Remote – Long Range Mountain, constructed access only	Average and Alpine Meteorological Loading Zones
2015 – 2147	Good – Taylors Brook to Birchy Lake, forestry trails and constructed access	Average and Alpine Meteorological Loading Zones
2148 – 2235	Remote – Dawe's Pond, Forestry trails and constructed access	Average Meteorological Loading Zone
2236 – 2415	Fair – Badger to Bay d'Espoir highway, existing and constructed access	Average Meteorological Loading Zone
2416 – 2649	Remote – Interior of Newfoundland, Terra Nova combination of forestry, existing and constructed access	Average Meteorological Loading Zone
2650 – 3223	Good – Avalon, Close Proximity to Trans-Canada Highway	Average and Eastern Meteorological Loading Zones

Through additional modelling work completed in 2021,[2] Hydro has identified critical tower locations on the basis of various environmental factors (unbalanced loading, wind speed-up, etc.). This allowed the engineering and operations groups to highlight critical towers and take them into account when planning for more exposed areas throughout the line from an emergency response perspective.

4.2 LIDAR IMAGERY

To understand the expected life of the LIL and appropriately adapt and engineer potential solutions in the event of an emergency, in 2020, Hydro acquired as-built light detection and ranging ("LiDAR") and orthophotography for LIL and obtained the processed data in 2021.

Information collected includes, but is not limited to, the following:

- As-built condition of the line;
- Conductor sag;
- Tower clearances;
- Access road network; and
- Right-of-way details.

Analysis of this information continues.

4.3 ARCGIS DATABASE

The previously discussed LiDAR data is incorporated into the ArcGIS geospatial database and is used for ongoing engineering, maintenance, environmental and emergency work. In 2022, Hydro plans to merge the ArcGIS database with its ongoing tracking system to record the following within the GIS database:

- Maintenance records;
- Historical damage and trends; and
- Inspection reports, including damage, icing, galloping, etc.

4.4 REAL-TIME MONITORING

Real-time monitoring ("RTM") stations aid in design loading analysis by recording certain conditions on the LIL such as ice loading, wind loading, galloping, and Aeolian vibrations. RTM devices can be installed directly on the line or on test spans.

Hydro currently maintains three passive test spans throughout Alpine regions of the LIL.

[2] "Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads," Haldar & Associate Inc., rev. April 11, 2021 (original March 10, 2021) and "Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads – Phase II," Haldar & Associate Inc., December 12, 2021 were completed as part of Hydro's ongoing Reliability and Resource Adequacy study.

The status of the new RTM sites is as follows:

- Engineering review of the existing RTM sites was awarded in 2020;
- Engineering and design for three stations and equipment in the Long Range Mountains (“LRM”), southern Labrador, and the eastern Avalon was completed in 2020;
- Tender and award for the construction, installation, commissioning of two weather stations took place in 2021 for construction in 2022.

5 ESTIMATED RESTORATION TIME

5.1 HYDRO’S ORIGINAL ESTIMATED RESTORATION TIME

In 2019, Hydro undertook an exercise to determine the estimated time to restore power based on the location of the failure. Table 2 provides an estimated timeline for restoration of power following a transmission line failure. Due to the design capacity of the LIL, it is less probable that large segments of towers will fail. As stated above, engineering analysis of failure scenarios by region identified the most exposed towers for various environmental conditions. This information will be taken into account when planning response activities in the future.

Table 2 provides several scenarios and their associated estimated restoration times. The assumptions reflected in this analysis were as follows:

- Unlimited resources, snow clearing, and construction at night (it is possible to acquire these extra resources when needed);
- Structures are located on snow-covered road ranging from 15 km to 80 km of the main road;
- Use of four to five pieces of the equipment such as nodwells, loaders, dump trucks, plows, and excavators, as well as ten excavators and three dozers for snow clearing;
- Time utilized to prepare guy wires (e.g., measuring and cutting) could be completed concurrently with clearing of site. Several trucks loaded and an external contractor utilized for shipping and loading;
- Four assembly crews of eight to ten people with one excavator per crew;
- Installation begins approximately three days after assembly begins, no helicopter or crane assistance, and suitable weather conditions for the raising of towers (four to five linesmen); and
- One crew (from contractor) stringing during daylight hours in addition to assembly crews.

On the basis of the above-noted assumptions and the experience and understanding available at the time, it was estimated that restoration could take up to seven weeks, depending on the circumstances of the failure.

Table 2: Estimated Restoration Time by Tower Failure (2019)

Number of Towers	Approx. Length (km)	Dead Ends Down?	Area/Location	Anchors and Foundations are Sound?	Guy Wire Reusability (%)	Temporary or Permanent Solution	Total Time
				Description of Failure			
<3	1	No	All	Yes	100%	Temporary Wood Pole	1 to 3 weeks
>3	1, 7	No	All	Yes	100%	Temporary Wood Pole (Monopole)	2 to 6 weeks
21	7	No	Terra Nova/LRM/ Labrador	Yes	50%	Permanent Steel (Bipole)	5 to 7 weeks
22	8	No	Avalon	Yes	50%	Permanent Steel (Bipole)	5 weeks

The emergency restoration structures (“ERS”) purchased in 2021, which are further discussed later in this report, are expected to reduce these response times slightly; however, it is anticipated that the response timeline would remain within a similar range presented in Table 2 the worst-case scenarios. Procedures and installation times have not been calculated as of the date of publishing this document.

5.2 LOCKE’S ELECTRICAL LIMITED 2021 ESTIMATE

In 2021, Locke’s Electrical Limited was consulted to assess the timelines for power restoration for seven discrete scenarios. The scenarios were chosen as the possible “worse case” and are summarized in Table 3. Please refer to Appendix B for the complete report.

Assumptions reflected in the estimated restoration timeframes were defined as follows:

- Restoration solutions were limited to wood-pole structures;[3]
- A number of activities will occur during the night such as snow clearing, pole and anchor work;
- Pre-event planning is in place to ensure a timely response; and
- Further weather issues would not impact power restoration.

[3] Timelines will be re-examined in the future to include the ERS solution.

Table 3: Summary of Scenarios Assessed by Locke's Electrical Limited

Scenario No.	Location/Season	Failure Circumstance	Restoration Circumstances	Estimated Restoration Time
1	Central Labrador Winter	Up to 3 towers failed	Temporary wood-pole structures to put into service 1 pole conductor and 1 electrode conductor	23 days
2	Central Labrador Winter	2 km of transmission line failed	Temporary wood-pole structures to put into service 1 pole conductor and 1 electrode conductor	33 days
3	Long Range Mountains Winter	Up to 4 km of transmission line filed	Temporary wood-pole structures to put into service 1 pole conductor and use the sea electrode for the return.	38 days
4	Central Labrador Winter	21 towers from dead end to dead end	All foundations are reused and 50% of the guy wires and anchors are reused to do a full restoration of the steel lattice towers.	42 days
5	Central Labrador Winter	7 towers filed	All foundations are reused and 50% of the guy wires and anchors are reused to do a full restoration of the steel lattice towers	33 days
6	Avalon Peninsula Winter	22 towers from dead end to dead end	All foundations are reused and 50% of the guy wires and anchors are reused to do a full restoration of the steel lattice towers	36 days
7	Central Labrador Winter	Electrode line failure in two separate locations	Location A at structures 360 to 369 with 5 electrode cross arms damaged and conductor damage at all 10 structures. Location B at structures 524 to 528 with 3 electrode cross arms damaged, a severed conductor at 1 tower and damaged conductor at 3 others	23 days

This report allowed for a more detailed verification of the timelines estimated by Hydro and is based on the knowledge and experience of this local contractor. The analysis evaluated the worst-case conditions with respect to damage location along LIL and the associated logistics such as material handling, snow clearing, and site preparation. The range of restoration timelines vary from three to six weeks for various bipole failure scenarios. Locke's Electrical Limited estimates align with Hydro's original estimates. As previously noted, further engineering solutions, such as the ERS will help reduce the installation times for bypasses; however, the overall ranges are expected to remain similar when considering logistics and line location.

6 ENGINEERING DESIGN ALTERNATIVES

Hydro has developed, and is continuing to develop, detailed engineering solutions which could potentially be used as an interim solution to expedite re-energization of the LIL following a bipole failure. This upfront engineering is intended to reduce response time by making a variety of solutions available for the operations team to choose from depending on the failure scenario. The engineering alternatives described in the sections that follow consider the capability of local contractors and line crews within the province. Hydro has commenced work on the following solutions outlined in following subsections.

6.1 WOOD POLE SOLUTION

In the event of a failure of multiple tangent towers on the line, installation of a wood pole bypass line is an option to temporary restore power until restoration of the permanent line is completed. This method was tested in a 2018 mock exercise, which is further detailed later in this report.

Wood poles, hardware, and glass insulators have been procured for this design and are stored in Argentia and Muskrat Falls.

Figure 2: Wooden Pole Solution Used in 2018 Mock Exercise

6.2 COMPOSITE INSULATOR ASSEMBLIES

Composite insulator assemblies are an option to replace the existing hardware and glass insulator strings during an emergency restoration event for the wood pole structures and backstay assemblies. Composite insulators are lighter than glass insulator strings and are therefore expected to make material transportation and constructability easier.

Clamps, hardware, and anchor materials have been procured. The composite insulator was designed and delivered in the winter of 2020. They are stored at Forteau Point and St. John's.

6.3 SWIVEL BASE ADAPTER

A swivel base adapter is intended to allow a replacement tower to be installed on an existing tower foundation in the event the damaged tower is irreparable. The designed swivel base can then attach to the modified tower base and allow the tower to be raised by a derrick, winches, and guys. The swivel base can then be removed and reused if necessary.

The design and work procedures for this solution were completed in 2019. The practicality of using this method to lift heavy tower components remains under review. As the ERS provide a more suitable option, the requirements and potential uses for the swivel base adaptor are undergoing further investigation in advance of procurement.

6.4 MODIFICATION TO HVDC TOWER

By modifying and adding tower members, an undamaged section of the existing tower from the failed line can be used to restore the line. This is done by reinforcing the tower and adding stand-off post insulators to the section of the tower under the existing crossarm. This option has the advantage of using the existing tower sections, anchors, and foundations.

The design and work procedures for this solution were complete in 2019. This solution was tendered with the swivel base tender in 2020 but, for the same reasons, has since been put on hold.

6.5 EMERGENCY RESTORATION STRUCTURES

ERS are structures designed to be installed quickly in the event of line failure. ERS towers are typically lightweight, modular aluminum structures and are associated with polymer insulators, hardware, and guying components. The lightweight modular components allow transportation to remote and difficult-to-access sites, either by land or helicopter. Unlike typical permanent transmission structures, an ERS design is driven by flexibility rather than optimization as it provides for many different structural concepts.

Figure 3: ERS Mock Exercise at Soldiers Pond

There are several types of ERS available in the market. These structures are generally supplied with the tools and equipment required for tower assembly and erection. The systems are largely similar and have been designed to be installed with minimal equipment. Most of the towers and equipment can be airlifted to the required location.

The design and supply of the ERS was awarded in 2020 and arrived in summer 2021.

Training for ERS tower assembly and erection was completed in October 2021 by the two crews that would be responsible for repair (one crew in Muskrat Falls and one crew in Soldiers Pond) and local support contactors.

7 MATERIAL STORAGE AND LOGISTICS

Materials must be stored in accordance with the manufacturers' recommendations to ensure usability during an emergency. Ideally, a closed environment is preferred. Loading and offloading equipment such as cranes and portable forklifts must be available at the storage locations to aid in loading-materials onto the tractor and trailers. Open trailers are preferred for material transportation to facilitate the movement of the materials from the laydown area directly via helicopters, if available.

7.1 MATERIAL STORAGE AREAS AND CAMPS

Hydro has been determined that storage areas will be required for long-term and short-term/temporary solution materials. Long-term storage solutions will require a location on the Island as well as in Labrador; the locations are currently as follows:

- Argentia (Island); and
- Muskrat Falls (Labrador).

With respect to short-term/temporary solution storage locations, a site will be required in Labrador as well as near the LRM since the LRM is the most heavily loaded area. The short-term solution locations are currently as follows:

- Hampden (Island); and
- Forteau (Labrador).

Further to these storage locations, Hydro's operations group is considering temporary equipment laydown and storage locations inside the LRM Alpine zone. A line crew camp in central Labrador is also under consideration. Construction of these facilities is expected to conclude in 2022.

7.2 MOVEMENT OF MATERIALS FROM STORAGE AREAS

To optimize the storage locations, materials for each store must be allocated based on the towers in that section(s) of the line.

As road infrastructure is available and in suitable condition and helicopters are readily available, Hydro plans to utilize tractors and trailers to bring the materials and equipment close to the line and airlift them into position in poor weather or site access conditions. All the storage locations must be fitted with suitable rigging equipment to assist in the loading and offloading of materials and equipment. Several transport companies are available to move the materials and equipment and many of the contractors on the Island have suitable equipment to assist in these activities.

Hydro plans to use open flatbed trailers for material transport as this will facilitate offloading of materials on-site using helicopters, thereby expediting the delivery of required materials and equipment to the site. All materials and equipment must be packaged in a manner which enables the utilization of helicopters in the restoration activities.

7.3 LINE REPLACEMENT SPARING PHILOSOPHY

Hydro has developed the following philosophy for stocking extra operational spares to be used in the event of maintenance or emergency repairs.

For the LIL, Hydro will maintain adequate maintenance spares to replace one section of the transmission line between anti-cascade structures. Anti-cascade structures are designed not to fail due to the failure of a conductor or adjacent structure; this is consistent with industry practice. The line design consists of no more than 21 structures between anti-cascade tower placements. Maintenance spares will be obtained for the following:

- All main tower bodies and extensions;
- Hardware assemblies (tangent suspension, dead end, jumper, optical ground wire ("OPGW") and overhead shield wire ("OHSW");
- Cables (conductor, OPGW and OHSW); and
- Insulators.

Due to the design capacities and line failure sequence, there will be no maintenance spares obtained for the transmission tower foundations. However, selected "ground level" foundation surplus have been retained following conclusion of construction. Due to diverse meteorological conditions encountered across the 350 kV HVdc transmission line, there are 11 tower types; therefore, a larger quantity of spares is required, mainly tower bodies and extensions. To determine the quantity of tower bodies and extensions required, an analysis was performed examining the quantity and type (including extensions) of structures used throughout the HVdc line. This ensures there will adequate parts available to quickly perform the required repairs if a cascade failure occurs on any section.

In addition, spare wood poles and accompanying equipment for two, 2 km sections (or one, 4 km section) of monopole bypass on the Island or 2 km of monopole bypass plus the electrode line in Labrador have been procured and stored for emergency response use. This quantity may change over the coming years as Hydro gains further operational experience with the LIL.

8 EMERGENCY AGREEMENTS

8.1 THIRD-PARTY CONTRACTOR AGREEMENT

Hydro currently has a contract in place from an operational perspective with a third-party transmission line contractor. The contractor is required to perform restoration activities in response to a transmission line incident that has caused a loss of power and to respond and mobilize on site within 24 hours.

As of June 2020, both Locke's Electrical Limited and Curtis Powerworks Inc. were give the Notice of Pre-Qualification and are now pre-qualified to supply services associated with potential projects.

8.2 MUTUAL ASSISTANCE AGREEMENTS

Operational agreements exist between regulated and non-regulated Hydro entities. In the event of an emergency, those agreements would be leveraged where possible to provide assistance in restoring power. Concurrently, Hydro is investigating opportunities for mutual assistance agreements with other utilities within the province and in neighbouring provinces to supplement the services provided by the third-party contractor. The assistance of contractors and neighbouring utilities such as Newfoundland Power Inc., Nova Scotia Power Inc., New Brunswick Power Corporation, Hydro-Québec, etc. may be essential during an emergency situation. Hydro will engage with these entities in 2022 to discuss the technical details and physical characteristic of the LIL.

9 MOCK EXERCISES

Since 2018, Hydro undertook a series of increasingly complex mock exercises to obtain experience in responding to potential types of failures in reasonably comparable environments. Doing such work in a controlled environment highlights gaps in coordination, documentation, processes, procedures, and logistics which can then be addressed in advance of a true emergency situation. Further, it provides first-hand experience which helps define roles and responsibilities and reduce response time and error for those who will be required to actively participate in emergency response.

In 2018, four mock exercises were undertaken, as follows:

- The first took place at the Soldiers Pond Emergency Operations Center ("EOC") with the purpose of working through the required steps to address and respond to a failure on the LIL. This exercise highlighted areas for improvement in relation to clarification around roles and responsibilities, coordination of the effort, planning and logistics, and certain documentation.
- The second exercise was for the construction of one of each of the three types of wood pole structures to be framed, erected and dressed, complete with foundations and guy wires. The purpose of this exercise was to confirm that the required hardware fits and work methods and procedures perform as expected. This exercise determined specific equipment which could potentially expedite construction, a requirement for contractors to have access detailed computer-aided design drawings, that a construction coordinator/supervisor should be identified to all persons at the site, and identified an adjustment which was required to jumper assembly clearance from guy wires.
- The second deployed a First Assessment Team to the field to test the process of gathering and relaying data from the incident site to engineering staff in real time. A number of learnings were achieved as a result of this exercise, including the criticality of communication between Soldiers Pond EOC and the site (including communication equipment), having all required resources on site in terms of personnel, materials, washroom/medical facilities, and potential improvements to preparedness in terms of having inventory of materials on site and current modelling of the LIL.
- The fourth exercise was a complete, integrated field exercise for the construction of a bypass. It was designed to test the ability to mobilize resources and construct a restoration solution on the HVdc transmission line right-of-way. Although it included a number of parameters which may not be the case in a true emergency situation, such as optimal weather conditions and an easily-accessible site, it provided the opportunity to get first-hand experience in the coordination and execution of such an effort. Again, a number of areas for improvement were identified through this exercise, primarily regarding required procedures, clear communication, the requirement for checklists and contact lists, having key resources on site (e.g., surveyor), and coordination of engineering efforts in real time.

In 2019, four mock exercises were undertaken, as follows:

- Two tower assembly exercises (one each for Island and Labrador crews). The purpose was to get experience for Hydro's staff which may be directly involved in such work should an emergency situation require it. Hydro gained an understanding of likely person hours required, the necessary tools and equipment, and external factors affecting construction.
- A tabletop exercise which did not involve deployment of labour or equipment but was designed to test response procedures (e.g., who to call, what information to share, etc.), ensure existing documentation and contact information is accurate and available, ability to retrieve data in a timely manner, and review potential solutions to assess suitability for the simulated failure scenario.[4] Learnings included the requirement to keep documentation current and accessible, ensure remote access for line crews (in addition to satellite phones, smart mobile devices, and GPS with current maps, etc.), and the requirement for inclusion of contracts for support partners in procedural documents (e.g., powerline contractors, materials/transportation, etc.)
- An engineering first response exercise to test the communication limitations between home office, where engineering will be completed, and the remote site location. Crews were sent to a site where a failure scenario had been placed (for the purposes of this exercise—the LRM) and were required to communicate back and forth with engineering until a solution had been identified and its constructability was verified. Through this exercise, it was determined that certain documentation needed to be updated, a transportation contract was required, snowmobile rentals needed to be investigated, a secondary communications link is required to reduce reliance on cell phones in remote locations, the requirement to research alternate access approaches for the LRM area, and the need for a similar exercise to take place in Labrador with Labrador crews.

In 2020, four mock exercises were undertaken, as follows:

- Execution of a backstay solution to mechanically secure certain conductors[5] of the HVdc line in the event of a failure of structures. It was determined that system can also be utilized to enable a bypass to be constructed under the line. Work procedures, bill of materials, drawings, and design briefs were created and collected to issue to contractor and the contractor executed the erection and installation of a temporary backstay installation while using a wood pole solution.
- A mock engineering and first response exercise was undertaken for Labrador to simulate a trouble call from Soldiers Pond's on-call supervisor to the lines supervisor stating which tower had fault. In this exercise, the helicopter patrol was cancelled due to weather so the line crew drove to the tower in Labrador and snowmobiles were used to access the tower from a distance to determine the extent of the (simulated) failure. The crew worked back and forth with Soldiers Pond and engineering to report the damage and to determine and implement a solution. Learnings from this exercise include ensuring the availability of a snow clearing contractor and crane/man lift, as well as development of work methods and tailboard risk assessment tools.
- An additional tabletop exercise was completed to test response procedures, ensure all required personnel contact information is accurate and available, timely retrieval of data, accessibility of key

[4] The scenario used for this exercise was a failure at Structure 597 in which the insulator string for Pole 2 had broken and fallen to the ground from what appeared to be excessive weight due to ice accumulation on the conductor.
[5] The 3,633 kcmil 110/7 ACSR conductors and the electrode conductor.

team members (e.g., engineering), and to review solutions to assess solutions to the simulated scenario. Lessons learned from this exercise include additional measures required to ensure contractors and line crew are fully accessible in the event of an emergency, the requirement for material transportation contract to be awarded, the implementation of a process to ensure contracts that are emergency response plan-related to not expire without a new contract in place, and the completion of engineering and procurement for ERS structures.

- A workshop specific to a transmission line failure was completed to provide key detailed engineering and operational actions based the approach required for a large-scale failure. This exercise was lead by third party transmission line construction/operations resource and was to run through logistical considerations and construction approach in the event of a catastrophic failure. Through this exercise, it was determined that an updated and more detailed description of the restoration timelines stated Section 6 would be appropriate.

In 2021, one mock exercise was undertaken to test the execution of ERS. This was completed in October 2021 over five field training days which were intended to demonstrate the necessary steps for several methods of installation. There were also three engineering and software[6] training days.

10 ELECTRODE REPAIR AND RESPONSE 2021

During the first week of January 2021, a freezing rain storm event occurred within central southeastern Labrador with larger than forecasted precipitation quantities. This storm caused damage to a specific region of L3501/2, within the central southeastern portion of Labrador where the line runs from Muskrat Falls to Forteau. Three specific sections of L3501/2 sustained damage towers from Structure 335 to 352; Structure 361 to 369; and Tower 505 to 527. The specific damage was contained to the electrode crossarms and conductors, which are carried on the same towers as the pole conductors. The damage ranged from minor to severe conductor damage, severe electrode line crossarm damage, and electrode conductor breaks. Final repairs were completed on February 24, 2021 (45 days total to repair the failures).

As a result of the investigation into the causes and the process of repairing and restoring the line, the following recommendations were identified for future examination:

- More specific monitoring of weather conditions in central Labrador, throughout the line removal as required. This would included both real time monitoring and line patrols;
- The need for several operational logistic focus lessons learned for similar events in the future. These included:
  - Operational understanding and coordination of electrical operation during failure invents. Including the coordination with the Newfoundland and Labrador System Operator on operational modes possible with certain components damaged.
  - Logistical handling of equipment in extreme cold weather conditions. Including snow-clearing efforts in remote regions.
  - Observation on improvements to be made for organizing onsite material management with multiple construction forces.

[6] Training is given on PLS-CADD LITE/PLS-POLE LW-MAST programs.

- Increased focus on communication methods in remote regions. Highlighting the need for satellite communications and pre-defined communication protocols for remote locations.

- Several design reviews to study contributing factors over and above that of the root cause or extreme ice loading. These include:
  - Examination of additional bracing on electrode crossarm to increase longitudinal capacity;
  - Alternate damper design—to improve damping and reduce failures due to harsh conditions;
  - Air spoiler to reduce the effects of galloping;
  - Alternate electrode suspension clamp design with increased slip strength; and
  - Increase distance between insulator and conductor in the electrode conductor.

11 TURNBUCKLE REPAIR AND RESPONSE 2021

There were two turnbuckle failures in February 2021. The first occurred on February 3, 2021 and the second February 12, 2021. Repairs were completed on February 18, 2021. It took 14 days to complete both repairs. However, if power transfer over the LIL was a necessity, the bipole forced outage could have been reduced by relocating resources working on the electrode line repairs to focus on the pole conductor repairs and reducing some of the inspection work on adjacent turn buckles in the area of the failures. It is estimated that one pole could have been returned to service in 174 hours.

As a result of the investigation into the causes and the process of repairing the turnbuckles, the following recommendations were identified for future implementation:

- Install air spoiler to prevent galloping;
- Completion of a galloping study;
- Check turnbuckle installation (this has since been checked and reinforced in area of failure); and
- Alternate dead end assembly design (not being considered at this time due to cost, practicality, and the method of failure).

12 FUTURE RECOMENDATIONS FOR ENGINEERING & OPERATIONS

Preparation and planning for emergency preparedness will be ongoing throughout the lifetime of the HVdc transmission line. All items discussed herein will be updated and expanded upon as detailed in the following sections. Ongoing investigations into further engineering solutions, including further discussion with other utilities with a focus on their lessons learned and practices, will also be ongoing. The following information summarizes the high-level plan for the next several years.

12.1 HELICOPTER WORK

Numerous recommendations from EFLA Consulting Engineers and lessons learned from mock exercises include the use of helicopter assistance for emergency response and preparedness. Hydro has aerial ice removal procedures under development to remove the ice from the line before the design loads are exceeded. These procedures, currently in draft, will support the implementation of internal process, procedures, tooling, and training for CFLCo[7] Air Services, supported by the Hydro line crew to complete ice removal if required this winter. Hydro in currently in negations with Hydro-Québec to finalize a contract to provide ice removal services as required. Hydro expects to have a contract in place early 2022.

12.2 FUTURE ENGINEERING ANALYSIS, REAL-TIME MONITORING, AND WEATHER PREDICTION MODELS

As mentioned above, further detailed engineering will aid in refining failure scenarios and operational readiness for the LIL. The following engineering objectives are planned for 2022–2023:

- An engineering analysis of failure scenarios by region to identify the estimated number of towers that are likely to fail sequentially. The results of this analysis will be utilized to refine operational response time and the estimated time to repair;
- An engineering and operational review of the LIL focusing on ground characteristics and logistics to identify the most probable method of failure, and ranking of the best restoration alternatives for each region;
- Continuous evaluation of the required quantities of spares for temporary and permanent restoration materials as well as the strategic placement of this material along the line; and
- Expand Hydro's Alpine region meteorological test spans. Identification of new test span locations was completed in 2020 with construction planned for one site in 2022.

As one of the most likely causes of a transmission line failure is extreme weather events, Hydro is investigating (and eventually implementing) a RTM and weather prediction model for the transmission line. The expected outcomes of these tools are:

- Increased awareness of impending weather events from locations of events and seasonality perspectives;
- Information that can be integrated with asset management philosophies to identify areas that are subjected to abnormal weathering to improve and optimize preventative maintenance cycles; and
- Information that can be used for verifying the various load cases leading to improved engineering design decisions.

[7] Churchill Falls (Labrador) Corporation ("CF(L)Co")

Appendix A

Labrador-Island Link Overhead Transmission Line Emergency Response Plan

Newfoundland and Labrador Hydro – Power Supply

Labrador-Island Link Overhead Transmission Line

Emergency Response Plan

Comments:	Total # of Pages: (Including cover and appendices): 22

2	12/1/21	Annual Update				
			Bob Woodman	Chad Wiseman	Bob Woodman	John Walsh
1	5/15/20	Initial Issue	Ryan Elliott			
			Safety Advisor	Chad Wiseman	Bob Woodman	John Walsh
Status / Revision	Date	Reason for Issue	Prepared / Revised by	Director, Transmission	Team Lead Work Execution Lines	Manager Transmission and Civil Engineering

Contents

List of Appendices

1. Purpose

The purpose of this Emergency Response Plan ("ERP") document is to supplement the information provided in the Emergency Response & Restoration Planning document which outlines Newfoundland and Labrador Hydro's ("Hydro") – Power Supply's progress and plans to date for all emergency restoration activities. This ERP provides information related to personnel, equipment, protocols, and logistical plans to be followed in the event of a line failure.

2. Background

The Labrador-Island Link ("LIL") is a 900 MW, +/- 350 kV HVdc transmission system between Muskrat Falls in Labrador and Soldiers Pond on the Island portion of the province. The LIL overhead HVdc transmission line traverses approximately 1,100 km from Muskrat Falls to Soldiers Pond. The elevation of the LIL varies from 0 m to approximately 630 m above sea level.

The Labrador section of the LIL includes two electrode conductors from the Muskrat Falls converter station to the grounding station in southern Labrador. Most of the electrode line in Labrador (370 km) is on the ±350 kV HVdc steel transmission towers above the pole conductors and below the tower's single optical ground wire. The remaining 14 km of the electrode line in Labrador is supported by wood poles.

Figure 1: Labrador-Island Link

3. Scope

This ERP has been prepared in conjunction with other emergency response and restoration plans specific to Hydro. It is applicable to line failures on:

- L3501/2 between Muskrat Falls and Forteau Point;
- L3501/2 between Shoal Cove and Soldiers Pond;
- The electrode line between Soldier's Pond and Dowden's Point (EL 3/4); and
- The electrode line between Muskrat Falls and L'Anse au Diable (EL 1/2).

Given the focus of this document on emergency response and restoration plans specific to the overhead transmission line, the converter stations, transition compounds and communication repeater sites are not included in the scope of this ERP.

This ERP provides guidance and procedures to ensure Soldiers Pond Emergency Operations Centre ("EOC") and the Corporate EOC are prepared to assemble to provide emergency support if required.

4. Roles and Responsibilities

The role and responsibilities of the Soldier's Pond EOC are summarized in Appendix A. Individual roles and responsibilities are summarized in Appendix B.

5. Emergency Response Protocol

When notification of a potential severe weather event is issued by Environment Canada, the Soldiers Pond EOC will meet to assess the risks to the system based on the storm information and the design parameters of the line. Based on the level of risk, preparations will be initiated to limit the impact of a storm and respond if an event occurs. The magnitude of the risk will also determine the level of engagement with contractors, up to and including initiating pre-event planning activities.

Upon receipt of notification of a line fault alarm at the Soldiers Pond Converter Station, technical operations will first identify the details of the fault. The approximate location[1] of the line fault will be identified using line fault location equipment that is located at both converter stations and both transition compounds. Line fault locating devices are accessible by technical operators at the Soldiers Pond and Muskrat Falls Converter Stations who will provide the initial assessment to direct crews to the location of the line fault. In the event of a sustained fault, maps and GPS tools would also be used to determine the physical location of the fault. Based on the location of the fault, information related to

[1] Line fault detectors are designed to detect a fault within several kilometers of the affected tower(s).

the environment, topography, road access, helicopter landing zones, external emergency service access, etc. is used to determine the appropriate method to access the line for inspection.

Once the location of the fault has been determined, an initial assessment team will be dispatched to survey the area of the line. Initial assessment teams are equipped with cellular and satellite communication devices. Power Supply has two line crews[2] that provide routine maintenance on the LIL overhead transmission line. In the event of a fault, the line crew responsible for the area where the fault occurs will execute the initial response, or Power Supply can call on other Hydro regions to deploy its personnel to execute the initial response.[3]

The purpose of the initial survey is to gather information about the failure including potential equipment damage, the terrain in the area of the fault, condition of access roads, etc. This information will be relayed to the engineering team, who are responsible for the development of the restoration solution. The initial assessment team will remain on-site or in the general area until the draft design is prepared so they can gather additional information required by the engineering team, as required.

For expediency purposes, the initial assessment team would travel to site and survey by helicopter; however, storm conditions are typically the cause of failures, so alternate modes of travel (trucks, all-terrain vehicles, snowmobiles, etc.) may be required. While the initial assessment team is travelling to the fault location, the Soldier's Pond EOC will provide early notifications to internal and external personnel who may be required to participate in a restoration effort.

If required based on the initial assessment of the failure, additional line crews will be dispatched to provide assistance. Power Supply maintains internal contact information, as well as that of contractors and mutual aid partners to provide additional resources as required based on the specific failure situation. Appendix C and D provide the relevant contact information. For larger failures that require access by machinery to conduct repairs, snow clearing contractors will be initiated as soon as the failure location is identified. If ice is involved in the incident, aggressive ice removal techniques should be initiated as soon as possible.

[2] One crew is located in Labrador, the other is located on the Island.

[3] Power Supply has agreements with other regions in Hydro for the provision of maintenance services, which can be used to dispatch personnel and equipment to perform the initial assessment in the event that Hydro's personnel are not attending to higher priority work on Hydro's assets and can arrive at the fault location before Power Supply's personnel.

The following example provides the sequence of events that would occur in the event of fault detection on both poles (i.e., a bi-pole event) during a winter ice storm:

1) Notification of impending severe weather (prior to the event)
    a. The Soldiers Pond EOC will meet to discuss the information about the storm.
    b. If the pending weather event is expected to exceed design parameters for wind and freezing rain and if it is anticipated that serious damage could happen to the line, the line crew would prepare their first response equipment and travel to the area of the storm ahead of the storm to standby for a fast response.
    c. Contractors would be notified to start preparations (i.e., assemble tools and equipment and place personnel on stand-by for a restoration effort). They would also be required to have procedures on hand and someone identified to be involved in response planning if a failure occurs.
2) Notification of fault
    a. The Soldiers Pond Station operator would receive an alarm indicating detection of a bipole fault on the LIL and will notify the Electrical Control Centre. The Soldiers Pond or Muskrat Falls Converter operator, depending on the line section impacted, would refer to the line fault locator to identify the location of the fault, and call the Power Supply on-call to report the trip.
3) Communication of fault to required parties
    a. The Power Supply on-call would activate the Soldier's Pond EOC.
    b. The Power Supply on-call would notify the appropriate lines supervisor of the fault, who would notify crew members and dispatch them to the fault location for an initial assessment.
    c. The Power Supply on-call would contact P&C[4] Engineering to review human-machine interface ("HMI") alarms/events and digital fault recorder traces to confirm correct protection operated.
    d. The Soldier's Pond Incident Commander would contact the EOC to notify the Corporate EOC staff on call to initiate the Corporate EOC protocols.

[4] Protection and controls ("P&C").

4) Identification of fault location and conditions
    a. The Soldier's Pond EOC team would use the fault location information provided by the technical operator to determine the location of the fault and weather and road conditions. They would determine the appropriate line crew to perform the initial assessment and the most appropriate method of travel to the fault location.
5) Initial assessment
    a. The initial assessment team will collect their initial assessment tool kit and begin to travel to site.
    b. While the initial assessment team is travelling, the transmission engineering group will be provided with the available information and, if possible, a timeframe related to the initial assessment team's report. Based on the severity of the situation, other restoration resources will be notified and deployed as appropriate information is available. The Soldier's Pond EOC Safety Officer would develop the appropriate safety plan, including reviews of contractor safety documentation, and determine the appropriate timing for regularly-scheduled site safety and environment visits based on the nature of the restoration effort.
    c. While on site, the initial assessment team would take pictures, record tower numbers, note terrain condition, access road condition, etc. and report back to the Soldier's Pond EOC and the Transmission Engineering group. The team would stay on site until the engineering group had sufficient information for the restoration design.
6) Proposed restoration design
    a. The engineering group would propose a design to the Soldier's Pond EOC with the focus on restoring to monopole operation as quickly as possible, and the Soldier's Pond EOC would shift focus from emergency response to emergency restoration.
    b. The restoration planning team will gather to plan the activities and approach required to effectively and efficiently implement the engineered solution. This planning team will consist of members of the Soldier's Pond EOC, supervisors, engineering, and contractors who will be involved in the restoration process.
    c. The need for an on-site command center and its location will be determined based on the restoration design, complexity, and duration.

6. Emergency Restoration Protocol

Once the extent of the damage has been determined, a restoration plan will be prepared and restoration resources will be dispatched to implement the emergency restoration plan. The restoration response is partially informed by the classification of the fault incident, which often cannot be confirmed until personnel arrive on site to assess the situation and quantify the impact.

6.1 Incident Classification

In 2017, Power Supply engaged EFLA Engineering Consultants Inc. ("EFLA") to assess common practices with respect to overhead lines emergency response planning. As part of its engagement, EFLA performed an analysis of various restoration aspects for the LIL overhead transmission line. EFLA's report classifies production failure incidents based on six levels, from zero to five with zero representing no immediate incident and five representing a catastrophic incident. Power Supply has adopted this incident classification level to classify risks to the LIL and to adequately plan its response approach.

Power Supply has a previously-established system for classifying general incidents based on a three-tier system which then informs the emergency response criteria and communication protocol required. The EFLA production incident classification system is used to determine which of the three levels of Power Supply's emergency response is appropriate for the incident.

Table 1 provides examples of the types of failures that would fall into each of the six levels and the corresponding incident response classification under Power Supply's system.

Table 1: Failure Description Using Incident Levels Classification

Incident Level	Short Description	Description	Action Needed	Example of Failure	Power Supply Incident Response Classification
0	None	Alert status, potential failure/outage	Emergency preparation	No failure	N/A
1	Minor	Localized failure, limited complications	Emergency preparation and site visit	Lightning, short term internal- or external clearance may last few hours, e.g. outage due to galloping or wind	N/A
2	Moderate	Localized failure, slight complications	Site visit and corrective action with limited equipment	Insulator, hardware, conductor damage, cross arm damage, guy failure with foundation damage	Incident Level 1
3	Major	Localized failure, moderate complications	Site visit and corrective action with some material and equipment	Tower failure	Incident Level 2
4	Severe	Multiple failure	Site visit and corrective action with material and equipment, site camp establishment	Multiple tower failures, same area, or failure of tension tower	Incident Level 3
5	Catastrophic	Multiple failure, considerable complications	Site visit and corrective action with significant material and equipment, several site camps, large logistical and materials planning effort	Dispersed multiple tower failures, cascade failure	Incident Level 3

Based on the emergency response requirements, the Soldiers Pond EOC will initiate the Corporate EOC support, if required. Primary emergency operational support will be provided by Soldier’s Pond EOC with additional supports provided by the Corporate EOC.

6.1.1 Power Supply Incident Level 1

A fault would be classified as an incident level one if it met the criteria of an EFLA production incident level 2. Such a fault would be considered a minor production issue that has not resulted in a sustained line power flow interruption. This could potentially be a monopole failure. Table 2 provides a description of a level one incident, as well as the associated emergency response criteria and mobilization required.

Table 2: Incident Level 1 Emergency Response Summary

<table>
<tr><th colspan="2">Soldiers Pond Emergency Operations Centre Team
Mobilized at Discretion of Incident Commander</th></tr>
<tr><td colspan="2">Description
• Minor local emergency confirmed.
• Minor operational issue or risk identified.
• Impact is confined to one area of the line.
• No immediate hazard to other employees, the public, or the environment.
• No uncontrolled escalation expected.
• Emergency can be managed at site.</td></tr>
<tr><td colspan="2">Emergency Response Criteria
• Personal Injury or Illness: Minor injury or illness requiring external medical intervention or notification.
• Fire: Contained and controllable fire.
• Operational Incident: Production Incident Level 2 - a minor production issue that has not resulted in any sustained power flow interruption; potentially a mono-pole failure.
• Explosion: An explosion has resulted in minimal on-site damage. Poses no threat.
• Bomb or Terrorist Threat: A bomb or terrorist threat has been received, but no further evidence of potential escalation is involved.</td></tr>
<tr><td colspan="2">Initial Notification or Mobilization</td></tr>
<tr><td>Field</td><td>Soldiers Pond / St John's</td></tr>
<tr><td>• Operations response dispatched.
• Local authorities related to the location are notified, if required.
• Contractor personnel are notified, if required.</td><td>• Power Supply on-call is notified
• Corporate Emergency Operations Centre is notified on the discretion of the incident commander
• Soldier's Pond Emergency Operations Centre team on stand-by in case of escalation</td></tr>
</table>

6.2.2 Incident Level 2

A fault would be classified as an incident level two if it met the criteria of an EFLA production incident level 3.[5] It is characterized by a production issue that has resulted in a sustained line power flow interruption, as well as equipment damage or a failure with the potential for further damage to a localized area of the line. This could potentially be a monopole or bipole failure. Table 3 provides a description of a level two incident, as well as the associated emergency response criteria and mobilization required.

[5] Until the initial assessment team has been at the site of the failure, the incident level will not be known. These classifications will be applied after the initial site assessment has been made.

Table 3: Incident Level 2 Emergency Response Summary

<table>
<tr><th colspan="2">Soldiers Pond Emergency Operations Team Mobilized and
Corporate Emergency Operations Centre on Stand-by</th></tr>
<tr><td colspan="2">Description
• Minor local emergency confirmed.
• Incident has resulted in a power outage.
• Impact extends to a broader area of the line.
• Has potential to result in serious impact to an area of the line.
• Some hazards to public or the environment may exist.
• Emergency can be handled locally with external support.</td></tr>
<tr><td colspan="2">Emergency Response Criteria
• Personal Injury or Illness: Major disabling injury or illness requiring external medical intervention.
• Fire: Worksite has experienced a fire, leading to major equipment damage with significant risk to an area of the line.
• Operational Incident: Production Incident Level 3 - a production issue has resulted in a sustained power flow interruption. Equipment damage or failure occurred with potential for further damage to a localized area of the line. Could be a mono-pole or a bi-pole failure.
• Explosion: An explosion has resulted in significant damage to equipment and an area of the line.
• Toxic Materials: An unexpected release of toxic materials has been confirmed with the potential to spread.
• Bomb or Terrorist Threat: A bomb was detonated or terrorist action has occurred, but no further evidence of potential escalation is involved.</td></tr>
<tr><td colspan="2">Initial Notification or Mobilization</td></tr>
<tr><td>Field</td><td>Soldiers Pond / St John’s</td></tr>
<tr><td>• Operations response dispatched
• The on-scene-commander shall take directions from Power Supply on call
• Power Supply on call will act as incident commander and report to the SOP EOC until the SOP EOC IC is in place.
• External agencies shall be dispatched
• Contractor personnel are notified if needed</td><td>• Soldier’s Pond EOC activated
• Corporate EOC Executive Member on-call notified by the incident commander at Soldier’s Pond Emergency Operations Centre
• Corporate EOC team on stand-by in case of escalation</td></tr>
</table>

6.2.3 Incident Level 3

A fault would be classified as an incident level three if it met the criteria of an EFLA production incident level 4 or 5. It is characterized by a production issue that has resulted in a long-term power flow interruption resulting from extensive equipment damage or a failure to multiple towers at one or more areas of the line. This would be a bipole failure. Table 4 provides a description of a level three incident, as well as the associated emergency response criteria and mobilization required.

Table 4: Incident Level 3 Emergency Response Summary

<table>
<tr><th colspan="2">Full Mobilization of Soldiers Pond Emergency Operations Centre and
Corporate Emergency Operations Centre Team</th></tr>
<tr><td colspan="2">Description
Resultant from one or more of the following:
Catastrophic emergency confirmed.
Incident has resulted in a long-term power flow interruption.
Site operating control and integrity has been lost.
Serious impacts extend outside the area of the line.
Uncontrolled escalation of the emergency.
Definite and serious hazards to public and/or environment exists.
Emergency cannot be efficiently managed at the site level.</td></tr>
<tr><td colspan="2">Emergency Response Criteria
Confirmed Personnel Loss
Fire: A major uncontrolled fire (eg., forest fire) causing threat to the integrity and safety of the line, personnel or the public.
Operational Incident: Production Incident Level 4 or 5. Long-term power flow interruption resultant from extensive equipment damage/failure to multiple towers at one or more areas of the line.
Major Spill: A major spill continues with the source not identified. Extensive mobilization of containment and recovery equipment is required.
Bomb or Terrorist Threat: A bomb has been located or detonated or terrorist action has occurred resulting in damage and a threat to the integrity of the line, personnel and/or the general public.</td></tr>
<tr><td colspan="2">Initial Notification or Mobilization</td></tr>
<tr><td>Field
Operations response dispatched
The on-scene commander shall take directions from Power Supply on-call
Power Supply on call will act as incident commander and report to the Soldier’s Pond EOC until the Soldier’s Pond EOC incident commander is in place
External agencies shall be dispatched</td><td>Soldiers Pond / St John’s
Soldier’s Pond EOC Activated
Corporate EOC manages the restoration effort with support from Soldier’s Pond EOC as well as external local, provincial and national resources.
Corporate EOC members are mobilized.</td></tr>
</table>

7. Emergency Restoration Activity

As the magnitude of a failure, the location, and the conditions at the time of the failure can vary materially, it is not possible to provide specific emergency restoration activities in this document. However, the typical steps to restore power to at least one of the HVdc lines in operation as quickly as possible are demonstrated in Figure 2.

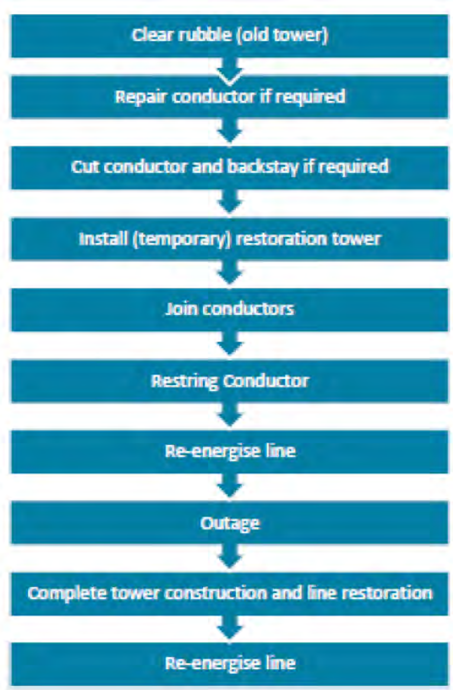

Figure 2: Emergency Restoration Steps

In a conventional line restoration method, transmission line towers are restored using the same right-of-way. Restoration may also be achieved by bypassing the damaged portion of the transmission line using temporary structures. In this scenario, the damaged portion of the transmission line is bypassed on either side of the existing right of way on temporary structures. The decision as to which method to use is determined on a case-by-case basis.

8. Emergency Restoration Resources

There are numerous resources available to perform restoration response activities for the LIL during the winter. This includes internal personnel, mutual aid agreements with other utilities, and contracts with third parties who typically perform transmission line construction work, as well as equipment and materials.

8.1 Personnel

8.1.1 Internal Personnel

Power Supply has two line crews, each consisting of a supervisor and four line workers. One crew is based in Labrador and the other crew is based on the Island. The primary function of the crews is to perform preventative maintenance and minor corrective maintenance activities within each region. Both crews work together for larger jobs and emergency restoration as required.

In emergency restoration situations, the Power Supply line crews will be supplemented with other Power Supply personnel, including engineering, general maintenance workers, safety and environment representatives, electrical and mechanical maintenance personnel and the vegetation coordinator for various support aspects of the restoration effort as the need is determined by the incident commander.

8.1.2 Mutual Aid Agreements

Agreements are in place with relevant legal entities within Hydro that facilitate the provision of personnel and equipment from other regions as required for maintenance activities. This provides a larger labour and equipment pool for emergency restoration activities.

8.1.3 Third-Party Contracts

Power Supply has a three-year contract with two local line contractor companies to provide line maintenance and construction support as required, including in emergency situations. This contract provides access to additional line workers, and equipment that is typical to line construction work. Power Supply maintains a list of other national contractors that can be contacted and an emergency contract entered into for larger restoration efforts where local resources are not sufficient. Please refer to Appendix D.

8.2 Equipment

Lines crews are provided with the equipment required for regular maintenance and repairs. Additionally, equipment specific to the Labrador-Island Link that is not readily available from third party contractors has been procured.[6] Following the ice storm event in January/February 2021, additional

[6] Power Supply primarily owns equipment that is used for regular maintenance purposes; equipment that is used for extraordinary maintenance and restoration is readily available and owned by contractors with which Power Supply has existing master service agreements. This includes equipment such as excavators, dump trucks, helicopters, 75’ tracked cranes, tractor trailers and flat bed decks for transporting materials.

tooling was identified and ordered to enable a more effective response to a similar situation. A list of equipment available for use in emergency response and restoration efforts is provided in Appendix E.

9. Reference Documents

- Emergency Response and Restoration Planning
- Corporate Emergency Response Plan ("CERP")

10. Emergency Call-Out Tree

Appendix F provides a call out sequence for emergencies requiring support from external agencies and first responders such as fire, medical, rescue or environmental release and for production failures.

Appendix A: Soldier's Pond Emergency Operations Centre Roles & Responsibilities

Soldier's Pond Emergency Operations Centre
Roles and Responsibilities
Maintain a fully functional Emergency Operations Centre to provide appropriate response expertise and resources to the Site Emergency Response, as required.
Communicate with external agencies, as required.
Determine the need to notify the Corporate Emergency Operations Centre through ECC as per determined incident level and circumstances pertaining to the incident. **<u>Level 1:</u>** **Minor Local Emergency** • Local Site Emergency Response • Production Incident Level 2 **<u>Level 2:</u>** **Major Local Emergency** • Advanced Emergency Response involving external agencies • Production Incident Level 3 **<u>Level 3:</u>** **Catastrophic Emergency** • Crisis Management • Production Incident Level 4 or 5
Ensure Corporate Emergency Operations Centre are informed and periodically updated as outlined in the Emergency Response Plan.
Ensure Regulatory Contacts are carried out as appropriate and as required in a timely manner and any communications are fully documented.
Coordinate with Support Services (as required)
Project Communications

Appendix B: Individual Roles & Responsibilities

Individual Roles and Responsibilities

Soldiers Pond On Call:

- Provide appropriate response expertise and resources to the Site Emergency Response, as required.
- Activate the Soldier's Pond Emergency Operations Centre, as required.
- Ensure contact has been made with responding agencies (911), and the Lines Supervisor.

Soldier Pond Incident Commander:

- Determine the level of the incident.
- Provide leadership and guidance while interacting with external agencies and first responders.
- Activate Soldier's Pond Emergency Operations Centre, if required.
- Notify Executive on Call, if required.

On-scene Commander:

- Respond to the incident scene.
- Contact responding agencies (911).
- Work with Soldier's Pond Emergency Operations Centre to mitigate any problems or concerns.
- Oversee execution of the restoration effort.

Corporate Emergency Operations Centre:

- Dependant on Incident Level and circumstances.

Soldiers Pond Converter Station Operator:

- Receive initial reports of incident from the Line Fault Locator computer
- Communicate with Power Supply on call, dispatch and first responders, as required.
- Act as the dispatch center for working alone and lightning notification.

First Responders, Fire & Medical:

- Respond to any emergency if required.
- Take direction from Power Supply on-scene commander, as required.

Appendix C: Internal Contact Numbers

Name	Number	Alt. Number	Position
Soldiers Pond on Call - 24/7	XXX-XXXX		
Soldiers Pond CS Control Room	XXX-XXXX		
Energy Control Center (ECC) 24/7	XXX-XXXX	XXX-XXXX	
MF Line Truck 1	XXX-XXXX	XXX-XXXX	
MF Line Truck 2	XXX-XXXX	XXX-XXXX	
SOP Line Truck 1	XXX-XXXX	XXX-XXXX	
SOP Line Truck 2	XXX-XXXX	XXX-XXXX	
Bob Woodman	XXX-XXXX	XXX-XXXX	Team Lead - Work Execution
Derek Michelin	XXX-XXXX		Line Supervisor - Lab
Patrick Keough	XXX-XXXX	XXX-XXXX	Line Supervisor - Nfld
Chad Wiseman	XXX-XXXX	XXX-XXXX	Director, Transmission
Perry Taylor	XXX-XXXX	XXX-XXXX	Regional Manager ,SOP
Mike Thompson	XXX-XXXX	XXX-XXXX	Technical Supervisor - Operations
Mark White	XXX-XXXX	XXX-XXXX	Technical Supervisor - Operations
Joe Lake	XXX-XXXX		Senior Safety Supervisor
Sean Foley	XXX-XXXX		Sr Advisor Safety Health and Environment, SOP
James Groves		XXX-XXXX	Sr Advisor Safety, Health and Environment, MF
Leah Fudge	XXX-XXXX	XXX-XXXX	Environmental Coordinator
Jackie Wells	XXX-XXXX	XXX-XXXX	Manager Environment & Sustainability (Acting)
John Walsh	XXX-XXXX	XXX-XXXX	Eng Mgr - Transmission
Maria Veitch	XXX-XXXX	XXX-XXXX	Transmission Engineer
Justin Baikie	XXX-XXXX	XXX-XXXX	Eng Mgr - HVdc
James Nugent	XXX-XXXX	XXX-XXXX	HVdc Engineer
Nicholas Keough	XXX-XXXX	XXX-XXXX	HVdc Engineer
Shane Bragg	XXX-XXXX	XXX-XXXX	Hydro Helicopter contact
Andrea Pelletier	XXX-XXXX		CF Chief Helicopter Pilot
Dave Hussey	XXX-XXXX	XXX-XXXX	CF Airport Manager

Appendix D: External Contact Numbers

Company / Agency	Number	Alt. Number	Comments
Provincial Emergency	911		Island-wide Dispatch
Ambulance / Hospital / RMP	911		Emergency Only
Oil Spill Response - Coast Guard 24/7	XXX-XXXX		St. John's
Forestry	XXX-XXXX		To report a wild fire
Wildlife	XXX-XXXX		Normal business hours
Air Ambulance	XXX-XXXX		
NLH OHS (Service NL)	XXX-XXXX		Serious Accident Reports
Canadian Coast Guard	XXX-XXXX		
CANUTEC	XXX-XXXX		
Provincial Health Line	XXX-XXXX		
Poison Control	XXX-XXXX		
Locke's Electrical – Kevin Gosse	XXX-XXXX		Local Line Work contractor
Curtis Powerworks	XXX-XXXX		Local Line Work contractor
Dept. Highways	XXX-XXXX		Highway Condition / Snow Clearing
Allteck - dispatch	XXX-XXXX	XXX-XXXX	Line Work Contractor
Valard – David Togerson	XXX-XXXX		Line Work Contractor
Canadian Helicopter – Dispatch (dedicated (24/7/365) B2 in BIF &HVY)	XXX-XXXX	XXX-XXXX	Contract Helicopter Service provider
Air Borealis (Casual 407, B2, 206 in HVY)	XXX-XXXX	XXX-XXXX	Alternate Helicopter Service provider
Newfoundland Helicopter – Dispatch (Casual 407 and 206 Island)	XXX-XXXX	XXX-XXXX	Alternate Helicopter Service provider
Nexans (Norway) - Peggy Aasheim	XXX-XXXX	XXX-XXXX	SOBI cable repair Peggy.aasheim@nexans.com www.nexans.no

Appendix E: Equipment Available for Emergency Restoration Activities

- Pick-up trucks
- Service Body Trucks
- Snowmobiles and sleighs
- All Terrain Vehicles (6X6, Sherp and Argo with tracks)
- Open snowmobile trailers
- Enclosed snowmobile / ATV trailers
- Two 18-ton tracked cranes with a 160’ boom. One stationed at Muskrat Falls, and one stationed at Bishop Falls. Both were key equipment for the 2021 ice storm response in Labrador.
- An insulated boom compatible with the 160’ tracked cranes was purchased to increase the capability for live line work.
- Live line tools to facilitate the correction of deficiencies on the line while transferring power, therefore reducing vulnerability due to severe weather.
- Satellite communication equipment
  - Satellite phones satellite data hubs and InReach devices
- GPS equipment with maps containing tower and access road information
- Emergency shelters
  - Prospector tent complete with wood stove
- Standard climbing and fall protection equipment for line workers
- Mini-excavator which can be transported by helicopter for initial site snow clearing and preparation
- Hand tools used to construct steel towers and temporary wood structures
  - Tool list was used and deemed effective during restoration exercises for wood pole and tower assemble exercises in 2018 and 2019
- Hoists, handlines and rigging equipment
- Tension meter for guy wires
- Conductor tensioner for stringing conductor
- Compression tools for joining conductors and guy wires

Appendix F: Labrador-Island Link Emergency Response Call Out

newfoundland labrador hydro

OHTL EMERGENCY RESPONSE CALL OUT
NOTIFICATION AND ROLES AND RESPONSIBILITIES

External Emergency Support

Fire Department, Ambulance, Police

Call 911

Corporate Emergency Operations Centre (CEOC)

In order to notify the executive on call you must call ECC.

ECC 24/7 Number

xxx-xxx-xxxx

xxx-xxx-xxxx

Power Supply On-call Supervisor

Call in the event of an emergency 24/7

xxx-xxx-xxxx

SOP Emergency Operations Centre Members

Director, Transmission
Wiseman, Chad xxx-xxxx(w) xxx-xxxx (c)

Safety Manager
Tilley, Steve xxx-xxxx (w) xxx-xxxx (c)

Safety Supervisor
Lake, Joe xxx-xxxx (w) xxx-xxxx (c)

HSE Advisor – Power Supply
Foley, Sean xxx-xxxx (c)

Work Execution, Team Lead, Lines
Woodman, Bob xxx-xxxx (w) xxx-xxxx (c)

Work Execution & Operations Manager
Oliver, Evan xxx-xxxx (w) xxx-xxxx (c)

Supervisors
Lines Supervisor – Island
Keough, Patrick xxx-xxxx (w) xxx-xxxx (c)

Lines Supervisor – Labrador
Michelin, Derek xxx-xxxx (c)

Technical Supervisors – Operations
Thompson, Mike xxx-xxxx (w) xxx-xxxx (c)
White, Mark xxx-xxxx (w) xxx-xxxx (c)

Engineering Manager, AC Terminals & HVDC Spec
Kavanagh, Dena xxx-xxxx (w) xxx-xxxx (c)

Engineering Manager, Transmission & Civil
Walsh, John xxx-xxxx (w) xxx-xxxx (c)

OBSERVER:

- Call 911 if necessary (provide details of location)
- Contract your immediate supervisor during regular hours
- Contact Power Supply On Call Supervisor after hours
- Contact external agency if necessary

↓

IMMEDIATE SUPERVISOR/ON-CALL SUPERVISOR:

- Contact external agency if necessary – 911
- Contact member of the SOP EOC
- If no response from SOP EOC then make a decision to call CERP if necessary
- Access to the scene & work to make the area safe
- Ensure OSC is identified and in place

↓

SOP EOC MEMBER:

- Contact external agencies as needed – 911 after confirming with OSC
- Receive information from the caller
- Determine the incident level – 1, 2, 3
- Work to make the area safe
- Ensure external agency meeting point
- Contact Engineering support if needed
- Activate SOP EOC if necessary
- Contact CEOC on call if needed
- Take actions to mitigate the emergency

↓

SOP EOC MEMBERS:

- Report to SOP EOC if activated
- Work with external agencies to mitigate the incident
- ECG Incident Commander will communicate with CEOC if necessary
- Maintain support & contact with OSC

↓

EXTERNAL AGENCIES:

- Receive request from On Call Supervisor, Observer, SOP EOC, etc...
- Report to Site and stage at security
- Work under direct supervision of Power Supply personnel
- Contain/Control the incident (OSC when on Site)

Appendix B

Emergency Response Timeline Report
Labrador Island Link

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Emergency Response Timeline Report
Labrador Island Link

Newfoundland and Labrador Hydro

A	25-Nov-21	Issued for Final Report	Terry Davis	John Grant	Kevin Gosse
Revision	**Date**	**Description**	**Originator**	**Reviewed**	**Approved**

	Emergency Response Timeline Report Labrador Island Link	REVISION		
		No. 0	25/11/2021	
		LEL-PLN-PR-2136-E1		

Table of Contents

1.0 Purpose

This report is to provide a timeline showing a level of response for specific scenarios suggested by Newfoundland and Labrador Hydro and a guideline on tasks required. This document is meant to outline the planned operational response in winter conditions for various locations including high level timelines to execute each task. It provides information related to the required personnel and equipment, material locations, work methods and logistical plans which should be followed in the event of a line failure during winter conditions where Right of Way travel can be challenging from a remote location with excessive travel from secondary roads and environmental concerns such as deep snow.

2.0 Background

The Labrador-Island Link is a 900 MW, +/- 350 kV HVdc transmission system between Muskrat Falls in Labrador and Soldiers Pond on the Island portion of the province. The Labrador-Island Link, LIL, overhead HVdc transmission line traverses approximately 1,100 km with elevations varying from 0m to approximately 630m above sea level.

The Labrador section of the Labrador-Island Link includes two electrode conductors from the Muskrat Falls converter station to the grounding station in southern Labrador. Most of the electrode line in Labrador (370 km) is on the ±350 kV HVdc steel transmission towers above the pole conductors and below the tower's single optical ground wire. The remaining 14 km of the electrode line in Labrador are supported by wood poles.

Figure 1: Labrador-Island Link

3.0 Scope

This document has been prepared in conjunction with other emergency response and restoration plans specific to NL Hydro. It is applicable to line failures in winter conditions on:

- Transmission lines L350 1&2 between Muskrat Falls and Soldiers Pond.
- Electrode lines between Muskrat Falls and Soldier's Pond, EL 1&2 and EL 3&4 respectively.

The scope of this report is to suggest possible response times for various hypothetical failures in different areas of the province and to provide support and/or refinement to the timeline assumptions that were made in 2019 as it pertains to the challenges of winter conditions.

The seven scenarios identified for consideration were:

1. 1-3 Towers down in Central Labrador (less than 1 km of transmission line) 100 km in the Saint Paul River Road from the Trans Labrador Highway. A wood pole solution to reinstate 1 pole and 1 electrode will be utilized.

2. 2 Km of Transmission Line in Central Labrador 100 km in the Saint Paul River Road from the Trans Labrador Highway. A wood pole solution to reinstate 1 pole and 1 electrode will be utilized.

3. 4 Km of Transmission Line in the Long-Range Mountains 80 km from a paved road. A wood pole solution to reinstate 1 pole and use the sea electrode for a return will be utilized.

4. 21 damaged towers in Central Labrador 100 km in the Saint Paul River Road from the Trans Labrador Highway. Solution is to fully replace all downed towers as well as 50% of the guy wires.

5. 7 damaged towers Central Labrador 100 km in the Saint Paul River Road from the Trans Labrador Highway. Solution is to fully replace all downed towers and 50% of the guy wires will be replaced.

6. 22 damaged towers in the Avalon. Solution is to fully replace all downed towers and 50% of the guy wires will be replaced.

7. Central Labrador Electrode Line Failure in two locations with conductor and tower damage in both locations. Solution is to replace all damaged cross-arms and repair conductors.

4.0 Assumptions

The assumptions listed below are specific to this report and the identified scenarios. Altering these assumptions would directly impact the estimated timelines for each scenario.

We have assumed that NL Hydro shall adopt of a probability matrix of potential extreme weather. This matrix would be utilized to assess weather events to classify them at a Level 3 or higher failure could occur. We are suggesting that this model would include the contractor <u>in the Pre-Planning</u> of an event estimated at a level 3 or higher allowing the securing of and/or <u>staging of personnel and equipment.</u> The following assumptions are seen as reasonable.

- An Event Probability Matrix has been developed and is being utilized.
- Snow clearing of roads and right of way and groundline construction activities such as pad development and laydown areas will continue at night.
- 6 - 10 excavators and 3 dozers are assigned to road clearing and repairs for project preparation.
- Guy wire preparation activities, i.e., measuring and cutting, are completed concurrently with clearing of the incident site.
- 3 - 4 assembly crews have been assigned, where each crew has 1 excavator.
- Pole and Anchor installation work shall be continuous, during both day and night shift.
- For scenarios requiring the replacement of steel towers, erection will begin approx. 3 days after assembly has started.
- Helicopter shall not be used for assistance during repairs however crane assistance of various sizes will be utilized for assembly and erection.

- The weather event has subsided and weather conditions are favorable for tower and conductor repairs as well as the raising of towers.
- Framing of structures will be done in daylight hours only.
- Stringing of conductor will be done in daylight hours only.
- Temporary shelters will be mobilized for keeping equipment relatively heated when not in service. If materials are stored and transported in enclosed trailers or sea cans, they could be strategically placed so that transmission timbers could be placed to span from one trailer to the other and a tarp system placed over the timbers and trailers and secured.
- Mechanics will be onsite continuously for all Level 3 responses.
- Based on the probability matrix of extreme weather location the mobilization of both tracked and rubber tire equipment from the pre-event stage may be initiated to remote locations requiring excessive right of way travel.
- Ice removal, if required, can occur concurrently and will not impact the timelines to power restoration.
- Outages shall be required during the repairs for scenarios 1 – 6 however, for scenario 7 strategic outages may be required.
- Typical crew compliment size is as follows-
    - Pole/ Anchor crew- 4 - 5 people
    - Assembly crew- 8 people
    - Tower Erection crew- 6 - 7 people
    - Wood pole framing crew- 5 people
    - Conductor crew- 10 - 12 people

5.0 Considerations Noted by Owner

Access roads are maintained during the spring and summer months, however, despite best efforts there may be instances where obstacles would hinder the ability of the response teams to access an incident location. Some considerations are:

- Access Roads
  - Snow clearing
  - Washouts
  - Debris and obstructions, i.e., trees, garbage, vehicles, etc.
- Equipment
  - Snow clearing equipment
  - Heavy equipment such as dozers, excavators, and loaders
  - Large Cranes capable of reaching the tallest structures of 150 to 170 feet.
  - Hydro has a small fleet of equipment consisting of a boom truck, two tracked E160 Cranes, snowmobiles, ATVs and two ATVs.
- Tools
  - Hydro has a limited number of tools that would be required for a large-scale Emergency Response situation (See Appendix E: Equipment Available for Emergency Restoration Activities). The bulk of the tools that would be required for construction activities would be provided by the contractor.
- Personnel
  - The primary responsibility of Hydro's Power Line Technician team (including CF and NLH) is the care and maintenance of their assets. They would require the assistance of a 3rd party contractor in the event of a large-scale Emergency response such as these events. Detailed damage assessment and preliminary access investigation is critical and a role that should be assigned to Hydro's first responders.

6.0 Roles and Responsibilities

The role and responsibilities of the Soldier's Pond Emergency Operations Centre are summarized in Appendix A. Overhead Transmission Line Individual roles and responsibilities are summarized in Appendix B. Both documents appear to highlight responsibilities once an event occurs however expanding these roles and including additional members to a pre-event situation based on an outage probability matrix for extreme weather events could greatly reduce outage time.

External local contractors should be embedded in the Pre-event planning for any event having a probability matrix of Level 3 or higher.

The minimum Key Personnel to be included in pre-event planning for a possible level 3 or higher event should be:

- Control Center Lead
- Engineering Lead
- First Responders Lead
- ROW Access Lead
- Execution/ Contractor Lead
- HSE Lead
- Logistics Lead

7.0 Event Preparation and Risk Mitigation

The key to an efficient and effective restoration is being prepared. Having an Event Probability Matrix in place that considers the pending weather expected (snow, Ice, wind, extreme cold, etc.), location of expected weather, system requirements, available internal resources, available external resources, transportation of materials, condition of tools and equipment, etc. and staffing accordingly pre-event is critical, especially in winter conditions. The “Event Probability Matrix” is currently not in place and is the cornerstone in executing in an efficient and effective manner in the future.

It should be noted that an extensive study on the climatic loading zones has been preformed. This study can be used in conjunction with the probability matrix as a weather event approaches, and used to assist in the planning process of premobilization of resources and materials to high-risk areas.

A layered response system for incident levels 3 and higher should always be in place and established pre-event. For example, Primary damage assessment for locations 30-80km from main road should be initiated with 2 layers- 1) aerial support and 2) ground support (snowmobile or ATV). Both tasks shall run concurrently, so that unforeseen circumstances such as weather condition deteriorating to a point where aerial support is not possible, the ground support will proceed.

The same philosophy of a layered response should be utilized in the planning of the execution of repairs where 1) tracked equipment and 2) rubber-tired equipment would be initiated.

8.0 Emergency Response Protocol - Pre-Event

A pre-event protocol was developed and shall be consistently applied to all 7 scenarios as all scenarios considered would be classified as a Level 3 event or higher using the table below based on an event probability matrix.

The Failure Description Incident Level Classification table, Table 1, and the Pre-Event planning tasks listings shall be applied to each scenario.

In the following sections detailing the tasks to be performed for each of the scenarios considered, the below color coding was used to identify the different phases of the incident life cycle.

Blue	Pre-Event Planning
Orange	Outage Confirmed
Yellow	Damage Assessment
Rose	Repair Execution
Green	Return to Service

Incident Level	Short Description	Description	Action Needed	Example of Failure	Power Supply Incident Response Classification
0	None	Alert status, potential failure/outage	Emergency preparation	No failure	N/A
1	Minor	Localized failure, limited complications	Emergency preparation and site visit	Lightning, short term internal- or external clearance may last few hours, e.g., outage due to galloping or wind	N/A
2	Moderate	Localized failure, slight complications	Site visit and corrective action with limited equipment	Insulator, hardware, conductor damage, cross arm damage, guy failure with foundation damage	Incident Level 1
3	Major	Localized failure, moderate complications	Site visit and corrective action with some material and equipment	Tower failure	Incident Level 2
4	Severe	Multiple failure	Site visit and corrective action with material and equipment, site camp establishment	Multiple tower failures, same area, or failure of tension tower	Incident Level 3
5	Catastrophic	Multiple failure, considerable complications	Site visit and corrective action with significant material and equipment, several site camps, large logistical and materials planning effort	Dispersed multiple tower failures, cascade failure	Incident Level 3

Table 1: Failure Description Using Incident Levels Classification

Pre-Event Tasks

Task Description	Comments/ Timeline	Duration	Start	Finish
Weather Event Forecasted and Event Preparation	• Event Probably Matrix Review and determined potential for Level 3 or higher incident. • PLT crews advised to be prepared. • EOC members notified, and availability confirmed in the event of an incident.	***	***	***
Crew Preparation and Readiness.	Crew ensures equipment used in supporting "First Responder efforts" are fully fueled and ready for deployment.	***	***	***
Crew Preparation and Readiness.	First responders to ensure that mobile electronic device with Line/ STR KMZ file is fully charged and Emergency Response plan Site assessment Check Sheet is loaded.	***	***	***
Planned or previous work/ tool history	Work Execution and/or Planning department will check tool and equipment PM's have been complete and note any changes to availability	***	***	***
Weather probability event evaluation and preparation	Level 3 events and higher shall have Line Support and Snow Clearing Contractor on Standby with agreed number of crew members	***	***	***
Weather probability event evaluation and preparation	Decision to be made to place Aerial support Contractor on standby in area where conditions are expected to affect the system.	***	***	***
Identify and secure key personnel	Identify key personnel that will be filling the various roles for this specific event from each group including an alternate support person.	***	***	***

Pre-event communication of key personnel	Communicate conference call # with EOC team and establish initial conference call to Identify and introduce the various key personnel. Key Personnel to include a Control Center Lead, Engineering lead, First Responder lead, Access lead, Execution/ Contractor lead, HSE Lead, Logistics Lead. There are many subcategories beneath each lead however the communication from each lead to subcategories may be complete in breakout sessions. Additional conference call numbers should be established so that this does not become an issue where many groups are trying to use the conference call number at the same time. Create text or email list for communication during the event	***	***	***
Environmental readiness	HSE team to review environmentally sensitive sites that should be known to first responders (primary and secondary teams) as well as contractors	***	***	***
Environmental readiness	Evaluate weather conditions for next 24 hours, 3 days and 7 days.	***	***	***

9.0 Failure Scenario 1: Central Labrador, 1 - 3 Towers Down

In this scenario the solution is to put one positive DC pole and one electrode line back in service using wood pole construction. The fault location is Central Labrador, 100 km on Saint Paul River Road from Trans Labrador Highway.

This type of potential incident is rated as a level 3 using the Incident Level Classification Table above and pre-planning and preparation is critically important especially for winter conditions.

The wood pole solution requires 22 wood pole structures, 11 for a Positive DC Pole Line and 11 for an Electrode Line, utilizing Back Stays at 2 locations for both.

Following the suggested pre-event planning, response time and travel time will be reduced as it shall be completed prior to the weather event and possible outage. This is especially true as the Fault location in this scenario is 100 km in Saint Paul River Road from the Trans Labrador Highway.

Estimated return to service is 23 days.

Task Description	Comments/ Timeline	Duration	Start	Finish
Outage is observed and acknowledged at Control Center	Outage begins		T-0	
Notify ERP Team that weather has in fact resulted in an event. First Response Leader (Hydro) to initiate primary and secondary response plan.	Within the hour	1 Hour	Day 1	Day 1
Initiate Work Protection	Within the first 4-6 hours	4 Hours	Day 1	Day 1
Complete fault location and provide to ERP team (First response Leader)	Within the hour	4 Hours	Day 1	Day 1
Deploy first responders (Hydro team 1) with aerial support.	Coordinate aerial support to Fault location provided by control center if conditions permit. Secondary Level of patrol should be initiated such as snowmobile or ATVs.	4hr- 8 hrs.	Day 1	Day 1
Initiate secondary response communications with local ground	Snowmobile or ATVs	4 Hours	Day 1	Day 1

support vehicles				
First responders identify fault location. Location is confirmed locally using structure list stored on mobile electronic device and communicated to supervisor on call. Pictures are taken from the air and electronic forms are started and emailed to supervisor.	within 24 hours if weather permits, within 1-2 days when weather is extreme (excessive winds, heavy snow or extreme cold)	1.5 Days	Day 1	Day 2
Standby Supervisor and Emergency Response Team will evaluate preliminary information for repairs required. Minor repairs- one span including- one Pole, one Electrode or OPGW damage or failure. Major- multiple conductors (pole or electrode) or significant tower damage up to 3 towers.	24-48 hrs. Level 3 Event- Up to 3 Towers	1 to 2 Days	Day 3	Day 4
Engineering will start preliminary design of temporary wood pole for approximately up to 11 structures for Electrode and Pole (Total 22 structures)	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Secure accommodations and meals in nearest location to site. Book minimum 50 rooms for 3 weeks tentative.	Logistics Team	1 Day	Day 3	Day 3
Deploy first group of Contract resources to assist with Staging and site preparation.	Contractor to send first 12-15 employees. This team will Support Identification of Staging areas, Site Preparation, Poles and Anchors	2 Days	Day 3	Day 4
Primary first responders will find suitable area to land and confirm Work Protection is in place. *** Safety distances from conductors must be maintained while completing the inspection from the ground locally filling out the rest of the Emergency Response Plan Site Assessment Check Sheet***.	Work Protection should be established as soon as significant damaged is found.	1 Day	Day 3	Day 3
Preliminary location of site staging area will be identified for closest access to damage site from map data	This is a key component as tarped hoarding area is very beneficial for winter conditions	1 Day	Day 3	Day 3

and environmental data.	to keep the equipment somewhat heated. This is an area identified on Saint Paul River Road where vehicles and equipment can be offloaded as close to the damage site as possible.			
Preliminary wood pole design by engineering will be reviewed with Emergency Response Team and Execution Contractor and shared with Surveyor	In this scenario we have assumed that there are no extremely wide river crossings, and most bogs are frozen. Engineers will confirm plan and profile view to confirm pole heights are adequate.	2 Day	Day 4	Day 5
Surveyor will be transported to site with first responder (Team 1) by helicopter to stake pole locations	This survey will help confirm the design as well as providing locates. If there are issues found a correction in pole heights should be found at this time.	4 Days	Day 6	Day 9
Road clearing in many areas is best suited for D-8 dozers and 3 dozers should be able to complete approximately 10km/ 12 hr. shift in extreme conditions. Extreme conditions for this model were based on three criteria 1) amount of accumulated snow, 2) type of drifting observed and 3) visibility. For this exercise we assume moderate to heavy accumulated snow 3 to 4 feet, drifts 8 to 10 feet wide greater than 4 feet in depth and moderate (1km to .5 km) to heavy snow fall (less than .5 km) visibility. In low to moderate conditions Loaders may be utilized.	100 km estimated on Saint Paul River Road from Trans Labrador Highway. 20km/24 hrs.= 5 days. Extreme caution will be used during night shift to be aware of environmental hazards such as wetlands and bogs.	5 Days	Day 5	Day 9
Confirm materials list in trailers and share with Contractor. Load material Trailers (or sea cans) on transport trucks and deploy to preliminary staging area. If extreme cold is anticipated prefabricated trusses, tarps and heaters should be deployed to be placed between Trailers (sea cans) for temporary heating of equipment. This list will be shared with the Execution Contractor incase	Contractor Second team will review and confirm. This team will be focused on Framing, and stringing. Again, the preliminary staging area is as close to the site as possible on the Saint Paul River Road. A final staging site may be developed closer to the damage area as road clearing progresses.	4 Days	Day 5	Day 9

additional items are required.				
Confirm location of wood product and transport to staging area.	There may be a need for higher poles after field survey is complete however this can be corrected in a day or two.	4 Days	Day 5	Day 9
Contractor to load equipment for 2 levels of <u>response</u>- Rubber Tire and Track. Again, weather and access can be very unpredictable, and a two-layer response is critical to ensure that time frames are met.	For this particular scenario multiple units are required for the follow but not limited to- Highway Tractors, Floats, Cranes, Excavators, Bucket units, Radial Boom Derricks, Dozers, Etc. When evaluating the preliminary responses, we should look at a combination of equipment. For example, even if we can plow the road to the failure site and rubber tire equipment can be utilized to secure the existing tower, the installation of poles for a temporary wood pole repair would probably require tracked equipment in the ROW.	4 Days	Day 5	Day 9
Cross reference tool and equipment lists with tools and equipment in totes. Evaluate delivery method. The use of helicopter vs transport could depend on factors such as weather, # of available transport trucks, road conditions, location of fault, etc. This list will be shared with the Execution Contractor in case additional items are required.	Primary delivery method for tools and equipment will be Highway Tractors with trailers. Helicopter may be used to transport personnel once first responders are complete damage assessment.	4 Days	Day 5	Day 9

Install reference points such as Ground rods to monitor undamaged towers for reference and document data. These points can be used as an aid to monitor the status of the towers in case of creeping until equipment can be placed to secure towers (Slug anchors).	This can provide a reference especially where the environmental issues may still be a factor such as excessive ice on conductor of undamaged towers. Check periodically.	1 Day	Day 3	Day 3
Priority to have Excavators on site and incident site as soon as possible. Four excavators and Two additional Excavators with Rock Buster (6 total) would be ideal to improve efficiency and delays when changing attachments in cold weather. Also, hydraulic O ring failure is more common in extreme cold so the amount of time that attachments are removed reduced the probability of equipment delays from this type of failure.	Contractor units.	3 Days	Day 6	Day 10
Excavator to support back staying of conductor as defined in Document 6122-001-PAD-008 Back Staying of Conductor Work Procedure.		1 Day	Day 11	Day 11
E160 to secure backer cables to tower on each side of the work site.	NL Hydro unit as per Back Staying Procedure	1 Day	Day 11	Day 11
Compression Dead end shall be installed on the Pole that will be re-energized to create isolation from the pole to the backer cable. The compression dead end will be installed on the non-tension side of conductor that has just been secured with the backer cable above.	As per Back Staying Procedure	1 Day	Day 11	Day 11
Once the compression dead end has been installed and insulator string attached the backer cable will be transferred to the end of the insulator string and tensioned to the Back stays. This may require a ball eye attachment with strain link. Repeat on pole to be energized in other direction	As per Back Staying Procedure	1 Day	Day 12	Day 12

Pole crew to begin to install poles and anchors for bypass. In this scenario we would install a temporary bypass of approximately 7 tangent structures and 4 Dead end structures for the Pole Line and Electrode Line. This would be 72 anchors and 44 wood poles.	3 anchor crews and 3 Pole Crews on Day shift and 3 anchor crews and 3 Pole Crews on Night shift using the same equipment.	5 Days	Day 11	Day 15
Conductor crew to prepare conductor pulling area and reel stand area.	Various PLT's, Ground person and operators	1 Day	Day 16	Day 16
Frame Tangent Structures and Install travelers. Running reel method will be used to pull conductor out. Conductor will be lifted into travelers by machine instead of a pilot line or bull rope.	PLT's and Groundmen	2 Days	Day 16	Day 17
Remove damaged tower and conductor.	Pole and anchor crew to relocate and remove conductor and damaged tower from ROW	2 days	Day 16	Day 17
Raise conductor into travelers and sag 18 span of conductor (9 pole +9 electrode)	PLT's and Groundmen	2 Days	Day 18	Day 19
Frame Dead end Structures and Install travelers on 2 of the 4 Dead end structures. Conductor will be attached to strain insulators on one end and pulled at the other end. This is the cross bus that will tie into the existing conductor.	PLT's, Groundman and Operators	2 Days	Day 18	Day 19
Cut Conductor and complete compression Dead end. Raise conductor and connect to insulators.	PLT's, Groundman and Operators	1 Day	Day 20	Day 20
Ensure adequate lead to height ratio for pull location is in place 2 to 1 minimum and 3 to 1 is preferred. Pull conductor to preferred sag as provided by engineering using Bull wheel tensioner. Mark conductor at end of insulator string and lower back to the ground. Cut conductor and install compression dead end.	PLT's, Groundman and Operators	1 Day	Day 20	Day 20
Pull conductor into place with bull wheel tensioner again maintaining the 2:1 or 3:1 led to height ratio.	PLT's, Groundman and Operators	1 Day	Day 20	Day 20
"Clip in" conductors on 40 tangent structures	PLT's, Groundman and Operators	2 Days	Day 21	Day 22

Complete visual inspection and check sheets that may be required.	Nalcor and Contractor Representative	1 Day	Day 23	Day 23
Notify Control center that work will be complete in the next couple of hours/ day so that resources can be assigned to return a pole to service.	Nalcor and Contractor Representative		Day 23	Day 23
Connect new by-pass to existing pole, and or electrode ensuring proper E, B & G philosophy is maintained (do not get between grounds)	PLT's, Groundman and Operators		Day 23	Day 23
Complete final turnover documentation for Ready to energize.	Nalcor and Contractor Representative		Day 23	Day 23
Remove all personal grounds.	Contractor		Day 23	Day 23
Surrender Work Protection	Contractor/ Nalcor		Day 23	Day 23
Re-Energize Pole	Nalcor		Day 23	Day 23

10.0 Failure Scenario 2: 2 Km of Transmission Line in Central Labrador 6-7 Towers

In this scenario a temporary Wood Pole (Monopole) Solution will be utilized putting one positive DC pole line and one electrode line back in service.

This type of potential incident is rated as a level 3 using the Incident Level Classification Table above and pre-planning and preparation is critically important especially for winter conditions.

The fault location is Central Labrador, 100 km on Saint Paul River Road from Trans Labrador Highway which will require 34 wood pole structures, 17 for the positive DC pole and 17 for the electrode line, backstays will be used for both in 2 locations.

Estimated return to service is 33 Days

Task Description	Comments/ Timeline	Duration	Start	Finish
Outage is observed and acknowledged at Control Center	Outage begins			
Notify ERP Team that weather has in fact resulted in an event. First Response Leader (Hydro) to initiate primary and secondary response plan.	Within the hour	1 Hour	Day 1	
Initiate Work Protection	Within the first 4-6 hours	4 Hours	Day 1	
Complete fault location and provide to ERP team (First response Leader)	Within the hour	4 Hours	Day 1	
Deploy first responders (Hydro team 1) with aerial support.	Coordinate aerial support to Fault location provided by control center if conditions permit. Secondary Level of patrol should be initiated such as snowmobile or ATV.	4hr- 8 hrs	Day 1	
Initiate secondary response communications with local ground support vehicles	Snowmobile or ATV	4 Hours	Day 1	

First responders identify fault location. Location is confirmed locally using structure list stored on mobile electronic device and communicated to supervisor on call. Pictures are taken from the air and electronic forms are started and emailed to supervisor.	within 24 hours if weather permits, within 1-2 days when weather is extreme (excessive winds, heavy snow or extreme cold)	1.5 Days	Day 1	Day 2
Standby Supervisor and Emergency Response Team will evaluate preliminary information for repairs required. Minor repairs- one span including- one Pole, one Electrode or OPGW damage or failure. Major- multiple conductors (pole or electrode) or significant tower damage up to 3 towers.	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Engineering will start preliminary design of temporary wood pole for approximately up to 17 structures for Electrode and Pole (Total 34 structures)	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Secure accommodations and meals in nearest location to site. Book minimum 60 rooms for 6 weeks tentative.	Logistics Team	1 Day	Day 3	
Deploy first group of Contract resources to assist with Staging and site preparation.	Contractor to send first 12-15 employees. This team will Support Staging areas, Site Preparation, Poles and Anchors	2 Days	Day 3	Day 4
Primary first responders will find suitable area to land and confirm Work Protection is in place. *** Safety distances from conductors must be maintained while completing the inspection from the ground locally filling out the rest of the Emergency Response Plan Site Assessment Check Sheet***.	Work Protection should be established as soon as significant damaged is found.	1 Day	Day 3	Day 3
Preliminary location of site staging area will be identified for closest access to damage site from map data and environmental data.	This is a key component as tarped hoarding area is very beneficial for winter conditions to keep the equipment somewhat heated.	1 Day	Day 3	Day 3

	This is an area identified on Saint Paul River Road where vehicles and equipment can be offloaded as close to the damage site as possible.			
Preliminary wood pole design by engineering will be reviewed with Emergency Response Team and Execution Contractor and shared with Surveyor	In this scenario we have assumed that there are no extremely wide river crossings, and most bogs are frozen. Engineers will confirm plan and profile view to confirm pole heights are adequate.	1 Day	Day 4	Day 4
Surveyor will be transported to site with first responder (Team 1) by helicopter to stake pole locations	This survey will help confirm the design as well as providing locates. If there are issues found a correction in pole heights should be found at this time.	4 Days	Day 6	Day 9
Road clearing in many areas is best suited for D-8 dozers and 3 dozers should be able to complete approximately 10km/ 12 hr shift in extreme conditions. Extreme conditions for this model were based on three criteria 1) amount of accumulated snow, 2) type of drifting observed and 3) visibility. For this exercise we assume moderate to heavy accumulated snow 3 to 4 feet, drifts 8 to 10 feet wide greater than 4 feet in depth and moderate (1km to .5 km) to heavy snow fall (less than .5 km) visibility. In low to moderate conditions Loaders may be utilized.	100 km estimated on Saint Paul River Road from Trans Labrador Highway. 20km/24 hrs= 5 days. Extreme caution will be used during night shift to be aware of environmental hazards such as wetlands and bogs.	5 Days	Day 5	Day 9
Confirm materials list in trailers and share with Contractor. Load material Trailers (or sea cans) on transport trucks and deploy to preliminary staging area. If extreme cold is anticipated prefabricated trusses, tarps and heaters should be deployed to be placed between Trailers (sea cans) for temporary heating of equipment. This list will be shared with the Execution	Contractor Second team will review and confirm. This team will be focused on Framing, and stringing. Again, the preliminary staging area is as close to the site as possible on the Saint Paul River Road. A final staging site may be developed closer to the damage area as road clearing progresses.	4 Days	Day 5	Day 9

Contractor in case additional items are required.				
Confirm location of wood product and transport to staging area.	There may be a need for higher poles after field survey is complete however this can be corrected in a day or two.	4 Days	Day 5	Day 9
Contractor to load equipment for 2 levels of response- Rubber Tire and Track. Again, weather and access can be very unpredictable, and a two-layer response is critical to ensure that time frames are met.	For this scenario multiple units are required for the follow but not limited to- Highway Tractors, Floats, Cranes, Excavators, Bucket units, Radial Boom Derricks, Dozers, Etc. When evaluating the preliminary responses, we should look at a combination of equipment. For example, even if we can plow the road to the failure site and rubber tire equipment can be utilized to secure the existing tower, the installation of poles for a temporary wood pole repair would probably require tracked equipment in the ROW.	4 Days	Day 5	Day 9
Cross reference tool and equipment lists with tools and equipment in totes. Evaluate delivery method. The use of helicopter vs transport could depend on factors such as weather, # of available transport trucks, road conditions, location of fault, etc. This list will be shared with the Execution Contractor in case additional items are required.	Primary delivery method for tools and equipment will be Highway Tractors with trailers. Helicopter may be used to transport personnel once first responders are complete damage assessment.	4 Days	Day 5	Day 9

Install reference points such as Ground rods to monitor undamaged towers for reference and document data. These points can be used as an aid to monitor the status of the towers in case of creeping until equipment can be placed to secure towers (Slug anchors).	This can provide a reference especially where the environmental issues may still be a factor such as excessive ice on conductor of undamaged towers. Check periodically.	1 Day		
Priority to have Excavators on site and incident site as soon as possible. Four excavators and Two additional Excavators with Rock Buster (6 total) would be ideal to improve efficiency and delays when changing attachments in cold weather. Also, hydraulic O ring failure is more common in extreme cold so the amount of time that attachments are removed reduced the probability of equipment delays from this type of failure.	Contractor units.	3 Days	Day 6	Day 10
Excavator to support back staying of conductor as defined in Document 6122-001-PAD-008 Back Staying of Conductor Work Procedure.		1 Day	Day 11	Day 11
E160 to secure backer cables to tower on each side of the work site.	NL Hydro unit as per Back Staying Procedure	1 Day	Day 11	Day 11
Compression Dead end shall be installed on the Pole that will be re-energized to create isolation from the pole to the backer cable. The compression dead end will be installed on the non tension side of conductor that has just been secured with the backer cable above.	As per Back Staying Procedure	1 Day	Day 11	Day 11
Once the compression dead end has been installed and insulator string attached the backer cable will be transferred to the end of the insulator string and tensioned to the Back stays. This may require a ball eye attachment with strain link.	As per Back Staying Procedure	1 Day	Day 12	Day 12

Repeat on pole to be energized in other direction				
Pole crew to begin to install poles and anchors for bypass. In this scenario we would install a temporary bypass of approximately 13 tangent structures and 4 Dead end structures for the Pole Line and Electrode Line. This would be 120 anchors and 52 wood poles total.	3 anchor crews and 3 Pole Crews on Day shift and 3 anchor crews and 3 Pole Crews on Night shift using the same equipment.	8 Days	Day 12	Day 19
Conductor crew to prepare conductor pulling area and reel stand area.	Various PLT's, Ground person and operators	1 Day	Day 16	Day 16
Frame Tangent Structures and Install travelers. Running reel method will be used to pull conductor out. Conductor will be lifted into travelers by machine instead of a pilot line or bull rope.	PLT's and Groundmen	6 Days	Day 16	Day 22
Frame Dead end Structures and Install travelers on 2 of the 4 Dead end structures. Conductor will be attached to strain insulators on one end and pulled at the other end. This is the cross bus that will tie into the existing conductor.	PLT's, Groundman and Operators	4 Days	Day 23	Day 26
Remove damaged tower and conductor.	Pole and anchor crew to relocate and remove conductor and damaged tower from ROW	4 Days	Day 20	Day 23
Raise conductor into travellers and sag 34 span of conductor (17+17)	PLT's and Groundmen	4 Days	Day 23	Day 26
Cut Conductor and complete compression Dead end. Raise conductor and connect to insulators.	PLT's, Groundman and Operators	1 Day	Day 26	Day 26

Ensure adequate lead to height ratio for pull location is in place 2 to 1 minimum and 3 to 1 is preferred. Pull conductor to preferred sag as provided by engineering using Bull wheel tensioner. Mark conductor at end of insulator string and lower back to the ground. Cut conductor and install compression dead end.	PLT's, Groundman and Operators	1 Day	Day 27	Day 27
Pull conductor into place with bull wheel tensioner again maintaining the 2:1 or 3:1 led to height ratio.	PLT's, Groundman and Operators	1 Day	Day 28	Day 28
"Clip in" conductors on 34 tangent structures	PLT's, Groundman and Operators	3 Days	Day 29	Day 31
Complete visual inspection and check sheets that may be required.	Nalcor and Contractor Representative	1 Day	Day 32	Day 32
Notify Control center that work will be complete in the next couple of hours/ day so that resources can be assigned to return a pole to service.	Nalcor and Contractor Representative		Day 32	Day 32
Connect new by-pass to existing pole, and or electrode ensuring proper E, B & G philosophy is maintained (do not get between grounds)	PLT's, Groundman and Operators		Day 32	Day 32
Complete final turnover documentation for Ready to energize.	Nalcor and Contractor Representative		Day 33	Day 33
Remove all personal grounds.	Contractor		Day 33	Day 33
Surrender Work Protection	Contractor/ Nalcor		Day 33	Day 33
Re-Energize Pole	Nalcor		Day 33	Day 33

11.0 Failure Scenario 3: 4 Km of Transmission Line, up to 20 Towers down in the Long-Range Mountains

In this scenario a proposed solution is to put one positive DC pole back in service and use a sea electrode for return. A single line consisting of 30 wood pole structures will be constructed utilizing Backstays at 2 locations.

The fault location is 80 km from a paved road in the Long-Range Mountains, on the Newfoundland section of the HVdc transmission line.

Construction of 30 structures may require multiple access points and will very likely require longer Right of Way travel durations.

Estimated return to service of 38 days is expected.

Task Description	Comments/ Timeline	Duration	Start	Finish
Outage is observed and acknowledged at Control Center	Outage begins			
Notify ERP Team that weather has in fact resulted in an event. First Response Leader (Nalcor) to initiate primary and secondary response plan.	Within the hour	1 Hour	Day 1	
Initiate Work Protection online segment	Within the first 4-6 hours	4 Hours	Day 1	
Complete fault location and provide to ERP team (First response Leader)	Within the hour	4 Hours	Day 1	
Deploy first responders (Hydro team 1) with aerial support.	Coordinate aerial support to Fault location provided by control center if conditions permit. Secondary Level of patrol should be initiated such as snowmobile or ATV.	4hr- 8 hrs	Day 1	
Initiate secondary response communications with local ground support vehicles	Snowmobile or ATV	4 Hours	Day 1	

First responders identify fault location. Location is confirmed locally using structure list stored on mobile electronic device and communicated to supervisor on call. Pictures are taken from the air and electronic forms are started and emailed to supervisor.	within 24 hours if weather permits, within 1-2 days when weather is extreme (excessive winds, heavy snow or extreme cold)	1.5 Days	Day 1	Day 2
Standby Supervisor and Emergency Response Team will evaluate preliminary information for repairs required. Minor repairs- one span including- one Pole, one Electrode or OPGW damage or failure. Major- multiple conductors (pole or electrode) or significant tower damage up to 20 towers.	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Engineering will start preliminary design of temporary wood pole for approximately up to 30 structures for Pole conductor only.	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Secure accommodations and meals in nearest location to site. Book minimum 60 rooms for 6 weeks tentative.	Logistics Team	1 Day	Day 3	
Deploy first group of Contract resources to assist with Staging and site preparation.	Contractor to send first 12-15 employees. This team will Support Staging areas, Site Preparation, Poles and Anchors	2 Days	Day 3	Day 4
Primary first responders will find suitable area to land and confirm Work Protection is in place. *** Safety distances from conductors must be maintained while completing the inspection from the ground locally filling out the rest of the Emergency Response Plan Site Assessment Check Sheet***.	Work Protection should be established as soon as significant damaged is found.	1 Day	Day 3	Day 3
Preliminary location of site staging area will be identified for closest access to damage site from map data and environmental data.	This is a key component as tarped hoarding area is very beneficial for winter conditions to keep the equipment somewhat heated.	1 Day	Day 3	Day 3

	This is an area identified on Saint Paul River Road where vehicles and equipment can be offloaded as close to the damage site as possible.			
Preliminary wood pole design by engineering will be reviewed with Emergency Response Team and Execution Contractor and shared with Surveyor	In this scenario we have assumed that there are no extremely wide river crossings, and most bogs are frozen. Engineers will confirm plan and profile view to confirm pole heights are adequate.	2 Day	Day 4	Day 5
Surveyor will be transported to site with first responder (Team 1) by helicopter to stake pole location	This survey will help confirm the design as well as providing locates. If there are issues found a correction in pole heights should be found at this time.	4 Days	Day 6	Day 9
Road clearing in many areas is best suited for D-8 dozers and 3 dozers should be able to complete approximately 10km/ 12 hr shift in extreme conditions. Extreme conditions for this model were based on three criteria 1) amount of accumulated snow, 2) type of drifting observed and 3) visibility. For this exercise we assume moderate to heavy accumulated snow 3 to 4 feet, drifts 8 to 10 feet wide greater than 4 feet in depth and moderate (1km to .5 km) to heavy snow fall (less than .5 km) visibility. In low to moderate conditions Loaders may be utilized.	80 km in the Long-Range Mountains	6 Days	Day 5	Day 10
Confirm materials list in trailers and share with Contractor. Load material sea cans on transport trucks and deploy to staging area. If extreme cold is anticipated prefabricated trusses, tarps and heaters should be deployed to be placed between sea cans for temporary heating of equipment. This list will be shared with the Execution	Contractor Second team will review and confirm. This team will be focused on Framing, and stringing. Again, the preliminary staging area is as close to the site as possible on secondary road accessing ROW. A final staging site may be developed closer to the damage area as road clearing progresses.	4 Days	Day 5	Day 9

Contractor in case additional items are required.				
Confirm location of wood product and transport to staging area.	There may be a need for higher poles after field survey is complete however this can be corrected in a day or two.	4 Days	Day 5	Day 9
Contractor to load equipment for 2 levels of response- Rubber Tire and Track. Again, weather and access can be very unpredictable, and a two-layer response is critical to ensure that time frames are met.	For this scenario multiple units are required for the follow but not limited to- Highway Tractors, Floats, Cranes, Excavators, Bucket units, Radial Boom Derricks, Dozers, Etc. When evaluating the preliminary responses, we should look at a combination of equipment. For example, even if we can plow the road to the failure site and rubber tire equipment can be utilized to secure the existing tower, the installation of poles for a temporary wood pole repair would probably require tracked equipment in the ROW.	4 Days	Day 5	Day 9
Cross reference tool and equipment lists with tools and equipment in totes. Evaluate delivery method. The use of helicopter vs transport could depend on factors such as weather, # of available transport trucks, road conditions, location of fault, etc. This list will be shared with the Execution Contractor in case additional items are required.	Primary delivery method for tools and equipment will be Highway Tractors with trailers. Helicopter may be used to transport personnel once first responders are complete damage assessment.	4 Days	Day 5	Day 9

Install reference points such as Ground rods to monitor undamaged towers for reference and document data. These points can be used as an aid to monitor the status of the towers in case of creeping until equipment can be placed to secure towers (Slug anchors).	This can provide a reference especially where the environmental issues may still be a factor such as excessive ice on conductor of undamaged towers. Check periodically.	1 Day		
Priority to have Excavators on site as soon as possible. Two excavators and third Excavator with Rock Buster would be idle to improve efficiency and delays when changing attachments in cold weather. Also, hydraulic O ring failure is more common in extreme cold so the amount of time that attachments are removed reduced the probability of equipment delays from this type of failure.	Contractor units.	3 Days	Day 6	Day 10
Excavator to support back staying of conductor as defined in Document 6122-001-PAD-008 Back Staying of Conductor Work Procedure.		1 Day	Day 11	Day 11
E160 to secure backer cables to tower on each side of the work site.	NL Hydro unit as per Back Staying Procedure	1 Day	Day 11	Day 11
Compression Dead end shall be installed on the Pole that will be re-energized to create isolation from the pole to the backer cable. The compression dead end will be installed on the non tension side of conductor that has just been secured with the backer cable above.	As per Back Staying Procedure	1 Day	Day 11	Day 11
Once the compression dead end has been installed and insulator string attached the backer cable will be transferred to the end of the insulator string and tensioned to the Back stays. This may require a ball eye attachment	As per Back Staying Procedure	1 Day	Day 12	Day 12

with strain link. Repeat on pole to be energized in other direction				
Pole crew to begin to install poles and anchors for bypass. In this scenario we would install a temporary bypass of approximately 26 tangent structures and 4 Dead end structures for the Pole Line and Electrode Line. This would be 112 anchors and 60 wood poles.	3 anchor crews and 3 Pole Crews on Day shift and 3 anchor crews and 3 Pole Crews on Night shift using the same equipment	8 Days	Day 12	Day 19
Conductor crew to prepare conductor pulling area and reel stand area.	Various PLT's, Ground person and operators	1 Day	Day 19	Day 19
Frame Tangent Structures and Install travelers. Running reel method will be used to pull conductor out. Conductor will be lifted into travelers by machine instead a pilot line or bull rope.	PLT's and Groundmen	10 Days	Day 17	Day 26
Frame Dead end Structures and Install travelers on 2 of the 4 Dead end structures. Conductor will be attached to strain insulators on one end and pulled at the other end. Running reel method will be used to pull conductor out.	PLT's, Groundman and Operators		Day 26	Day 27
Install 30 span of conductor	PLT's and Groundmen	4 Days	Day 28	Day 31
Cut Conductor and complete compression Dead end. Raise conductor and connect to insulators.	PLT's, Groundman and Operators		Day 32	Day 33
Ensure adequate lead to height ratio for pull location is in place 2 to 1 minimum and 3 to 1 is preferred. Pull conductor to preferred sag as provided by engineering. Mark Conductor at end of insulator string and lower back to the ground. Cut	PLT's, Groundman and Operators		Day 33	Day 33

conductor and install compression dead end.				
Pull conductor into place with steel backing cable again maintaining the 2:1 or 3:1 led to height ratio.	PLT's, Groundman and Operators	1 Day	Day 33	Day 33
"Clip in" conductors on 30 tangent structures	PLT's, Groundman and Operators	3 Days	Day 34	Day 36
Complete visual inspection and check sheets that may be required.	Nalcor and Contractor Representative	1 Day	Day 37	Day 37
Notify Control center that work will be complete in the next couple of days so that resources can be assigned to return a pole to service.	Nalcor and Contractor Representative		Day 37	Day 37
Connect new by-pass to existing pole, and or electrode ensuring proper E, B & G philosophy is maintained (do not get between grounds)	PLT's, Groundman and Operators		Day 37	Day 37
Complete final turnover documentation for Ready to energize.	Nalcor and Contractor Representative		Day 38	Day 38
Remove all personal grounds.	Contractor		Day 38	Day 38
Surrender Work Protection	Contractor/ Nalcor		Day 38	Day 38
Re-Energize Pole	Nalcor		Day 38	Day 38

12.0 Failure Scenario 4: 21 Towers Central Labrador

This scenario is a Level 5 incident, in this scenario 21 steel lattice towers will be reinstalled on existing foundations and utilize existing anchors. 50% of the guys can be reused and the remainder will be surveyed and cut to length using the Hydro spares.

The higher the number of structures to be replaced, the harder it is to accurately estimate the required duration in Winter conditions in Newfoundland and Labrador. There are many weeks in the winter months where cranes and Helicopters can not be utilized for several days at a time.

The location again is Central Labrador

Estimated return to service is 42 days

Task Description	Comments/ Timeline	Duration	Start	Finish
Outage is observed and acknowledged at Control Center	Outage begins			
Notify ERP Team that weather has in fact resulted in an event. First Response Leader (Hydro) to initiate primary and secondary response plan.	Within the hour	1 Hour	Day 1	
Initiate Work Protection	Within the first 4-6 hours	4 Hours	Day 1	
Complete fault location and provide to ERP team (First response Leader)	Within the hour	4 Hours	Day 1	
Deploy first responders (Hydro team 1) with aerial support.	Coordinate aerial support to Fault location provided by control center if conditions permit. Secondary Level of patrol should be initiated such as snowmobile or ATV.	4hr- 8 hrs	Day 1	
Initiate secondary response communications with local ground support vehicles	Snowmobile or ATV	4 Hours	Day 1	

First responders identify fault location. Location is confirmed locally using structure list stored on mobile electronic device and communicated to supervisor on call. Pictures are taken from the air and electronic forms are started and emailed to supervisor.	within 24 hours if weather permits, within 1-2 days when weather is extreme (excessive winds, heavy snow or extreme cold)	1.5 Days	Day 1	Day 2
Standby Supervisor and Emergency Response Team will evaluate preliminary information for repairs required. Minor repairs- one span including- one Pole, one Electrode or OPGW damage or failure. Major- multiple conductors (pole or electrode) or significant tower damage up to 3 towers.	24-48 hrs. Level 3 Response Multiple Tower Damage	1 to 2 Days	Day 3	Day 4
Engineering will start preliminary review of towers and prepare to order guys as required- 21 towers with 50% of the guys having damage.	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Secure accommodations and meals in nearest location to site. Book minimum 45 rooms for 6 weeks tentative.	Logistics Team	1 Day	Day 3	
Deploy first group of Contract resources to assist with Staging and site preparation.	Contractor to send first 15-20 employees. This team will Support Staging areas, Site Preparation, Tower/ Conductor removal	2 Days	Day 3	Day 4
Primary first responders will find suitable area to land and confirm Work Protection is in place. *** Safety distances from conductors must be maintained while completing the inspection from the ground locally filling out the rest of the Emergency Response Plan	Work Protection should be established as soon as significant damaged is found.	1 Day	Day 3	Day 3

Site Assessment Check Sheet***.				
Preliminary location of staging area will be identified for closest access to damage site from map data and environmental data.	This is a key component as tarped hoarding area is very beneficial for winter conditions to keep the equipment somewhat heated.	1 Day	Day 3	Day 3
Preliminary Tower Replacement design by engineering will be reviewed with Emergency Response Team and Execution Contractor and shared with Surveyor	In this scenario we have assumed that there are no extremely wide river crossings, and most bogs are frozen. Engineers will confirm plan and profile view to confirm pole heights are adequate.	1 Day	Day 4	Day 4
Road clearing in many areas is best suited for D-8 dozers and 3 dozers should be able to complete approximately 10km/ 12 hr shift in extreme conditions. Extreme conditions for this model were based on three criteria 1) amount of accumulated snow, 2) type of drifting observed and 3) visibility. For this exercise we assume moderate to heavy accumulated snow 3 to 4 feet, drifts 8 to 10 feet wide greater than 4 feet in depth and moderate (1km to .5 km) to heavy snow fall (less than .5 km) visibility. In low to moderate conditions Loaders may be utilized.	100 km estimated on Saint Paul River Road from Trans Labrador Highway. 20km/24 hrs= 5 days	5 Days	Day 5	Day 9
Confirm materials list in trailers and share with Contractor. Load material Trailers (or sea cans) on transport trucks and deploy to preliminary staging area. If extreme cold is anticipated prefabricated trusses, tarps and heaters should be	Contractor Second team will review and confirm. This team will be focused on Framing, and stringing. Again, the preliminary staging area is as close to the site as possible on the Saint Paul River Road. A final staging site may be developed closer to the	10 Days	Day 5	Day 14

deployed to be placed between Trailers (sea cans) for temporary heating of equipment. This list will be shared with the Execution Contractor in case additional items are required.	damage area as road clearing progresses.			
Initiate procurement of 50% of the guys required.		4 Days	Day 5	Day 9
Contractor to load equipment for 2 levels of response- Rubber Tire and Track. Again, weather and access can be very unpredictable, and a two-layer response is critical to ensure that time frames are met.	For this scenario multiple units are required for the follow but not limited to- Highway Tractors, Floats, Cranes, Excavators, Bucket units, Radial Boom Derricks, Dozers, Etc. When evaluating the preliminary responses, we should look at a combination of equipment. For example, even if we can plow the road to the failure site and rubber tire equipment can be utilized to secure the existing tower, the installation of conductor would probably require tracked equipment in the ROW.	4 Days	Day 5	Day 9
Cross reference tool and equipment lists with tools and equipment in totes. Evaluate delivery method. The use of helicopter vs transport could depend on factors such as weather, # of available transport trucks, road conditions, location of fault, etc. This list will be shared with the Execution Contractor in case additional items are required.	Primary delivery method for tools and equipment will be Highway Tractors with trailers. Helicopter may be used to transport personnel once first responders are complete damage assessment.	4 Days	Day 5	Day 9

Install reference points such as Ground rods to monitor undamaged towers for reference and document data. These points can be used as an aid to monitor the status of the towers in case of creeping until equipment can be placed to secure towers (Slug anchors).	This can provide a reference especially where the environmental issues may still be a factor such as excessive ice on conductor of undamaged towers. Check periodically.	1 Day		
Priority to have Excavators on site as soon as possible. Two excavators and third Excavator with Rock Buster would be idle to improve efficiency and delays when changing attachments in cold weather. Also, hydraulic O ring failure is more common in extreme cold so the amount of time that attachments are removed reduced the probability of equipment delays from this type of failure.	Contractor units.	3 Days	Day 6	Day 10
Excavator to support back staying of conductor as defined in Document 6122-001-PAD-008 Back Staying of Conductor Work Procedure.		1 Day	Day 11	Day 11
E160 to secure backer cables to tower on each side of the work site.	NL Hydro unit as per Back Staying Procedure	1 Day	Day 11	Day 11
Compression Dead end shall be installed on the Pole that will be re-energized to create isolation from the pole to the backer cable. The compression dead end will be installed on the non tension side of conductor that has just been secured with the backer cable above.	As per Back Staying Procedure	1 Day	Day 11	Day 11

Once the compression dead end has been installed and insulator string attached the backer cable will be transferred to the end of the insulator string and tensioned to the Back stays. This may require a ball eye attachment with strain link. Repeat on pole to be energized in other direction	As per Back Staying Procedure	1 Day	Day 12	Day 12
Crew will prepare sites to remove damaged towers and create Crane pad and Assembly pads. 21 sites	various crews with 35-45 ton boom trucks	3 days	Day 12	Day 14
Conductor crew to prepare conductor pulling area and reel stand area.	Various PLT's, Ground person and operators	1 Day	Day 14	Day 14
Transport Towers to laydown area		3 Days	Day 15	Day 17
Tower Assembly	3 crews with telehandler or 35-45 tone cranes	7 days	Day 12	Day 18
Tower Erection (Including Guys)	3 crews- with 200-ton crane	7 Days	Day 17	Day 23
Install conductor (Pole, Electrode, OPGW)	Various PLT's, Ground person and operators	12 days	Day 24	Day 35
Clip Conductors in and Dead End	Various PLT's, Ground person and operators	5 Days	Day 36	Day 40
Complete visual inspection and check sheets that may be required.	Nalcor and Contractor Representative	2 Day	Day 41	Day 42
Notify Control center that work will be complete in the next couple of days so that resources can be assigned to return a pole to service.	Nalcor and Contractor Representative		Day 42	Day 42
Connect new conductor to existing pole, and or electrode ensuring proper E, B & G philosophy is maintained (do not get between grounds)	PLT's, Groundman and Operators		Day 42	Day 42

Complete final turnover documentation for Ready to energize.	Nalcor and Contractor Representative		Day 42	Day 42
Remove all personal grounds.	Contractor		Day 42	Day 42
Surrender Work Protection	Contractor/ Nalcor		Day 42	Day 42
Re-Energize Pole	Nalcor		Day 42	Day 42

13.0 Failure Scenario 5: 7 Towers Central Labrador

This scenario is a level 4 to 5 Incident, in this scenario 7 steel lattice towers will be reinstalled on existing foundations, utilizing existing anchors. 50% of the guys can be reused and the remainder will be surveyed and cut to length using Hydro spares.

The higher the number of structures to be replaced, the harder it is to accurately estimate the required duration in Winter conditions in Newfoundland and Labrador. There are many weeks in the winter months where cranes and Helicopters can not be utilized for several days at a time.

The location again is Central Labrador

Estimated return to service is 33 days

Task Description	Comments/ Timeline	Duration	Start	Finish
Outage is observed and acknowledged at Control Center	Outage begins			
Notify ERP Team that weather has in fact resulted in an event. First Response Leader (Nalcor) to initiate primary and secondary response plan.	Within the hour	1 Hour	Day 1	
Initiate Work Protection online segment	Within the first 4-6 hours	4 Hours	Day 1	
Complete fault location and provide to ERP team (First response Leader)	Within the hour	4 Hours	Day 1	
Deploy first responders (Hydro team 1) with aerial support.	Coordinate aerial support to Fault location provided by control center if conditions permit. Secondary Level of patrol should be initiated such as snowmobile or ATV.	4hr- 8 hrs	Day 1	
Initiate secondary response communications with local ground support vehicles	Snowmobile or ATV	4 Hours	Day 1	

First responders identify fault location. Location is confirmed locally using structure list stored on mobile electronic device and communicated to supervisor on call. Pictures are taken from the air and electronic forms are started and emailed to supervisor.	within 24 hours if weather permits, within 1-2 days when weather is extreme (excessive winds, heavy snow or extreme cold)	1.5 Days	Day 1	Day 2
Standby Supervisor and Emergency Response Team will evaluate preliminary information for repairs required. Minor repairs- one span including- one Pole, one Electrode or OPGW damage or failure. Major- multiple conductors (pole or electrode) or significant tower damage up to 3 towers.	24-48 hrs. Level 3 Multiple Tower Damage	1 to 2 Days	Day 3	Day 4
Engineering will start preliminary review of towers and prepare to order guys as required- 7 towers with 50% of the guys having damage.	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Secure accommodations and meals in nearest location to site. Book minimum 45 rooms for 6 weeks tentative.	Logistics Team	1 Day	Day 3	
Deploy first group of Contract resources to assist with Staging and site preparation.	Contractor to send first 15-20 employees. This team will Support Staging areas, Site Preparation, Tower/ Conductor removal	2 Days	Day 3	Day 4
Primary first responders will find suitable area to land and confirm Work Protection is in place. *** Safety distances from conductors must be maintained while completing the inspection from the ground locally filling out the rest of the Emergency Response Plan Site Assessment Check Sheet***.	Work Protection should be established as soon as significant damaged is found.	1 Day	Day 3	Day 3

Preliminary location of staging area will be identified for closest access to damage site from map data and environmental data.	This is a key component as tarped hoarding area is very beneficial for winter conditions to keep the equipment somewhat heated.	1 Day	Day 3	Day 3
Preliminary Tower Replacement design by engineering will be reviewed with Emergency Response Team and Execution Contractor and shared with Surveyor	In this scenario we have assumed that there are no extremely wide river crossings, and most bogs are frozen. Engineers will confirm plan and profile view to confirm pole heights are adequate.	1 Day	Day 4	Day 4
Road clearing in many areas is best suited for D-8 dozers and 3 dozers should be able to complete approximately 10km/ 12 hr shift in extreme conditions. In moderate conditions Loaders can be utilized.	100 km estimated on Saint Paul River Road from Trans Labrador Highway. 20km/24 hrs= 5 days	5 Days	Day 5	Day 9
Confirm materials list in trailers and share with Contractor. Load material sea cans on transport trucks and deploy to staging area. If extreme cold is anticipated prefabricated trusses, tarps and heaters should be deployed to be placed between sea cans for temporary heating of equipment. This list will be shared with the Execution Contractor in case additional items are required.	Contractor Second team will review and confirm. This team will be focused on Framing, and stringing.	4 Days	Day 5	Day 9
Initiate procurement of 50% of the guys required.		4 Days	Day 5	Day 9
Contractor to load equipment for 2 levels of response- Rubber Tire and Track. Again, weather and access can be very unpredictable, and a two-layer response is critical to ensure that time frames are met.	For this scenario multiple units are required for the follow but not limited to- Highway Tractors, Floats, Cranes, Excavators, Bucket units, Radial Boom Derricks, Dozers, etc.	4 Days	Day 5	Day 9

Cross reference tool and equipment lists with tools and equipment in totes. Evaluate delivery method. The use of helicopter vs transport could depend on factors such as weather, # of available transport trucks, road conditions, location of fault, etc. This list will be shared with the Execution Contractor in case additional items are required.	Primary delivery method for tools and equipment will be Highway Tractors with trailers. Helicopter may be used to transport personnel once first responders are complete damage assessment.	4 Days	Day 5	Day 9
Install reference points such as Ground rods to monitor undamaged towers for reference and document data. These points can be used as an aid to monitor the status of the towers in case of creeping until equipment can be placed to secure towers (Slug anchors).	This can provide a reference especially where the environmental issues may still be a factor such as excessive ice on conductor of undamaged towers. Check periodically.	1 Day		
Priority to have Excavators on site as soon as possible. Two excavators and third Excavator with Rock Buster would be idle to improve efficiency and delays when changing attachments in cold weather. Also, hydraulic O ring failure is more common in extreme cold so the amount of time that attachments are removed reduced the probability of equipment delays from this type of failure.	Contractor units.	3 Days	Day 6	Day 10
Excavator to support back staying of conductor as defined in Document 6122-001-PAD-008 Back Staying of Conductor Work Procedure.		1 Day	Day 11	Day 11
E160 to secure backer cables to tower on each side of the work site.	NL Hydro unit as per Back Staying Procedure	1 Day	Day 11	Day 11

Compression Dead end shall be installed on the Pole that will be re-energized to create isolation from the pole to the backer cable. The compression dead end will be installed on the non tension side of conductor that has just been secured with the backer cable above.	As per Back Staying Procedure	1 Day	Day 11	Day 11
Once the compression dead end has been installed and insulator string attached the backer cable will be transferred to the end of the insulator string and tensioned to the Back stays. This may require a ball eye attachment with strain link. Repeat on pole to be energized in other direction	As per Back Staying Procedure	1 Day	Day 12	Day 12
Crew will prepare sites to remove damaged towers and create Crane pad and Assembly pads. 7 sites	various crews with 35–45-ton boom trucks	3 days	Day 12	Day 14
Conductor crew to prepare conductor pulling area and reel stand area.	Various PLT's, Ground person and operators	1 Day	Day 14	Day 14
Transport Towers to laydown area		2 Days	Day 15	Day 16
Tower Assembly	3 crews with telehandler or 35-45 tone cranes	3 Days	Day 17	Day 19
Tower Erection (Including Guys)	3 crews- with 200-ton crane	3 Days	Day 20	Day 22
Install conductor (Pole, Electrode, OPGW)	Various PLT's, Ground person and operators	4 days	Day 23	Day 26
Clip Conductors in and Dead End	Various PLT's, Ground person and operators	3 Days	Day 27	Day 29
Complete visual inspection and check sheets that may be required.	Nalcor and Contractor Representative	1 Day	Day 30	Day 30
Notify Control center that work will be complete in the next couple of hours so that resources can be assigned to return a pole to service.	Nalcor and Contractor Representative		Day 30	Day 30

Connect new conductor to existing pole, and or electrode ensuring proper E, B & G philosophy is maintained (do not get between grounds)	PLT's, Groundman and Operators		Day 31	Day 32
Complete final turnover documentation for Ready to energize.	Nalcor and Contractor Representative		Day 33	Day 33
Remove all personal grounds.	Contractor		Day 33	Day 33
Surrender Work Protection	Contractor/ Nalcor		Day 33	Day 33
Re-Energize Pole	Nalcor		Day 33	Day 33

14.0 Failure Scenario 6: Fully replace 22 Towers Avalon

This is scenario is a Level 5 incident, in this scenario 22 steel lattice towers will be reinstalled on existing foundations and utilizing existing anchors. 50% of the guys can be reused and the remainder will be surveyed and manufactured.

The higher the number of structures to be replaced, the harder it is to accurately estimate the required duration in Winter conditions in Newfoundland and Labrador. There are many weeks in the winter months where cranes and Helicopters can not be utilized for several days at a time.

The location is in the Avalon.

Estimated return to service is 36 days

Task Description	Comments/ Timeline	Duration	Start	Finish
Outage is observed and acknowledged at Control Center	Outage begins			
Notify ERP Team that weather has in fact resulted in an event. First Response Leader (Nalcor) to initiate primary and secondary response plan.	Within the hour	1 Hour	Day 1	
Initiate Work Protection online segment	Within the first 4-6 hours	4 Hours	Day 1	
Complete fault location and provide to ERP team (First response Leader)	Within the hour	4 Hours	Day 1	
Deploy first responders (Hydro team 1) with aerial support.	Coordinate aerial support to Fault location provided by control center if conditions permit. Secondary Level of patrol should be initiated such as snowmobile or ATV.	4hr- 8 hrs	Day 1	
Initiate secondary response communications with local ground support vehicles	Snowmobile or ATV	4 Hours	Day 1	
First responders identify fault location. Location is confirmed locally using structure list stored on mobile electronic device and communicated to supervisor on call. Pictures are taken from the	within 24 hours if weather permits, within 1-2 days when weather is extreme (excessive winds, heavy snow or extreme cold)	1.5 Days	Day 1	Day 2

air and electronic forms are started and emailed to supervisor.				
Standby Supervisor and Emergency Response Team will evaluate preliminary information for repairs required. Minor repairs- one span including- one Pole, one Electrode or OPGW damage or failure. Major- multiple conductors (pole or electrode) or significant tower damage up to 3 towers.	24-48 hrs. Level 3 Response Multiple Tower Damage	1 to 2 Days	Day 3	Day 4
Engineering will start preliminary review of towers and prepare to order guys as required- 22 towers with 50% of the guys having damage.	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Secure accommodations and meals in nearest location to site. Book minimum 45 rooms for 6 weeks tentative.	Logistics Team	1 Day	Day 3	
Deploy first group of Contract resources to assist with Staging and site preparation.	Contractor to send first 15-20 employees. This team will Support Staging areas, Site Preparation, Tower/ Conductor removal	2 Days	Day 3	Day 4
Primary first responders will find suitable area to land and confirm Work Protection is in place. *** Safety distances from conductors must be maintained while completing the inspection from the ground locally filling out the rest of the Emergency Response Plan Site Assessment Check Sheet***.	Work Protection should be established as soon as significant damaged is found.	1 Day	Day 3	Day 3
Preliminary location of staging area will be identified for closest access to damage site from map data and environmental data.	This is a key component as tarped hoarding area is very beneficial for winter conditions to keep the equipment somewhat heated.	1 Day	Day 3	Day 3

Preliminary Tower Replacement design by engineering will be reviewed with Emergency Response Team and Execution Contractor and shared with Surveyor	In this scenario we have assumed that there are no extremely wide river crossings, and most bogs are frozen. Engineers will confirm plan and profile view to confirm pole heights are adequate.	1 Day	Day 4	Day 4
Road clearing in many areas is best suited for D-8 dozers and 3 dozers should be able to complete approximately 10km/ 12 hr shift in extreme conditions. In moderate conditions Loaders can be utilized.	Access Road clearing expected to be 3 days for this scenario. It may be quicker with loaders in this area.	3 Days	Day 5	Day 7
Confirm materials list in trailers and share with Contractor. Load material sea cans on transport trucks and deploy to staging area. If extreme cold is anticipated prefabricated trusses, tarps and heaters should be deployed to be placed between sea cans for temporary heating of equipment. This list will be shared with the Execution Contractor in case additional items are required.	Contractor Second team will review and confirm. This team will be focused on Framing, and stringing. Again, the preliminary staging area is as close to the site as possible in the proposed access roads. A final staging site may be developed closer to the damage area as road clearing progresses.	4 Days	Day 5	Day 9
Initiate procurement of 50% of the guys required.		4 Days	Day 5	Day 9
Contractor to load equipment for 2 levels of response- Rubber Tire and Track. Again, weather and access can be very unpredictable, and a two-layer response is critical to ensure that time frames are met.	For this scenario multiple units are required for the follow but not limited to- Highway Tractors, Floats, Cranes, Excavators, Bucket units, Radial Boom Derricks, Dozers, etc.	4 Days	Day 5	Day 9
Cross reference tool and equipment lists with tools and equipment in totes. Evaluate delivery method. The use of helicopter vs transport could depend on factors such as weather, # of available transport trucks, road conditions, location of fault, etc. This list will be shared with the Execution Contractor in case additional items are required.	Primary delivery method for tools and equipment will be Highway Tractors with trailers. Helicopter may be used to transport personnel once first responders are complete damage assessment.	4 Days	Day 5	Day 9

Install reference points such as Ground rods to monitor undamaged towers for reference and document data. These points can be used as an aid to monitor the status of the towers in case of creeping until equipment can be placed to secure towers (Slug anchors).	This can provide a reference especially where the environmental issues may still be a factor such as excessive ice on conductor of undamaged towers. Check periodically.	1 Day		
Priority to have Excavators on site as soon as possible. Two excavators and third Excavator with Rock Buster would be idle to improve efficiency and delays when changing attachments in cold weather. Also, hydraulic O ring failure is more common in extreme cold so the amount of time that attachments are removed reduced the probability of equipment delays from this type of failure.	Contractor units.	3 Days	Day 6	Day 10
Excavator to support back staying of conductor as defined in Document 6122-001-PAD-008 Back Staying of Conductor Work Procedure.		1 Day	Day 11	Day 11
E160 to secure backer cables to tower on each side of the work site.	NL Hydro unit as per Back Staying Procedure	1 Day	Day 11	Day 11
Compression Dead end shall be installed on the Pole that will be re-energized to create isolation from the pole to the backer cable. The compression dead end will be installed on the non tension side of conductor that has just been secured with the backer cable above.	As per Back Staying Procedure	1 Day	Day 11	Day 11
Once the compression dead end has been installed and insulator string attached the backer cable will be transferred to the end of the insulator string and tensioned to the Back stays. This may require a ball eye attachment	As per Back Staying Procedure	1 Day	Day 12	Day 12

with strain link. Repeat on pole to be energized in other direction				
Crew will prepare sites to remove damaged towers and create Crane pad and Assembly pads. 22 sites	various crews with 35-45 boom trucks	3 days	Day 12	Day 14
Conductor crew to prepare conductor pulling area and reel stand area.	Various PLT's, Ground person and operators	1 Day	Day 14	Day 14
Transport Towers to laydown area		2 Days	Day 15	Day 16
Tower Assembly	3 crews with telehandler or 35-45 tone cranes	5 days	Day 17	Day 21
Tower Erection (Including Guys)	3 crews- with 200-ton crane	5 Days	Day 20	Day 24
Install conductor (Pole, Electrode, OPGW)	Various PLT's, Ground person and operators	7 days	Day 25	Day 31
Clip Conductors in and Dead End	Various PLT's, Ground person and operators	4 Days	Day 32	Day 35
Complete visual inspection and check sheets that may be required.	Nalcor and Contractor Representative	1 Day	Day 36	Day 36
Notify Control center that work will be complete in the next couple of days so that resources can be assigned to return a pole to service.	Nalcor and Contractor Representative		Day 36	Day 36
Connect new conductor to existing pole, and or electrode ensuring proper E, B & G philosophy is maintained (do not get between grounds)	PLT's, Groundman and Operators		Day 36	Day 36
Complete final turnover documentation for Ready to energize.	Nalcor and Contractor Representative		Day 36	Day 36
Remove all personal grounds.	Contractor		Day 36	Day 36
Surrender Work Protection	Contractor/ Nalcor		Day 36	Day 36
Re-Energize Pole	Nalcor		Day 36	Day 36

15.0 Failure Scenario 7: Central Labrador Electrode Line Failure

This scenario is a level 3 to 4 Incident, in this scenario there are 2 locations identified as having damage.

The solution is to replace all damaged cross-arms and repair conductor in both locations.

Location 1- towers 360-369 has 5 electrode arms damaged and conductor damage at all 10 structures

Location 2- towers 524-528 has 3 electrode arms damaged, the conductor has separated at one location and has damage at the other 4 towers.

Estimated return to service is 23 Days.

Task Description	Comments/ Timeline	Duration	Start	Finish
Outage is observed and acknowledged at Control Center	Outage begins			
Notify ERP Team that weather has in fact resulted in an event. First Response Leader (Nalcor) to initiate primary and secondary response plan.	Within the hour	1 Hour	Day 1	
Initiate Work Protection online segment	Within the first 4-6 hours	4 Hours	Day 1	
Complete fault location and provide to ERP team (First response Leader)	Within the hour	4 Hours	Day 1	
Deploy first responders (Hydro team 1) with aerial support.	Coordinate aerial support to Fault location provided by control center if conditions permit. Secondary Level of patrol should be initiated such as snowmobile or ATV.	4hr- 8 hrs	Day 1	
Initiate secondary response communications with local ground support vehicles	Snowmobile or ATV	4 Hours	Day 1	

First responders identify fault location. Location is confirmed locally using structure list stored on mobile electronic device and communicated to supervisor on call. Pictures are taken from the air and electronic forms are started and emailed to supervisor.	within 24 hours if weather permits, within 1-2 days when weather is extreme (excessive winds, heavy snow or extreme cold)	1.5 Days	Day 1	Day 2
Standby Supervisor and Emergency Response Team will evaluate preliminary information for repairs required. Minor repairs- one span including- one Pole, one Electrode or OPGW damage or failure. Major- multiple conductors (pole or electrode) or significant tower damage up to 3 towers.	24-48 hrs. Level 3 response Significant Tower and Conductor damage	1 to 2 Days	Day 3	Day 4
Engineering will be involved to review 10 tower span, 5 electrode arms require replacement, conductor damaged at all 10 towers (str 360-369). A second location 5 tower span, 3 electrode arms require replacement, conductor dropped at 3rd structure and damaged at the other 4 structures (str 524-528) has also been identified.	24-48 hrs.	1 to 2 Days	Day 3	Day 4
Secure accommodations and meals in nearest location to site. Book minimum 45 rooms for 4 weeks tentative.	Logistics Team	1 Day	Day 3	
Deploy first group of Contract resources to assist with Staging and site preparation.	Contractor to send first 15-20 employees. This team will Support Staging areas, Site Preparation, Tower/ Conductor removal	2 Days	Day 3	Day 4

Primary first responders will find suitable area to land and confirm Work Protection is in place. *** Safety distances from conductors must be maintained while completing the inspection from the ground locally filling out the rest of the Emergency Response Plan Site Assessment Check Sheet***.	Work Protection should be established as soon as significant damaged is found.	1 Day	Day 3	Day 3
Preliminary location of staging area will be identified for closest access to damage sites from map data and environmental data.	This is a key component as tarped hoarding area is very beneficial for winter conditions to keep the equipment somewhat heated.	1 Day	Day 3	Day 3
Preliminary tower drawings reviewed by engineering will be shared with Emergency Response Team and Execution Contractor.	In this scenario we have assumed that there are no extremely wide river crossings, and most bogs are frozen. Engineers will confirm plan and profile view to confirm pole heights are adequate.	1 Day	Day 4	Day 4
Road clearing in many areas is best suited for D-8 dozers and 3 dozers should be able to complete approximately 10km/ 12 hr shift in extreme conditions. In moderate conditions Loaders can be utilized.	Structure 360 is near the TLH about 140 km from Goose Bay, the other structures are on the SPRR about 60 km from the TLH. Access for all would be from the Goose Bay side.	3 Days	Day 5	Day 7
Confirm materials list in trailers and share with Contractor. Load material sea cans on transport trucks and deploy to staging area. If extreme cold is anticipated prefabricated trusses, tarps and heaters should be deployed to be placed between sea cans for temporary heating of equipment. This list will be	Contractor Second team will review and confirm. This team will be focused on Framing, and stringing.	4 Days	Day 5	Day 9

shared with the Execution Contractor in case additional items are required.				
Confirm location of structural steel as well as conductor and sleeves.		4 Days	Day 5	Day 9
Contractor to load equipment for 2 levels of response- Rubber Tire and Track. Again, weather and access can be very unpredictable, and a two-layer response is critical to ensure that time frames are met.	For this scenario multiple units are required for the follow but not limited to- Highway Tractors, Floats, Cranes, Excavators, Bucket units, Radial Boom Derricks, Dozers, etc.	4 Days	Day 5	Day 9
Cross reference tool and equipment lists with tools and equipment in totes. Evaluate delivery method. The use of helicopter vs transport could depend on factors such as weather, # of available transport trucks, road conditions, location of fault, etc. This list will be shared with the Execution Contractor in case additional items are required.	Primary delivery method for tools and equipment will be Highway Tractors with trailers. Helicopter may be used to transport personnel once first responders are complete damage assessment.	4 Days	Day 5	Day 9
Install reference points such as Ground rods to monitor undamaged towers for reference and document data. These points can be used as an aid to monitor the status of the towers in case of creeping until equipment can be placed to secure towers (Slug anchors).	This can provide a reference especially where the environmental issues may still be a factor such as excessive ice on conductor of undamaged towers. Check periodically.	1 Day		
Excavator to support back staying of conductor as defined in Document 6122-001-PAD-008 Back Staying of Conductor Work Procedure.		1 Day	Day 11	Day 11

E160 to secure backer cables to tower on each side of the work site.	NL Hydro unit as per Back Staying Procedure	1 Day	Day 11	Day 11
Compression Dead end shall be installed on the Pole that will be re-energized to create isolation from the pole to the backer cable. The compression dead end will be installed on the non tension side of conductor that has just been secured with the backer cable above.	As per Back Staying Procedure	1 Day	Day 11	Day 11
Once the compression dead end has been installed and insulator string attached the backer cable will be transferred to the end of the insulator string and tensioned to the Back stays. This may require a ball eye attachment with strain link. Repeat on pole to be energized in other direction	As per Back Staying Procedure	1 Day	Day 12	Day 12
Crew will prepare sites to remove damaged electrode arms and conductor sleeve sites.		3 days	Day 12	Day 14
Conductor crew to prepare conductor pulling area for Conductor splicing.	Various PLT's, Ground person and operators	1 Day	Day 14	Day 14
Transport Electrode Arms to laydown area		2 Days	Day 15	Day 16
Electrode Arm Replacement (8 Arms)		4 Days	Day 15	Day 18
Conductor repairs (14 damaged conductors)		4 Days	Day 19	Day 22
Conductor sag and splice		1 Day	Day 23	Day 23
Complete visual inspection and check sheets that may be required.			Day 23	Day 23

Notify Control center that work will be complete in the next couple of days so that resources can be assigned to return a pole to service.			Day 23	Day 23
Connect new conductor to existing pole, and or electrode ensuring proper E, B & G philosophy is maintained (do not get between grounds)			Day 23	Day 23
Complete final turnover documentation for Ready to energize.			Day 23	Day 23
Remove all personal grounds.	Contractor		Day 23	Day 23
Surrender Work Protection	Contractor/ Nalcor		Day 23	Day 23
Re-Energize Pole	Nalcor		Day 23	Day 23

16.0 Summary

It is very difficult to have a step-by-step response to these scenarios with so many variables at play in winter conditions. The time frames suggested in winter conditions can only be used if the weather event that caused the actual damage has subsided and there are very limited amounts of residual effects such as extreme ice loading to towers or conductor left to managed.

The key to having a successful restoration is the preplanning, preparation and mobilization based on a probability matrix so that response can be executed smoothly once the weather subsides. All of the documentation provided by others and reviewed by Locke's Electrical to date is post event. These types of events are usually monitored for days in advance and on many occasions may pass without issues. For the ones that do cause a level 3 or higher event, staging of personnel, equipment, support services, logistics, etc. pre-event to the area suspected to be most affected is of the highest importance.

A more robust focus on communication, planning, preparation, and mobilization pre-event should be the area of consideration. Engaging internal resources and external contractors 3-5 days in advance would be a huge benefit.

Also, a focus on temporary hoarding of equipment with a form of heat would help the process as not all equipment will be used 24/7. Mechanics should also be on site at the heated hoarding location. This can be done with strategically placing the trailers with timbers or prefabricated trusses across them with Tarps covering them.

In level 3 and above Hydro employees could focus primary on damage assessment and Transmission contractor could lead the execution of repairs. Having these direct lines of accountability will also greatly improve efficiency.

The effects of Covid-19 will also be an issue for the short term and shortages of materials could also be a contributing factor. This continues to drive home the importance of regularly checking stock and procuring any items that may have been used for repairs.

Regular PM schedule to include operation of tools and equipment to ensure that they are not only in hand but also operable.

Appendix A: Soldier's Pond Emergency Operations Centre Roles & Responsibilities

Soldier's Pond Emergency Operations Centre

Roles and Responsibilities

Maintain a fully functional Emergency Operations Centre to provide appropriate response expertise and resources to the Site Emergency Response, as required.

Communicate with external agencies, as required.

Determine the need to notify the Corporate Emergency Operations Centre through ECC as per determined incident level and circumstances pertaining to the incident.

<u>Level 1:</u> **Minor Local Emergency**	**<u>Level 2:</u>** **Major Local Emergency**	**<u>Level 3:</u>** **Catastrophic Emergency**
• Local Site Emergency Response • Production Incident Level 2	• Advanced Emergency Response involving external agencies • Production Incident Level 3	• Crisis Management • Production Incident Level 4 or 5

Ensure Corporate Emergency Operations Centre are informed and periodically updated as outlined in the Emergency Response Plan.

Ensure Regulatory Contacts are carried out as appropriate and as required in a timely manner and any communications are fully documented.

Coordinate with Support Services (as required)

Project Communications

Appendix B: Individual Roles & Responsibilities

Overhead Transmission Line

Roles and Responsibilities

Soldiers Pond On Call:

- Provide appropriate response expertise and resources to the Site Emergency Response, as required.
- Activate the Soldier's Pond Emergency Operations Centre, as required.
- Ensure contact has been made with responding agencies (911), and the Lines Supervisor.

Soldier Pond Incident Commander:

- Determine the level of the incident.
- Provide leadership and guidance while interacting with external agencies and first responders.
- Activate Soldier's Pond Emergency Operations Centre, if required.
- Notify Executive on Call, if required.

On-scene Commander:

- Respond to the incident scene.
- Contact responding agencies (911).
- Work with Soldier's Pond Emergency Operations Centre to mitigate any problems or concerns.
- Oversee execution of the restoration effort.

Corporate Emergency Operations Centre:

- Dependant on Incident Level and circumstances.

Soldiers Pond Converter Station Operator:

- Receive initial reports of incident from the Line Fault Locator computer
- Communicate with Power Supply on call, dispatch and first responders, as required.
- Act as the dispatch center for working alone and lightning notification.

First Responders, Fire & Medical:

- Respond to any emergency if required.
- Take direction from Power Supply on-scene commander, as required.

Appendix C: Equipment Available for Emergency Restoration Activities

- Pick-up trucks
- Snowmobiles and sleighs
- All Terrain Vehicles (6X6 and Argo with tracks)
- Open snowmobile trailers
- Enclosed snowmobile / ATV trailers
- Satellite communication equipment
  - Satellite phones and In Reach devices (currently used)
  - Power Supply has access to a satellite data hub owned by the construction group in Muskrat Falls, which will be transferred to Power Supply after construction is complete.
  - A satellite data hub unit will be purchased for the island prior to the 2020/21 winter operating season.
- GPS equipment with maps containing tower and access road information
- Emergency shelters
  - Prospector tents complete with wood stove
- Standard climbing and fall protection equipment for line workers
- Mini excavator which can be transported by helicopter for initial site snow clearing and preparation
- Hand tools used to construct steel towers and temporary wood structures
  - Tool list was used and deemed effective during restoration exercises for wood pole and tower assemble exercises in 2018 and 2019
- Hoists, handlines and rigging equipment
- Tension meter for guy wires
- Conductor tensioner for stringing conductor
- Compression tools for joining conductors and guy wires
  - Required compression dies have been purchased and are expected to be available prior to the winter 2020-2021 operating season.

Appendix D: Labrador-Island Link Emergency Response Call Out

LIL OHTL EMERGENCY RESPONSE CALL OUT
NOTIFICATION AND ROLES AND RESPONSIBILITIES

External Emergency Support

Fire Department, Ambulance, Police

Call 911

Corporate Emergency Operations Centre (CEOC)

In order to notify the executive on call you must call ECC.

ECC 24/7 Number

XXX-XXX-XXXX

XXX-XXX-XXXX

Power Supply On-call Supervisor

Call in the event of an emergency 24/7

XXX-XXX-XXX

SOP Emergency Operations Centre Members

Director, Transmission		
Wiseman, Chad	XXX-XXXX(w)	XXX-XXXX (c)
Safety Manager		
Tilley, Steve	XXX-XXXX(w)	XXX-XXXX (c)
Safety Supervisor		
Lake, Joe	XXX-XXXX(w)	XXX-XXXX (c)
HSE Advisor– Power Supply		
Elliott, Ryan	XXX-XXXX(w)	XXX-XXXX (c)
Work Execution Team Lead – Lines		
Woodman, Bob	XXX-XXXX(w)	XXX-XXXX (c)
Work Execution & Operations Manager		
Oliver, Evan	XXX-XXXX(w)	XXX-XXXX (c)
Supervisors		
Lines Supervisor – Island		
Keough, Patrick	XXX-XXXX(w)	XXX-XXXX (c)
Technical Supervisor – Operations		
White, Mark	XXX-XXXX(w)	XXX-XXXX (c)
Technical Supervisor – Operations		
Thompson, Mike	XXX-XXXX(w)	XXX-XXXX (c)
Lines Supervisor - Labrador		
Michelin, Derek	XXX-XXXX (c)	
Engineering Manager – AC Terminals and HVDC Spec		
Baikie, Justin	XXX-XXXX(w)	XXX-XXXX (c)
Engineering Manager – Transmission & Civil		
Walsh, John	XXX-XXXX(w)	XXX-XXXX (c)

OBSERVER:

- Call 911 if necessary (provide details of location)
- Contact your immediate supervisor during regular hours
- Contact Power Supply On Call supervisor after hours
- Contact External Agency if necessary

↓

IMMEDIATE SUPERVISOR/ON-CALL SUPERVISOR:

- Contact External Agency if Necessary -911
- Contact member of the SOP EOC
- If no response from SOP EOC then make a decision to call CERP if necessary
- Access the scene & work to make the area safe
- Ensure OSC is identified and in place

↓

SOP EOC MEMBER:

- Contact external agencies as needed – 911 after confirming with OSC
- Receive information from the caller
- Determine the Incident Level – 1,2,3
- Work to make the area safe
- Ensure external agency meeting point
- Contact engineering support if needed
- Activate SOP EOC if necessary
- Contact CEOC on call if needed
- Take actions to mitigate the emergency

↓

SOP EOC MEMBERS:

- Report to SOP EOC if activated
- Work with external agencies to mitigate the incident
- EOC Incident Commander will communicate with CEOC if necessary
- Maintain support & contact with OSC

↓

EXTERNAL AGENCIES:

- Receive request from On Call Supervisor, Observer, SOP EOC, etc
- Report to site and stage at security
- Work under direct supervision of Power Supply personnel
- Contain / Control the incident (OSC when on site)

Appendix E: Emergency Response Plan Site Assessment Check Sheet

Incident Checklist	Yes	No
1. What is the possible cause of the fault?		
a. Tower foundation damage b. Guy foundation damage c. Guyed tower Failure d. Guyed tower failure and foundation failure e. Guyed tower failure with foundation failure and 2 Guy failure f. Tower failure with tower and 2 guys and guy foundation damage g. Self-supporting tower failure h. Self-supporting tower failure and 2 legs foundation failure i. Self-supporting tower failure and 2 legs and foundation failure j. Tower head and cross arm damage k. Cross arm failure l. Cross arm failure with insulator damage m. Cross arm failure with insulator and hardware damage n. Cross arm failure with insulator, hardware and conductor damage o. Self-supporting Tower leg failure p. Guyed tower mast failure q. Guyed tower mast failure and guy failure r. Guyed tower mast failure, guy and guy foundation failure s. Guyed tower mast failure, foundation, guy and guy foundation failure t. Tower leaning with foundation and guy damage u. Tower leaning with tower and guy foundation and guy wire damage v. Guy wire failure w. Guy wire failure with guy foundation damage x. Guy wire failure with insulator damaged y. Guy wire failure with guy foundation and insulator damage z. Earth wire peak failure aa. Earth wire peak failure with conductor damage bb. Earth wire peak failure with earth wire damage cc. Earth wire peak failure with earth wire and conductor damagedd. Conductor damage external fault ee. Conductor damage vibration/galloping/lightningff. Earth wire conductor damage gg. Insulator failure hh. Insulator failure with conductor damage ii. Insulator failure with conductor and hardware damagejj. Hardware failure kk. Hardware failure with insulator damage ll. Hardware failure with insulator and conductor damage		

2. How many structures are damaged? (Ensure to check adjacent structures for damage damage that may not be initially apparent).
3. Record the identification numbers of the structures that are damaged or have damaged hardware on them.
4. Can the legs/mast of the tower be re-used? – (take pictures of tower sections).
Yes No ☐ ☐ Comments
5. If conductor is damaged, between which structures is the damage located?
6. Can the structures be reused?
Yes No ☐ ☐ Comments
7. Can the structure foundations be reused?
Yes No ☐ ☐ Comments
8. Can the guy wire foundations be reused?
Yes No ☐ ☐ Comments
9. How many meters of conductor is damaged? (1 full step ~ 1m)
10. Give a description of the failure and possible cause.

11. Give details of possible bypass route (include GPS coordinates or measurements).

12. Is the access route clear of obstacles? Provide any details on obstacles (waterbodies, culverts, bridges).

Yes ☐ No ☐

Comments

13. Give details on soil conditions in the area (rock outcrops, wetland/bogs).

14. Give details on snow depth and clearance to lines/jumpers.

15. Any other notes, observations.

Power Supply - Nalcor Energy
Emergency Response Plan Site Assessment Check sheet
Date:

PURPOSE: Try and record as much information about the fault as possible so that the correct response can be implemented.

Safety Check	Yes	No
Is the power to TL 3501 shut off (confirmed with ECC)?		
Is the section of failed line isolated (grounds in place)?		
Are there nearby transmission or distribution lines that might be of concern for flashover or induction?		

Incident Checklist	Yes	No
1. What is the possible cause of the fault?		
a. Tower foundation damage		
b. Guy foundation damage		
c. Guyed tower Failure		
d. Self-supporting tower failure		
f. Cross arm failure		
g. Self-supporting Tower leg failure		
h. Guyed tower mast failure		
i. Guy wire failure		
j. Anchor failure		
k. Earth wire peak failure		
l. Conductor damage external fault		
m. Conductor damage vibration/galloping/lightning		
n. OPGW damage		
o. Insulator failure		
p. Hardware failure		

2. How many structures are damaged? (Ensure to check adjacent structures for damage that may not be initially apparent).

3. Record the identification numbers of the structures that are damaged or have damaged hardware on them.

4. Can the legs/mast of the tower be re-used? – (take pictures of tower sections).

Yes ☐ No ☐

Comments

5. If conductor is damaged, between which structures is the damage located?

6. Can the structures be reused?

Yes ☐ No ☐

Comments

7. Can the structure foundations be reused?

Yes ☐ No ☐

Comments

8. Can the guy wire anchors be reused?

Yes ☐ No ☐

Comments

9. How many meters of conductor is damaged (considering both pole)? (1 full step ~ 1m)

10. Give a description of the failure and possible cause.

11. Give details of possible bypass route (include GPS coordinates or measurements).

12. Is the access route clear of obstacles? Provide any details on obstacles (waterbodies, culverts, bridges).

Yes No

Comments

13. Give details on soil conditions in the area (rock outcrops, wetland/bogs).

14. Give details on snow depth and clearance to lines/jumpers.

15. Any other notes, observations.