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April 30, 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* – Assessment of Labrador-Island Link Reliability – Further Information

On March 12, 2021, as part of its summary report on the Labrador-Island Link ("LIL") Reliability Assessment, Newfoundland and Labrador Hydro ("Hydro") advised the Board of Commissioners of Public Utilities ("Board") that it was undertaking a preliminary assessment of the additional considerations identified in Haldar & Associates' *Assessment of Labrador Island Transmission Link (LIL) Reliability in Consideration of Climatological Loads.* Hydro committed to provide further information by April 30, 2021 with respect to any additional steps it deemed necessary to undertake.

On March, 25, 2021, through correspondence to Hydro, the Board identified specific information it wished to receive with respect to the findings and recommendations of the Haldar & Associates report. The Board's requests, as well as Hydro's responses follow.

Request 1: An explanation as to its [Hydro's] position on each of the findings, setting out clearly whether it agrees.

Response:

The Ultimate Limit States ("ULS") analysis identified a return period of 1:160 years with an associated annual failure rate of 0.48%. Hydro accepts this finding. Based on the assessment completed by Haldar & Associates, Hydro believes that the LIL has the greatest risk of an extended bipole outage under an ULS scenario. As indicated in Hydro's summary report, a high-level assessment was completed considering an ULS analysis which stretched various system components to their ultimate limit, thus resulting in a higher probability of a forced outage of power delivery.

Based on CSA 60826 which dictates a Damage Limit State ("DLS") analysis, the as-built design of the LIL reflects a return period of 1:72 years with an associated annual failure rate of 1.10%. Hydro accepts this finding. Exceeding DLS limits is not expected to result in an extended outage.

Additional scenarios and return periods were identified by Haldar & Associates based on line length considerations. The original design of the LIL did not contemplate the impact of line length on reliability as this is not a requirement under the CSA standard. Haldar & Associates identified the independency between glaze and rime icing and the line length to be an important consideration. Correlations under both a DLS and a ULS scenario resulted in both having a return period of less than 50 years. Hydro has yet to determine its position with respect to this finding identified by Haldar & Associates. The consideration of overall line length and regional correlation impact will have a material impact on the overall calculated assessment of reliability of the line. Over the course of the coming weeks, Hydro will continue to evaluate the considerations identified by Haldar & Associates with respect to this concept to determine whether it should proceed with further work in this regard. As an example and to provide context for the need for further consideration, to achieve a reliability rating of a 1:150 year return period if overall line length were to be deemed appropriate for utilization, the infrastructure would have to be built to a 1:1500 year return period. Hydro believes further discussion is required, both internally and with stakeholders to the Resource and Reliability Adequacy proceeding, to better inform its position on this recommendation.

The LIL has been designed and constructed to either meet or exceed design criteria established from Hydro's extensive operational experience within the province. Hydro supports the further investigation of the recommendations related to unbalanced ice loading, wind speed up factors, pole conductor sizing, and combined wind and ice. The majority of these items are expected to apply only to specific locations throughout the line as opposed to application along the full line. Investigation of these items will further validate the overall reliability of the line and provide a better understanding of the risk of exposure to the infrastructure. Some of the items identified are considered to be over and above typical design within the utility industry and not commonly practised in past engineering designs completed by Hydro and, as such, additional research is warranted to determine if the impact is of concern.

The study completed by Haldar & Associates met the objective outlined which was to determine the strengths and weaknesses of the infrastructure. The items identified for further investigation will improve Hydro's understanding of the risks/exposures in areas of limited operational experience and aid in improving maintenance and emergency response based on priority locations.

Requests 2, 3, and 4:

- **An explanation as to its [Hydro's] position on each of the recommendations, setting out clearly whether it agrees.**

- **Its [Hydro's] plan to undertake the recommended additional analyses.**

- **The scope of the work to be done with respect to each of the recommended additional analysis.**

Response:

The following is a summary of the recommendations identified in the Haldar & Associates report, as well as Hydro's position and plan of work with respect to each.

Unbalanced Ice Loading

The design of the LIL included specific load cases for unbalanced loading but the cases differed from both the scenario presented in the CSA standard for certain tower types and specific load cases utilized in the past by Hydro on specific projects. The Haldar & Associates report recommended the completion of further studies to consider a specific load case for unbalanced ice loading as per both CSA and past Hydro designs. The load case in particular allows for full side reduction on all phases as opposed to partial loading only. After examination of this recommendation, it has been determined that the only towers impacted by this added loading scenario are located in the line segments 1 to 3 (Labrador) where the structures support five cables including the electrodes. The island portion of the line is capable of accommodating the added load as a result of reserve capacity in the structures. The design of the LIL did account for a variety of unbalanced loads which will improve the ability of the designs to accommodate the added load with minimal adjustments to the design. It is suspected that only a small percentage of the support structures will be impacted by incorporating this additional loading scenario.

Recent observations in Labrador indicate that ice shedding is a possibility which potentially could result in unbalanced loading and, as a result, additional work will be conducted to consider this scenario. The results of the recent storm damage investigation will provide further insight into the potential impact of structures within this area and will be required to properly assess the risk.

Hydro plans to complete additional analysis with the addition of the specified load case for the Labrador section to determine what, if any, remedial action could be undertaken. Remedial actions could include tower modifications, installation of mid spans and updating of Emergency Response Plan to identify the area as a high priority for advanced preparation and increased monitoring.

Wind Speed Up Factors

The Haldar & Associates report identified that the effect of wind speed up as a result of sloping terrain has the potential to increase the loading on the lower portion of existing support structures by approximately 35%. A sensitivity analysis for an area known to the author of the Haldar & Associates report was completed to determine the impact. In this particular case, the existing structure had adequate reserve capacity within the design to accommodate the additional load. Haldar & Associates recommended that specific areas throughout the line be reviewed to ensure an appropriate understanding of unknown areas outside of the Alpine zone that may be subject to such unique loading.

It is Hydro's understanding that for any suspected locations where this scenario may be a possibility, the LIL has been designed to incorporate increased wind loads due to the funneling effect, specifically in the Long Range Mountains where increased efforts were focused during the design stage as a result of limited operating experience.

Hydro acknowledges the possibility that within the 1,100 km line there are other locations that could be prone to such effect, resulting in increased risk. The impact of this load would primarily be on the tower and not the cable system, which would reduce the impact on reliability (given the cable system is the governing component[1] of the line). However, a failure of a tower due to such loading could result in an extended outage. It should be noted that this phenomenon has not been considered in past Hydro designs and is only briefly mentioned in the CSA code without any significant discussion or direction. The following is an extract from the CSA code:

> It is important to note that requirements for winds associated with localized events such as tornadoes are not specifically covered in this standard. These winds can cause serious damage to transmission lines either directly (due to wind forces) or indirectly (due to impact of wind carried objects). Furthermore, the effects of acceleration due to funnelling between hills or due to sloping grounds are not covered and may require specific studies to assess such influences.

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[1] Governing component is that by which the system strength is dictated as it proves to be the weakest link.

The potential for this increased loading has limited potential to increase risk; however, until a complete terrain assessment has been completed for the entire line, it is difficult to quantity the risk as a result of potential hot spots. This type of terrain analysis is not typically performed within the utility industry and usually if there are any areas of concern as a result of operating experience, adjustments are made to the design and implemented in the field to increase reserve capacity to accommodate the potential for increased wind bursts. It is possible that there are other locations that may be impacted, but due to the additional reserve capacity in the towers they may be adequate.

Hydro plans to complete terrain models for the entire line to determine if there are any potential hot spots that have not been previously identified. These findings will be evaluated in accordance with existing use factors to determine if there are any associated risks.

Impact Due to Pole Conductor Size

The Haldar & Associates report introduced a concept related to reduced ice accumulation on large conductors. Icing values identified within CSA are based on a standard 30 mm rod diameter compared to the 50 mm pole conductor utilized on the LIL. Modelling completed by Environment Canada has determined that accumulation of ice on larger cables (as is used on the LIL) reduces ice load in the range of approximately 30% by thickness. This provides additional buffer against unknowns within the design, including unbalanced loading and wind speed up factors and can lead to positive impacts in reliability assessment. Haldar & Associates recommended that an engineering assessment be completed to confirm how the revised loading due to reduced ice accumulation on the pole conductor will impact the overall line reliability.

As this concept is not introduced in CSA and the LIL is the only line in the province with such a large pole conductor, this concept was not implemented during the design. It is expected there will be an increase in tower reserve capacity and therefore improved reliability.

Hydro plans to further investigate this concept by analyzing critical towers in various segments of the line to determine how this will impact reliability and offset other issues such as unbalanced loading and wind speed up effects.

Combined Wind & Ice

The Haldar & Associates report indicated that the governing load scenario which dictates the overall reliability of the LIL is based on the combined wind and ice criteria in accordance with CSA recommendations. In addition, questions were raised through the Reliability and Resource Adequacy regulatory proceeding as to what the effect on reliability would be if the upper range of the wind and ice combination was considered. The CSA standard provides direction on two critical load cases with varying factors, but does not provide solid direction on which factors should be utilized. The combined loads identified in the CSA are very onerous and the use of such should be validated through study and operational experience to ensure they are in fact valid for the area in question. The use of such onerous load cases, in circumstances that do not support such occurrence could be considered to be quite conservative.

Hydro has extensive local operating experience and knowledge in areas throughout the province that are in close proximity to the LIL, with the exception of the Long Range Mountains and the Southern Labrador section. For segments of the LIL where Hydro has adjacent assets, the design team utilized loads that were equivalent to or greater than the past design criteria used by Hydro. As a result of such experience, Hydro believes that by adopting the high range of the combined wind and ice loads in accordance with CSA standards, the design would have been conservative. This includes the heavily loaded Avalon section where Hydro has the ability to compare to design upgrades completed in 2000, and which have not since experienced any major issues.

Haldar & Associates recommended that additional investigation should be completed to identify any areas where operational experience is limited (i.e., Labrador) and where such an increase in load could result in failure if these extreme loads are experienced. During the Haldar Assessment, the Long Range Mountains were assessed with respect to the high range of combined wind and ice factors and therefore would not require any additional assessment.

The Southern Labrador section of the LIL has the least operating experience from Hydro's perspective. Due to limited lines in the area, it is difficult to determine if the line could potentially be exposed to such onerous combined wind and ice loading. In addition, due to the sustained cold temperatures in Labrador during the winter months, the residence time of ice accumulation on the cable will increase the likelihood that the infrastructure could potentially experience the upper level of the combined wind and ice scenario as there will not be an opportunity for the ice melt between storms as commonly seen on the island portion of the province due to warmer temperatures. Due to unknowns in the area, the designers of the LIL actually increased the maximum ice loading for this area when compared to CSA standards, which should enable the support structures to better accommodate the additional combined wind and ice load.

Hydro plans to complete the further analysis as suggested by Haldar & Associates to understand the effects of using the high range of combined wind and ice factors on the Labrador section only. It is felt that as a result of inadequate operational experience in this area and recent storm damage occurrence; there is merit in better understanding the risk associated with such unknowns. This is of particular concern for any areas that may be exposed to increased wind loads as a result of wind speed up effects due to sloping terrain.

Progressive Tower Analysis

Based on the design criteria and current modelling techniques, a support structure analysis will fail based on the weakest load carrying member becoming over utilized. A member failure does not mean that the tower will actually fail. In some cases, as the governing member becomes overstressed and fails, the load will re-distribute to other tower members. The reliability analysis discussed in the Haldar & Associates report is based on the governing member and is dependent upon the weakest tower component failing, which does not necessarily result in tower collapse and therefore power interruption if repairs are made in a planned fashion.

Haldar & Associates recommended a progressive tower analysis for a few critical structures to estimate the collapse probability of a coupled structure support-wire support system. The progressive tower analysis is a specialized finite element analysis that allows these non-critical members to fail, thereby re-distributing load to other members systematically until the load is transferred to a main structural member that upon failure will indeed cause the tower to collapse. In theory, this analysis will increase the reliability of the infrastructure as it will now be based on the actual tower collapse and not just local buckling of a member, which is the basis for the DLS and ULS conclusions. A local member buckling may not cause any power flow interruption and therefore be sustainable through a power supply season and provide the utility with an opportunity to replace prior to the next loading season.

The Haldar & Associates report identified that the cable system is the governing component which dictates the reliability of the LIL. This differs from typical utility practise in that the cable system is typically the strongest component to avoid a major cascade event. As the governing component is the cable system, Hydro does not feel that a progressive tower failure analysis that focuses on the tower components and not the cables is warranted for the entire line. However, it has been identified that there are some critical support structures that when analyzed under increased loads (i.e., increased combined wind and ice, wind speed up factors, and unbalanced loading), as identified during the sensitivity analysis carried out by Haldar & Associates, become the governing line component.

Hydro plans to further investigate critical structures, via progressive tower analysis, that may pose an increased risk to reliability of the LIL (i.e., at what point the tower will actually collapse thereby resulting in an extended bi-pole outage) in instances where increased structure loading (as identified as per sensitivity analysis) has the potential to result in transition of critical components from the cable system to the support system. The extent of this work will be dependant upon results observed from several of the other recommendations.

Extreme Event Correlation Study

The Haldar & Associates 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. The alternative method used in the Haldar & Associates report assesses the reliability based on the establishment of four different climatological regions established by past operational experience. This methodology is outside of the CSA as the standard does not account for the impact of line length. Effectively, within the CSA, the reliability of a 1,100 km line is calculated in the same manner as a shorter line (i.e., 200–250 km of line of which Hydro has many). Haldar & Associates feels that this is not a valid approach for a line of such length and has identified that, in comparison to failure statistics experienced by other utilities throughout the world for similar length infrastructure, the increased probability of failure is a realistic possibility and similar results would be expected as additional operating experience is gained. To Hydro's knowledge, consideration of full line length was not a standard design consideration pre-CSA 60826 and it remains unclear how widely adopted such an approach is at present.

The Haldar & Associates report recommended the completion of a correlation study for extreme events to validate the criteria used in the analysis. If it is determined that similarities exist between correlated regions, there would be evidence to reduce the number of regional groupings thereby reducing the probability of failure and improving the assessed reliability.

As noted in Hydro's response to Board Request 1, Hydro has yet to finalize its position with respect to Haldar & Associates' recommendation on line length and extreme event correlation. Hydro plans to investigate this concept further before accepting any findings. The concept of having a higher probability of failure based on an increased line length is a practical deduction (i.e., the longer the line, the greater potential for exposure); however, based on this theory, in order to obtain a specific reliability based on established design criteria, the utility would have to design all sections in exceedance of the actual requirements. In addition to this, the concept is not acknowledged by the governing Canadian Electrical Utility and does not appear to be widely practised within the utility industry.

Event Tree Analysis

Based on the DLS analysis, the mechanical failure limits of the LIL are not expected to be reached and therefore, theoretically, it should not represent an extended outage scenario for the LIL. Exceeding DLS limits could potentially result in operating issues if the environmental conditions (hazards) that led to the exceedance of DLS persist for a long duration or occur frequently; for example, if the cables stretched under conditions beyond DLS parameters but did not fail and windy conditions prevailed, such stretched cables could encroach on other equipment causing intermittent interruptions of power flow. Haldar & Associates recommended investigating the effects of surpassing the DLS limits with respect to violation of critical electrical clearances which potentially result in momentary outages.

Hydro recognizes the operating risk associated with load scenarios that could potentially result in the exceedance of the DLS and approaching ULS limits. Hydro plans to complete the analysis as suggested by Haldar & Associates to understand the effects of surpassing DLS limits with respect to violation of critical electrical clearances which could potentially result in momentary outages by assessing critical clearances between different components under specific load cases that could result in such occurrence. As this occurrence is not suspected to result in a bipole outage, it is considered to be a lower priority for the purpose of this study.

Request 5: A schedule with identified milestones to complete all the recommended analyses.

Response:

Table 1 outlines Hydro's schedule for the work it plans to undertake with respect to the additional considerations identified by Haldar & Associates in its recent assessment.

Table 1: Additional Considerations – Anticipated Schedule

	Activity	Completion Date
1	Unbalanced Ice	June 30, 2021
2	Wind Speed Up	August 31, 2021
3	Pole Conductor Size	June 30, 2021
4	Combined Wind & Ice	July 31, 2021
5	Progressive Tower Analysis	To be determined – this activity will be dependent upon results from activities 1–4 and, if required, will be completed for critical structures that are negatively impacted due to the combined effect of the recommendations above. If undertaken, the analysis is expected to take up to 3 months.
6	Extreme Event Correlation	To be determined – Hydro has yet to determine its position with respect to this consideration and over the course of the coming weeks expects to determine whether it should proceed with further work in this regard. Hydro will update the Board upon its final determination.
7	Event Tree Analysis	To be determined – this investigation is not critical to the reliability analysis as it is not expected to have an impact on an extended outage and should not influence Hydro's system planning requirements as part of the Reliability and Resource Adequacy Review. Hydro will further assess this activity to determine if concerns exist with respect to short interruptions.

It is Hydro's intent to complete as much of the work as possible in parallel to minimize the overall time required. As noted in Table 1, activity 5 is dependent on activities 1–4 and, therefore, will have to be completed sequentially.

Conclusion

Hydro accepts the findings of Haldar & Associates with respect to the CSA and ULS return periods. Hydro has yet to determine its position with respect to Haldar & Associates' consideration of overall line length and regional correlation impact. Hydro supports the further investigation of the recommendations related to unbalanced ice loading, wind speed up factors, pole conductor sizing, and combined wind and ice. Some of the items identified are considered to be over and above typical design within the utility industry and not commonly practised in past engineering designs completed by Hydro and, as such, additional research is warranted to determine if the impact is of concern.

Hydro will present its results to the Board once all components of its work have been completed. Hydro will update the Board at the end of July 2021 as to the status of the remaining items identified in the table.

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

SWalsh

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