Fourteenth Quarterly Monitoring Report on the Integration of Power Supply Facilities to the Island Interconnected System

Presented to:

The Board of Commissioners of Public Utilities
Newfoundland and Labrador

Presented by:

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1. Purpose of this Report

This report examines fourth quarter 2021 scheduled and completed activities undertaken as part of completing the Lower Churchill Project (LCP) assets and integrating them into the province's electrical system. Previous reports focused significantly on the efforts of the Transition to Operation (TTO) organization to which Nalcor assigned a large role in these activities. That organization ceased its operation as 2021 ended, with the range of the activities formerly within its scope narrowed to a comparatively small number of open items. Its remaining completion and integration activities have transferred to elements of the management structure responsible for the functions and responsibilities to which those activities relate. The management structure itself has changed, with planning, design, construction, and operating responsibilities formerly performed by Nalcor now integrated into an organization led by Hydro's executive team. Our monitoring of work remaining to complete construction, testing, and transitioning LCP generation and transmission assets continues to engage the same leads, but operating now under Hydro direction.

This report therefore continues to address key elements remaining to transition the Muskrat Falls generating and transmission assets to commercial operations. The report examines current status of progress made in addressing overhead dc line, synchronous condenser, and sea electrode issues raised previously. While moving the generating units at Muskrat Falls into commercial operation has gone more smoothly, issues remain there as well. Finally, progress in completing the vast

majority of what had fallen under the TTO organization has nevertheless left open the completion of other important activities now transferred to designated Hydro groups.

The LIL has continued to suffer major setbacks, which continued after our regularly scheduled meetings with management to address events of the last quarter of 2021. Those meetings took place on February 11 and 17. We preceded the first meeting with a detailed list of agenda items for discussion, supplementing it after receipt of the early February Hydro Board update on LIL status. Written information provided by Hydro and those meetings gave great concern about the methods being employed to surmount very longstanding issues with LIL protection and control (P&C) software still under development by GE, and raised other issues as well.

We posed to Hydro on February 14 what we hoped would comprise a final list of questions. We still await answers to them more than three weeks later. While awaiting the answers, we learned through Hydro's regular LIL update to the Board of another disappointing event - - this one raising very large concerns about the manner of conducting LIL testing and even about the prospects for bringing it into full scale, as-designed operation on the basis that planning standards require for assessing reliability.

This report addresses events, circumstances, and concerns from and about the first two months of this year as well. Their significance compels discussion now - - a report limited to the last quarter of 2021 could present a representation of where work on the LIL stands that exists too far at variance from what we have become convinced is the case now.

We have reviewed each Hydro monthly LIL update since our last quarterly report, including, as noted, the March 3 version. We have also reviewed and discussed with Hydro responses to a series of questions. We have at present no promised date for answers to the most recent questions. We will revise this report if and as we receive them, but feel it important to report now on what we do know, particularly given its seriousness.

2. Major Observations

LIL Progress: The LIL returned to operation on October 15, 2021, after which its intermittent energization permitted dynamic commissioning tests. Those tests employed a December 9, 2021 GE Stafford ("GE") release of a version of the Full Function Bipole ("FFB"). The tests led to LIL release for operation. A December 11, 2021 Bipole trip, with the LIL carrying 300MW, resulted in underfrequency load shedding (UFLS) disrupting service to approximately 22,000 customers, with power restoration within 18 minutes. Management described the bipole trip as an expected event under the circumstances. We categorically disagree. Management should find most troubling the continued existence of critical software flaws after an already extraordinarily long software development period.

Testing has continued to fail the purpose of finding and correcting defects before pressing the system and customers into service as the test bed for discovering remaining problems. Their existence must, as has been true now for a long time, be presumed to continue to exist. We found equally disquieting management's reference to continuous operation since December 12 (then about two months) as indicative of its ability to operate reliably. Unsound even then, its inaptness

became more clear with another, soon-to-occur failure of the software to operate correctly. Following a trip of one pole resulting from fire alarm activation, an additional failure of the software to operate properly occurred. That failure has produced yet another indefinite LIL shutdown while GE explores the additionally discovered and critical software deficiency, even as it continues to address other problems with the software. Note that the alarm falsely indicated a fire threat due to a sensor failure, fortunately meaning no fire threat to personnel or equipment had actually occurred.

Even before this latest LIL setback, we raised with management the concern that it had become impossible to assign any realistic completion date for the LIL. Management contested that notion, but now, just a few weeks later, it appears that the latest setback has made it no longer willing to peg even a broad date range for expected commercial operation. Before the most recent events, its approach had been to assign an "adder" to GE's estimated dates for key milestones.

In short there is no projected or projectible schedule for LIL completion from management; we can offer none, and we place no confidence in the schedule now indicated by GE. There is no basis for projecting a reasonably confined date range date for LIL commercial operation at full capability as designed. That date may well come as far as 12 months or so from now, and perhaps significantly longer. As troubling as the implications are regarding the eventual ability of Hydro to secure the assets and performance for which customers must pay, we believe a more immediate, critical concern exists. Hydro now faces the need to select the best path forward for operating through yet another coming winter season without a reliably performing LIL.

Right now, the P&C software will not support operation at any power level in a manner that system operators can consider dependable. The ***first question*** that arises is whether the LIL will prove important in ensuring reliability next winter at some reduced power level. If so, the ***second question*** becomes whether there is some means for providing software that will support reliable operation at that reduced level. If not, then continuing the current struggle with no clear end date in sight remains a viable course. If so, however, a ***third question*** arises; *i.e.*, will a focus on that struggle foreclose reliable LIL operation next winter on which system operators can rely in accord with their normal conception of reliability (considering both shorter underfrequency load shedding and longer duration outage events). If we reach the answer to the third question and that answer is "yes," then the time has come to take a LIL path designed to make it a dependable contributor in serving next winter's needs. In any event, if it took more, the latest failure should make clear the risks of continuing to make the system and customers, not simulation, the environment for discovering new software problems and for ensuring that changes make only fixes and not new problems.

We understand the frustration of those whose mission has for so long been defined as reaching key LCP completion milestones. We also give them credit for respecting the need to do so without damage to other needs and priorities. That said, however, it is time for those responsible for operating the system to lead efforts, with project expertise where and as it exists and is needed, to answer the three questions in short order. Should those answers all be in the affirmative, their interests as system operators, as opposed to project and commercial milestones need to prevail in guiding efforts to place the LIL in reliable operating mode for next winter. Those responsible for

those milestones did not offer sufficient comfort in framing the discussion of reliability or in with respect to normalcy of and tolerance for the system and customer consequences risked by "live" testing.

Synchronous Condensers: GE continues to maintain that the elliptical bearing modifications to the synchronous condensers have managed the vibration issues and that the machines demonstrate fitness for their intended purposes. However, Hydro has reported that analysis of vibration data continuing to be collected has indicated several non-conformances related to shaft critical speed, foundation size, and resonance. We had been given to understand previously that no non-conformances existed, although concern existed about long-term effects of a solution that counteracted, without eliminating vibration root causes.

We have understood for a long time now the concern of the outside consultants about long-term impacts of operating with the equipment as modified by elliptical bearing modification. Hydro plans to continue vibration monitoring during the warranty period and as key operating milestones approach, for purposes of assessing whether it has grounds for further modification or relief. The circumstances make clear that the underlying issues create a risk of long-term implications (*e.g.*, outage rates, repair needs, early unit retirement), whatever warranty and performance milestone decision points may arise. Hydro continues not to feel confident (immediately, it is important to emphasize) in urging a change from the current configuration, but plans to assess impacts of the current configuration and continuation of the root cause of the vibration issues on long term operations. We requested additional information about the monitoring program to identify the specific data needed to determine whether long-term risk exists. Circumstances raise the possibility that commercial negotiations will provide the vehicle for addressing the uncertainties involved. We stress the importance of assessing the risk and likely consequences of long-term consequences in determining how best to apportion risk and responsibility.

Synchronous Condenser Unit 1 (SC1) experienced a bearing failure in early 2022. The failure resulted from adjustments to the lubrication system and subsequent damage to the bearing. Hydro anticipates a five-month duration to repair the bearing - - three months to replace the bearing and two months for post commissioning checks.

Storm Event Repairs: After last quarter's completion of repairs following the previous winter's weather conditions in Labrador, a drone-supported inspection confirmed management's belief that no significant repair and replacement issues remain. Delivery issues delayed completion of planned anti-galloping devices on southern Labrador spans. Risks of similar exposure at other locations remain under investigation, with plans to address those exposures as part of the Reliability and Resource Adequacy Study. Plans continued for the securing of 24/7 road clearing resources and for adding access to additional line contractors to expand resources for responding to line failures.

An outside engineering firm has completed a report finding the elevation of the breakwater protecting the L'Anse aux Diable Electrode Site Sea electrode elevation about one meter lower than required, given the winds and waves that occurred in this area. Several additional recommended studies remain underway, with a scheduled end-of-March 2022 completion. The

results of these studies will inform redesign and modification of the breakwater to make it less likely that a similar event will damage the sea electrode in the future. Construction to an updated design is slated for 2022.

A review of design of the electrode on the island of Newfoundland, equally essential for reliable operation of the LIL, had not been considered. We did not find sufficiently cautious management's observation that no damage had occurred at this electrode site. Without proper study, there can be no confirmation that full parity exists in any of its design, construction, or conditions it may face. We found troubling the lack of attention to date either to validating that threat parity exists between the two sites, or in the absence of such validation, commencing the work needed to assess risk and consequence at the second site.

We also continue to have concern about the absence of remote monitoring to check electrode integrity at hard-to-reach sites. Essential equipment remains exposed to unrecognized damage and too high electrical resistance. Such damage could have the potential to cause UFLS, in the event of a fault producing a LIL pole failure. We have seen remote electrode monitoring at other GE projects, but it is not being considered for this project.

Muskrat Falls Generators: All units have been released to operations. Unit 2 has returned to service at a constant power of 140MW following a vibration incident. Andritz remains engaged in determining vibration root causes. After identification, an outage on the unit is intended to further pursue the issue. The duration and schedule for the repair will be determined after the root cause has been identified.

Overall TTO Schedule Status: The TTO activities' schedule completed in December of 2021. Any TTO activities not completed were turned over to Hydro for completion. The majority of the original TTO activities are complete with some remaining items open relating to staffing, O&M Procedures, Emergency Plans and Training.

Staffing and Training: Human Resources has responsibility for filling positions under the current plans, which comprise approximately 200 positions. It has filled all but 13 of the positions called for by current plans. Manitoba Hydro International personnel continue to fill five Hydro Operations positions under a services contract. All training associated with asset release for service Phase I and Phase II are now complete with the exception of eight outstanding training sessions (two Phase I and six Phase II).

Muskrat Falls Site Emergency Response: The Muskrat Falls site Emergency Response ("ER") responsibilities transitioned from the project to the site at the end of December. Seventy-five percent of the standard operating guidelines was complete as of the end of 2021. A contract was awarded to an ER consultant to provide resources to supplement the volunteer ER team. The contracted support is for a period of 12 months with the intention to gain sufficient resources to no longer need a contractor.

Maintenance Programs Build Out: A total of 238 O&M manuals require completion for the project for the generation and transmission assets. Of these, a total of 202 O&M manuals are complete. Of the 36 remaining, 22 are complete and in review with 14 still outstanding.

MPPA/IOA Progress: Yet again, we received word at our meeting with Hydro on February 17 of the imminence of completion of the MPPA (on which execution of the reportedly completed IOA is conditioned). However, Hydro's March 3 monthly update reported another in what amounts to numerous extensions of time for completing it. It does not appear from Hydro's perspective that the flow of energy into and through the Hydro Quebec system that agreement completion will permit has near-term criticality. MPPA completion has now found itself hung up for many months for reportedly minor matters still in resolution or language crafting. The length of time it has taken and is still taking suggests more than non-substantive matters remain. We no longer have comfort in assessing the continuing belief of Hydro that the agreements are on the verge of execution, whatever the significance of what remains to do so.

Other Agreements: All 56 transmission support contracts are in place and most generation O&M contracts reached completion (58 of 61), with turnover to operations. Remaining contracts for inventory spares and establishment of long-term warehousing remain outstanding. However, a lag in completing the open Andritz maintenance contract, on hold pending resolution of commercial issues, bears continued monitoring.

3. Detailed Findings

a. LIL Progress

No problems have been reported with the replaced beams. After returning to operation on October 15, 2021, the LIL was energized intermittently to permit dynamic commissioning tests. On December 9, 2021 GE released a version of the FFB software to site. Following a series of Dynamic Commissioning tests, the LIL was released for operation. However, on December 11, 2021 the LIL experienced a Bipole trip while carrying 300MW, resulting in UFLS affecting approximately 22,000 customers until full power restoration after about 18 minutes.

A Bipole trip's should occur very rarely, at rates of once per ten years or less. They can cause very large customer impact. The length of and the number of customers affected by the December 11 Bipole trip indicate that the LIL was not carrying a very high load, *i.e.*, not more that 335MW, with adequate supply sources available at the time.

However, the event raises serious concerns with respect of the quality of the P&C Software, and the likelihood of achieving full operation of the LIL in the near future. GE and LCP management were aware that this version of software was not suitable for Trial Operations and Final Commissioning due to an unknown number of unresolved critical punches. The LCP permitted GE to release this version of software to test the stability and robustness of the software, not in a simulated environment, but employing the province's electrical system and its customers as the "test bed." Management sought to describe this approach as normal and expected, given the inability of simulation to operate sufficiently effectively to provide a suitable test environment. We strongly disagree that this is normal of software. That the software here still suffers significant

failings after so many years of development and failed testing may expose customers and the HVDC system equipment to risk. Good management should not consider doing so normal.

GE has designed other HVDC schemes that achieves Bipole Operation without these issues, so it is possible. We question whether adequate testing of the software, at both GE Stafford and at site, was performed before the software was released. GE seem to perform insufficient Bipole testing on the software before submitting it to site. Extensive testing in the factory can be safely performed, without impact on consumers, and is the normal practice by most manufacturers.

At the time of our January 2022 meeting, GE and LCP also hoped that this next planned version would support Trial Operations and Final Commissioning, with a completion targeted for May 31, 2022.

We placed no confidence in that date at the time of our meeting with management. We addressed at that time the grounds for concluding that no firm schedule date or even a range could be established, expressing the view that circumstances suggested a high risk that completion could extend for an additional 12 or more months. Management pushed back against those observations, stating that adding a further 30 days to GE's schedule made sense under the circumstances.

Given GE's past experience on this project with control software development over several years, the likelihood of successful completion of Trial Operation (the last step in reaching commercial operation) by May 31, 2022 was already highly improbably - - seemingly impossible - - at the time of our meeting with Hydro. However, circumstances may leave open the possibility for the LIL to transmit power from Labrador at reduced level in time for the winter session that will begin later this year.

Management stated that the present version of software had been operating continuously at various levels, up to 435MW, since December 17, 2021. However, Hydro's March 3 monthly LIL report brought more bad news about the LIL software, which had reportedly operated at levels up to about 320MW during February. A February 20, 2022 Pole 1 fire alarm activation (later fortunately determined to be false) caused a trip, with load effectively transferred to Pole 2. During Pole 1 re-energization and restoration of bipole operation, an operator error tripped Pole 1 again on February 25, necessitating execution of the LIL ramp down procedures. A software failure prevented correct operation of the ramp down process, leading to a LIL shutdown for investigation. The LIL has remained shut down since then.

This additional software failure adds significantly to the extent of software failings, the emergence of yet another one, its criticality to LIL operation, the failure of test after test to have identified it previously, the risk that fixes of current problems are creating new ones, and the hazards of using field operations as a substitute for effective simulation-based testing. It also raises the need to consider questions about operating procedure and training effectiveness

The circumstances also underscore what we had concluded before the late- February events - - no reasonable projection of LIL commercial operation at full capability can have substantial

credibility. The March 3 Hydro report may be moving finally in a similar direction - - it contains no projection of delay length, which it now simply describes as "impossible to predict."

b. Synchronous Condensers

Two Synchronous Condenser units (SC2 and SC3) are available for immediate service. SC1 suffered bearing damage during a lube oil adjustment during testing by GE. In-progress SC1 work has a June 2022 completion schedule. Both SC1 and SC2 successfully completed the 100 percent load tests and SC1 will undergo load testing following bearing work. GE continues to maintain that the elliptical bearing modifications have adequately addressed the SC vibration issue, leaving machines fit for purpose. Steady state vibration levels remain within specification requirements per ISO 7919-5. However, expert analysis of vibration signatures reveals circumstances first learned by us this quarter - - several specification non-conformances relating to the critical shaft speed, foundation size and resonance are occurring.

Management has reported that the configuration, while bringing vibration levels to within requirements, nevertheless entails operation that continues to produce vibration signature anomalies. LCP's outside experts indicate that resonance and vibration present could prove detrimental to long term operation of the units. However, it remains difficult to quantify the vibration anomalies and their impact on long term operation. Monitoring of vibration data remains ongoing. We requested copies of the third-party expert reports and the specifics regarding the additional vibration monitoring plan. Hydro continues to find insufficient basis to direct GE immediately to undertake foundation modification at this time

c. HVDC OHL

We reported last quarter that management had completed all repairs required to restore power transfer capability to the LIL overhead transmission line (OHTL) in Labrador and conducted a drone-supported inspection. Repair and inspection work has disclosed no significant issues. Delivery issues have delayed completion of the installation of anti-galloping devices in the southern Labrador spans considered at risk. Management continues its longer-term investigation of the risks of similar exposure at other locations and means for addressing any found across the line's full length, for consideration as part of the overall Reliability and Resource Adequacy Study.

Management plans to secure 24/7 availability of additional road clearing resources to expedite access to repair locations. Management also has under preparation a solicitation designed to secure by this coming October access to resources from an additional line contracting company that can provide power line technicians, engineering expertise, heavy equipment, and tooling to expand resources available to address line failures.

d. Sea Electrode Issues

Tiller Engineering has completed its report, which determined that the breakwater that protected the L'Anse aux Diable Electrode Site Sea electrode was about 1m lower than required, given the winds and waves that occurred in this area. Several additional recommended studies are being performed with a completion date of end of March 2022. The result of these studies will enhance the design of the breakwater and will make it less likely that a similar event will damage the sea electrode in the future. Construction to an updated design is slated for 2022.

No plans existed to assess the design of the Newfoundland-side electrode and the external conditions to which it is exposed. This second electrode site and its design also require review.

The absence of remote monitoring of this remote site, to check the integrity of the electrode, will leave it exposed to unrecognized damage and too high resistance. Remote monitoring of the electrode exists at other GE projects. Damage or degradation of the electrode could have the potential to cause UFLS, in the event of a fault on one pole, by producing a LIL bipole failure.

e. Muskrat Falls Generators

The head cover modifications and additional welding are now complete for the Muskrat Falls generating units, with each unit released to operations. Unit 1 experienced an oil release in September during the securing of oil samples. During the water-up of the unit, the turbine pit became flooded. The unit has returned to service.

Unit 2 experienced multiple unit trips due to high vibrations during power reductions. The installation contractor completed an interim assessment of the event, and the unit returned to service on October 14, with operations restrictions (to keep unit operation at a constant 140MW) until investigation and resolution of the vibration issue. Preliminary assessment of the unit indicates that one of the runner blades moves out of alignment with the other runner blades when reducing power. The contractor has not provided a date to complete the root cause analysis of the vibration issues. The root cause analysis will also address the other units' susceptibility to the vibration issues of unit 2.

f. Staffing

All changes to the organization now fall under the responsibility of the Human Resources organization. The next chart shows vacancies using the current organization structure, alignment, and positions that Human Resources has responsibility for addressing.

Organization Title	Vacancies
Transmission Operations Work Mgmt. and MF	0
Transmission Operations Soldiers Pond	2
Power Supply Production & Energy Marketing	8
Engineering Services	0
Engineering Services Operations Support	0
Engineering Services Project Execution Gen.	0
Eng. Services Business Services	3
Portfolio Asset Mgmt.	0
Totals	**13**

Management still records five Hydro Operations positions as vacancies (shown in the Power Supply Production & Energy Marketing total). Manitoba Hydro International personnel have filled these operations positions under a services contract. Five hydro operations' apprentices have completed the two-year apprenticeship program, with offers now under preparation to fill the positions. We did not find the vacancy numbers unusual or troubling under the circumstances.

g. Training

Two HVdc courses remain outstanding. GE provided planned training dates for these courses but they were postponed due to winter readiness taking a higher priority. 45 of the 53 generation training sessions have been delivered to date. Thirty-two of the 34 planned Phase I training sessions are complete, as are 13 of the 19 planned Phase II sessions. The six outstanding sessions consist of two sessions for the load management systems, two for the fire and protection systems, and two re-runs of the turbine and generator sessions.

h. Procedures

There is a total of 238 O&M manuals to be completed for the project for both the generation and transmission assets. A total of 202 O&M manuals is complete. Of the 36 remaining O&M manuals, 22 are complete and in review and 14 are still outstanding.

i. Emergency Response

Management established an interim operations ER model in the fourth quarter 2021 and awarded a contract to an ER consultant to supplement the volunteer ER team. The long-term goal remains to grow the volunteer base sufficiently to obviate the need for contractor resources. Work also continued on finalizing the standard operating guidelines with about 75 percent of the guidelines complete as of the end of the last quarter 2021.

j. O&M Contracts

All 56 transmission O&M contracts included in the TTO plan are complete and turned over to operations. Fifty-eight of the 61 generation O&M service contracts are complete. The three remaining O&M contracts include:

- Andritz Hydro O&M service contract
- Site Reclamation/Spares Consolidation
- SCADA Systems Support Contract

Hydro now leads the effort to complete these contracts.

k. Emera Agreements

One activity, the Regulation Service Agreement remains open. This activity is 95 percent complete and scheduled for completion by the end of year.

l. MPPA/IOA Progress

Hydro reported progress in resolving the issues preventing execution of the IOA, and that the MPPA remains conditionally approved by the parties subject to IOA execution. However, the expected date for execution has slipped to March 2022. Two material issues have advanced

sufficiently for turnover to counsel for drafting language incorporating consensus reached on the treatment of inadvertent energy and inclusion of CFL Co. as a party to the IOA for purposes of ensuring continuation of certain grandfathered circumstances and practices existing under legacy agreements involving CFL Co. that engage Hydro Quebec. Several other issues not deemed material by management reportedly are approaching resolution as well. They involve matters like CFL Co. IOA party status after 2041, defining the standard for measuring party performance under the agreement, and settling on the jurisdiction under whose laws the IOA will be interpreted.

Management does not expect the drafting process underway for the two larger issues or completion of agreement on the lesser ones as a threat to March IOA completion. However, history suggests caution in deeming March completion more than simply more likely than not to occur. An executed IOA is necessary to ensure the ability for imports to Labrador through Hydro Quebec or to support exports from Labrador. However, management reports no material threat of lost economy through inability to import or export to or through Hydro Quebec in the near-term. Potential sources of growth in electricity use in Labrador, however, do have the ability to have a material impact on energy and capacity resources after the next year or so.