Review of the Newfoundland and Labrador Hydro March 4, 2015 Voltage Collapse

Presented to:

Newfoundland and Labrador Board of Commissioners of Public Utilities

Presented by:

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1. Summary

On the morning of March 4, 2015, Hydro experienced system outages as a result of a voltage collapse. The system outages affected approximately 83,000 customers at the height of the event. Interruptions resulted from the triggering of automatic protection schemes and manual load shedding. Hydro and Newfoundland Power conducted investigations, and engaged in discussions with the Board. Board staff retained Liberty to review the utility reports, and present any material findings to the Board. The scope of Liberty's review included determining if any linkages existed to the underlying causes and contributing factors of the January 2014 outage events.

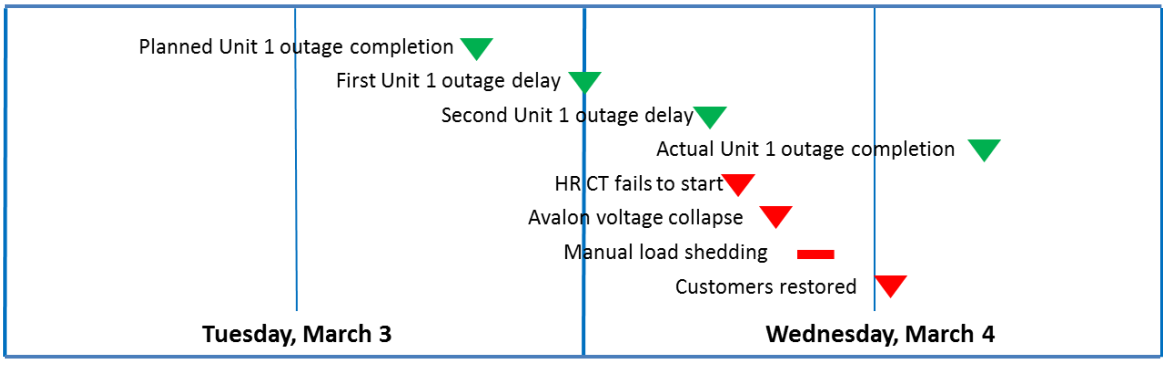
Liberty's examination shows that Hydro and Newfoundland Power took many positive and effective actions to deal with a situation with the potential for becoming far worse. Events unfolded quickly, which does not offer a blanket excuse, but does acknowledge that operators faced challenging circumstances. Counterbalancing these positive actions, Hydro has continued to plan for and react to contingencies less aggressively than do many other utilities. Liberty observed such an approach in our work associated with the January 2014 outages. Hydro's operating culture continues to comprise a matter of concern. With the operating culture issue identified in the aftermath of the January 2014 incidents, it nevertheless appears that Hydro has not accepted changing that culture as a priority. Liberty found that Hydro's reliability culture contributed to the causation and to the management of the March 4 event.

Looking forward, Hydro will face more severe system operating challenges when the Labrador - Island Link (LIL) enters service. Liberty considers it essential for Hydro to implement a more robust operating philosophy before that time.

2. Background

Illustration 1 summarizes the timeline of the March 4, 2015, events.

Illustration 1



a. Holyrood Unit 1

A February 19, 2015 routine inspection disclosed the presence of oil in the Unit 1 brushgear housing, a component associated with the generator. Hydro concluded at that time that the leak was small enough, and was not increasing, thus justifying deferral of repair until the next maintenance outage. The situation was monitored closely and Hydro's assessment changed on

February 26th with the observation that the contamination had increased. The observation that the danger of fire or flashover had also increased made prompt repair more urgent.

Hydro seeks to avoid any outages during the winter season, but it had no option in this case. System Operations, upon request from plant management, scheduled the outage to start the next day (Friday 27, 2015) and to end by the evening of Tuesday, March 3, 2015. Table 1 shows the planned and actual outage times. The voltage collapse occurred on Wednesday morning; *i.e.*, between the planned and actual outage completion times.

Table 1

Event	Planned	Actual
Outage start	Friday at 1200	Friday at 1500
Outage complete	Tuesday at 2000	Wednesday at 1600

Hydro initially delayed Holyrood Unit 1's return to service (originally planned for 2000 on Tuesday) to midnight of the same day. The station notified the System Operator at 0020 and 0028 on Wednesday of startup delay, but advised that the unit would be available in time to support the Wednesday morning peak (expected at 0730 or 0800). Holyrood personnel continued to work through the night to restore the unit. Notice came to the System Operator at 0524 that the unit would not be available for the peak. Unit 1 became ready for restart later that morning, but further delay occurred because Hydro gave priority to restarting Unit 3 after it tripped during the event. This further delay was not especially relevant since it occurred after the event. The fact that Holyrood can restart only one unit at a time due to staffing may be problematic, however, in other circumstances.

As Holyrood personnel worked to restore the unit, they were not aware that failure of the unit to be available for the morning peak would make the system highly vulnerable to a single contingency that could lead to load shedding.

b. Reliability Analysis

When Holyrood plant management requested the outage, System Operations and System Planning conducted the appropriate studies to assure maintenance of system reliability throughout Unit 1's unavailability. Further analyses on Monday, March 2, sought to identify potential voltage issues and facility overloads, assuming N-1 circumstances. Liberty's discussions with System Planning and System Operations produced the following understanding of the key conclusions that Hydro reached from these analyses:

- It was well known that voltage was the issue of primary concern.
- There was little concern for Monday or Tuesday, even with Unit 1 off, because the anticipated loads were not high enough to create risk.
- Hydro anticipated higher Wednesday loads, but the assumption that Unit 1 would be back for that day's peak alleviated concern.
- The modeling indicated that a single contingency could have serious consequences, should Unit 1 not return in time for the peak on Wednesday.

The analytical techniques used by System Planning and System Operations appeared to be adequate and to forecast correctly what configurations would and would not survive the

forecasted loads. Therefore, system vulnerability in the event of Unit 1's non-return was known. Liberty did not find any indication that this vulnerability was effectively communicated.

c. System Operations

Hydro's preparations for March 4th included plans to start all three combustion turbines at about 0600. Stephenville and Hardwoods (*i.e.*, the half of Hardwoods then available) started when called upon. However, at 0612, the biggest of the three (the 123 MW Holyrood unit) failed to start initially and on repeated attempts that operators made through 0630. Hydro deemed the delay in Unit 1 return to service and the failure of the 123 MW unit an N-2 event. Hydro also recognized that its modeling showed the need for load shedding under these two conditions. Reactions by the operators, however, indicate that they were not aware of this consequence, and Liberty could not determine that they were so informed.

In any event, the two people on shift at that time, the Shift Supervisor and the System Operator, were left on their own to deal with the deteriorating situation. Operators understand in such circumstances the criticality of monitoring closely and taking corrective measures to bolster voltage support. At no time before the event did generating reserves on the IIS become an issue. In contrast, reactive supply on the Avalon would create significant issues as voltage declined.

In the next half hour (0630–0700), the System Operator ordered more generation from Newfoundland Power, requested capacity assistance from Corner Brook and Vale, and ordered maximum voltage support from Holyrood Units 2 and 3. Nevertheless, as morning load continued to grow, voltage continued to decline.

At 0704, the System Operator advised Newfoundland Power that the need for rotating outages was near. At 0714, the system began to collapse. Capacitor banks, transmission lines, and generating units tripped on under-voltage throughout the next few minutes. During this time, approximately 83,000 customers were interrupted. Rotating outages, starting at 0805, continued through 1030. Operators succeeded in restoring all load at about 1230.

d. The Holyrood Combustion Turbine

The new 123 MW combustion turbine at Holyrood had operated well on prior days, but failed to start when called upon at 0612 on Wednesday morning. A fuel valve was positioned incorrectly. Hydro has provided no explanation for how the position of the valve changed from one day to the next, if indeed it had changed at all. Hydro considers the valve sensitive, which gives minor rotation of the handle a disproportionate effect on the flow of fuel. This sensitivity made it more difficult to align the valve for startup. Operators did so on their third try. Given the nature of this failure, plant personnel deserve credit for diagnosing the cause and adjusting the valve as quickly as they did. The unit started at 0725, but too late to prevent the event.

e. Communications

Following the January 2014 system events, Newfoundland Power and Hydro jointly developed an Advance Notification Protocol to guide customer communications when generation reserve margins are expected to dip below predetermined thresholds. To address lessons learned from those events, Hydro modified its T001 protocol to guide system operations personnel in notifying

senior leadership, Newfoundland Power, and other key stakeholders in the event of a projected shortfall of island reserves. Additionally, Newfoundland Power and Hydro created The Joint Storm/Outage Communications Plan to guide the timing and release of public information, depending upon the severity of the events involved.

However, the March 4th events did not cause the T001 protocol thresholds to be exceeded, because reserve margins were not the issue. As a result, Hydro's system operations personnel did not provide advance notification to senior leadership, Newfoundland Power, and other key stakeholders. Notifications began at 0718, subsequent to numerous trips and customer interruptions that had already occurred.

3. Analysis and Conclusions

a. The Primary Root Cause: Operating Culture

There are many lessons to be learned from the March 4th events, but Liberty has determined one overriding root cause. The current operating culture at Hydro, which does not appear to have changed since our review of the January 2014 events, continues to adversely influence Hydro's decision making and contributes to operational incidents.

Liberty developed concerns about Hydro's operating culture early in its review of the January 2014 events. Initial conversations with Hydro personnel disclosed that Hydro did not view the need to shed load during the supply shortage as a particularly unusual event. Operators felt that they remained in sufficient control of the system, and did not declare an emergency. Liberty's experience indicates the need to resort to rotating outages to comprise an exceedingly rare (once-in-a-career) event. Many system operators never experience it. Further, when events begin to require special measures, caution dictates concern and a special preparedness for identifying next contingencies that might take major sectors of or even the whole system down. Hydro's approach does not sufficiently consider such possibilities, because the ability to shed even more load remains as the primary response.

Liberty's preliminary report on the January 2014 events discussed "a culture more tolerant of rotating outages." The peculiarities of Hydro's system have necessitated a degree of automatic load shedding on the Avalon Peninsula. Liberty questions whether this inevitability contributes to a greater acceptance of outages in general. In any event, the existence of a similar culture, more accepting of shedding load and more tolerant of outages, remains evident some 18 months after the major events of January 2014.

This culture has three elements of consequence here:

- A greater tolerance for outages than Liberty has seen elsewhere.
- An uncommon approach to reliability engineering and analysis.
- A less rigorous approach to emergency management and preparedness.

As was true in our review of the January 2014 events, we have not sought to critique the long history of Hydro's use of these three elements. Liberty does, however, have concerns with whether Hydro's operating culture has adequately responded to changes in customer reliability

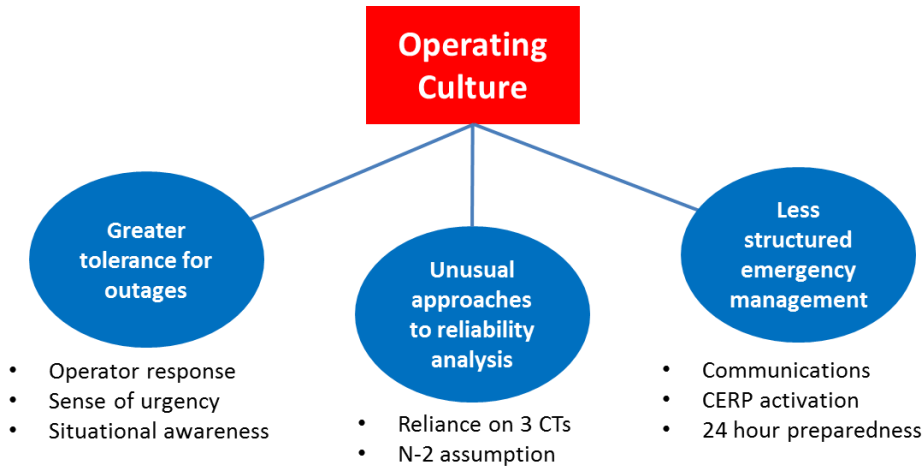
expectations that have moved toward alignment with those of other developed areas. Even if there were good reasons to settle for less in the past, it remains necessary to respond to what customers expect today. In addition, electric reliability has substantial public safety implications. They are, if anything, more significant on the Island, given its harsh winters and high degree of dependence on electric heat.

The arrival of the LIL in a few years will increase the stakes substantially. If managed properly, reliability should improve. But new operating challenges will arise from a massive source of supply from a single off-island source. Both now, and even more so in the near future, Hydro needs to enhance its operating culture and associated practices to assure customers that this new operating environment will be managed responsibly.

b. The Operating Culture and March 4th

A number of factors contributed to or exacerbated the events of March 4, 2015. The following illustration summarizes their relationship to Hydro's operating culture, which Liberty views as the root cause of the March 4th events.

Illustration 2



1. System Planning and System Operations should have communicated the vulnerability of the system to responsible operators and managers, including the System Operator and shift personnel and Holyrood plant management on the morning of March 4th.

System Planning states that it modeled the March 4th situation days earlier, and that modeling correctly simulated a voltage collapse under the assumptions of a concurrent Unit 1 failure to return to service and a single, other failure. It does not appear that operators knew of this potential. Holyrood personnel clearly did not know it. At 0524, upon learning that Unit 1 would not be available for the peak, the System Operator should have known that the system operated in a precarious state.

Liberty believes that, had the System Operator known of the true situation, he would have triggered actions at 0524 or sooner. Those actions presumably would have included immediate startup of the three combustion turbines. Upon failure of any of these three sources, the System

Operator would logically have been expected to take other steps, up to and including emergency preparations and notifications for potential load shedding.

Awareness of the true nature of vulnerabilities would also logically have caused Holyrood operators (knowing the urgency associated with a delay to startup) to seek other means to return the unit to service or, at least, to be more specific and accurate on when the unit would be available. Plant management does not agree, and insists that plant personnel were already doing everything possible. Regardless, questions remain about what they would have done with full awareness of the criticality of the unit's return. Operators and maintenance people become maximally innovative when confronted with a true emergency. Alternative solutions, cutting a few corners on an informed basis, and responsible taking of atypical risk become important to consider in such conditions, while recognizing the primacy of personal safety and avoiding plant damage.

Liberty discussed with Hydro how information valuable for plant management to consider is communicated. Hydro advised that a daily report of system generation and load status comes from System Operations to Holyrood personnel, Newfoundland Power, the Board, and others. Communications such as these daily reports to such a broad audience do not have the depth required to communicate to operators the kind of matters at issue here.

2. Hydro's characterization of the event as N-2 is questionable and the philosophy underlying it comprised a significant contributing factor to the event and its management.

Hydro has squarely attributed this event to "the combination of both these units (Holyrood Unit 1 and the Holyrood CT) being unavailable as customers' morning demand rapidly increased." Hydro describes the unavailability of both units as two separate, independent contingencies. Hydro's view would have more validity had Unit 1 tripped on the morning of March 4th, but the unit had not been on for a period of time prior to the event, and continued to be off as the events unfolded.

Recognizing the precarious situation that would result if Unit 1 could not be placed in service, sound reliability analysis should assume unit unavailability. This approach becomes increasingly more correct and urgent as one gets closer to the start time. For example, when the unit was not back in service by midnight, as planned, and a delay was announced at 0020, the risk it would not be available grew significantly. At 0524, it was no longer a risk but a reality. Yet Hydro believes that the event that occurred two hours later was an N-2 condition.

We have been critical of Hydro's approaches to and capabilities in reliability engineering. There have been numerous examples cited in our prior reports of reasoning that we have termed unusual at best. The events of March 4, 2015 provide another example. The characterization of the events as N-2 does not hold together. It may have made sense a day or two before the event, but not hours before the event, and certainly not now, months later. Liberty continues to believe that Hydro should be significantly enhancing its capabilities to plan and manage reliability contingencies. To suggest today that this event was N-2, and therefore unexpected and somehow acceptable, is wrong.

3. Reliance on three combustion turbines to start does not reflect a reasonable view of their reliability record.

Hydro entered Wednesday morning with a 165 MW unit still cold and assuming that three combustion turbines (two of which have a poor reliability record), would start when needed. The chance that all three combustion turbines would actually start when requested at 0600 reflects little more than a 50-50 proposition. Liberty finds Hydro's reliance on a start of all three units when called a too aggressive planning assumption. Relying on all three units to start involved too great a risk.

4. The System Operator's lack of urgency, whether due to lack of good information or otherwise, contributed to the event.

Operators often find themselves in challenging situations with limited time and sometimes limited information with which to make important decisions. No utility person wants to be in the position of having to "open the switch" on customers. We can observe a number of actions that might have occurred differently, but do not necessarily find fault at the individual level, given the weight of the pending decisions, the limited timeframe for analysis and action, and the lack of added support that otherwise might have been available through activation of the Corporate Emergency Response Plan (CERP).

Specific actions that could have been taken, and in retrospect probably should have been taken, but were not include:

- Given that the system could not survive an N-1 event, emergency notifications might have been made at 0524 when it was learned that Unit 1 would not be available.
- The failure of the new CT to start at 0612 could have precipitated an activation of the emergency plan.
- Notification of the Holyrood CT's unavailability was delayed to 0651, with the System Operator anticipating its startup "at any moment." It is not clear what basis, if any, existed for this expectation.
- The request for only 20 of the 60 MW available from Corner Brook at 0636 and delay of the Vale request until 0700 suggest an underestimation of the emerging problem.
- Rotating outages, the possibility of which should have been apparent all morning, were not suggested as possible until 0704 and not implemented until 0805. A quicker start to load shedding may have prevented or mitigated the loss of control.
- Holyrood diesels were not called upon until 0913.

5. Hydro's unwillingness to declare an emergency and activate its Corporate Emergency Response Plan (CERP) was not appropriate.

The decision not to declare an emergency or activate its CERP reflects a culture that considers major outages "normal" and easily managed. This approach places undue burden on operators. Liberty found Hydro's failure to activate CERP during the supply emergency of 2014 inappropriate. We believe the failure to do so on March 4, 2015 is also inappropriate. These decisions are symptomatic of a culture that does not view such emergencies as demanding an aggressive management response. A number of reasons exist to mobilize under CERP in these situations. There is a need for more resources on-site in emergencies to provide a critical source of assistance to operators. This support enables operators to concentrate on the focused set of

actions needed to manage the system. In the meantime, a broader group of managers can focus on the other issues, such as anticipating the next contingency, handling public communications, coordinating restoration and repair efforts, providing technical support, and maintaining overall command and control of the incident.

It is not clear why Hydro continues to be reluctant to take this important step as emergencies emerge. The results are that system operators are not provided the support they need and other tasks, such as effective communications, are not given sufficient attention.

6. Hydro was not well prepared for an emergency at this particular time of day.

Numerous Hydro employees cited what they viewed as the unfortunate timing of the event. Circumstances found them just waking up, getting families going for the day, and less able to respond as promptly as they might. This thinking on the part of management does not give respect to the fact that emergencies can come at any hour and that response personnel must be available. Moreover, an hour or less before the morning peak should not be considered an unusual or inconvenient time for utility personnel. More likely, it represents a time of comparatively high probability of disruptive events, and certainly a time when such events have the potential for maximum adverse consequence.

The March 4th circumstances ran their course over several hours without substantial help coming to operators until well after the worst was over. This result should not be viewed as appropriate. Moreover, had appropriate information about potential problems been communicated earlier, those responding would likely have been better able to respond.

7. Hydro has corrected a flaw in its analytical approach by developing an approach that can focus particularly on Avalon Peninsula, as opposed to overall IIS, load and reserves.

Hydro understood the March 4th events at the outset to be an Avalon Peninsula issue. However, even the post-event analysis by Hydro focused on IIS loads and margins, not Avalon conditions. Hydro has demonstrated awareness of the concern that this narrow focus caused, and has corrected its approach. Specifically, Hydro has issued a new operating instruction focused on Avalon Peninsula operating capability in addition to IIS coverage.

8. Hydro's initial designation of the March 4th event as a "power warning" rather than a "power emergency" does not reflect a sufficient appreciation of customer expectations; Newfoundland Power had already begun load shedding at that point.

In the early stages of the March 4th event, the Communications teams at Hydro and Newfoundland Power interpreted the events differently under the Advance Notification Protocol and Joint Storm/Outage Communications Plan. That plan determines the level of notification to deliver to the public. Newfoundland Power designated the event as a "power emergency," while Hydro designated the event as a lower-grade "power warning." Hydro ultimately changed its designation after discussions with Newfoundland Power. Curiously, Hydro's team viewed the event as a warning rather than an emergency, even though Hydro's System Operations had already advised Newfoundland Power to begin load shedding. The fact that Newfoundland

Power communications personnel had this information before their Hydro counterparts, evidences a communications failure within Hydro.

9. The Joint Storm/Outage Communications Plan was followed appropriately during and subsequent to the March 4th events.

Both Hydro and Newfoundland Power had very little time to prepare communications surrounding the March 4th event. The Joint Storm/Outage Communications Plan proved a key success factor, enabling a prompt, coordinated response on the morning of the outage, once both teams agreed upon the severity of the event.

Within a week, both communications teams met to discuss lessons learned from the events. Discussions identified several enhancements to The Joint Storm/Outage Communications Plan, including shortening the time to respond at the onset of an event (from 30 to 15 minutes), and the need for initial holding statements. The companies have updated the Plan appropriately.

4. Recommendations

1. Hydro should assign a team to implement a program to establish a more robust operational philosophy regarding reliability.

Hydro has not agreed that there is a problem in this area. The continuation of a reliability culture that does not place higher value on service continuity requires as a first step an internal evaluation to understand the issue and set objectives for improvement. The present operational approach will become even more problematic when the LIL enters service. Hydro should adjust it promptly.

2. Hydro should enhance the skills and capabilities it brings to reliability engineering and analysis.

Our report following the January 2014 outages found a number of examples of non-standard industry thinking associated with reliability. The March 4th incident provides another telling example. This suggests that more conventional approaches and the skills to implement them are appropriate.

3. Hydro should take steps to assure situational awareness among operators and others who need the information to respond promptly and ably to adverse system conditions.

Hydro would have been better able to cope with the events of March 4th if key personnel were aware of the system's vulnerability. A process should be implement by which appropriate personnel are informed whenever unusual exposures are present.

4. Hydro should implement a more robust approach to the CERP.

Hydro should become more willing to activate CERP when appropriate. In addition, it may be beneficial to allow for intermediate alerts where a full activation might not be needed. For example, on March 4th, an alert may have been issued after midnight when the return of Unit 1 was delayed, escalated at 0524 when the unit was again delayed, and a full CERP activation when the CT failed to start.

5. Advance Notification Protocols should appropriately identify potential impact in terms of the loss of power to customers.

The Joint Storm/Outage Communications Plan details response based on the level of severity of an event. Notification from Hydro's Systems Operations team should clearly indicate the loss of power or potential loss of power in terms of the number of customers. If Hydro advises Newfoundland Power to begin load shedding, then the level of impact should be determined (in terms of the number of customers who will lose power and the duration). This approach will enable the communications teams to jointly agree on the severity of the event so the appropriate resources and response can be implemented.

Additionally, Hydro should review the Advance Notification Protocols to ensure that the full range of scenarios that could trigger a loss of power for customers are adequately identified and addressed by the Protocols.