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July 24, 2020

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: Newfoundland and Labrador Hydro – Reliability and Resource Adequacy Study Review – The Liberty Consulting Group Summary of and Comments on Labrador-Island Link Study Reports Issued in April 2020 – Hydro's Response

On June 17, 2020, the Board of Commissioners of Public Utilities ("Board") circulated the report provided by The Liberty Consulting Group ("Liberty") titled "Summary of and Comments on LIL Study Reports Issued in April 2020." The report contained several recommendations for Newfoundland and Labrador Hydro ("Hydro") to present schedules and plans and to report to the Board on important activities, particularly with respect to the Board's current proceedings examining short- and long-term reliability and resource adequacy. This document addresses recommendations presented by Liberty within their report."[1]

Liberty Recommendation 1

"The TGS work identifies the need for up to 120MW of generation on the Avalon Peninsula. These observations underscore the importance of prompt completion of the ongoing analysis of extending the life of at least some of the Holyrood steam units, now planned for retirement after the LCP reaches a steady state of operations consistent with its designed capabilities. Whether these steam units have the capability to respond adequately in meeting the remaining Avalon generation need forms a central part of the ongoing Hydro study."

This issue is referenced in Section 3.2.3 of the "Stage 4D: Transition to High Power Operation study."[2] As presented in Table 1, the requirement for generation on the Avalon Peninsula is to avoid voltage collapse during peak load conditions and is a function of system load and the availability of the synchronous condensers at Soldiers Pond Terminal Station ("SOP"). As indicated, the requirement for generation ranges from 0 MW when all three SOP synchronous condensers are in service, up to 120 MW if the three synchronous condensers were unavailable and system load were to exceed 1,750 MW.

During peak load conditions, it is anticipated that all three SOP synchronous condensers and the Holyrood Gas Turbine would be available for operation. In the event of an unplanned outage to one or

[1] Liberty's Recommendations were not numbered in the report; they are shown in the sequential order they appeared.
[2] Technical Note TN1205.71.06, "Stage 4D LIL Bipole: Transition to High Power Operation," TransGrid Solutions Inc., April 7, 2020.

multiple SOP synchronous condensers during peak load conditions, the availability of the Holyrood Gas Turbine would ensure sufficient capacity to avoid customer impact. Hydro will incorporate these contingency requirements in its operational protocols and, in the event that operation of the Holyrood Gas Turbine is forecast in the operating horizon, this will be identified in the Day Ahead unit dispatch tables.

Table 1: Minimum Avalon Thermal Generation Required to be In-Service to Prevent Voltage Collapse Following Labrador-Island Link Bipole Trip

Island Interconnected System Demand (MW)	Avalon Generation (MW)			
	0 SOP Syncs	**1 SOP Sync**	**2 SOP Syncs**	**3 SOP Syncs**
1,750 to 1,850	120	70	40	None
1,700 to 1,750	70	15	None	None
1,600 to 1,700	30	None	None	None

Liberty Recommendation 2

"The TGS work highlights a number of critical changes that will come when the LIL becomes capable of reliably performing with all its intended capabilities under Full-Power Operation. Fully functional operation of the final LIL control and protection software comprises the most critical element in reaching this state. Hydro needs to press Nalcor to do all it can to secure completion of General Electric's work and to make progress, problems, risks, and schedule exposures clear to the Board and stakeholders, as the proceedings addressing reliability and resource adequacy continue."

This response has been provided by Nalcor Energy ("Nalcor").

> Nalcor takes exception to Liberty's implication that it is necessary for Hydro to put additional pressure on Nalcor to secure completion of General Electric's ("GE") work because it infers Nalcor is doing something less than necessary to get GE to complete the work. Nalcor's efforts to assist GE with completion of the protection and control ("P&C") software for Labrador-Island Link ("LIL") have gone far beyond what is normally necessary to ensure that a contractor meets its contractual obligations. While GE has completed more than 99% of the construction scope of their contract, they have struggled to deliver the P&C software scope of work. Extensive research by Nalcor that has been previously communicated to Liberty demonstrates that delivery of GE software has been marked, on virtually every recent project it has undertaken, by quality and delivery issues. In reference to Liberty's statement that "Hydro needs to press Nalcor to do all it can to make progress, problems, risks, and schedule exposures clear to the Board and stakeholders," Nalcor has been and will continue to provide updates to the Board of Commissioners of Public Utilities ("Board") and its stakeholders. These written reports have been followed by monthly meetings with Hydro, the provincial Oversight Committee, the federal government and Independent Engineer, and quarterly meetings with the Board and Liberty, which have recently been increased to a monthly frequency as well.

As consistently reported and discussed through these regular and timely communications with the Board, Liberty, Hydro, and external stakeholders, Nalcor has taken numerous steps to ensure GE completes development of the P&C software in a manner that meets the requirements of our customers for highly reliable electricity, including:

- Established a continuous management and technical presence at GE's PES facility in Stafford to monitor progress and collaborate with GE to resolve issues in a timely manner;
- Added HVdc technical expertise to GE's team;
- Engaged Independent Third Parties ("ITP"), with expertise in software development and HVdc functionality, to monitor and report monthly on progress, schedule, quality, and technical risks. The ITP assesses GE's readiness to progress through software testing phases and deploy software to site, acting as an arbiter between Nalcor and GE, if required;
- Conducted weekly senior management meetings to discuss progress, quality, and commercial items;
- Conducted a minimum of twice weekly technical meetings (includes ITP), as well as regular quality and engineering meetings to resolve technical issues in a timely fashion;
- Provided additional construction resources to GE to assist with installation, troubleshooting, testing, and problem resolution;
- Met at the senior executive level on several occasions to express Nalcor's concerns with GE's inability to meet schedule milestones; and
- Negotiated changes to the contract with GE to ensure that any obstacles to delivery that did not affect the overall reliability of the system were removed.

The level of engagement and collaboration between Nalcor and GE is very high, all in an effort to ensure GE delivers quality, reliable P&C software. Nalcor has discussed these measures in detail with Liberty during regular Lower Churchill Project ("LCP") progress briefings. During the February 12, 2020 briefing, Liberty concurred that Nalcor was taking the prudent approach to focus on quality over schedule.

Nalcor will continue to keep all stakeholders informed of progress, as well as any risks to schedule or quality.

Liberty Recommendation 3

"The TGS analyses demonstrated the importance of Soldiers Pond synchronous condenser availability. The completion of the condensers remains subject to significant uncertainties. It is important for Nalcor to identify temporary and permanent solutions promptly, and to provide a clear assessment of the impacts of unavailability or constrained operation on LIL completion, commissioning, and Initial Operation. Such information has a clear connection to and importance for the Board's current proceeding for addressing short- and long-term reliability and resource adequacy."

An analysis has been performed to assess the impact of the availability of the synchronous condensers at SOP. This study[3] was performed using PSSE software and further analysis will be performed in PSCAD to validate results. The outcomes of these latter studies will include operational limits for the LIL when the SOP synchronous condensers are not available. These results will be formalized into operating instructions to ensure reliable operation of the transmission system. PSCAD analysis is ongoing and a final report will be provided to the Board in the fourth quarter of 2020.

Liberty Recommendation 4

"General Electric reportedly has not yet agreed to power transfers in excess of 225MW in the absence of synchronous condenser availability. Hydro should make sure it always has from Nalcor a current understanding of the situation, and management should keep the Board informed monthly of efforts to get that decision made and assess its consequences."

This response has been provided by Nalcor. Based on Nalcor's response, Hydro does not believe further reporting on this point is required.

> GE Grid has not placed a power transfer restriction beyond 225MW in the absence of synchronous condensers. GE contractual requirements for low power dynamic commissioning of Interim Bipole software is limited to 225 MW power transfer. The low power dynamic commissioning considers no availability of synchronous condensers. Once low power dynamic commissioning is successfully completed, including trial operations, it is possible to increase power transfer above 225 MW with or without synchronous condensers. At that point, LIL power transfer levels will be determined by a number of factors, including availability of generation in Labrador, system loads, power transfer conditions on the Maritime Link, and system stability constraints. Ultimately, the decision regarding the energy transfer over LIL to the Island is made by the Newfoundland and Labrador System Operator and Hydro's System Planning group.

Liberty Recommendation 5

"Potential *thermal overloads resulting from single contingencies ("N-1") and from further events following them ("N-1-1") have been identified. Customer impacts of actions to prevent and respond to those contingencies remain to be studied. Operational protocols remain to be developed by Hydro to manage the relevant overload conditions, which could include limits on ML exports. Hydro should present a schedule for their completion."*

All restrictions to avoid overload conditions identified in operational studies are to be implemented in Operating Procedure "TOP-P-076 - NL Transmission System Operating Limits" by the end of the third quarter of 2020. These operating restrictions will not result in customer impact, but would result in the curtailment of Maritime Link exports. Maritime Link export curtailment requirements will be defined in the operating procedure described above.

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[3] Technical Note TN1205.72.03, "Stage 4E LIL Bipole: High Power Operation," TransGrid Solutions Inc., April 7, 2020.

Liberty Recommendation 6

"Full-Power Operation of the LIL at less than 2,833MVA requires General Electric approval, with PSCAD studies required to determine acceptable transfer limits. Hydro should present a schedule for their completion."

As presented in Hydro's response to Liberty Recommendation 3, PSCAD analysis is ongoing in support of the development of operating instructions. A final report will be provided to the Board in the fourth quarter of 2020.

Liberty Recommendation 7

"A three-phase fault in the area near Soldiers Pond can cause a commutation failure (from a voltage disturbance preventing valve current from being transferred quickly enough to the next valve). Additional studies using the more appropriate PSCAD software to investigate this matter remain to be performed. Hydro should present a schedule for their completion."

Please refer to Hydro's response to Liberty Recommendation 6.

Liberty Recommendation 8

"TGS also did not consider temporary HVDC overhead line faults, which Hydro has agreed are required. Hydro should present a plan and schedule for performing the required analysis."

Hydro's investigation of overhead line faults is underway. A PSSE study[4] to assess restart times was completed and included the following conclusions:

- During the transitional period,[5] one LIL restart attempt can be accommodated for a dc line fault since the Maritime Link runback needed to keep the Interconnected Island System frequency above 59 Hz for loss of a LIL pole can be delayed by a maximum of 500 ms.
- For long-term operation, two LIL restart attempts can be used for a dc line fault, since the Maritime Link runback needed to keep the Island Interconnected System frequency above 59 Hz for loss of a LIL pole can be delayed by a maximum of 900 ms.

PSCAD analysis will also be performed to assess overhead line faults. As indicated in Hydro's response to Liberty Recommendation 3, this analysis is ongoing and will be included in the report provided to the Board in the fourth quarter of 2020.

Liberty Recommendation 9

"System instability resulting from a three-phase fault on line TL267 under some conditions at load flows above 650MW requires correction or a restriction on LIL operation. Hydro plans to address this threat through tuning of synchronous condenser system stabilizers. Delayed by coronavirus-related work, Hydro hopes still to complete the work this year. Hydro should report on the effectiveness of its solution as soon as it reasonably can."

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[4] Technical Note TN1205.77.03 "Operational Considerations of LIL Restarts and ML Runbacks," TransGrid Solutions Inc., June 3, 2020 (provided as Attachment 1).

[5] The transitional period refers to period in time when LIL overload capability and LIL frequency controller are not yet in service.

Hydro is undertaking an operating project to activate power system stabilizers ("PSS") on all large hydraulic units as well as the three thermal units at the Holyrood Thermal Generating Station. Hydro plans to complete this work in 2020. In the event that PSS activation cannot be completed on all units in 2020 due to complexities associated with the COVID-19 outbreak, outstanding PSS activations will be completed in 2021.

As PSS are placed in service, operational studies will be performed to assess impacts on system limits and procedures will be updated accordingly. As PSS activation will impact the capacity to deliver power to the Avalon Peninsula, updated corridor limits will be an input to Hydro's ongoing Reliability and Resource Adequacy Study.

Liberty Recommendation 10

"In response to our questions about restrictions General Electric has placed on LIL operation, Hydro stated that it has no role in what it termed a commercial matter. Hydro responded similarly when asked about responsibility for potential damage to LIL or other equipment connected to the ac network. Wherever responsibility lies, definitive answers to these questions should come soon enough to be considered in current proceedings examining reliability and resource adequacy."

This response has been provided by Nalcor.

> Please refer to the response to Liberty Recommendation 4. GE Grid has not placed an operating restriction on LIL with respect to the synchronous condensers.

Liberty Recommendation 11

"The analyses performed included consideration of the need for embedding an Automatic Stability Runback function in the ML to address outages that might cause too low a short circuit level at Bottom Brook. TGS had to perform manual activities to supplement the ML model available for conducting the analysis. Hydro should secure an updated ML model version to support more accurate future modeling."

Hydro has submitted a request to Emera Newfoundland and Labrador ("Emera") for a revision to the PSSE model of the Maritime Link that includes the Automatic Stability Runback function. Emera will work with ABB to assess this request.

Liberty Recommendation 12

"Hydro's calculation of maximum expected UFLS (at present 963MW) is not yet accompanied by a mapping of the areas affected, frequencies that will trigger disconnection by area, or load shed by area. Hydro plans to, and it should as promptly as possible, map this information upon identifying the specific feeders planned to be tripped. Similarly, Hydro should follow through on its plan, as stated to us, to provide an analysis of and estimates of likely restoration times. The resulting documentation of each should be made available as soon as possible."

Hydro has identified next steps in implementation of the new under frequency load shedding ("UFLS") scheme. A study will be undertaken to refine the load shedding scheme specified in the Stage 4A

Operational Study.[6] The study will involve the optimization of load shedding blocks and will include a review of system restoration. Newfoundland Power has been engaged and will be consulted as this study progresses. Hydro anticipates that the study will be filed with the Board in the first quarter of 2021.

Upon completion of the study, Hydro will continue to work with Newfoundland Power to plan the implementation of the new UFLS. This work will involve the specification and selection of feeders for load shedding blocks and the development of plans for rotation and restoration.

Liberty Recommendation 13

"The TGS technical notes addressed a possible voltage collapse in the Bay d'Espoir -Soldiers Pond corridor, caused by a reactive power problem. Hydro should follow through on its plan, stated to us, to address this collapse as part of resource adequacy study activities."

Voltage collapse concerns as a result of an extended bipole loss are being investigated as part of Hydro's ongoing Reliability and Resource Adequacy Study. To date, analyses have been completed including the TransGrid Solutions Avalon Capacity Study[7] and technical note TP-TN-068.[8] Hydro will continue to assess risks and develop mitigating solutions to transmission planning concerns as the Reliability and Resource Adequacy Study continues.

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

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Encl.

ecc: **Board of Commissioners of Public Utilities**
Jacqui Glynn
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[6] Technical Note TN1205.62.05 "Stage 4A: Preliminary Assessment of High Power Operation," TransGrid Solutions Inc., November 21, 2018.
[7] R1529.01.02 "Solutions to Serve Island Demand during a LIL Bipole outage," TransGrid Solutions Inc., May 23, 2019.
[8] Technical Note TP-TN-068 "Application of Emergency Transmission Planning Criteria for a Labrador Island Link Bipole Outage," Newfoundland and Labrador Hydro, July 30, 2019.

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Engineering Support Services for:

RFI Studies

Newfoundland and Labrador Hydro

Attention: Mr. Rob Collett

Operational Considerations of LIL Restarts and ML Runbacks

Technical Note: TN1205.77.03
Date of issue: June 3, 2020

Prepared By:
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Disclaimer

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1. Summary

This technical note provides operational guidelines for how many restart attempts the Labrador Island Link ("LIL") can make after a DC fault has occurred on the LIL DC overhead line. LIL controls are equipped with up to four restarts attempts, which can be enabled/disabled by the Operator, as shown in Figure 1–1.

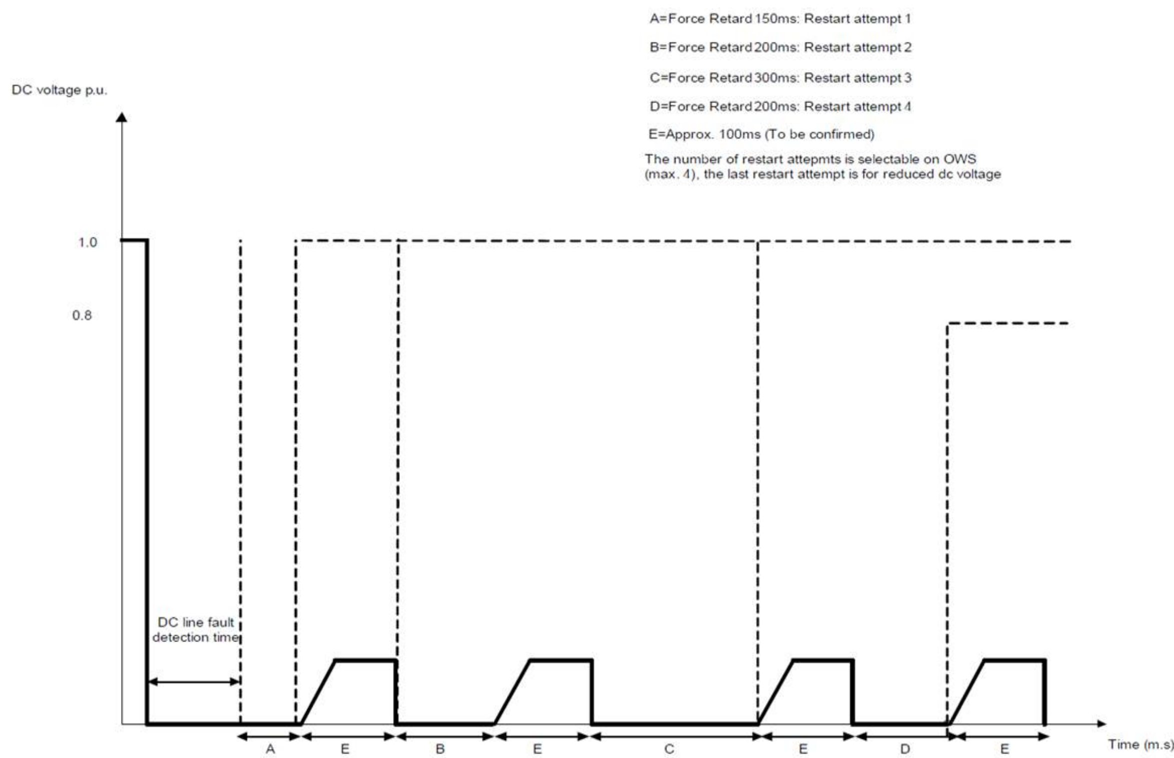

Figure 1–1. Timing for LIL restart attempts

In order to meet frequency-related Transmission Planning Criteria, the following guidelines apply when the Maritime Link ("ML") is exporting and runbacks are required:

1. If the contingency involves loss of the LIL bipole, no LIL restarts should be attempted because an ML runback needs to occur immediately after the infeed from the LIL bipole is lost.
2. During the transitional period[1], one LIL restart attempt can be used for a DC line fault, since the ML runback needed to keep the Interconnected Island System ("IIS") frequency above 59 Hz for loss of a LIL pole can be delayed by a maximum of 500 ms.
3. During the transitional period, if there are fewer than two SOP synchronous condensers in-service, reduced LIL transfer limits are required under high ML export scenarios as described in this report in Section 3.1.2 to allow a 500 ms delay in ML runback.

[1] Transitional period refers to period in time when LIL 2 pu overload capability and LIL frequency controller are not yet in-service.

4. For long-term operation[2], two LIL restart attempts can be used for a DC line fault, since the ML runback needed to keep the IIS frequency above 59 Hz for loss of a LIL pole can be delayed by a maximum of 900 ms.

If the ML is importing or if the ML is export can be adequately curtailed using frequency controller action, there are no limitations on the number of LIL restart attempts that can be used since there is no ML runback action.

This technical note also describes an equation that can be used to calculate the amount of ML runback needed for any given IIS operating condition if a LIL pole were to trip.

[2] Long-term operation is when LIL is operating with full functionality, including 2 pu overload capability and frequency controller.

2. ML Runback Equation

If the LIL bipole trips while ML exports exceed frequency controller capacities, ML export is automatically runback to 0 MW[3].

If a LIL pole trips while the ML is exporting[4], the ML needs to runback its exports under certain operating conditions to ensure IIS frequency remains above 59 Hz, as previously defined in the Stage 4D[5] and Stage 4E[6] reports. The amount of ML runback should be equal to the net loss of real power infeed to the IIS to ideally result in the least impact to the IIS frequency. This means that the ML runback should be approximately equal to the loss of infeed at Soldiers Pond ("SOP"). The loss of infeed at SOP can be calculated by considering the resulting power transfer on the healthy LIL pole and the losses in the DC line after the faulty LIL pole has tripped.

Using an equation to calculate the ML runback will enable Operators to easily set the ML runback requirement for any given operating condition.

The following equation calculates the ML runback based on the net loss of infeed at SOP:

$$\boxed{ML_R = K(LIL_{SOP\_Before} - LIL_{SOP_{After}})}$$

$$ML_R = K\left(\left(LIL_{MFA_{Before}} - L_B\right) - \left(LIL_{MFA_{After}} - L_M\right)\right)$$

$$If\ LIL_{SOP\_Before} > 450, \quad then\ LIL_{MFA\_After} = 450MW$$

$$L_B = 0.00008x^2 + 0.0076x - 0.5101$$

$$L_M = 0.0002y^2 + 0.04y - 2.1875$$

The equation above does not, however, consider the changes in IIS transmission losses that occur when moving from the pre-fault condition to the post-fault condition. During the pre-fault condition, IIS transmission losses are higher, due to higher power flow from SOP to Bottom Brook ("BBK") because of ML exports. It was found if the ML is runback by the amount calculated by the above equation, that for some operation conditions, especially during light demand, the IIS could experience a large overfrequency swing (> 62 Hz in some cases) because the ML runback was more than what was needed to balance the post-fault system due to the reduction in transmission losses in the post-fault system.

For the transitional period, before the LIL frequency controller is in-service, it was found that a multiplier of 0.9 (K in the equation above) applied to the ML equation provides an ML runback amount that is sufficient to keep the IIS frequency above 59 Hz if a LIL pole trips, while significantly reducing the overfrequency swing that was observed without the multiplier.

[3] Assuming that NetDC is greater than 0 MW.

[4] Runback requirement for LIL pole contingencies are provided in the following sections.

[5] TGS report TN1205.71.07 "Stage 4D LIL Bipole: Transition to High Power Operation" dated April 7, 2020.

[6] TGS report TN1205.72.04 "Stage 4E LIL Bipole: High Power Operation" dated April 7, 2020.

Alternatively, instead of applying the 0.9 multiplier, the overfrequency can be mitigated if the ML frequency controller is in-service and is able to automatically reduce the amount of runback if an overfrequency occurs. The assumption has been that the ML frequency controller will not be activated following a ML runback, but this scenario could possibly be an exception and would require further investigation.

For long term operation, once the LIL frequency controller is in-service, the K multiplier is not required (i.e. can be set to 1) as the LIL frequency controller is able to reduce the overfrequency to acceptable levels.

3. LIL Restarts and ML Runback Delays

The LIL transfer limits for the transitional period[7] and for long term operation[8] were re-visited to determine the maximum time delay that could occur from the inception of a DC line fault to the faulted LIL pole tripping, since tripping of the LIL pole is the trigger for an ML runback. The ML runback is required to ensure the IIS frequency remains at or above 59 Hz to avoid UFLS. This maximum delay in initiation of ML runback will determine how many LIL restart attempts can be applied within that time delay without resulting in the IIS frequency dropping below 59 Hz if the LIL restart(s) were not successful.

3.1 Transitional Period (Stage 4D)

During the transitional period, it is assumed that LIL frequency controller and 2 pu overload functionality are not yet available. Therefore, loss of a LIL pole requires an ML runback when the LIL is transferring more than approximately 525 MW (if the ML frequency controller in-service) or more than approximately 440 MW (if the ML frequency control out of service).

Additionally, during the transitional period, the SOP synchronous condensers may not be available yet.

Loss of a LIL pole was simulated with two SOP synchronous condensers in-service to determine the maximum delay possible in initiating the ML runback without resulting in a reduction of Stage 4D LIL transfer limits. The cases were then evaluated with 0 and 1 SOP synchronous condensers to determine if any reduction in LIL transfer limit is required to achieve the same delay in ML runback initiation, or to determine whether LIL restarts can be allowed with fewer than two SOP synchronous condensers.

3.1.1 2 SOP Synchronous Condensers In-Service

With two SOP synchronous condensers in-service, the maximum delay in initiating ML runback without affecting Stage 4D LIL transfer limits is 500 ms, which will allow enough time for one LIL restart attempt. The results of the loss of LIL pole analysis with delayed ML runback are shown in Table 3-1. The results from the analysis with delayed ML runback (and using the ML runback calculation amount) are shown in purple text. The remainder of the table shows the original results from the Stage 4D report, which did not include restart considerations, and a different ML runback amount not calculated with the equation.

[7] According to Table 3-1 of the Stage 4D report.
[8] According to Table 3-1 of the Stage 4E report.

Table 3-1. Two SOP Synchronous Condensers – Delayed ML Runback for Loss of LIL Pole – Transitional Period

Demand (MW)		Generation (MW)	ML (MW)	ML Frequency Controller IN							ML Frequency Controller OUT						
				TWO SOP Syncs							TWO SOP Syncs						
				From Stage 4D Report					Delayed ML Runback		From Stage 4D Report					Delayed ML Runback	
				Loss LIL Bipole Transfer Limit (MW)	Minimum Frequency (Hz)	Loss LIL Pole Transfer Limit (MW)	ML Runback-100ms (MW)	Minimum Frequency (Hz)	ML Runback Calculation (MW)	ML Runback - 500 ms (Hz)	Loss LIL Bipole Transfer Limit (MW)	Minimum Frequency (Hz)	Loss LIL Pole Transfer Limit (MW)	ML Runback* (MW)	Minimum Frequency (Hz)	ML Runback Calculation (MW)	ML Runback - 500 ms (Hz)
Peak	1866	1530**	500	900	58.08	900	400	59.6	392	59.3	900	58.08	900	400	59.6	392	59.3
Ipeak	1428	1094	500	900	57.97	900	400	59.2	392	59.15	900	57.97	900	400	59.2	392	59.15
Int	1038	703	500	900	57.81	900	400	59.2	392	59.05	900	57.81	900	400	59.2	392	59.05
Light	812	476	500	820	57.93	820	350	59.5	315	59.27	820	57.93	820	350	59.5	315	59.27
ExLight	606	401	500	750	58	750	260	59.4	236	59.36	750	58	750	260	59.4	236	59.36
Peak	1821	1285**	300	900	57.71	780	300	59.2	299	59.42	900	57.71	780	300	59.1	299	59.42
Ipeak	1400	915	300	750	57.79	750	300	59.8	276	59.33	750	57.79	750	300	59.3	276	59.33
Int	994	589	300	630	57.87	630	190	59.13	196	59.62	630	57.87	630	190	59.13	196	59.62
Light	760	452	300	580	57.87	580	130	59.4	116	59.66	580	57.87	580	130	59.4	116	59.66
ExLight	553	409	300	470	58.05	470	0	59.17	50		470	58.05	470	45	59.4	50	59.75
Peak	1815	1303**	158	720	57.73	640	158	59.15	158	59.14	720	57.73	640	158	59.15	158	59.14
Ipeak	1391	889	158	600	57.72	600	158	59.75	156	59.62	600	57.72	600	158	59.22	156	59.62
Int	980	548	158	480	57.86	480	0	59.17	58		480	57.86	480	40	59.15	58	59.62
Light	742	433	158	410	57.88	410	0	59.31	27		410	57.88	410	0	59.13	27	
ExLight	537	402	158	300	58.02	300	0	59.45	17		300	58.02	300	0	59.45	17	
Peak	1820	1330**	0	670	57.92	570	-	59.03	-	-	510	57.81	470	-	59.08	-	-
Ipeak	1391	906	0	540	57.87	540	-	59.01	-	-	400	57.85	400	-	59.5	-	-
Int	972	538	0	450	57.92	450	-	59.23	-	-	310	57.91	310	-	59.66	-	-
Light	735	403	0	340	57.99	360	-	59.31	-	-	230	57.93	230	-	59.83	-	-
ExLight	535	404	0	130	59.05	130	-	59.99	-	-	130	58.1	130	-	59.99	-	-
Peak	1815	1049**	-150	650	57.95	570	-	59.04	-	-	510	57.77	465	-	59.06	-	-
Ipeak	1389	757	-150	540	57.91	540	-	59.03	-	-	400	57.87	400	-	59.6	-	-
Int	972	424	-150	410	57.99	410	-	59.3	-	-	300	57.88	300	-	59.45	-	-
Light	740	402	-150	190	58.82	190	-	59.8	-	-	190	57.99	190	-	59.8	-	-
ExLight	536	400	-46	90	59.15	90	-	59.99	-	-	90	58.4	90	-	59.99	-	-
Peak	1824	998**	-320	500	57.85	460	-	59	-	-	500	57.85	460	-	59	-	-
Ipeak	1402	724	-320	400	57.83	400	-	59.46	-	-	400	57.83	400	-	59.46	-	-
Int	987	421	-320	250	57.98	250	-	59.8	-	-	250	57.98	250	-	59.8	-	-
Light	750	400	-260	90	58.6	90	-	59.99	-	-	90	58.6	90	-	59.99	-	-

Loss of Pole is more limiting that loss of LIL bipole

Not included in plot since not a limiting case

No ML runback needed

*In all cases, it is assumed that if ML runback is used, there is no additional support provided by the ML frequency controller.

** HRD CT dispatched to avoid voltage collapse following loss of LIL bipole, and HRD units dispatched to provide sufficient generation for system conditions.

Minimum IIS Generation

3.1.2 0 or 1 SOP Synchronous Condensers In-Service

With fewer than two SOP synchronous condensers in-service, some reduction in Stage 4D LIL transfer limits is required during ML 500 MW export scenarios to maintain the same 500 ms delay in ML runback initiation. The results of the loss of LIL pole analysis with a 500 ms delay in ML runback are given in Table 3-2.

Please note the following with regards to the table:

- The LIL transfer limits required to keep frequency above 59 Hz for loss of a LIL pole using a 500 ms delay in ML runback are highlighted in green for scenarios with no SOP synchronous condensers in-service, and in purple for scenarios with one SOP synchronous condenser in-service. Please note that limits are provided both for the scenario with the ML frequency controller in and out of service.
- LIL transfer limits shown in **red text** are cases where reduction in LIL transfer limit is required if there are fewer than two SOP synchronous condensers in-service.
- According to a previous operational study report[9], if there are no SOP synchronous condensers in-service, a minimum of two HRD units must be in-service to switch the 4th and 5th LIL filters at SOP, which applies to LIL transfers 504 MW or greater. Two HRD units (HRD unit 1 dispatched at 70 MW and HRD unit 3 as a synchronous condenser) were placed in-service accordingly in the cases with no SOP synchronous condensers in-service.

[9] Section 4 of TGS report TN1205.74.02 “Operational Consideration with 0 and 1 SOP Synchronous Condensers”.

Table 3-2. 0 and 1 SOP Synchronous Condensers – Delayed ML Runback for Loss of LIL Pole – Transitional Period

Demand (MW)		Generation (MW)	ML (MW)	ML Frequency Controller IN										ML Frequency Controller OUT							
				TWO SOP Syncs	0 SOP Syncs with Stage 4D Limits			Updated LIL Transfer Limits with 0 and 1 SOP Syncs						TWO SOP Syncs	0 SOP Syncs with Stage 4D Limits			Updated LIL Transfer Limits with 0 and 1 SOP Syncs			
				From Stage 4D Report	Delayed ML Runback			0 SOP Syncs			1 SOP Sync			From Stage 4D Report	Delayed ML Runback			0 SOP Syncs		1 SOP Sync	
				Loss LIL Pole Transfer Limit with 2 SOP Syncs (MW)	ML Runback Calculation (MW)	ML Runback - 100 ms (Hz)	ML Runback - 500 ms (Hz)	SCL (MVA)	Loss LIL Pole Transfer Limit (MW)	Min Frequency, 500 ms delay ML runback, if applicable (Hz)	SCL (MVA)	Loss of LIL Pole Transfer Limit (MW)	Min Frequency, 500 ms delay ML runback, if applicable (Hz)	Loss LIL Pole Transfer Limit with 2 SOP Syncs (MW)	ML Runback Calculation (MW)	ML Runback - 100 ms (Hz)	ML Runback - 500 ms (Hz)	Loss LIL Pole Transfer Limit (MW)	Min Frequency, 500 ms delay ML runback, if applicable (Hz)	Loss of LIL Pole Transfer Limit (MW)	Min Frequency, 500 ms delay ML runback, if applicable (Hz)
Peak	1866	1530**	500	900	392	59.37	58.98		875	59.03		900	59.18	900	392	59.37	58.98	875	59.03	900	59.18
Ipeak	1428	1094	500	900	392	59.45	58.93		850	59.05		875	59.00	900	392	59.45	58.93	850	59.05	875	59.00
Int	1038	703	500	900	392	59.40	58.50		700	59.27		800	59.13	900	392	59.40	58.50	700	59.27	800	59.13
Light	812	476	500	820	330	59.50	58.75		650	59.26		750	59.27	820	330	59.50	58.75	650	59.26	750	59.27
ExLight	606	401	500	750	276	n/a	n/a		n/a	n/a		725	59.25	750	276	n/a	n/a	n/a	n/a	725	59.25
Peak	1821	1285**	300	780	299	59.37	59.19		780	59.19		780		780	299	59.37	59.19	780	59.19	780	
Ipeak	1400	915	300	750	276	59.24	59.01		750	59.01		750	*	750	276	59.24	59.01	750	59.01	750	*
Int	994	589	300	630	180	59.82	59.35		630	59.35		630		630	180	59.82	59.35	630	59.35	630	
Light	760	452	300	580	140	59.81	59.40		580	59.40		580		580	140	59.81	59.40	580	59.40	580	
ExLight	553	409	300	470	0	n/a	n/a		n/a	n/a		470	59.65	470	50	n/a	n/a	n/a	n/a	470	59.65
Peak	1815	1303**	158	640	158	59.08	58.99		640	58.99		640		640	158	59.08	58.99	640	58.99	640	
Ipeak	1391	889	158	600	156	59.73	59.48		600	59.48		600	*	600	156	59.73	59.48	600	59.48	600	*
Int	980	548	158	480	0	59.15	59.15		480	59.58		480		480	58	59.66	59.58	480	59.58	480	
Light	742	433	158	410	0	59.29	59.29		410	59.16		410		410	0	59.16	59.16	410	59.16	410	
ExLight	537	402	158	300	0	n/a	n/a		n/a	n/a		300	59.1	300	0	n/a	n/a	n/a	n/a	300	59.1

Loss of Pole is more limiting that loss of LIL bipole
No ML runback needed
LIL cannot be deblocked with IIS demand below 750 MW if no SOP syncchronous condensers are in-service due to overvoltages.
*Cases with 1 SOP sync not simulated, since simulation results were OK with 0 SOP synchronous condensers.
**In all cases, it is assumed that if ML runback is used, there is no additional support provided by the ML frequency controller.
*** HRD CT dispatched to avoid voltage collapse following loss of LIL bipole, and HRD units dispatched to provide sufficient generation for system conditions.
Minimum IIS Generation

3.2 Long Term Operation (Stage 4E)

Long term operation assumes that all LIL control functionality, including frequency controller and 2 pu overload, are in operation and that there are at least two SOP synchronous condensers in-service. Loss of a LIL pole requires an ML runback when the LIL is transferring more than approximately 850 MW (if the ML frequency controller in-service) or more than approximately 700 MW (if the ML frequency control out of service).

Under long term operation, it was found that the ML runback required for loss of a LIL pole can be delayed by up to 900 ms without impacting the LIL transfer limits from the Stage 4E report. Table 3-3 summarizes the results. Note that the analysis was originally done with a 1000 ms delay, and with this delay the table shows one case in red text that violated the 59 Hz criteria. This violation is mitigated if the delay is reduced to 900 ms, and therefore the maximum delay of ML runback under long term operation is 900 ms.

The ML runbacks were calculated based on the ML runback equation from Section 2, assuming a K multiplier of 1.0. It was found that if the ML runback calculated is less than 100 MW, it is not necessary to perform the ML runback, as long as the ML frequency controller is in-service. If the ML frequency controller is not in-service, then the ML runback is required.

Table 3-3. Two SOP Synchronous Condensers – Delayed ML Runback for Loss of LIL Pole – Long Term Operation

				ML Frequency Controller IN										ML Frequency Controller OUT									
	Demand	Generation	ML	Loss LIL Bipole Transfer Limit (MW)	Minimum Frequency (Hz)	Loss LIL Pole Transfer Limit (MW)	ML Runback* (MW)	Minimum Frequency (Hz)	Matt's ML runback calc. (MW)	ML Runback 100 ms (Hz)	ML Runback 300 ms (Hz)	ML Runback 600 ms (Hz)	ML Runback 1000 ms (Hz)	Loss LIL Bipole Transfer Limit (MW)	Minimum Frequency (Hz)	Loss LIL Pole Transfer Limit (MW)	Matt's ML runback calc. (MW)	ML Runback - 100 ms (Hz)	ML Runback - 300 ms (Hz)	ML Runback - 600 ms (Hz)	ML Runback - 1000 ms (Hz)	ML Runback* (MW)	Minimum Frequency (Hz)
Peak	1866	1530	500	900	58.61	900	-	59.03	125	59.70	59.63	59.54	59.42	900	58.61	900	125	59.70	59.63	59.54	59.42	90	59.02
Ipeak	1428	1094	500	900	58.5	900	-	59.00	125	59.66	59.60	59.49	59.36	900	58.5	900	125	59.66	59.60	59.49	59.36	85	59.07
Int	1038	703	500	900	58.28	900	110	59.04	125	59.47	59.39	59.27	59.11	900	58.28	900	125	59.47	59.39	59.27	59.11	110	59.04
Light	812	476	500	900	58.18	900	100	59.04	125	59.67	59.59	59.45	59.20	900	58.18	900	125	59.67	59.59	59.45	59.20	100	59.04
ExLight	575	401	500	750	58.44	750	-	59.19						750	58.44	750	90	59.65	59.64	59.57	59.4	30	59.01
Peak	1821	1285	300	900	58.26	900	-	59.00	125	59.53	59.48	59.41	59.30	900	58.26	900	125	59.53	59.48	59.41	59.30	100	59.05
Ipeak	1400	915	300	900	58.15	900	110	59.02	125	59.38	59.32	59.22	59.09	900	58.15	900	125	59.38	59.32	59.22	59.09	110	59.02
Int	994	589	300	860	57.91	860	-	59.02	115	59.74	59.70	59.52	59.32	860	57.91	860	115	59.74	59.70	59.52	59.32	120	59.00
Light	760	452	300	705	58.06	705	-	59.23						705	58.06	705	81	59.61	59.6	59.59	59.47	76	59.01
ExLight	553	409	300	470	58.5	470	-	59.48						470	58.5	470						-	59.64
Peak	1815	1303	158	900	58.11	900	-	59.00	125	59.49	59.44	59.37	59.27	900	58.11	900	125	59.49	59.44	59.37	59.27	98	59.01
Ipeak	1391	889	158	900	57.84	900	118	59.01	125	59.18	59.15	59.07	58.94	900	57.84	900	125	59.18	59.15	59.07	58.94	118	59.01
Int	980	548	158	680	57.97	680	-	59.29						680	57.97	680						-	59.22
Light	742	433	158	520	58.09	520	-	59.46						520	58.09	520						-	59.43
ExLight	537	402	158	300	58.5	300	-	59.63						300	58.5	300						-	59.63

Loss of Pole is more limiting that loss of LIL bipole

Not included in plot since not a limiting case

No ML runback

*If ML runback is used, there is no additional support provided by the ML frequency controller.

Minimum IIS Generation