Newfoundland and Labrador Hydro
Hydro Place. 500 Columbus Drive
P.O. Box 12400. St. John's. NL
Canada A1B 4K7
t. 709.737.1400 I f. 709.737.1800
nlhydro.com

July 10, 2026

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

Attention: Mike McNiven
Board Secretary

Re: *Reliability and Resource Adequacy Study Review* – Avalon Reactive Power Study (Phase 1)

Please find enclosed Newfoundland and Labrador Hydro's Avalon Reactive Power Study (Phase 1), as committed in the *Reliability and Resource Adequacy Study Review* semi-annual update.[1]

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

SWalsh

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

Encl.

ecc:

Board of Commissioners of Public Utilities
Jacqui H. Glynn
Ryan Oake
Board General

Island Industrial Customer Group
Paul L. Coxworthy, Stewart McKelvey
Denis J. Fleming, Cox & Palmer
Glen G. Seaborn, Poole Althouse

Labrador Interconnected Group
Senwung F. Luk, Olthuis Kleer Townshend LLP
Nicholas E. Kennedy, Olthuis Kleer Townshend LLP

Consumer Advocate
Adrienne H.Y. Ding, O'Dea Earle
Justin W. King, O'Dea Earle
Consumer Advocate General

Newfoundland Power Inc.
Dominic J. Foley
Douglas W. Wright
Regulatory Email

[1] "*Reliability and Resource Adequacy Study Review* – Semi-Annual Update for the Second Quarter of 2026," Newfoundland and Labrador Hydro, June 30, 2026.

Avalon Reactive Power Study (Phase 1)

Overview

July 10, 2026

A report to the Board of Commissioners of Public Utilities

Contents

List of Attachments

1.0 Context within the RRA Study Review

Newfoundland and Labrador Hydro ("Hydro") filed the initial Reliability and Resource Adequacy Study ("RRA Study") with the Board of Commissioners of Public Utilities ("Board") in November 2018 ("2018 Filing").[1] Since the 2018 Filing, throughout the continued *Reliability and Resource Adequacy Study Review* proceeding ("*RRA Study Review*"), Hydro has filed regular updates to the RRA Study, including numerous technical notes, additional studies, and third-party reports.

The regulatory record is appropriately robust given the rapid transformation of the provincial electricity system, including interconnection, asset retirement, new resources, and increasing demand.

Hydro's most recent study is its 2024 Resource Adequacy Plan,[2] submitted to the Board on July 9, 2024, containing Hydro's recommended Minimum Investment Required Expansion Plan.

After completing a series of technical conferences with Board staff and intervening parties, Hydro and the intervenors gained consensus on a number of issues ("Settled Issues") which were enumerated in a Settlement Agreement.[3] The Settled Issues include an agreement that the recommendation to build a new 150 MW unit at Bay d'Espoir ("BDE") (Unit 8) and a 150 MW Combustion Turbine ("CT") on the Avalon Peninsula ("Avalon CT") is appropriate as part of the first step in addressing the requirements for additional capacity for the Island Interconnected System, and applications for these projects should be filed for evaluation. In line with the Settled Issues, Hydro filed its 2025 Build Application for both of these assets in March 2025; the regulatory proceeding is ongoing.

Hydro will have to make significant investments in the coming years and decades to maintain its legislative obligation of the provision of safe, least-cost, reliable electrical service in an environmentally responsible manner to the province.[4] The recommended assets within Hydro's Minimum Investment Required portfolio are just that, the Minimum Investment Required to meet Hydro's obligations, with additional investment necessary to meet Hydro's most likely to occur Reference Case. As such, through the *RRA Study Review*, Hydro models its system expansion in consideration of various forecast scenarios

---

[1] "Reliability and Resource Adequacy Study," Newfoundland and Labrador Hydro, rev. September 6, 2019 (originally filed November 16, 2018).
[2] "2024 Resource Adequacy Plan – An Update to the Reliability and Resource Adequacy Study," Newfoundland and Labrador Hydro, rev. August 26, 2024 (originally filed July 9, 2024).
[3] "2025 Build Application – Bay d'Espoir Unit 8 and Avalon Combustion Turbine ("2025 Build Application")," Newfoundland and Labrador Hydro, March 21, 2025, sch. 2.
[4] *Electrical Power Control Act*, 1994, SNL 1994, c E-5.1, s 3(b)(iii).

and within the context of continuously evolving energy policy. The numerous studies that Hydro has completed and planned are all necessary to validate and justify the information that Hydro inputs into its models, which produce critical information on which timely, prudent decisions are to be made.

The enclosed study is intended to inform Hydro and stakeholders of the reactive power requirements necessary to support system stability and reliability on the Avalon Peninsula following the retirement of the Holyrood Thermal Generating Station ("Holyrood TGS") and the addition of the Avalon CT and BDE Unit 8. Additional analysis, to be completed within Phase 2 of the Avalon Reactive Power Study, will further assess the reactive power requirements associated with the development of off-Avalon generation beyond BDE Unit 8.

While the enclosed study provides valuable, necessary information, it cannot and should not be considered independent of the rest of the studies and analyses ongoing through the *RRA Study Review*. Rather, the study is an input that will—along with other studies completed and ongoing—inform Hydro's broader system resource planning process now and into the future.

2.0 Background

The Avalon Reactive Power Requirements for the LIL[5] Bipole Contingency Study ("Avalon Reactive Power Study (Phase 1)"), provided as Attachment 1, was performed by TransGrid Solutions Inc. ("TransGrid") to determine the requirement for reactive power compensation on the Avalon Peninsula after the retirement of the Holyrood TGS to prevent voltage collapse following a LIL bipole trip. A total loss of the LIL bipole results in increased power flow from BDE to Soldiers Pond ("SOP") to supply demand on the Avalon Peninsula, as LIL imports from Muskrat Falls are no longer being delivered directly to the load center. The increased flow from BDE to SOP presents two key challenges during high-load periods: thermal overloads and voltage collapse, as discussed in Sections 2.1 and 2.2, respectively.

2.1 Thermal Overloads – 230 kV Line Trips during LIL Shortfall Scenario

During an extended LIL bipole outage ("LIL Shortfall Scenario") at higher island demands, a sustained period may arise during which elevated power transfers are required to supply the Avalon Peninsula via the 230 kV transmission system from BDE to SOP. Under sufficiently high loading conditions, the loss of a 230 kV transmission line may result in thermal overloading, leading to excessive conductor sag and an

[5] Labrador-Island Link ("LIL").

associated risk to public safety. At present, Holyrood TGS operation is needed to meet demand and reliability requirements during high load conditions, which naturally reduces BDE–SOP flow to a level sufficient to mitigate the risk of thermal overloads.

After the retirement of the Holyrood TGS, there would not be enough downstream generation to avoid thermal overload conditions following 230 kV line trips. Accordingly, mitigation may be required through reinforcement of the 230 kV transmission system **or** the implementation of a Remedial Action Scheme ("RAS").

Reinforcement of the 230 kV system would likely include the addition of a third 230 kV transmission line between Western Avalon ("WAV") Terminal Station and the SOP Terminal Station, at an estimated cost of approximately $216 million. Hydro is also investigating the application of Dynamic Line Rating ("DLR") technology to select 230 kV lines between BDE and WAV. Should Island demand exceed forecast levels, additional capital investment in the BDE–SOP transmission system may be required. The proposed Avalon CT would partially offset the loss of the Holyrood TGS by reducing loading on the 230 kV transmission system; however, it would not provide sufficient relief to fully eliminate the thermal overloads necessitating additional transmission upgrades beyond a third line and DLR.

A lower cost alternative is a RAS or "Avalon RAS," which would shed customer load immediately following a 230 kV line trip between BDE and SOP. The technical feasibility of the Avalon RAS was evaluated in a study completed by Hydro's consultant, TransGrid. This study, submitted to the Board on October 14, 2025,[6] determined that the Avalon RAS could accommodate Island demand levels up to 2,000 MW before reactive power compensation between BDE and SOP would be required to maintain steady-state voltage performance. Hydro is currently working with Newfoundland Power Inc. on the design and implementation of the Avalon RAS, which is expected to have an associated cost estimate materially lower than that of constructing a third line between WAV and SOP. While the Avalon RAS introduces a potential for customer load shedding, it would be a very infrequent event for significantly less cost. Load shedding would be anticipated only under a specific set of conditions: a 230 kV line trip between BDE and SOP occurring during a LIL Shortfall Scenario, coincident with periods of high system

[6] Please refer to "Avalon Remedial Action Scheme Feasibility Study – Overview," Newfoundland and Labrador Hydro, October 14, 2025, att. 1.

demand. The Avalon CT would reduce the amount of load shedding following a RAS activation, since it would offload the BDE to SOP transmission while dispatched.

The need for either transmission upgrades or the Avalon RAS is independent of the generation expansion plan and is primarily driven by the retirement of Holyrood TGS. While additional generation on the Avalon may provide partial mitigation, the underlying system constraints persist unless approximately the equivalent amount of capacity of Holyrood TGS is added on the Avalon Peninsula. The Avalon CT would complement the Avalon RAS by reducing the magnitude of customer impacts when the RAS is activated. As a result, the combined implementation of these solutions is strongly recommended to address the LIL Shortfall Scenario and the associated risk of transmission line thermal overloads, once the Holyrood TGS is retired.

2.2 Voltage Collapse – LIL Bipole Trip

A contingency involving a trip of the LIL bipole under peak loading conditions results in an immediate step change in real power transfer from BDE to SOP. If the post-contingency transfer exceeds the available reactive power support and voltage stability limits, the Sunnyside ("SSD") area may experience voltage instability potentially leading to collapse. While the Holyrood TGS operation currently acts to mitigate this risk, as noted above, the severity of this risk is exacerbated following its retirement. Without the Holyrood TGS, the incremental change in BDE-to-SOP power flow is inherently greater due to reduced local generation downstream of SSD. It was this operating scenario that was analyzed as part of the Avalon Reactive Power Study (Phase 1).

The study evaluated two potential measures to mitigate voltage collapse: (i) installing additional reactive power support (MVArs)[7] at SSD, and (ii) reducing power flow on the BDE–SOP corridor by increasing generation dispatch on the Avalon Peninsula to a minimum level.

The drawback of dispatching additional Avalon generation solely to provide voltage support is that it would need to come from either the existing Holyrood CT or the proposed Avalon CT, potentially resulting in increased fuel consumption. As the dispatch of thermal generation inherently introduces fuel costs, Hydro undertook this study to inform reactive power requirements to avoid the use of

[7] Megavolt-amperes reactive ("MVArs").

thermal resources for voltage support to reduce the costs and environmental impact associated with the increased fuel consumption.

The purpose of the Avalon Reactive Power Study (Phase 1) was to assess and quantify the Minimum Avalon Generation and reactive power compensation requirements at SSD necessary to prevent voltage collapse following an LIL bipole trip, under conditions with and without BDE Unit 8 in service and with the Holyrood TGS retired, to support future economic evaluations of mitigation options.

Hydro has determined that additional analysis is required beyond the scope of Phase 1 to assess further off-Avalon generation expansion beyond BDE Unit 8. Accordingly, Hydro will proceed with a Phase 2 study to be completed by December 2026 that will focus on other potential off-Avalon generation expansion scenarios beyond just BDE Unit 8.

3.0 Avalon Reactive Power Study (Phase 1)

3.1 Study Cases and Assumptions

The following are the base case assumptions for the Avalon Reactive Power Study (Phase 1) that were applied by TransGrid when conducting the analysis:

- The analysis was performed on the 2025[8] and the 2033 base cases.
- The generation expansion scenario for the 2033 base case was assumed to be BDE Unit 8 (154 MW) and the Avalon CT (3 x 50 MW).
- Two SOP Synchronous Condensers (“SC”) in-service.
- Holyrood TGS Unit 3 (“HRD3”) was online as an SC.
- The new Avalon CT was available in the 2033 base cases as SCs or a generation source.
- The Hardwoods Gas Turbine was in-service as an SC.
- One Come-By-Chance (“CBC”) capacitor in-service unless otherwise noted.
- The analysis was performed with the Final Under-Frequency Load Shedding Scheme applied.[9]

[8] The study commenced in late 2025.
[9] Please refer to “February 2026 Under-Frequency Load Shedding Events – Detailed Analysis Report,” Newfoundland and Labrador Hydro, April 30, 2026.

- The applicable Transmission Planning Criteria for this study is summarized below:
  - Steady state voltage: 0.95 pu[10]–1.05 pu during n-0 conditions.
  - Steady-state voltage: 0.90 pu–1.1 pu during n-1 conditions.
  - Post-fault recovery voltages on the alternating current system shall be as follows:
    - Transient undervoltages following fault clearing should not drop below 70%.
    - The duration of the voltage below 80% following fault clearing should not exceed 20 cycles.
    - Under normal operating scenarios, no single contingency event should lead to system instability, including a 3-phase fault.
  - Post-fault system frequencies shall not drop below 59 Hz and shall not rise above 63 Hz.

3.2 Study Methodology

The contingency under study was the sudden loss of the LIL bipole. The following methodology was used to perform the study:

1) Minimum Avalon Generation required to be in-service pre-contingency was determined such that transient voltage performance criteria were met for the following two scenarios:

  a. With BDE Unit 8

  b. Without BDE Unit 8

2) Reactive power requirements (STATCOM[11] and SC options) were evaluated in order to eliminate the need for Avalon generation to be in-service for the most conservative scenarios from 1a and 1b above that would not otherwise be needed for serving Island Interconnected System demand. The most conservative case ultimately assumed BDE Unit 8 in-service because less Avalon generation is inherently required to serve demand if more supply is dispatched off-Avalon.[12]

[10] Per Unit ("pu").
[11] Static Synchronous Compensator ("STATCOM").
[12] In this study, if more generation was needed to serve demand (assuming BDE Unit 8 (2034 only), the Holyrood CT and new 3 x 50 MW Holyrood units were already fully dispatched), the Holyrood thermal units were then used to serve demand.

The following system conditions were assessed:

- Maritime Link export ranging from 0 MW to 500 MW.
- LIL transfer from 750 MW to 800 MW to match forecasted dispatch.
- Island Interconnected System demand from 1,500 MW to 2,100 MW.

The following sensitivities were assessed as part of the Avalon Reactive Power Study (Phase 1):

Table 1: Sensitivity Scenarios

Scenario	Number of SOP SCs	HRD3 as SC	Proposed Avalon CT
Base Case	2	Yes	No
1	2	No	No
2	2	No	Synch. Condenser
3	2	Yes	Synch. Condenser
4	2	No	Generation Mode*
5	2	Yes	Generation Mode*
6	3	Yes	No
7	1	Yes	No
*Dispatched as generators in the 2033 case to meet demand			

3.3 Study Results

The results of the Avalon Reactive Power Study (Phase 1) are summarized in Table 2. The table compares the total forecasted dispatch of the existing Holyrood CT and proposed Avalon CTs with the Minimum Avalon Generation requirement established by TransGrid through transient stability analysis under scenarios with and without BDE Unit 8 in service. Minimum Avalon Generation represents the amount of generation that must be dispatched on the Avalon Peninsula to offset BDE–SOP power flow and prevent voltage collapse following a LIL bipole trip.

Table 2: Avalon Reactive Power Study (Phase 1) Results[13]

Island Demand (MW)	No BDE8					BDE8				
	HRD Forecasted Dispatch (MW) (Provided by Hydro)			Minimum Avalon Generation (MW)		HRD Forecasted Dispatch (MW) (Provided by Hydro)			Minimum Avalon Generation (MW)	
	Proposed HRD CT Dispatch (MW)	Existing HRD CT Dispatch (MW)	Total Dis-patch (MW)	HRD3 SC Online	HRD3 SC Offline	Proposed HRD CT Dispatch (MW)	Existing HRD CT Dispatch (MW)	Total Dis-patch (MW)	HRD3 SC Online	HRD3 SC Offline
1,800	130	0	130	10	34	0	0	0	2	25
1,900	142	65	207	61	82	60	0	60	60	80
2,000	142	124	266	<266	<266	135	0	135	135	155
2,100	142	124	266	<266	<266	142	80	222	195	215

Note: Red cells indicate cases where the Minimum Avalon Generation exceeds the forecasted HRD dispatch required to meet system demand, or where additional generation is needed for voltage regulation to prevent voltage collapse following a LIL bipole trip

The following can be concluded from Table 2:

- **BDE Unit 8 Not In-service:** Reactive power support at SSD is not required to prevent voltage collapse following a LIL bipole trip for Island demands up to 2,100 MW, as the total dispatched generation from both the Holyrood CT and the Avalon CT exceeds the Minimum Avalon Generation requirements.
- **BDE Unit 8 In-service:** With BDE Unit 8 in-service, the output from the Holyrood CT and the Avalon CT is offset, reducing the total forecasted HRD dispatch needed to meet system demand. With HRD3 SC online, the Minimum Avalon Generation requirement is achieved without the need for reactive power support (orange-shaded cells). If HRD3 SC is not available, the Minimum Avalon Generation requirements exceed the forecasted dispatch from both the Holyrood CT and the Avalon CT by 20–25 MW for Island demand levels between approximately 1,700 MW and 2,000 MW (red-shaded cells). The red-shaded cells can be mitigated by having three CBC capacitors in-service instead of one.[14] At higher demand (2,100 MW), the system requires more generation from the Holyrood CT and the Avalon CT to be dispatched to serve demand even

[13] The "Existing HRD CT" is referred to in Hydro's overview as the "Holyrood CT," and the "Proposed HRD CT" is the "proposed Avalon CT."

[14] Having fewer CBC capacitors in-service increases Minimum Avalon Generation and having more CBC capacitors in-service reduces Minimum Avalon Generation. However, adding more CBC capacitors raises the steady state voltage. If the voltage increases beyond 1.05 pu, BDE voltage setpoint was reduced to be able to add additional CBC capacitors; however, this resulted in an increase in Minimum Avalon Generation. Therefore, keeping BDE voltage setpoint higher is more beneficial than adding additional CBC capacitors at the expense of lowering BDE voltage setpoint.

with BDE Unit 8 in service. Under these conditions, total Holyrood CT and Avalon CT dispatch exceeds the Minimum Avalon Generation requirement. However, this conclusion is contingent on current generation expansion assumptions and may not hold if new generation is added off-Avalon to supply system demand.

The study also identified the most conservative operating conditions in terms of Minimum Avalon Generation for the existing Island Interconnected System. This condition occurred in a 2,000 MW peak-demand scenario with BDE Unit 8 in service, Maritime Link exporting 200 MW, and the LIL operating at 900 MW—100 MW above its forecasted dispatch level of 800 MW. Results are presented for varying numbers of SOP and HRD SCs in service. The analysis indicates that the SOP SCs have a significantly greater impact on reducing the Minimum Avalon Generation requirement (approximately 50–85 MW) than the HRD3 SC (approximately 10–20 MW).

Neither the Holyrood CT nor the Avalon CT are required to meet system demand and are required solely for voltage support, under the most conservative operating scenario. Consequently, the full Minimum Avalon Generation values presented in Table 3 are required solely to satisfy transient voltage stability criteria. An alternative to dispatching the Holyrood CT and the Avalon CT and consuming fuel for voltage support is the installation of reactive power compensation at SSD. The study also quantified the amount of reactive power support, in the form of STATCOMs and SCs, required under these conditions, with the results summarized in Table 4.

Under normal operating conditions and based on the current forecasted dispatch from both the Holyrood CT and Avalon CT, there is no requirement to install reactive power support at SSD for the foreseeable future, as those CTs are already expected to be online to meet system demand at Island load levels up to 2,100 MW. However, this conclusion is dependent on current generation expansion assumptions. If additional off-Avalon generation is developed beyond BDE Unit 8, there is a reduction in the forecasted dispatch of the Holyrood CT and Avalon CT to meet system demand,[15] and/or if Island demand increases significantly beyond current forecasts, reactive power compensation at SSD could become a viable alternative to using Avalon generation for voltage support.

Additional analysis was also performed assessing today's peak conditions to confirm that Minimum Avalon Generation requirements are not violated under any normal operating scenario. Voltage collapse

[15] Which could be driven by increased LIL import transfer levels beyond 800 MW.

concerns are not anticipated for Hydro's current winter operating configuration with two 70 MW Holyrood units in service.

Table 3: Minimum Avalon Generation (MW)*

Avalon Generation Required to Serve Demand (MW)	Avalon Generation required to meet transient voltage criteria (MW)				
	2 SOP SC HRD3 SC	1 SOP SC HRD3 SC	3 SOP SC HRD3 SC	2 SOP SC HRD3 SC off	2 SOP SC HRD3 SC 3 HRD x SC
0	130	215	83	150	120

*2,000 MW demand, LIL 900 MW, Maritime Link 200 MW, 1 CBC capacitor

Table 4: SSD Reactive Power Compensation Requirements for Most Conservative Scenario

Demand (MW)	Generation (MW)	Avalon Gen (MW)	LIL (MW)	ML (MW)	# CBC caps	HRD3 as SC	HRD 3xCT as SC	# SOP SC	SC @ SSD (MVA)	STATCOM @ SSD (MVAR)
2027	1399	0	900	200	1	**on**	**off**	**2**	**195**	**330**
						on	on	2	180	305
						off	off	2	230	390
						off	on	2	210	360
						on	off	1	310	535
						on	on	1	275	490
2027	1399	0	900	200	4	on	off	2	120	215
						on	on	2	105	195
						off	off	2	150	275
						off	on	2	130	245
						on	off	1	230	400
						on	on	1	190	360

4.0 Conclusion

The Avalon Reactive Power Study (Phase 1) demonstrates that for scenarios involving the addition of BDE Unit 8 and Avalon CT, normal dispatch of the Avalon CT to meet reserve requirements is sufficient to ensure voltage stability for an Island demand up to 2,100 MW. Further, the Avalon CTs will also be equipped with SC capability, providing an additional means of mitigating voltage collapse risk without the need to burn fuel, particularly at intermediate Island demand levels. Scenarios involving increased off-Avalon generation will be assessed as part of the Phase 2 study to evaluate the requirement of either increased Avalon CT dispatch for voltage support or the addition of reactive power support at SSD. The analysis also demonstrated that there is no immediate risk of voltage collapse following a LIL bipole trip under current normal system conditions.

Voltage stability concerns emerge following the retirement of the Holyrood TGS, at which point additional Avalon generation or reactive power support may be required to satisfy transient voltage stability criteria. The need for these measures will depend on several factors, including the location and size of future generation additions, Island demand growth, and the forecasted dispatch levels of the existing Holyrood CT and the proposed Avalon CT that are driven by projected LIL import levels.

5.0 Next Steps

The following initiatives are proposed to address the findings and recommendations from the Avalon Reactive Power Study (Phase 1):

- **Advance the Avalon Reactive Power Study into Phase 2:** This phase will evaluate alternative generation expansion scenarios, with a particular focus on increased off-Avalon generation, to determine the Minimum Avalon Generation and reactive power compensation requirements needed to mitigate the risk of voltage collapse following a LIL bipole trip during high demand periods. Depending on the study findings, Hydro may also undertake an economic assessment to compare the cost of dispatching additional CT generation solely for voltage support against the cost of installing reactive power compensation at SSD. Analysis will also be performed to assess the impacts of the retirement of HRD3. As per the TransGrid study, continued operation of this SC has a relatively small impact. Cost-benefit analyses will therefore be undertaken to assess if continued investment would serve as a least-cost solution for customers.
- **Development of Operation Instructions for Minimum Avalon Generation:** Hydro, with support from TransGrid, will develop detailed operating instructions pertaining to the risk of voltage collapse following a LIL bipole trip. This will involve the development of equations to determine Minimum Avalon Generation based on system conditions and operating scenarios. The Phase 1 analysis demonstrated that there is no immediate risk of voltage collapse following a LIL bipole trip under current normal system conditions, and therefore the focus of the operating instructions would focus on extreme operating scenarios.

Attachment 1

Avalon Reactive Power Requirements for the LIL Bipole Contingency

Avalon Reactive Power Requirements for the LIL Bipole Contingency

NEWFOUNDLAND & LABRADOR HYDRO

Attention: Matthew Carter
Technical Note no.: TN1205.100.05
Date of issue: May 29, 2026

Prepared By:
TransGrid Solutions Inc.
100-78 Innovation Dr.
Winnipeg, MB R3T 6C2
CANADA

Disclaimer

This technical note was prepared by TransGrid Solutions Inc. (part of Ramboll) (“TGS”), whose responsibility is limited to the scope of work as shown herein. TGS disclaims responsibility for the work of others incorporated or referenced herein. This technical note has been prepared exclusively for Newfoundland & Labrador Hydro and the project identified herein and must not be reused or modified without the prior written authorization of TGS.

Revisions

Document Title:	Avalon Reactive Power Requirements - LIL Bipole Contingency
Document Type:	Technical Note
Document No.:	TN1205.100.05
Last Action Date:	May 29, 2026

Rev. No.	Status	Prepared By	Checked By	Date	Comments
00	DFC	R. Brandt	R. Ostash	February 27, 2026	Preliminary draft for review.
01	DFC	R. Brandt	R. Ostash	March 19, 2026	Updated draft based on comments received on March 3, 2026.
02	DFC	R. Brandt	R. Ostash	March 19, 2026	Updated draft based on comments received on March 19, 2026.
03	DFC	R. Brandt	R. Ostash	May 11, 2026	Updated based on additional comments.
04	IFA	R. Brandt	R. Ostash	May 27, 2026	Updated based on additional comments.
05	IFA	R. Brandt	R. Ostash	May 29, 2026	Updated based on additional comments.

Legend of Document Status:

Approved by Client	ABC
Draft for Comments	DFC
Issued for Comments	IFC
Issued for Approval	IFA

Table of Contents

1. Executive Summary

The Bay d'Espoir (BDE) to Soldiers Pond (SOP) 230 kV transmission system is critical to the Island Interconnected System (IIS), in particular when the Labrador Island Link (LIL) is unavailable ("LIL Shortfall Scenario"). Once the Holyrood (HRD) thermal generating station and Hardwoods (HRD) gas turbine are retired, the BDE-SOP transmission system must supply the majority of the Avalon Peninsula demand if the LIL is unavailable since no LIL imports would be delivered to SOP.

Earlier studies have identified two main BDE–SOP 230 kV corridor issues that become increasingly significant after the retirement of HRD and HWD:

- **LIL Shortfall Scenario**: appreciable transmission constraints limit the amount of BDE-SOP flow based on single contingency events causing thermal overloads or low voltage conditions, worst during high demand conditions.
- **LIL Bipole Trip during High Load Conditions**: voltage collapse occurs near Sunnyside (SSD) within around 0.5 to 1 second after a LIL bipole trip during high demand conditions, resulting in system instability.

Previous studies investigated the first issue above by evaluating transmission system upgrades[1] and the feasibility of a Remedial Action Scheme (RAS)[2] that aims at mitigating thermal overloads and low voltage conditions that limit BDE-SOP flow during a LIL shortfall scenario. The RAS sheds load on the Avalon in the event of a 230 kV line contingency between BDE-SOP in order to offload the lines remaining in service to avoid thermal overloads or abnormal voltage conditions.

This study evaluates the second issue above by determining the reactive power requirements needed to mitigate the transient voltage performance at SSD following a LIL bipole trip under high IIS demand conditions. Previous studies[3] have observed the voltage collapse and demonstrated that a minimum amount of generation ("Minimum Avalon Generation") is required to be in-service on the Avalon prior to the LIL bipole trip in order to prevent the voltage collapse. This study is an extension of this previous work and will have the following objectives:

1. Determine the Minimum Avalon Generation requirements over a broader range of system conditions and the "delta" between how much Avalon generation is needed to serve demand and how much additional is needed to meet transient voltage criteria. A significant reliance on thermal generation for voltage regulation on the Avalon to support LIL operation is not considered an optimal long-term solution.
2. Determine the amount and type of reactive power compensation required at SSD to reduce the Minimum Avalon Generation such that it does not exceed the forecasted Avalon dispatch (i.e. reduce the delta to zero), thereby avoiding the associated additional fuel consumption.

---

[1] TGS report TN1817.01.05 "Assessment of the BDE/SOP Transmission Constraints", dated October 25, 2023
[2] TGS report TN1943.01.05 "Avalon Remedial Action Scheme (RAS) Feasibility Study", dated October 7, 2025
[3] TGS report R1205.01.03 "Final LCP Operational Study ("Stage 4F") Report" (Section 7.1), dated June 26, 2025.

1.1 Conclusions

Objective #1: Minimum Avalon Generation Requirement

Under Normal Forecasted Dispatch

The forecasted dispatch of HRD CTs, under scenarios with and without BDE8 in service, was provided by Hydro and is shown in Table 1-1, along with the Minimum Avalon Generation determined in this study under matching system conditions with 2 SOP SCs and 1 CBC capacitor[4] in-service, with LIL transferring between 750-800 MW and ML exporting 158 MW.

Table 1-1. Hydro's Forecasted HRD CT Dispatch (1,800 MW to 2,100 MW)[5]

Island Demand (MW)	No BDE8					BDE8				
	HRD Forecasted Dispatch (MW) (Provided by Hydro)			Minimum Avalon Generation (MW)		HRD Forecasted Dispatch (MW) (Provided by Hydro)			Minimum Avalon Generation (MW)	
	Proposed HRD CT Dispatch (MW)	Existing HRD CT Dispatch (MW)	Total Dis-patch (MW)	HRD3 SC Online	HRD3 SC Offline	Proposed HRD CT Dispatch (MW)	Existing HRD CT Dispatch (MW)	Total Dis-patch (MW)	HRD3 SC Online	HRD3 SC Offline
1,800	130	0	130	10	34	0	0	0	2	25
1,900	142	65	207	61	82	60	0	60	60	80
2,000	142	124	266	<266	<266	135	0	135	135	155
2,100	142	124	266	<266	<266	142	80	222	195	215

Note: Red cells indicate cases where the Minimum Avalon Generation exceeds the forecasted HRD dispatch required to meet system demand, or where additional generation is needed for voltage regulation to prevent voltage collapse following a LIL bipole trip

The following conclusions can be drawn from Table 1-1 under normal system conditions:

- BDE8 Not In-service (Blue-shaded)
  - Reactive power support at SSD is not required to prevent voltage collapse following a LIL bipole trip for Island demands up to 2,100 MW, as the total dispatched HRD CT generation exceeds the Minimum Avalon Generation requirements.
- BDE8 In-service (Green-shaded)
  - With BDE8 in-service, HRD output is offset, reducing the forecasted HRD dispatch needed to meet system demand. With HRD3 SC on-line, the system is on the verge of meeting the

[4] Having fewer CBC capacitors in-service increases Minimum Avalon Generation and having more CBC capacitors in-service reduces Minimum Avalon Generation. However, adding more CBC capacitors raises the steady state voltage. If the voltage increases beyond 1.05 pu, BDE voltage setpoint was reduced to be able to add additional CBC capacitors, however, this resulted in an increase in Minimum Avalon Generation. Therefore, keeping BDE voltage setpoint higher is more beneficial than adding additional CBC capacitors at the expense of lowering BDE voltage setpoint.

[5] ML exporting 158 MW – additional HRD dispatch is required for higher ML export levels. Hydro does not plan to export more than 158 MW over peak.

Minimum Avalon Generation requirement without the need for reactive power support (orange-shaded cells). If HRD3 SC is not available, the Minimum Avalon Generation requirements exceed the forecasted HRD dispatch by 20-25 MW for Island demand levels between approximately 1700 MW and 2000 MW (red-shaded cells). The red-shaded cells can be mitigated by having 3 CBC capacitors in-service instead of 1. At higher demand (2,100 MW) demand, the system requires more HRD generation to be dispatched to serve demand even with BDE8 in service. Under these conditions, HRD dispatch exceeds the Minimum Avalon Generation requirement. However, this conclusion is contingent on current generation expansion assumptions and may not hold if new generation is added off-Avalon to supply system demand.

Under Worst-Case System Conditions

This study also looked to find the worst-case system conditions resulting in the highest "delta" of Minimum Avalon Generation, meaning the maximum difference (delta) between how much Avalon generation is required to serve demand and how much additional Avalon generation is required to meet transient voltage criteria. It was found to be a 2,000 MW peak case with BDE8 dispatched, ML exporting 200 MW and LIL operating at 900 MW. Under these system conditions, no HRD units need to be dispatched to serve demand, therefore the entire Minimum Avalon Generation listed in Table 1-2 is needed to mitigate the voltage issue, with amounts shown for varying number of in-service SOP and HRD SCs. It is evident that the SOP SCs have a larger impact (50-85 MW) on the Minimum Avalon Generation than the HRD SCs (10-20 MW).

Table 1-2. Largest Delta of Minimum Avalon Generation (MW)*

Avalon Generation Required to Serve Demand (MW)	Avalon Generation required to meet transient voltage criteria (MW)				
	2 SOP SC HRD3 SC	1 SOP SC HRD3 SC	3 SOP SC HRD3 SC	2 SOP SC HRD3 SC off	2 SOP SC HRD3 SC 3 HRD x SC
0	130	215	83	150	120

*Worst case - 2000 MW demand, LIL 900 MW, ML 200 MW, 1 CBC capacitor

Objective #2: Reactive Power Support Requirements

In scenarios where the Minimum Avalon Generation exceeds Hydro's forecasted HRD CT dispatch, the addition of reactive power support at SSD may be warranted if increasing HRD generation is deemed more costly. Reactive power support at SSD becomes more justifiable if future HRD dispatch were to decrease to less than the Minimum Avalon Generation as a result of the addition of new off-Avalon generation to meet system demand or as a result of increased demand beyond 2100 MW depending on whether new generation built to serve this demand is located on-Avalon or off-Avalon.

Table 1-3 lists the reactive power support (SC or STATCOM)[6] needed at SSD to eliminate the highest deltas in Minimum Avalon Generation corresponding to the worst case system conditions in Table 1-2.

Table 1-3. Reactive Power Support to meet Transient Voltage Criteria corresponding to Table 1-2

Demand (MW)	Generation (MW)	Avalon Gen (MW)	LIL (MW)	ML (MW)	# CBC caps	HRD3 as SC	HRD 3xCT as SC	# SOP SC	SC @ SSD (MVA)	STATCOM @ SSD (MVAR)
2027	1399	0	900	200	1	**on**	**off**	**2**	**195**	**330**
						on	on	2	180	305
						off	off	2	230	390
						off	on	2	210	360
						on	off	1	310	535
						on	on	1	275	490
2027	1399	0	900	200	4	on	off	2	120	215
						on	on	2	105	195
						off	off	2	150	275
						off	on	2	130	245
						on	off	1	230	400
						on	on	1	190	360

Summary of Conclusions

Summary: Minimum Avalon Generation and the amount of reactive power support needed at SSD to avoid dispatching additional Avalon generation beyond what would be required to serve demand varies significantly based system operating conditions.

The Minimum Avalon Generation / transient voltage issue starts becoming an issue at around 1700 MW demand if two SOP SCs are in-service, and at around 1600 MW demand if only one SOP SC is in-service.

As demand increases and additional generation is needed, the impact to Minimum Avalon Generation will depend on generation expansion assumptions and whether the new generation is added off-Avalon or on-Avalon to supply system demand. Adding new off-Avalon generation (beyond BDE8) to meet demand increases the Minimum Avalon Generation requirements which would justify the requirement for the installation of reactive power compensation in SSD.

Assuming the Island Interconnected System operates under normal operating conditions[7] over peak, the Minimum Avalon Generation should not exceed the forecasted HRD dispatch up to an Island Demand of 2100 MW. Therefore, voltage collapse following a LIL bipole trip would be avoided based on the current system configuration and forecasted HRD dispatch, both with and without BDE8 in-service.

---

[6] The size of the STATCOM required to obtain a similar performance as the SC would be more than double the rating due to differences in current capabilities between the two devices as explained in Section 4.2.1. However, even so, the STATCOM is still likely to cost less.

[7] ML Exports = 158 MW, 3 CBC capacitor banks are available, and at least 2 SOP units are online

However, If HRD CT dispatch assumptions decrease below the Minimum Avalon Generation requirements due to an increase in new off-Avalon generation (beyond BDE8), and/or Avalon reactive power sources are removed from service (such as SOP SCs or CBC capacitors), a business case may emerge for additional reactive power support at SSD—particularly if the cost of dispatching additional HRD CTs solely for voltage regulation becomes significant.

Today's System (peak ~1800 MW): During the winter season in today's system, Hydro operates at least two HRD units operating at a minimum of 70 MW each, resulting in a combined generation of 140 MW. Analysis of today's system conditions confirmed that Minimum Avalon Generation does not exceed this level under any scenario included. Therefore, voltage collapse concerns are not anticipated for Hydro's current winter operating configuration with two 70 MW HRD units in service. The system becomes vulnerable to voltage collapse following the retirement of HRD thermal generation and/or if island demand increases significantly.

Future Work: Hydro, with support from TGS, plans to develop a more detailed operating instruction involving an equation(s) to determine Minimum Avalon Generation based on various factors (i.e. Island Demand, Status of Reactive Power Sources, etc.).

2. Study Cases, Assumptions & Criteria

2.1 Study Cases

The power flow cases were set up from the 2033-34 base cases[8]. Two sets of cases were studied – year 2025 and year 2034.

The following system conditions were assessed:

- ML export ranging from 0 MW to 500 MW
- LIL transfer from 600 MW to 900 MW
- IIS demand from 1500 MW to peak

The following sensitivities were assessed:

- 2 SOP SCs + HRD3 as SC ("base assumption")
- 3 SOP SCs + HRD3 as SC
- 1 SOP SC + HRD 3 as SC
- 2 SOP SCs (HRD3 off-line) [9]
- 2 SOP SCs (HRD3 off-line) + 3xHRD CTs as SCs
- 2 SOP SCs + HRD3 as SC+ 3xHRD CTs as SCs
- In the 2034 year cases, the 3x50 MW HRD CTs were dispatched as generators up to full capacity if the power was needed to meet demand.

2.2 Study Assumptions

The following are the key assumptions for this study:

- The new 3x50 MW HRD CTs are available in the 2033 base cases.
- The new 3x50 MW HRD CTs can operate as synchronous condensers.
- HWD gas turbine is in-service as a synchronous condenser.
- 1 CBC capacitor in-service unless otherwise noted.
- The analysis was performed with the Final UFLS scheme.
- The analysis was performed on the 2025 and the 2033 base cases.

[8] Assumes BDE8 is in-service in the 2034 cases.
[9] Hydro is considering the retirement of HRD3 which may make this scenario more likely as being the "base case". A description of possible impacts is provided in Section 4.3.

2.3 Dynamic Models

The following dynamic models were used to represent the reactive power support options evaluated in this study:

- Synchronous condenser at SSD – same as the SOP SC models (with MVA rating adjusted as needed for this study)
- STATCOM at SSD – PSSE library model SVSMO3U2 (FACTS model) with typical parameters

2.4 Criteria

The applicable Transmission Planning Criteria for this study is summarized below:

- Steady state voltage: 0.95 pu – 1.05 pu during n-0 conditions
- Steady state voltage: 0.90 pu – 1.1 pu during n-1 conditions
- Post fault recovery voltages on the AC system shall be as follows:
    - Transient undervoltages following fault clearing should not drop below 70%
    - The duration of the voltage below 80% following fault clearing should not exceed 20 cycles
    - Under normal operating scenarios, no single contingency event should lead to system instability, including a 3PF
    - Under emergency operating scenarios (e.g. LIL bipole outage during higher load conditions), system instability or voltage collapse is allowed following a 3PF.
- Post fault system frequencies shall not drop below 59 Hz and shall not rise above 63 Hz

3. Study Methodology

The contingency under study is loss of the LIL bipole. The following methodology was used to perform the study for the 2025 and 2033 year cases:

1. Minimum Avalon Generation required to be in-service pre-contingency was determined such that transient voltage performance criteria for the following two scenarios:
    a. With BDE8
    b. Without BDE8
2. Reactive power requirements (STATCOM and SC options) were evaluated in order to eliminate the need for Avalon generation to be in-service for the worst case scenarios from 1a) and b) above that would not otherwise be needed for serving IIS demand. This worst case ended up being with BDE8 in-service because less Avalon generation is inherently required to serve demand if more supply is dispatched off-Avalon[10].

The following system conditions were assessed:

- ML export ranging from 0 MW to 500 MW
- LIL transfer from 600 MW to 900 MW
- IIS demand from 1500 MW to peak

The following sensitivities were assessed:

- 2 SOP SCs + HRD3 as SC (“base assumption”)
- 3 SOP SCs + HRD3 as SC
- 1 SOP SC + HRD 3 as SC
- 2 SOP SCs (HRD3 off-line) [11]
- 2 SOP SCs (HRD3 off-line) + 3xHRD CTs as SCs
- 2 SOP SCs + HRD3 as SC+ 3xHRD CTs as SCs
- In the 2034 year cases, the 3x50 MW HRD CTs were dispatched as generators to full capacity if the power was needed.

[10] In this study, if more generation was needed to serve demand (assuming BDE8 (2034 only), HRD CT and new 3x50 HRD units were already fully dispatched), the HRD thermal units were then used to serve demand.
[11] Hydro is considering the retirement of HRD3 which may make this scenario more likely as being the “base case”. A description of possible impacts is provided in Section 4.3.

4. Study Results

4.1 Minimum Avalon Generation Requirement

Previous studies have observed that voltage collapse occurs near SSD following a LIL bipole trip under high demand conditions. It was demonstrated in previous studies that a minimum amount of generation is required to be in-service on the Avalon prior to the LIL bipole trip in order to prevent the voltage collapse.

This study further investigated these Minimum Avalon Generation requirements over a broader range of system conditions. These requirements could be determined for two sets of criteria, as demonstrated in the plot of voltage at SSD in Figure 4-1 and as listed below. Hydro requested that the analysis be performed to meet criteria.

- Meeting the transient voltage criteria at SSD (green plot)
- Stability Maintained (Transient Voltage Criteria Violated) (blue plot)

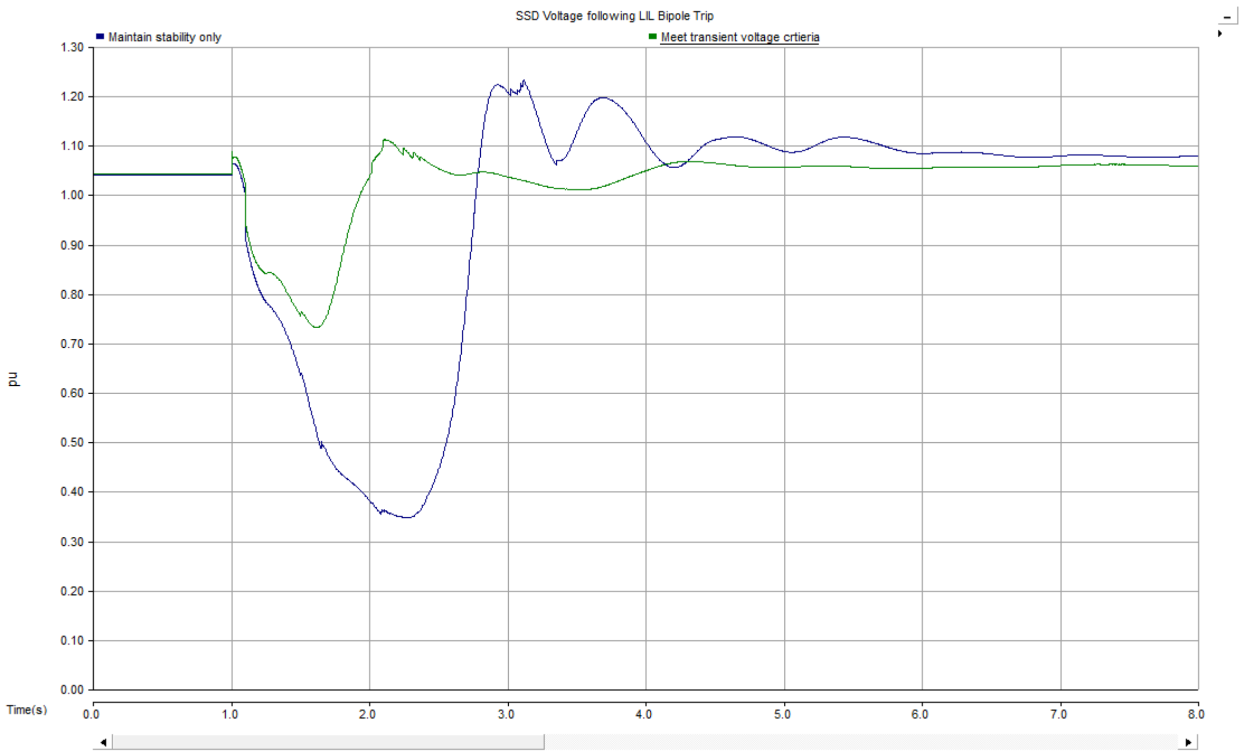

Figure 4-1. SSD 230 kV Voltage Profile: Meeting Transient Voltage Criteria (Green) and Stability Maintained (Transient Voltage Criteria Violated) (Blue)

The Minimum Avalon Generation requirements were found to be dependent on ML export and LIL transfer levels, as well as statuses of SOP SCs and HRD unit and the number of CBC capacitors in-service. All else being equal, the study results showed the following:

- Higher ML export levels -> higher Minimum Avalon Generation requirement
- Lower LIL transfer levels -> higher Minimum Avalon Generation requirement

- Higher demand levels -> higher Minimum Avalon Generation requirement
- Meeting transient voltage criteria -> higher Minimum Avalon Generation requirement compared to just maintaining system stability
- Lower number of SOP SCs or HRD SCs in-service -> higher Minimum Avalon Generation requirement

Table 4-1 and Table 4-2 summarize the Minimum Avalon Generation requirements to meet transient voltage criteria during the “base” system assumptions with 2 SOP SCs in-service and 1 CBC capacitor in-service, for the scenarios with and without BDE8, and for scenarios with and without HRD3 SC. Please note the following regarding the table:

- Yellow-highlighted cell is the worst-case scenario, i.e. the highest additional Avalon generation required in comparison to what would otherwise be needed to serve demand (i.e. largest delta in MW between what is required to serve demand and what is needed to meet transient voltage criteria).
- Grey cells indicate that no additional Avalon generation is needed beyond what is required to serve demand.

Further analysis in Section 4.2.2 shows that the 2000 MW demand case with ML=200 MW requires 130 MW of Avalon generation (or 150 MW if HRD 3 is not in-service) to meet transient voltage criteria, which is the highest additional amount of Avalon generation that is needed. It is noted that higher Minimum Avalon Generation values occur in other cases, for example the 2100 MW demand case with ML=200 MW has a Minimum Avalon Generation requirement of 190 MW, however, 80 MW of this is required to serve load, which means that 110 MW (190 MW – 80 MW = 110 MW) of additional Avalon generation (delta) is required to meet transient voltage criteria, which is less than the 130 MW required in the 2000 MW demand case. Analysis performed in Section 4.2.2 confirms that a smaller STATCOM size is needed for the 2100 MW case compared to the 2000 MW case if the Avalon generation were to be reduced to only what is needed to serve demand.

Table 4-1. Minimum Avalon Generation (MW) – BDE8, 2 SOP SC, 1 CBC Capacitor – with and without HRD3 SC

LIL (MW)	ML (MW)	2100 MW Demand			2000 MW Demand			1900 MW Demand			1800 MW Demand			1700 MW Demand		
		BDE8			BDE8			BDE8			BDE8			BDE8		
		for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3
900	500				340			210	<210	<210	100	<100	<100	0	0	13
	400	315	<315	<315	230	<230	<230	100	<100	115	0	42	60	0	0	0
	300	195	205	228	115	158	175	0	83	100	0	7	26	0	0	0
	200	80	190	210	0	130	150	0	50	70	0	0	12	0	0	0
	158	50	180	200	0	115	140	0	40	58	0	0	2	0	0	0
800	500													90	<90	<90
	400							170	<170	<170	80	<80	<80	0	0	10
	300	270	<270	<270	190	<190	<190	60	92	111	0	30	50	0	0	0
	200	180	200	225	100	150	170	0	78	98	0	17	43	0	0	0
	158	120	195	215	50	145	158	0	55	75	0	10	34	0	0	0
700	500															
	400										170	<170	<170	70	<70	<70
	300				270	<270	<270	150	<150	<150	50	<50	62	0	0	10
	200				170	<170	176	50	93	105	0	35	54	0	0	0
	158	225	<225	<225	150	152	170	0	80	98	0	12	33	0	0	0
600	500															
	400															
	300										150	<150	<150	70	<70	<70
	200							150	<150	<150	50	<50	57	0	0	7
	158	310	<310	<310	223	<223	<223	100	<100	108	33	<33	50	0	0	0

Table 4-2. Minimum Avalon Generation (MW) – no BDE8, 2 SOP SC, 1 CBC capacitor – with and without HRD3 SC

LIL (MW)	ML (MW)	2100 MW Demand			2000 MW Demand			1900 MW Demand			1800 MW Demand			1700 MW Demand		
		no BDE8			no BDE8			no BDE8			no BDE8			no BDE8		
		for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3	for MW	HRD3 SC	no HRD3
900	500															
	400										130	<130	<130	50	<50	<50
	300							120	<120	<120	25	<25	40	0	0	0
	200							20	62	82	0	0	12	0	0	0
	158	200	<200	<200	146	<146	<146	0	42	67	0	0	2	0	0	0
800	500															
	400															
	300										115	<115	<115	25	<25	<25
	200							110	<110	<110	0	17	43	0	0	0
	158	270	<270	<270	218	<218	<218	60	61	82	0	10	34	0	0	0
700	500															
	400															
	300													100	<100	<100
	200													0	0	0
	158	370	<370	<370	258	<258	<258	150	<150	<150	50	<50	<50	0	0	0
600	500															
	400															
	300															
	200															
	158	455	<455	<455	361	<361	<361	238	<238	<238	150	<150	<150	50	<50	<50

To observe how the Minimum Avalon Generation requirements are affected by the number of SOP SCs in-service and the number of HRD SCs in-service, Table 4-3 provides a summary of sensitivity analysis performed on the worst-case 900 MW LIL, ML 200 MW, 2000 MW demand scenario.

Table 4-3. Largest Delta of Minimum Avalon Generation (MW) – varying number of SCs*

Avalon Generation Required to Serve Demand (MW)	Avalon Generation required to meet transient voltage criteria (MW)				
	2 SOP SC HRD3 SC	1 SOP SC HRD3 SC	3 SOP SC HRD3 SC	2 SOP SC HRD3 SC off	2 SOP SC HRD3 SC 3 HRD x SC
0	130	215	83	150	120

*Worst case - 2000 MW demand, LIL 900 MW, ML 200 MW, 1 CBC capacitor

The largest impact on the Minimum Avalon Generation requirements is the number of SOP SCs in-service. The existing and proposed HRD SCs also have an impact, but to a lesser extent.

4.2 Reactive Power Support Requirements

In scenarios where the Minimum Avalon Generation exceeds Hydro's forecasted HRD CT dispatch, the addition of reactive power support at SSD may be warranted if increasing HRD generation for voltage support is determined to be more costly.

The worst-case scenario was determined in Section 4.1. This case was further analyzed to determine the approximate rating of a synchronous condenser (SC) or STATCOM that would be needed to eliminate the requirement for Avalon generation to be in-service beyond what is otherwise required for serving IIS demand.

4.2.1 Synchronous Condenser versus STATCOM

Prior to discussing the reactive power requirements, a general comparison is presented in this section regarding the mitigation provided by a synchronous condenser compared to a STATCOM solution.

A STATCOM's reactive current is limited to around 1 pu, however, a SC can transiently provide much larger current (more MVAR). When the voltage drops, the STATCOM's reactive power output drops proportionally, however, the SC can even produce more than 1 pu during low voltages. Therefore, when voltage drops significantly, the larger contribution from the SC can bring the voltage up more effectively than the same size STATCOM. Our investigation found that in order to get similar transient voltage performance at SSD, the STATCOM rating needs to be more than double the rating of a SC. That being said, the STATCOM option is still likely to cost less than the SC option.

Figure 4-2 provides an example that shows similar transient voltage performance at SSD after a LIL bipole trip if there is a 130 MVA SC at SSD (blue plot) or if there is a 275 MVA STATCOM at SSD (green plot), demonstrating the higher STATCOM rating needed compared to a SC.

Figure 4-2. SC versus STATCOM to mitigate voltage collapse following LIL bipole trip

4.2.2 Reactive Power Requirements – Worst Case

Various simulations were performed over demand levels up to 2100 MW demand, with ML export levels ranging from 0 MW to 500 MW to determine which system conditions require the largest amount of reactive power support near SSD to reduce the Minimum Avalon Generation requirements to only what needs to be dispatched to serve demand.

The results are summarized in Table 4-4, with the worst case highlighted in yellow.

The worst-case system condition is that which resulted in the highest “delta” of Minimum Avalon Generation, meaning the maximum difference (delta) between how much Avalon generation is required to serve demand and how much additional Avalon generation is required to meet transient voltage criteria.

The 2000 MW peak demand case with ML exporting 200 MW (BDE8 in-service) was found to require the highest amount of reactive power support (330 MVAR) and also the highest Minimum Avalon Generation requirement of 130 MW (increases to 150 MW if HRD3 SC is not in service). This is the case with the highest demand combined with the highest ML export that requires no Avalon generation to be in-service to serve load; in other words, the IIS demand + ML export can be supported without having any of the HRD generators producing any real power. However, when the LIL bipole trips, this case experiences voltage collapse near SSD. In order to meet transient voltage criteria without the need for Avalon generation to be in-service pre-contingency, a 330 MVAR STATCOM is needed near SSD.

Table 4-4. STATCOM Size to eliminate need for Minimum Avalon Generation (beyond what is needed to serve demand)

LIL (MW)	ML (MW)	2100 MW Demand			2000 MW Demand			1900 MW Demand			1800 MW Demand		
		BDE8			BDE8			BDE8			BDE8		
		Avalon Gen for MW (MW)	Avalon Gen to meet criteria (MW)	STATCOM (MVAR)	Avalon Gen for MW (MW)	Avalon Gen to meet criteria (MW)	STATCOM (MVAR)	Avalon Gen for MW (MW)	Avalon Gen to meet criteria (MW)	STATCOM (MVAR)	Avalon Gen for MW (MW)	Avalon Gen to meet criteria (MW)	STATCOM (MVAR)
900	500				340			210	<210	0	100	<100	0
	400	315	<315	0	230	<230	0	100	<100	0	0	42	80
	300	195	205	25	115	158	95	0	83	180	0	7	25
	200	80	190	260	0	130	330	0	50	135	0	0	0
	158	50	180	315	0	115	305	0	40	70	0	0	0
800	500												
	400							170	<170	0	80	<80	0
	300	270	<270	0	190	<190	0	60	92	70	0	30	70
	200	180	200	40	100	150	115	0	78	185	0	17	20
	158	120	195	170	50	145	210	0	55	110	0	10	5
700	500												
	400										170	<170	0
	300				270	<270	0	150	<150	0	50	<50	0
	200				170	<170	0	50	93	80	0	35	55
	158	225	<225	<225	150	152	~0	0	80	180	0	12	50

Table 4-5 summarizes the worst-case reactive power requirements under various sensitivities (HRD and SOP SCs) in order to meet transient voltage performance at SSD following a LIL bipole trip.

Table 4-5. Reactive power support to meet transient voltage criteria without HRD CTs dispatched (2,000 MW Island Demand)

Demand (MW)	Generation (MW)	Min Avalon Gen (MW)	LIL (MW)	ML (MW)	# CBC caps	CBC volt (pu)	HRD3 as SC	HRD 3xCT as SC	# SOP SC	SC @ SSD (MVA)	STATCOM @ SSD (MVAR)
2023	1396	**130**	900	200	1	1.01	on	off	2	none	None
2023	1396	**150**	900	200	1	1.01	Off	Off	2	None	none
2027	1399	0	900	200	1	1.01	**on**	**off**	**2**	**195**	**330**
							on	on	2	180	305
							off	off	2	230	390
							off	on	2	210	360
							on	off	1	310	535
							on	on	1	275	490
2027	1399	0	900	200	4	1.04	on	off	2	120	215
							on	on	2	105	195
							off	off	2	150	275
							off	on	2	130	245
							on	off	1	230	400
							on	on	1	190	360

If the installation of a reactive power solution is further pursued, additional studies can be performed to more accurately determine the rating required based on what the system should be designed to and what other mitigating solutions might be considered for the IIS. The reactive power support needed will depend on what is assumed to be in- or out-of-service, for example, should reactive support be designed to cover the system when operating with only 1 SOP SC in-service followed by a LIL bipole trip.

4.3 Impact of HRD3 Retirement

This study considered the "base assumption" to be 2 SOP SCs in-service and HRD3 as SC in-service. Sensitivities were performed for other operating scenarios involving SCs being in or out of service.

Hydro is considering the retirement of HRD3, however, which may make the scenario with 2 SOP SCs in-service and HRD3 out-of-service more likely.

HRD3 has a relatively small impact compared to the impact of an SOP SC, however, with it not in-service it does require a higher level of Minimum Avalon Generation and a larger amount of reactive power support as SSD to eliminate the need for Minimum Avalon Generation. Table 4-6 provides an example[12] of a comparison of the operating conditions where 1 CBC capacitor is in-service as summarized below:

[12] Example is the 2,000 MW scenario with 1 CBC capacitor in-service, and 3x50 MW HRD CTs out-of-service.

Table 4-6. Impact of HRD3 retirement

	2 SOP SCs + HRD3 SC	2 SOP SCs / HRD3 out
Minimum Avalon Generation over peak	130 MW	150 MW
STATCOM at SSD to eliminate need for Minimum Avalon Generation	330 MVAR	390 MVAR
SC at SSD to eliminate need for Minimum Avalon Generation	195 MVA	230 MVA

5. Current Operational Considerations

The minimum Avalon generation requirements were evaluated considering today's operational scenarios to assess whether there are any operating points of concern that may result in voltage collapse if the LIL bipole were to trip.

Table 5-1 lists the minimum Avalon generation requirements for today's IIS were determined considering the following:

- No BDE8
- ML exporting 158 MW
- Number of CBC capacitors in-service – 0, 1, 2, 3, 4
- HRD3 as a SC – in-service (black text) / out-of-service (blue text)
- LIL transfer levels – 600 MW to 900 MW
- IIS demand – 1600 MW to 2000 MW

Two columns are provided:

- "Meet criteria" – Avalon generation requirement to meet transient voltage criteria
- "Stable only" – Avalon generation requirement to maintain stability only (with transient voltage criteria violation)

Table 5-1. Minimum Avalon Generation - Existing System Configuration

LIL (MW)	CBC Caps	2000 MW Demand		1900 MW Demand		1800 MW Demand		1700 MW Demand		1600 MW Demand	
		Meet criteria	Stable only	Meet criteria	Stable only	Meet criteria	Stable only	Meet criteria	Stable only	Meet criteria	Stable only
900	4	146**	146**	40 (65)	0 (10)	0 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	3	146**	146**	20 (42)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	2	146**	146**	20 (50)	0 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	1	146**	146**	42 (67)	0 (10)	0 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	0	146**	146**	60 (87)	10 (30)	0* (20)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
800	4	218**	218**	60** (68)	60**	12 (30)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	3	218**	218**	60** (60**)	60**	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	2	218**	218**	60** (66)	60**	0 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	1	218**	218**	61 (60**) (82)	60**	10 (34)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	0	218**	218**	78 (60**) (110)	60**	27 (50)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
700	4	258**	258**	150**	150**	50**	50**	0 (0)	0 (0)	0 (0)	0 (0)
	3	258**	258**	150**	150**	50**	50**	0 (0)	0 (0)	0 (0)	0 (0)

	2	258**	258**	150**	150**	50**	50**	0 (0)	0 (0)	0 (0)	0 (0)
	1	258**	258**	150**	150**	50**	50**	0 (0)	0 (0)	0 (0)	0 (0)
	0	258**	258**	150**	150**	50** (58)	50**	0 (5)	0 (0)	0 (0)	0 (0)
600	4	361**	361**	238**	238**	150**	150**	50**	50**	0 (0)	0 (0)
	3	361**	361**	238**	238**	150**	150**	50**	50**	0 (0)	0 (0)
	2	361**	361**	238**	238**	150**	150**	50**	50**	0 (0)	0 (0)
	1	361**	361**	238**	238**	150**	150**	50**	50**	0 (0)	0 (0)
	0	361**	361**	238**	238**	150**	150**	50**	50**	0 (0)	0 (0)

**all of the Avalon generation is needed to serve load

(blue text) corresponds to HRD3 SC out-of-service

During the winter season, Hydro operates at least two HRD units operating at a minimum of 70 MW each, resulting in a combined generation of 140 MW. Table 5-1 confirms that Minimum Avalon Generation does not exceed this level under any scenario included. Therefore, voltage collapse concerns are not anticipated for Hydro's current winter operating configuration with two 70 MW HRD units in service. The system becomes vulnerable to voltage collapse following the retirement of HRD thermal generation and/or island demand increases significantly.

6. Conclusions

Summary: Minimum Avalon Generation and the amount of reactive power support needed at SSD to avoid dispatching additional Avalon generation beyond what would be required to serve demand varies significantly based system operating conditions.

The Minimum Avalon Generation / transient voltage issue starts becoming an issue at around 1700 MW demand if two SOP SCs are in-service, and at around 1600 MW demand if only one SOP SC is in-service.

As demand increases and additional generation is needed, the impact to Minimum Avalon Generation will depend on generation expansion assumptions and whether the new generation is added off-Avalon or on-Avalon to supply system demand. Adding new off-Avalon generation (beyond BDE8) to meet demand increases the Minimum Avalon Generation requirements which would justify the requirement for the installation of reactive power compensation in SSD.

Assuming the Island Interconnected System operates under normal operating conditions[13] over peak, the Minimum Avalon Generation should not exceed the forecasted HRD dispatch up to an Island Demand of 2100 MW. Therefore, voltage collapse following a LIL bipole trip would be avoided based on the current system configuration and forecasted HRD dispatch, both with and without BDE8 in-service.

However, If HRD CT dispatch assumptions decrease below the Minimum Avalon Generation requirements due to an increase in new off-Avalon generation (beyond BDE8), and/or Avalon reactive power sources are removed from service (such as SOP SCs or CBC capacitors), a business case may emerge for additional reactive power support at SSD—particularly if the cost of dispatching additional HRD CTs solely for voltage regulation becomes significant.

Today's System (peak ~1800 MW): During the winter season in today's system, Hydro operates at least two HRD units operating at a minimum of 70 MW each, resulting in a combined generation of 140 MW. Analysis of today's system conditions confirmed that Minimum Avalon Generation does not exceed this level under any scenario included. Therefore, voltage collapse concerns are not anticipated for Hydro's current winter operating configuration with two 70 MW HRD units in service. The system becomes vulnerable to voltage collapse following the retirement of HRD thermal generation and/or if island demand increases significantly.

Future Work: Hydro, with support from TGS, plans to develop a more detailed operating instruction involving an equation(s) to determine Minimum Avalon Generation based on various factors (i.e. Island Demand, Status of Reactive Power Sources, etc.).

[13] ML Exports = 158 MW, 3 CBC capacitor banks are available, and at least 2 SOP units are online