Q. Sunnyside Replacement Equipment: Please provide all available Hydro and AMEC documentation from the 1990s and 2000s addressing analyses conducted in connection with implementing an overhauling program rather than just replacing its aged ABCBs.

A. Hydro has provided various documents to the Board as part its annual Capital Budget Application filings dealing with the issue of overhauling rather than simply replacing air blast circuit breakers. See, for example, PR-PUB-NLH-048 Attachment 1, which was filed in 2008 as part of Hydro's 2009 Capital Budget Application. As background, discussions took place between Hydro's maintenance engineering personnel and OEM for the breakers, ABB Ltd., regarding aging air blast circuit breakers in the late 1990s and early 2000s. It was determined at that time that refurbishment was the least cost alternative that would continue to provide reliable service to Hydro's customers when compared to a complete breaker replacement program. To the end of 2006, approximately 25 percent of air blast circuit breakers had been overhauled.

For year 2007, the Board approved the first upgrade circuit breakers capital project. From this point forward, budget proposals continued to be submitted to the Board and refurbishments were justified and refurbish/replace options considered in the capital budget submissions to the Board. As noted above, analysis carried out by Hydro has been previously filed with the Board as part of the Capital Budget Submissions for years 2007 through 2015.

As well, some treatment of refurbishment versus replacement discussion of air blast circuit breakers can be found in AMEC's report entitled "Accelerated Air Blast

Circuit Breaker Replacement Program" dated July 30, 2014, and included in Appendix B of the August 1, 2014 compliance filings for Air-Blast Circuit Breakers, attached as PR-PUB-NLH-048 Attachment 2.

Project Title: Upgrade Circuit Breakers
Location: Various Terminal Stations
Category: Transmission and Rural Operations - Terminal Stations
Definition: Pooled
Classification: Normal

Project Description:

This project is required as part of an upgrading program to refurbish all Brown Boveri DCVF, DCF and DLF styles of air blast circuit breakers, at a rate of four each year. The breakers will be completely dismantled, cleaned, refitted with new parts, gaskets and seals as required and reassembled. The porcelain housings will be inspected and tested for cracks or weaknesses. Depending on the results of these tests, the porcelain housings will also be replaced as part of the upgrades. The breaker will then be tested to confirm that it is ready for return to service.

The order of the upgrades is done according to the priority and criticality of the breaker on the system. The highest priority breakers are those serving the generation units and the main power transformers. The upgrade rate of four units each year is based on system requirements, available outages to remove and re-install the breakers, and the available personnel to complete the work.

Project Cost: *($ x1,000)*	**2009**	**2010**	**BEYOND**	**TOTAL**
Material Supply	220.0	0.0	0.0	220.0
Labour	103.0	0.0	0.0	103.0
Consultant	0.0	0.0	0.0	0.0
Contract Work	0.0	0.0	0.0	0.0
Other Direct Costs	15.5	0.0	0.0	15.5
O/H, AFUDC & Escln.	49.4	0.0	0.0	49.4
Contingency	33.9	0.0	0.0	33.9
TOTAL	**421.8**	**0.0**	**0.0**	**421.8**

Existing System:

There are 66 air blast breakers on the Hydro system, critical to maintaining reliable system operations. The first generation of air blast circuit breakers on Hydro's systems has seen approximately 40 years of service. Problems have been experienced with air leaks, sticking valves, and other issues, resulting not only in maintenance costs but also breaker unavailability.

Project Title: Upgrade Circuit Breakers **(cont'd.)**

Existing System: (cont'd.)

Age of Equipment or System:

The air blast circuit breakers were installed in the 1960's and 1970's.

Major Work/or Upgrades:

There have been no major upgrades to these breakers since they were originally installed. There have been some minor modifications done on some units according to the manufacturer's recommendations. Other than this, the units have seen the standard maintenance inspections and servicing over the years.

Anticipated Useful Life:

The normal service and economic life of power circuit breakers is 30 years. Beyond 30 years, it is normally expected that such equipment would either have to be upgraded or replaced.

Maintenance History:

Hydro has experienced problems with air leaks or valves sticking, resulting in increased maintenance costs and breaker unavailability. Some maintenance modifications as recommended by the manufacturer, were completed to correct these problems. In particular there have been problems with the generator breakers at Bay d'Espoir which have resulted in the generating unit being unavailable. The problems being experienced by Hydro are common in the utility industry and owners of these types of air blast breakers have addressed the problem through similar upgrading programs. Detailed maintenance costs by breaker are not readily available.

At the Sunnyside Terminal Station, broken insulator supports caused breaker interrupter heads to drop off and fall to the ground. This caused damage to adjacent equipment and resulted in system outages.

At Massey Drive Terminal Station, there were timing and phase disagreement problems that could have caused an extended outage to the Corner Brook Pulp and Paper Mill. At Bay d'Espoir, there were timing and air quality problems with breakers serving the generation units. These problems

Project Title: Upgrade Circuit Breakers **(cont'd.)**

Existing System: (cont'd.)

Maintenance History: (cont'd.)

had the potential of causing generation and system wide outages. Other nuisance trips and outages of shorter nature have also occurred at various points on the system.

Maintenance inspections performed in the earlier in-service years of these breakers provided little evidence of the anticipated wear of parts and gasket fatigue. In later years, however, inspections of gaskets and seals, plus evidence of wear and tear of other mechanical components confirmed that a 'one time' upgrade program is the best approach to extending the service lives of the breakers. This conclusion was derived through consultations with other utilities and with the original equipment manufacturer.

Outage Statistics:

Table 1 below lists the 15 and five year averages for the performance of Air Blast Circuit Breakers. A comparison is made between Hydro's last five years performance to the latest Canadian Electrical Association (CEA) five-year average (2001-2005). There have been 25 forced outages due to problems with these breakers over the last 15 years.

Table 1. Breaker Performance

	Number of Forced Outages	Frequency (per a) [1]	Unavailability (percent) [2]
230 kV			
1993-2007	20.00	0.02	0.016
2003-2007	3.00	0.01	0.023
CEA (2001-2005)	254.00	0.07	0.216
138 kV			
1993-2007	5.00	0.03	0.037
2003-2007	3.00	0.05	0.004
CEA (2001-2005)	158.00	0.08	0.444

[1] Frequency (per a) is the number of failures per year.

[2] Unavailability is the percent of time per year the unit is unavailable.

Project Title: Upgrade Circuit Breakers **(cont'd.)**

Existing System: (cont'd.)

Industry Experience:

Hydro's experience is that the breakers are capable of providing reliable service to the system, however, there have been operational issues centered around leaking seals and gaskets, malfunctioning valves, failing capacitors and resistors, porcelain failures and minor controls issues.

Hydro consulted with other Canadian utilities and their experiences were the same as Hydro's.

In addition, Hydro consulted with the manufacturer of these breakers. Again, Hydro's experience is the same as other utilities using these breakers. Other utilities are managing the issue by either replacing the breakers or doing upgrades similar to Hydro. A replacement would be necessary if there was some system expansion or modification that required a breaker with ratings greater than the one in service. Otherwise, other utilities are upgrading the air blast circuit breakers.

Maintenance or Support Arrangements:

Normal operation and maintenance work is performed by Hydro staff.

Vendor Recommendations:

Hydro obtains support and advice on its major terminals equipment through regular consultations with the equipment manufacturers. The breaker manufacturer confirms that these breakers are at the end of their expected service lives. They recommend that unless system requirements or rating increases require a breaker with ratings greater than the one in service, the appropriate action to extend the service lives is to upgrade the breakers as proposed in this project.

Availability of Replacement Parts:

Replacement parts for the existing breakers are generally readily available.

Safety Performance:

The safety performance of the air blast breakers has been good. The breakers meet all applicable codes and standards for the industry. However, failure to properly maintain and refurbish the breakers may cause a safety risk by allowing pressure to increase sufficiently to forcefully spread porcelain pieces throughout the station.

Project Title: Upgrade Circuit Breakers **(cont'd.)**

Existing System: (cont'd.)

Environmental Performance:

There are no specific environmental issues regarding the air blast breakers other than the proper disposal of the retired parts.

Operating Regime:

The breakers are employed in full time continuous operation on the system, feeding the transmission and sub-transmission networks.

Justification:

The Brown Boveri air blast circuit breakers are the first generation air blast breakers in use by Hydro. These breakers are generally reliable but as they age they tend to create operational problems. The highlights of these problems are summarized in the Maintenance History Section.

The upgrades are the least cost alternative to replacement of the breakers with newer models.

Other utilities with air blast breakers of the same style and vintage as Hydro's, and with similar experiences, have taken or are taking, the same course of action.

Some breakers are located in highly critical locations on the Hydro system relative to generation and transmission requirements. These breakers have the greatest potential for affecting overall system reliability and must provide unquestionable performance. Any upgrade program would be directed at the most critical breakers first. These upgrades are required to maintain system performance and reliability.

Hydro's system requirements are well below the design ratings of these breakers in terms of fault interrupting capacity and expected number of operations. All breakers are suitably rated for their particular duty requirements, and there are no anticipated upgrades required for these locations in the foreseeable future.

Project Title: Upgrade Circuit Breakers **(cont'd.)**

Justification: (cont'd.)

Net Present Value:

There are two solutions to the problems described with the air blast beakers. These are to upgrade the breakers, as proposed, or to replace them. The operation and maintenance costs of either alternative are generally the same. Upgrading the breakers is more cost effective than a replacement program. The average upgrade cost is approximately $73,000 as indicated in Table 2, whereas the average replacement cost of a 230 kV breaker is $350,000. Replacements would include costs for modifications to civil, mechanical, electrical, and controls subsystems associated with each breaker. With the upgrades, these costs are eliminated. These upgrades are estimated to extend the life of the breakers to that equivalent to a replacement.

Levelized Cost of Energy:

The capital expenditures for this project will not affect the levelized cost of energy for the system.

Cost Benefit Analysis:

A cost benefit analysis is not required for this project proposal, as there are no quantifiable financial benefits.

Legislative or Regulatory Requirements:

The existing breakers comply with all applicable codes and standards of the industry.

Historical Information:

The upgrade program was started in 2007 and is forecast to continue until 2013. For the years 2007 and 2008. Table 2 shows the summary costs for each year.

Table 2. Budget

Year	Capital Budget ($000)	Actual Expenditures ($000)	Units	Cost per unit ($000)	Comments
2008F	$315.2	-	4		Work in preliminary stages
2007	$257.8	$146.4	2	$73.2	-

Project Title: Upgrade Circuit Breakers **(cont'd.)**

Justification: (cont'd.)

Historical Information: (cont'd.)

It should be noted that the cost per unit to upgrade a breaker will vary depending on a number of factors related to location, weather, outages, systems requirements, etc. The unit cost is the quotient of the total actual divided by the number of breakers upgraded.

Forecast Customer Growth:

The forecast customer load on the system has no affect on this project.

Energy Efficiency Benefits:

There are no issues related to energy efficiencies associated with this project.

Losses During Construction:

The removal and re-installation of each breaker will be coordinated with the normal outage plans for the transmission system. These outage plans are designed around the system load requirements. Therefore, there are no production or revenue losses resulting from this project.

Status Quo:

The status quo is not an option as the breakers must be upgraded to maintain system reliability.

Alternatives:

There are two solutions to the problems described with the air blast beakers. These are to upgrade the breakers, as proposed, or replace them. The operation and maintenance costs of either alternative are generally the same. The upgrade option was chosen because it has the least cost and is the simplest solution.

Replacement would require purchase of newer technology - SF6 gas breakers - which have a different arrangement and size as compared to the air blast units. Replacement with gas breakers would mean major modifications to the breaker foundations, controls systems, station protection systems and general station arrangements. This is why the cost for the replacement alternative is significantly higher than the upgrade alternative.

Project Title: Upgrade Circuit Breakers **(cont'd.)**

Conclusion:

The justification for this project is based on the deteriorated condition of the breakers. Upgrading is required for the breakers to operate properly and reliably, and to extend the reliable service lives of the breakers.

Project Schedule:

Table 3 presents the anticipated project schedule.

Table 3. Project Schedule

Activity	Milestone
Project Start	January 2009
Initial Planning and Equipment Ordering Tendering	February 2009
Equipment Delivery	July 2009
Equipment installations and Commissioning	November 2009
Project In Service	November 2009
Project Completion and Close Out	December 2009

Future Plans:

Future upgrades will be proposed in future capital budget applications.

NEWFOUNDLAND AND LABRADOR HYDRO

Accelerated Air Blast Circuit Breaker Replacement Program

July *30*, 2014

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Table of Contents

1) Executive Summary

Newfoundland and Labrador Hydro (Hydro) has an on-going program to replace circuit breakers at the end of the asset's useful life. This includes replacing all 63 air blast circuit breakers with SF6 circuit breakers by 2031. Although historically the performance of air blast circuit breakers has been reasonable, Hydro has experienced two significant outage incidents in the last two years in which the failure of air blast circuit breakers was a significant contributing factor. As a consequence Hydro now plans to initiate a program to carry out the replacement on an accelerated schedule. This document provides a strategic plan for accomplishing this.

The accelerated air blast circuit breaker replacement program is designed to be implemented in two three-year phases with the first installation of breakers in 2015. A partnership arrangement would be established between Hydro and an external contractor for each phase for the supply and installation of breakers. Breakers purchased under the current replacement program would be installed in 2014 but beginning in 2015 the existing program would be merged into the accelerated program.

The overall program scheduled to be completed by 2020 provides a significant reduction in the time required to replace all air blast circuit breakers while maintaining safety, ensuring reliability and maximizing the use of available resources.

2) Introduction

Hydro plans to initiate a program to replace all air blast circuit breakers on an accelerated schedule. There are a total of 63 air blast circuit breakers on the Hydro system. Although historically the performance of these breakers has been reasonable, Hydro has experienced two significant outage incidents in the last two years in which the failure of air blast circuit breakers was a significant contributing factor.

During the next few years there are a number of activities already in progress which will result in the replacement of a number of these breakers. The activities include the LCP program at Holyrood, Bay D'Espoir and Hardwoods, the NL/NS link at Bottom Brook, breaker replacement associated with the transformer repairs at Sunnyside and the program currently underway to replace breakers at end-of-life. The accelerated replacement program will be carried out in addition to these other programs but must consider the overall impact of all activities on the system and resources. Close coordination with these other programs is required.

3) Background

In July 2012 Hydro submitted an *Upgrade Circuit Breaker* plan to the Board of Commissioners of Public Utilities (PUB) as part of its 2013 capital plan. The plan contained two components. One was to refurbish and replace aging air blast and SF6 circuit breakers to ensure system reliability. The other was to comply with legislation to remove PCB contaminated bushings on oil circuit breakers by replacing the oil circuit breakers with new SF6 circuit breakers.

No changes are anticipated for either the oil circuit breaker replacement program or the SF6 refurbishment and replacement program

The July 2012 plan for air blast circuit breakers had been to overhaul these breakers at about 40 years of service and replace them at the useful end of the asset life between 50 and 55 years of service. Replacement breakers would be SF6 type breakers and the replacement program would be completed by 2031. This meant that four to five overhauls would be completed per year and about three replacements per year. The report indicated that the experience in Newfoundland and from other utilities was that overhauls were effective in maintaining the reliability of air blast circuit breakers and extending their lifecycle.

In January 2013 and January 2014 Hydro experienced major system outages. In both incidents air blast circuit breakers failed to operate properly. During the PUB investigation into the January 2014 power outages its consultant, the Liberty Consulting Group, made a number of recommendations regarding air blast circuit breakers. These recommendations included exercising breakers, catching up on overdue maintenance, reducing the preventive maintenance cycle from 6 years to 4 years and periodically operating breakers from protection. Furthermore, the PUB in its May 15th Interim Report has requested that Hydro file a report on August 1st on the acceleration of the replacement of air blast circuit breakers.

This Accelerated Air Blast Breaker Replacement program has been independently developed for Hydro to address the recent experience with the decreased reliability of air blast circuit breakers and the recommendations of the Liberty Consulting Group. Factors considered in the development of the program include the criticality of the circuit breaker to system reliability, the age of the breaker and time since its last overhaul, the optimal use of resources through selection of the number work sites and avoiding delays in removal of air systems. Data for the development of the program was obtained from Hydro's Breaker 20 Year Plan dated Mar 26, 2014 and revisions to it up to July 3, 2014.

4) Program Goal and Scope

The overall program goal is to replace all air blast circuit breakers on an accelerated schedule in order to eliminate reliability issues associated with failure of air blast circuit breakers. This requires a balanced approach that replaces the breakers on a timely basis but maintains reliability of the power system during the work required to replace them. A six (6) year project schedule has been chosen that would begin in 2015. A partnership arrangement would be established between Hydro and an external contractor. Initially, Hydro would prepare and issue tender documents, evaluate bids and award the contract. The external contractor would supply and install the breakers. During the contract execution, Hydro would disconnect existing breaker, review and approve drawings including protection and control, provide outage coordination and on-site supervision, and oversee commissioning.

The scope of the contract would include:

- Removal of existing breaker and foundation
- Construction of a new foundation for the circuit breaker structure
- Supply and installation of new breaker
- Installation of new protection equipment and control cables
- Commissioning of new breaker

The accelerated air blast circuit breaker replacement program is designed to be implemented in two three-year phases. For each phase, a multi-year contract (3 years) will be issued for supply and installation of breakers. The contract will contain specific numbers of breakers to be supplied and installed each year. The contract should also contain an option to supply and install additional breakers on an incremental basis by year that allows for flexibility to adapt to changing system conditions. By breaking the contract into two phases Hydro can ensure a competitive and competent supplier is used throughout while still benefitting from the economies resulting from large orders and dealing with one (either through a successful re-bid or a contract extension) or two suppliers.

5) Schedule

Due to the time required to procure circuit breakers it is not practical to implement an accelerated breaker replacement plan in the field prior to 2015. In 2014 the procurement process would be put in place that incorporates and replaces the existing Upgrade Circuit Breaker project to have the necessary breakers and services available in 2015. Current activities will ensure that a number of air blast circuit breakers get replaced in 2014. This also enables time to properly analyze the requirements, prepare a plan and put in place a contract for the accelerated replacement of circuit breakers beginning in 2015.

The plan requires that a tender be prepared and issued in the fall of 2014 for the first phase of the program to secure a contractor for the years 2015-2017. Breakers required for installation in 2015 need to be delivered in the spring of 2015. Installation would then take place during the construction season of April – October. Subsequent years 2016 and 2017 would follow a similar schedule. Preparation for Phase 2 would take place during the summer/fall of 2017. At that time either the existing contract could be extended for an additional 3 years or a new contract awarded in time to continue the replacement program without interruption.

It is important that a thorough review of the specific breakers to be replaced be conducted on an annual basis. This review should include all affected departments including system operations (ECC), regional operations and maintenance, engineering, plant operations as required and protection and control. The first review should take place in the fall to finalize the list for the following year. A preliminary schedule and resource requirements should be looked at. With this if there are resource issues then there is still time to address them. Three months prior to the beginning of the construction season the outage schedule needs to be finalized. During the construction season final scheduling and approval of outages would be done in accordance with Hydro procedures.

6) Risk

The accelerated air blast circuit breaker replacement program contains significant but manageable risks. During the years 2015 and 2016 there are 12 air blast circuit breakers being replaced each year. This is in addition to oil circuit breaker replacements (5 and 4 respectively), overhauls and preventive maintenance. This represents a significant risk to schedule and resource availability. However, in both 2015 and 2016 there are other breaker replacement programs already active such as LCP that would mitigate the risk somewhat. Coordination of the work by Hydro and the contractor / partner is critical to the success of this program.

7) General

The overall plan for accelerated circuit breaker replacement needs to meet the following criteria:

- ***Safety*** of personnel and equipment must be a priority at all times. Hence any plan that incorporates external resources needs to ensure that all safety requirements of Hydro are met or exceeded.
- ***Reliability*** of power system is continuously maintained. Although the outages incurred to install new breakers will impact the ability of the power system to respond to disturbances the overall plan should not create undue risks. It is imperative that the plan be coordinated with system operations.
- The replacement of the circuit breakers should consider ***effective use of resources*** including technical capabilities and capacity of available labour, equipment and materials as well as be ***economic***.
- ***Timely***. Accelerating the replacement of circuit breakers will reduce the potential for further outages caused by failures of air blast circuit breakers.

A number of factors were used to select and prioritize the breaker replacements. These included the criticality of the breaker to system reliability, the age of the breaker and time since its last overhaul, optimizing use of resources through selection of the number work sites and avoiding delays in removal of air systems. Locations where the breakers were critical to system reliability or where breakers with known problems existed were given the highest priority. For continuity and efficient use of resources, the number of work locations was constrained and once a Terminal Station was started replacements continued at that location until completed. This also ensured that the air systems could be removed on a timely basis. Coordination with other on-going breaker replacement programs was an important consideration due to the impact on both resources and reliability of the system. The age and the time of the last overhaul were used to guide the replacement when other more critical factors had been satisfied.

During **Phase 1** of the accelerated program from 2015 – 2017 a total of 18 air blast circuit breakers will be replaced. These are in addition to those being done under other programs currently in progress. By the end of 2017 a total of 34 breakers (all 230 kV) at 7 locations will have been replaced. This will also enable the associated air systems at 5 of these locations to be de-commissioned. At Sunnyside, the portion of the air system used to supply the 230 kV breakers can also be de-commissioned. The air systems which are an integral component required for the reliable operation of air blast circuit breakers require a significant amount of maintenance

In the years 2014 – 2016 other programs are in place that will result in replacement of air blast circuit breakers. The LCP program will result in ten (10) 230 kV breaker replacements at Holyrood and Bay D'Espoir. Two breakers (1 – 230 kV, 1 – 138 kV) are scheduled to be replaced in 2014 at Sunnyside in conjunction with the transformer T1 replacement. The NL/NS link requires that all four (4) 230 kV breakers at Bottom Brook be replaced in 2016.These are to be replaced by Emera and at this time are treated separately from the accelerated breaker program. In addition, the Upgrade Circuit Breakers project has air blast circuit breakers scheduled for replacement in 2015 and 2016 but these breakers have been included in the accelerated program beginning in 2015. For efficiency, consideration should also be given to incorporating the Emera work within the accelerated program.

During **Phase 2** of the accelerated program from 2018 – 2020 the remaining 29 air blast circuit breakers will be replaced (18 – 230 kV, 11 – 138 kV) at five locations. The air systems at these locations will also be de-commissioned. All 138 kV breaker replacements are scheduled to occur during Phase 2 because the 138 kV system is less critical to the overall reliability of the

electrical grid and resultant outages tend to be more localized. Moreover, from a project perspective the initial procurement need not address 138 kV breakers.

The following table provides a summary of the complete air blast breaker replacement programs. A more detailed description of the replacement program by location is included in Section 9 and Appendix 1 contains a complete list of all breakers to be replaced.

Air Blast Circuit Breaker Replacement

		Phase 1			Phase 2			
Description	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Total**
Accelerated Program		9	4	5	11	10	8	47
LCP	3	3	4					10
NL/NS Link			4					4
Other	2							2
Total	5	12	12	5	11	10	8	63

8) Circuit Breaker Planned Maintenance and Overhauls

On June 2, 2014 Hydro filed a report with the PUB on work required on air blast circuit breakers. In it Hydro identified that 40 breaker Preventive Maintenance (PMs) were due to be completed by the end of 2015. The schedule would be to complete 23 in 2014 (14 planned, nine overdue) and 17 in 2015 (eight planned, nine overdue). In 2016 and beyond the PMs would return to nine or ten per year and decrease over time.

The PM program for air blast circuit breakers has not been reviewed as part of this study. It is anticipated, however, that all overdue work will still be completed by the end of 2015 and the number of scheduled PMs for air blast circuit breakers should decrease rapidly between 2016 and 2019 with no PMs required in 2020. Although the PM program for air blast breakers will decrease and then end by 2019, the PM program for SF6 breakers will correspondingly increase as new SF6 breakers are added.

Hydro also had plans for overhauls of existing breakers at about 40 years. The current plan is to complete overhauls in 2014 and 2015. Beyond 2015 the circuit breaker replacement program would eliminate the need for overhauls of air blast circuit breakers.

This overhaul program for air blast breaker was briefly reviewed to determine if any opportunities existed for eliminating some overhauls by advancing the schedule for breaker replacement. It was noted that Hydro had advanced a couple of breakers, one at Bay D'Espoir (B1B10) and another at Sunnyside (L100L109). Given the aggressive schedule for breaker replacement and the desire to replace the most critical breakers first, no further opportunities were identified. Moreover, completion of the overhauls in 2014 and 2015 will be beneficial to the accelerated breaker replacement program by providing some added flexibility in the scheduling of breakers in the latter years of the program.

Air blast circuit breakers that have been scheduled for an overhaul have been identified in the detailed description of the breaker replacement program by location contained in Section 9.

Appendix 1 also includes the date of the last overhaul for all breakers in the replacement program.

It is recommended that Hydro retain some breakers and/or breaker parts from those recently removed from service to be used as spares until the completion of the breaker replacement program. The inventory kept should be comparable to what is used for a breaker overhaul since maintenance personnel are familiar with the overhaul procedure.

9) Breaker Replacement Program by Location

There are currently 63 air blast circuit breakers at 10 locations still in service. A plan for each site follows. Programs that are already in place such as the LCP program are included to provide a complete picture of the activity level by year and location. Consideration has been given to reliability, efficient use of resources, and a balancing of the effort by year. A specific breaker replacement schedule is included. However, there is flexibility in the overall schedule that would allow for some swapping of breaker replacements while still achieving the same overall results.

a) Holyrood

Holyrood contains nine (9) 230 kV air blast circuit breakers. All of these breakers will be replaced between 2014 and 2016 as part of the LCP program. This program will be operated separately from the accelerated program but the numbers will be tracked. No changes to this program are anticipated.

Breaker replacement schedule[1]:
2014 – B2B11, B1B11, B1L17[2]
2015 – B2L42[3], B3L18, B3B13
2016 – B12L42, B12L17, B12B15

Notes
1. All breakers replaced as part of the LCP program.
2. Breaker failed in Jan 2014
3. Breaker scheduled for overhaul in 2014

b) Bay D'Espoir

Bay D'Espoir Terminal Station contains thirteen (13) 230 kV air blast circuit breakers. This generating station is critical to the reliability of the integrated island electrical system. During phase 1 eleven (11) of the breakers will be replaced.

There are 6 generator unit breakers that need to be replaced. These breakers are operated frequently as the hydro units are brought on and off line. The concern with these breakers is not with failure to having them exercised but rather with wear and tear due to the number of operations. Hydro has identified these breakers as the most critical to the system driven by the fact they are generator breakers without an alternate route to get power to the grid. Due to on-going work at other locations such as Sunnyside, Holyrood and Oxen Pond and the challenge of attempting to schedule outages for all generator breakers in one year, these breakers have

been scheduled to be replaced in 2015 and 2016. This will also mitigate risks associated with having the hydro plant available for energy, peak demand and reserve.

From a risk perspective, if a generator breaker fails before it is replaced then the consequence is the loss of that generator until it can be repaired or replaced. For a hydro unit the risk is primarily loss of capacity and/or reserve in times when total supply is limited such as during peak load conditions. To mitigate this it is recommended that a plan be developed to rapidly deal with the failure of one of these breakers. This could include keeping a spare breaker or key parts set aside specifically for these locations. It is also recommended that a PM be performed in 2015 on the three breakers that are not scheduled for replacement until 2016.

The remaining seven breakers are part of the ring bus. The outage required to remove any one breaker will not impact the output of the plant or the delivery of energy to the system via the connecting transmission lines. However, the system will be at risk and tripping of any of the transmission lines at Bay D'Espoir may result in the loss of additional transmission lines or unit generation. Each outage will need to be carefully planned and the generation levels at Bay D'Espoir may need to be adjusted to ensure the overall system reliability is maintained. Given the complications and risks associated with replacing these breakers, the number of breakers scheduled in any one year has been limited to three. The result is that the outages for these breakers are spread over the four years to minimize system related reliability risks. One of the breakers B4B5 will be replaced in 2016 as part of the LCP program.

From a risk perspective, if a ring breaker fails before it is replaced then the consequence is that other breakers will operate to isolate the failed breaker. The most common failure mode occurs when a breaker is commanded to operate such as for a fault but fails to do so. The impact on the system is less predictable because of the numerous potential configurations and load levels but could be severe.

The air system will be de-commissioned in 2018 at the end of the breaker replacements.

Breaker replacement schedule:
2015 – B1T2, B2T3, B2T4, B1B2
2016 – B1T1, B3T5, B3T6, B4B5[1]
2017 – B3B4, B6B10, B2B3
2018 – B5B6, B1B10[2]

Notes:
1. Breaker to be replaced as part of LCP program
2. Breaker scheduled for overhaul in 2014. Advanced from 2016.

c) Sunnyside

Sunnyside Terminal Station contains four (4) 230 kV and six (6) 138 kV air blast circuit breakers. Sunnyside occupies a critical location in the Newfoundland electrical grid connecting the large generation supply of Bay D'Espoir to the major load area of the Avalon peninsula. Therefore, maintaining the integrity of the 230 kV ring bus at Sunnyside is crucial to the reliability of the grid. In the major outage of January 2014, tie transformer T1 failed and the 230 kV air blast circuit breaker B1L03 failed to operate. Work will be carried out in 2014 to replace

the tie transformer, 138 kV breaker B2T1 which was damaged during the transformer fire and breaker B1L03.

During Phase 1 the remaining 230 kV breakers are scheduled to be replaced over a two year period. This will ensure that this critical location will be upgraded with new equipment by the end of 2016.

During Phase 2, the remaining air blast circuit breakers, all at 138 kV, will be replaced.

Breaker replacement schedule:
2014 – B1L03[1], B2T1[2]
2015 – B1L02, L06L07[3]
2016 – L02L07
2017
2018 – B3T4, B2L12[3], L19L100[3]
2019 – L109T4[4], L100L109[5]

Notes

1. Breaker failed to operate Jan 2014. New breaker purchased for Hardwoods moved to Sunnyside
2. Breaker damaged during transformer fire.
3. Breaker scheduled for overhaul in 2014
4. Breaker scheduled for overhaul in 2015
5. Breaker scheduled for overhaul in 2014. Advanced to 2014 due to condition assessment.

d) Hardwoods

One (1) 230 kV air blast circuit breaker remains in service at Hardwoods Terminal Station. Early replacement will allow for the air system to be de-commissioned. It was scheduled for replacement in 2014 but has been swapped with a breaker at Sunnyside. It has been re-scheduled to 2015.

Breaker replacement schedule:
2015 – B1L01[1]

Notes:

1. Purchased in 2013, scheduled for installation in 2014 but moved to Sunnyside.

e) Oxen Pond

Oxen Pond Terminal Station contains two (2) 230 kV air blast circuit breakers. To coordinate with transformer upgrade / tie breaker design one breaker will be installed in 2014 and placed in service in 2015. The other breaker will be scheduled for 2016 to complete the station and enable the air system to be de-commissioned.

Breaker replacement schedule:
2014/15 – B1L18[1]
2015 – B1L36

Notes:

1. Breaker to be installed in 2014 but commissioned in 2015. Therefore it is not included in accelerated replacement program.

f) Bottom Brook

All four (4) 230 kV breakers at Bottom Brook Terminal Station are air blast circuit breakers. These breakers are scheduled for replacement by Emera in 2016 for the NL/NS link. The breakers are configured in a ring bus arrangement and Bottom Brook supplies the southwestern part of NL. The removal from service of each breaker will need to be carefully planned. Although treated separately, the replacement of breakers at Bottom Brook will need to be coordinated with the accelerated breaker replacement program. Hydro should explore the possibility of managing this work under the accelerated program. When complete the air system can be de-commissioned.

Breaker replacement schedule[1]:
2016 – B1B11, B1L09, L09L33, L11L33

Notes:

1. All breakers to be replaced by Emera as part of NL/NS link

g) Massey Drive

Massey Drive Terminal Station contains two (2) 230 kV air blast circuit breakers. They are scheduled for replacement in 2017. This schedule needs to be reviewed prior to initiating the work to replace the breakers at Bottom Brook. If transmission line TL211 can be removed from service then one breaker at Massey Drive and two at Bottom brook can be replaced simultaneously under the same outage.

Breaker replacement schedule:
2017 – B1L28, B5L11

h) Stony Brook

Stony Brook Terminal station contains six (6) 230 kV air blast breakers and six (6) 138 kV air blast breakers. The replacement program is included in Phase 2. Four breakers are scheduled per year with a mixture of 230 kV and 138 kV breakers each year. Most of the 138 kV breakers will require a line or transformer outage for the duration of the replacement work. Work on this station has been delayed until Phase 2 because all 230 kV breakers have been overhauled since 2008 and should be reliable. Some of the 138 kV breakers are scheduled for an overhaul in the next couple of years. Due to the large number of breakers to be replaced and the requirement for outages for the 138 kV work, the scheduling of this work will require extra discussion and be carefully planned to ensure reliability and to minimize outage times. The air system can be de-commissioned in 2020.

Breaker replacement schedule:
2018 – B2L04, L05L31, B3L130, B3T2
2019 – B1L31, L05L35, B1L32, B1L35
2020 – B3L22[1], B3L133[2], B3T1[2], B3L10[2]

Notes:
1. Breaker scheduled for overhaul in 2014
2. Breaker scheduled for overhaul in 2015

i) Western Avalon

Western Avalon contains six (6) 230 kV air blast circuit breakers. These are all scheduled for replacement in Phase 2.The primary reason is that all six breakers will have been overhauled between 2005 and 2014. Two breakers per year are scheduled for replacement. This assumes that all breakers continue to perform well regardless of model. If issues arise with a particular model (e.g. B1L03 is an older model type DCVF), then adjustments may need to be made in the schedule. This can be done during the annual review process.

Breaker replacement schedule:
2018 – B1L17, B1L37
2019 – B1L08, L03L17
2020 – L01L03[1], B1B3[2]

Notes:
1. Breaker scheduled for overhaul in 2014
2. Breaker scheduled for overhaul in 2015

j) Buchans

Buchans Terminal station contains four (4) 230 kV breakers. These breakers are scheduled for replacement over a two year period in 2019 – 2020 at the end of Phase 2. With overhauls recently completed or scheduled for the current year the reliability of the station should be good. Hence, the installation of replacement breakers can be delayed. The breakers are configured in a ring bus configuration that enables the removal of one breaker at a time without causing any outages. The air system can be de-commissioned in 2020.

Breaker replacement schedule:
2019 – L05L33, B1L05[1]
2020 – L28L32[1], B1L28[1]

Notes:
1. Breaker scheduled for overhaul in 2014

10) Conclusions and Recommendations

This report provides a plan for the implementation of an accelerated air blast circuit breaker program. During the current year, 2014, previously scheduled work to replace breakers, undertake breaker overhauls and perform preventive maintenance will occur. In addition preparation work for the accelerated program should begin in 2014 with tender preparation, selection of a partner/contractor and ordering the first set of breakers. Installation of the air blast circuit breakers would then take place over a 6-year period between 2015 and 2020. At the end

of 2020 all 63 air blast circuit breakers that were on the Hydro system at the beginning of 2014 would be replaced.

This report includes a discussion of the many factors affecting the replacement of the air blast circuit breakers and provides a summary by year and location of each breaker to be replaced. Some of the key recommendations contained in the report are repeated below.

R1. Implement the accelerated air blast circuit breaker replacement program in two phases. The actual implementation may be done through separate contracts or a single contract with extension. This will minimize spares as well as ensure efficiencies in the implementation.

R2. Coordinate the accelerated air blast circuit breaker replacement programs with other breaker replacement programs including LCP and NL/NS link.

R3. Review the plan annually to ensure the specific breakers selected are the most appropriate for replacement and to address any scheduling and resource issues.

R4. Maintain a set of spares from recently replaced breakers to have available in case of premature failure of a still-in-service air blast circuit breaker.

Appendix 1

Accelerated Air Blast Breaker Replacement Program

Location	NLH ID	Year Built	Oper Volt (kV)	Overhaul Year	Replacement Year	Age at Replacement	Criticality
HRD TS	B1B11	1974	230	-	2014	40	B
HRD TS	B1L17	1973	230	2014	2014	41	B
HRD TS	B2B11	1974	230	-	2014	40	B
SSD TS	B1L03	1966	230	2002	2014	48	B
SSD TS	B2T1	1969	138	-	2014	45	C
BDE TS1	B1B2	1966	230	2004	2015	49	B
BDE TS1	B1T2	1966	230	1999	2015	49	A
BDE TS1	B2T3	1966	230	2000	2015	49	A
BDE TS1	B2T4	1968	230	2000	2015	47	A
HRD TS	B2L42	1973	230	2014	2015	42	B
HRD TS	B3B13	1978	230	-	2015	37	B
HRD TS	B3L18	1978	230	-	2015	37	B
HWD TS	B1L01	1972	230	NA	2015	43	B
OPD TS	B1L18	1969	230	2008	2015	46	B
OPD TS	B1L36	1969	230	2008	2015	46	B
SSD TS	B1L02	1966	230	2003	2015	49	B
SSD TS	L06L07	1968	230	2014	2015	47	B
BBK TS	B1L09	1971	230	-	2016	45	C
BBK TS	B1L11	1971	230	-	2016	45	C

BBK TS	L09L33	1973	230	-	2016	43	C
BBK TS	L11L33	1978	230	-	2016	38	C
BDE TS1	B1T1	1966	230	2002	2016	50	A
BDE TS1	B3T5	1969	230	2000	2016	47	A
BDE TS1	B3T6	1966	230	2001	2016	50	A
BDE TS1	B4B5	1964	230	2003	2016	52	B
HRD TS	B12B15	1978	230	-	2016	38	B
HRD TS	B12L17	1973	230	-	2016	43	B
HRD TS	B12L42	1978	230	-	2016	38	B
SSD TS	L02L07	1966	230	2002	2016	50	B
BDE TS1	B2B3	1968	230	2006	2017	49	B
BDE TS1	B3B4	1972	230	2005	2017	45	B
BDE TS1	B6B10	1968	230	2005	2017	49	B
MDR TS	B1L28	1966	230	2007	2017	51	C
MDR TS	B5L11	1967	230	2006	2017	50	C
BDE TS1	B1B10	1975	230	2014	2018	43	B
BDE TS1	B5B6	1968	230	2007	2018	50	B
SSD TS	B2L12	1966	138	2014	2018	52	D
SSD TS	B3T4	1966	138	2012	2018	52	C
SSD TS	L19L100	1966	138	2014	2018	52	D
STB TS	B2L04	1966	230	2011	2018	52	C
STB TS	B3L130	1968	138	2012	2018	50	D
STB TS	B3T2	1969	138	2012	2018	49	C
STB TS	L05L31	1969	230	2008	2018	49	C

WAV TS	B1L17	1969	230	2009	2018	49	B
WAV TS	B1L37	1968	230	2005	2018	50	B
BUC TS	B1L05	1973	230	2014	2019	46	C
BUC TS	L05L33	1973	230	2013	2019	46	C
SSD TS	L100L109	1968	138	2014	2019	51	D
SSD TS	L109T4	1968	138	2015	2019	51	C
STB TS	B1L31	1966	230	2008	2019	53	C
STB TS	B1L32	1968	230	2009	2019	51	C
STB TS	B1L35	1966	230	2010	2019	53	C
STB TS	L05L35	1966	230	2009	2019	53	C
WAV TS	B1L08	1968	230	2010	2019	51	B
WAV TS	L03L17	1969	230	2009	2019	50	B
BUC TS	B1L28	1975	230	2014	2020	45	C
BUC TS	L28L32	1972	230	2014	2020	48	C
STB TS	B3L10	1977	138	2015	2020	43	D
STB TS	B3L133	1969	138	2015	2020	51	D
STB TS	B3L22	1967	138	2014	2020	53	D
STB TS	B3T1	1969	138	2015	2020	51	C
WAV TS	B1B3	1977	230	2015	2020	43	B
WAV TS	L01L03	1969	230	2014	2020	51	B