

MEETINGS IN ST. JOHN'S AND VISITS TO LOWER CHURCHILL PROJECT SITES, JULY 15 TO 19, 2019

Prepared for: Natural Resources Canada and Nalcor Energy
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Quality Assurance Statement

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1. GENERAL

The Independent Engineer (IE) team visited Muskrat Falls Generating Station and Converter Station as well as the Soldiers Pond Station and attended project briefings and meetings at the Lower Churchill Project Delivery Office in St. John's on July 16, 17 18 and 19th. NALCOR senior management representatives and technical specialists, representatives from the Government of Newfoundland & Labrador and Government of Canada also attended the presentations and site visits.

IE team: Nik Argirov (IE Team Lead)
Paul Hewitt (IE Infrastructure and Cost Subject Matter Expert (SME))
Vlad Kahle (IE Electrical SME)
Hamdy Khalil (IE Transmission SME)
Tim Little (IE Geotechnical SME)

NALCOR Meeting and Site Visit Coordinator: Ms. Rosanne Williams

Trip itinerary:

July 15:

- Arrive and overnight in St John's

July 16:

- Project update meetings at LCP office
- SOP Converter Station and Switchyard visit
- Return to and overnight in St John's

July 17:

- Travel to Goose Bay
- Muskrat Falls powerhouse visit
- North Spur site visit

July 18:

- MF Converter Station, GIS building and Switchyard visit
- Travel to St John's

July 19:

- Transition To Operations (TTO) presentation
- Project update teleconference
- Depart from St John's

July 20:

- Depart for home bases

2. TECHNICAL UPDATE AT LCP OFFICE – JULY 16, 2019

2.1 Project progress update:

- Safety remains #1 priority. It has been more than two years since the last loss time incident during which period the crews worked 47.2 million staff hours.
- Project progress and schedule:
 - With 94% of work completed as of end of May 2019, the powerhouse construction is on track.
 - With 91% of work completed as of end of May 2019, the spillway construction is also on track.
- All prerequisites for impoundment to full pool level of 39 m are in place and public notice was issued for a planned start date of August 07, pending final approval from Management.
 - All permanent reservoir retaining structures are ready for impoundment.
 - All temporary cofferdams are decommissioned or removed.
 - Spillway bays 1 and 5 are complete and will control flows during impoundment.
 - Spillway bay 3 is currently closed for concrete rollway construction. Bays 2 and 4 will be closed to commence impoundment; once approved by NALCOR, rollway completion in those bays will begin.
 - Dam safety instrumentation is installed, and monitoring systems and programs are in place. More frequent dam safety inspections and instrument readings will be carried out during the impoundment period. An independent dam safety audit by Hatch in April concluded that the dam safety management program complies with Canadian Dam Association guiding principles and meets or exceeds good industry practices.
 - Hydrologic conditions are being monitored and forecasted inflows and upstream and downstream water levels are updated regularly.
 - Contractors are prepared with all necessary equipment and safety measures ready. Contingency planning has been done for potential malfunctions or problems that may arise.

2.2 Turbine and Generator Update:

- All four unit bays are at pit-free status or better (i.e. the unit bay is ready for unimpeded installation of the turbine and generator).
- Bridge crane is certified for the full length of the powerhouse.
- Unit 1 turbine was installed in May. The stator windings are complete, the rotor was lifted into place on July 12th, P&C installation is nearing completion. Exciter and turbine governor have been installed. Forecasted “ready to turn” date is late September.
- Unit 2 mechanical component installation is in progress. Piling of the stator is completed.
- Unit 3 is ready for mechanical component installation and stator frame is being installed.

- Unit 4 is being readied for machining of embedments and welding repairs to draft tube liners.
- Power intakes are complete and intake gates have been commissioned.
- Integrated commissioning plan is currently under development by the commissioning team.
- Intake gate and spill gate controls are complete; control room controls have not yet been completed.
- Tailrace rock plug was blasted but a portion has been left in place to maintain the construction access road across it as long as possible for convenience. The blasted rock plug is scheduled to be excavated in early August.

2.3 Presentation to IE on Completion Plans:

- Process Milestones:
 - Factory Acceptance Tests (FAT)
 - Mechanical Completion (site installation complete)
 - Static commissioning (offline)
 - Dynamic commissioning (online)
 - Handover
 - Start- up
 - Asset Transfer
- Project Completion System (PCS) is NALCOR's equipment inventory tracking relational database. All factory and commissioning test records and certificates are filed electronically in this database.
- Asset management may use the PCS for maintenance management.
- Commissioning Plans:
 - Site Completion Lead is responsible for the system integration tests
 - Generation Project Completion Plan is now available in the data room
 - Generation Project Start- up Plan is now available in the data room
- 315 kV Grid Energization Plan is as follows:
 - Q4 '19 - 1st power, Unit 1 energization and synchronization
 - Q4 '19 - Unit 1 release for service and ready for asset turnover to operations
 - Q1 '20 - Unit 2 release for service
 - Q2 '20 - Unit 3 release for service
 - Q3 '20 - Unit 4 release for service

2.4 P&C Philosophies Review:

Following the ANDRITZ facility visit on Nov. 6, 2018 IE prepared and submitted to NALCOR discussion points and questions pertaining to Protection design changes to the Design, Supply and Install Agreement of 22 August 2012. More discussions and correspondence between IE and NALCOR took place in the intervening period. NALCOR responded to IE team as follows:

- NALCOR agrees with the IE that closing the intake gates for electrical and mechanical faults constitutes 'over tripping'. That said, NALCOR expressed confidence that the intake gates are designed for this duty and will not experience undue wear. The IE remain in disagreement with this approach, NALCOR will revisit this issue at a later date after turnover to 'Operations'.
- NALCOR stated that it is acceptable to run the MF units with up to 3 failed shear pins (SP). There may be grid contingencies that will necessitate keeping the unit online with failed shear pin(s) regardless of the potential for additional equipment damage. Operations propose to depend on the site operator taking the appropriate action upon receipt of the SP failure alarm. Due to the potential for human error IE disagree with that approach and maintain that unit shut-down for SP failure is more prudent action.
- NALCOR proposes to leave bulkhead (BH) operation procedure as is and to rely on the crane load cell and operator's judgment to safely lift the BH's. IE are of the opinion that permissive interlock of the hoist command should be in place before the BHs are lifted.
- NALCOR accepted IE recommendation to implement directly wired connections for the intake gate emergency close.
- NALCOR accepted IE recommendation to implement the intake gate emergency close for turbine pit high- high level.
- Formal response from NALCOR to IE will follow.

2.5 Transmission Link Project update

- Strait of Belle Isle 100%
- Labrador Transmission Asset (LTA) is 99.99% complete.
- Labrador Island Transmission Link (LITL) is 99.92% complete.
- Oversight of the software development is provided by independent consultants Systematic and Amplitude.
- HVDC Monopole status:
 - Software (S/W) version 17c was commissioned between May 25 and June 4
 - LIL transferred up to 140MW during this period
 - LIL tripped on May 31 due to external AC fault
 - LIL was taken out of service on June 4th to permit Bipole commissioning
 - That concludes the monopole testing
 - It is noted that NL Hydro has not planned to receive recall power from the LIL for winter 2019-2020

- HVDC Protection and Control Software Development
 - GE presented a list of approx. 50 S/W 'non-critical' (Category B) bugs to NALCOR for review. Nalcor required resolution for the bugs,
 - Nalcor is forecasting a Seven week slip for delivery of the FAT Interim Bipole S/W from the milestone dates established in the current Amendment Agreement
 - Expected S/W Milestones Dates (as per the May 2019 Project Forecast Schedule):

Interim (limited functionality) Bipole Software

- FAT version of S/W delivered to site - Oct 18, 2019
- Static commissioning - Oct 18 - Nov 26, 2019
- Dynamic Commissioning including all associated testing - Nov 27 - Dec 17, 2019
- Christmas Break - Dec 18 - Jan 5, 2020
- Dynamic commissioning - Low Load test - Jan 7 - Feb 15, 2020
- Dynamic commissioning - Trial Operations at Low Power - Feb 16 - April 15, 2020

Final (fully functional) Bipole Software

- FAT version delivered to site - April 22, 2020
- Static commissioning - April 22 - May 12, 2020
- Dynamic Commissioning - Confirmation Tests - May 13 - June 1, 2020
- Dynamic commissioning - Low Load Test - June 2 - June 21, 2020
- Dynamic commissioning - High Power Test - June 22 - July 21, 2020
- Dynamic commissioning - Trial Operations at High Power - July 22, 2020

- Soldiers Pond Synchronous Condensers (SC) are covered in the following section.
- NALCOR's schedule for remaining work:
 - AC switchyard asset has been handed over to Operations
 - SC's are to be completed by Oct. 2019
 - Bipole interim S/W FAT completion is expected in Oct. 2019
 - Bipole interim S/W low load tests are scheduled for Feb. 2020
 - Bipole final S/W low load tests are scheduled for June. 2020

3. SOLDIERS POND (SOP) PROJECT SITE – JULY 16, 2019

3.1 Converter building:

- Hardware installation has been completed (Appendix 2- Photo 1).
- Control room and HMI's have been installed awaiting implementation of the GE S/W.

3.2 Switchyard:

- Power equipment installation has been completed.

3.3 Synchronous Condenser (SC) building (Appendix 2- Photo 2):

- Lube contamination remediation work is in progress. Units 1 and 3 have been completed, Unit 2 bearing and housing have been reinstalled and oil flush completed.
- Unit 1, 2 and 3 rotor lift upgrades have been completed.
- Hydrogen system replacement piping is being fabricated.
- Static and dynamic testing is in progress. Unit 1 static commissioning is in progress. Unit 2 is slated for dynamic commissioning in Aug. 2019. Unit 3 has been synchronized and rotated.

4. MUSKRAT FALLS PROJECT SITE – JULY 17, 2019

All major Civil water retaining structures are completed and ready for reservoir impoundment to full pool level.

The IE team made an extensive tour of the powerhouse and other project structures, including:

- Intake deck, intake gate hoist building and powerhouse roof.
- Powerhouse interior including mezzanine floors, generator floor, turbine floor, galleries, Unit 1 draft tube cone and unit 3 intake passage.
- Spillway.
- North RCC dam gallery.
- South embankment dam.

Reservoir:

- Reservoir level was at about El. 24.5 m and water was impounded against the upstream faces of all water retaining structures.
- Some segments of the debris boom were missing due to failure of chains. The boom needs to be repaired prior to reservoir filling. IE understands that boom repairs are included as part of ongoing overall impoundment preparations. (Post meeting Note: The repairs were completed as of August 7, 2019.)

Power Intakes:

- All intake gates have been commissioned and were in closed position.

Powerhouse:

- Status of Units 1 to 4 was as described at July 16 project update.
- Assembly of Unit 2 turbine runner and rotor was in progress.

- Balance of plant installations continue. Emergency diesel and station service equipment are installed and undergoing final tests.
- Seepage flows in drainage galleries were observed to be small; several flow monitoring weirs are installed in gallery gutters.
- Tailrace was flooded to same level as downstream river. Remaining portion of rock berm is scheduled for removal in early August.

Spillway:

- Rollway construction was in progress in bay 3.
- Some spillway stoplogs are stored on spillway deck and others are reported to be stored nearby on site on trailers for quick mobilization when required.

See Appendix 2 for photographs.

5. MUSKRAT FALLS NORTH SPUR – JULY 17, 2019

- North Spur construction works were completed in 2017 and there has been no further construction activity since then. The constructed upstream and downstream slopes remain in good condition.
- Portions of the hydroseeded slopes are starting to “green up” quite well, although it is difficult for vegetation to become established on sandy slopes exposed to wind. Some local minor surface erosion has occurred due to natural runoff. NALCOR plans to have small alder trees planted in some areas of the North Spur soon.
- Dam safety instrumentation consists of piezometers, inclinometers, a flow meter at the outlet of the kettle lakes and a strong motion seismograph fixed to bedrock near the south end of the upstream slope. The surface collars of the piezometer and inclinometer installations are protected with lengths of partially buried corrugated metal pipe with locked steel lids. Readout leads for the piezometers are buried in shallow trenches and run to a common instrumentation building that houses an automatic data acquisition system and the original pump well control system. The seismograph is housed in a separate building.
- The current reservoir level of about El. 24.5 m is about 4 m above the top of the upstream cutoff wall, which is connected to the till blanket. With this initial impoundment, piezometers indicate that the cutoff is performing as intended, and the piezometric level on the downstream side of the cutoff is below reservoir level.
- The inclinometers are regularly read manually with a downhole probe. To date no significant movements have been measured, therefore there is no reason to install automated probes at specific depths.
- No earthquake shaking has been recorded to date.
- The design for the North Spur does not rely on the pump well system, which has been turned off since mid-February 2019. The well system remains in place and could be restarted if determined to be required in future.

- NALCOR reported that there is no history of vandalism at the North Spur. However, considering the isolated location and potential for public access, the IE suggests that NALCOR review if security/protection against vandalism for dam safety monitoring equipment and buildings at the North Spur is adequate.

See Appendix 2 for photographs.

6. MUSKRAT FALLS CONVERTER, SWITCHYARD AND GIS – JULY 18, 2019

6.1 Converter building:

- Hardware installation has been completed.
- Control room and HMI's have been installed awaiting implementation of the GE SW.

6.2 Switchyard:

- Power equipment installation has been completed.

6.3 Gas Insulated Switchyard (GIS) building:

- Power equipment installation has been completed.
- Four transmission lines from the powerhouse are in place but the jumpers have not yet been connected. Those serve as the demarcation points between the construction and operations.

7. TTO UPDATE AT LCP OFFICE– JULY 19, 2019

The update was presented by Mr. Rob Henderson:

7.1 Transition To Operations (TTO) update:

- Overall program completion stands at 74.2%.
- Preparation of Generation, Transmission and Operations contracts is in progress.
- Coordination meetings are held between project delivery team and operation staff. IE were advised that the ECC will develop their own HMI screens and the GE has the responsibility for development of the converter station HMI screens.

IE Comment: Development and the style of the Synchronous Condenser (SC) control HMI and MF generator units/control room has not been discussed. With ABB supplying the SC HMI screens and Andritz being responsible for the MF powerhouse control room screens, 4 different systems, perhaps using different symbols and equipment designations may be implemented. Mr. Henderson suggested that reconciliation and cross references between the systems will be required. In IE opinion such an approach creates potential for miscommunication and operating errors. It is a good utility practice to have

a single point of responsibility for all the operating information including operating instructions, HMI screen layouts and the operating diagrams. Only one and unique designation is typically used on all station engineering drawings, operating single line diagrams, HMI screens and the equipment nameplates. IE recommends further discussions on this issue. In the event of natural, environmental or complex emergencies, response risk assessment will focus on people and equipment safety.

Post meeting note: NALCOR Energy and Hydro procurement policy results in purchasing equipment from different vendors who may apply a variety of technologies of different vintages, unique designations and design philosophies. This requires careful preparation of standard operating instructions at the ECC, standardized operating diagrams and training programs. In addition, Hydro applies standardized nomenclature to the ECC HMI's and its engineering drawings, single line diagrams and equipment cabinet nameplates. The system operating diagrams (operating single line drawings) are prepared using a centralized drafting group and a prescribed approval process. This ensures accuracy and consistency in these drawings to mitigate potential safety and reliability risks associated with drawing interpretation. Formal response and explanations from NALCOR can be found in Appendix 3.

- Site safety coordinators have been recruited. Generation safety program is 47% completed (6 out of 27 modules). Transmission is 99% completed.
- P&C, mechanical and electrical staff participate in commissioning on rotational basis.
- Recruitment and training of the staff is in progress, new hires are trained and mentored. Manitoba Hydro International has supplied the journey person operators and will train and mentor apprentice operators. Manitoba Hydro International staff assists in preparation of the Operating Instructions.
- An existing dam safety group based at Churchill Falls will be responsible for Muskrat Falls dam safety program. Dam safety monitoring will transfer to that group after reservoir impoundment is completed.
- Generation dump sequences are in place for simultaneous loss of both 315kV line to CF.
- All units will be capable of black start; there are no provisions for operating MF units in SC mode.
- Generator models have been developed by Andritz and forwarded to Hydro Quebec. It is anticipated that when completed, the MF plant will be operated in 500 to 600MW range.
- Commissioning test results and OEM instructions will serve as a baseline for development of maintenance program. OEM recommended time-based maintenance criteria will be used during the initial warranty period. Asset management will use the PCS data to populate their own data base.

7.2 Ready For Integration (RFI):

- Unit 1, SC operations, unit transformer energization and Hi Power operational studies are in progress.
- Operating limits are being determined.
- 25k documents and GIS data have been transmitted to Operations.
- NERC Reliability Standards are under review for voluntary adoption. Cyber security is being implemented.

7.3 Ready For Commercial Integration (RFCI):

- RFCI is 96.4% complete.
- Draft agreement for optimization of hydraulic resources is being circulated for comments.
- SOP, Churchill Falls AC substation and MF HVDC have been turned over to Operations.
- Labrador grounding line has been completed.
- Outstanding items are telecom links, teleprotection to grounding stations, SOP SC plant HVAC and distribution circuits.

8. CONCLUSIONS AND COMMENTS

- Equipment installation, commissioning and site reclamations have either been progressing well or been completed.
- Target dates for GE Protection and Control software development and FAT have been revised several times and appear to be somewhat fluid.
- NALCOR and IE are not in agreement on the philosophy affecting some of the MF generator protection systems. Formal response from NALCOR is pending.
- IE propose further discussions and clarification on how the equipment designations will be reconciled between different documents, HMI's and equipment nameplates.

Post meeting note: Formal response and explanations from NALCOR has been provided in Appendix 3.

- The IE suggests that NALCOR review if security/protection against vandalism of dam safety monitoring equipment and buildings at the North Spur is adequate, considering the isolated location and potential for public access.

Appendix 1

List of Acronyms

Acronym	Full Name
BH	Bulkhead
CF	Churchill Falls
ECC	Electrical Control Centre
FAT	Factory Acceptance Test
GIS	Gas Insulated Switchyard
HMI	Human Machine Interface
HVAC	Heating Ventilation Air Conditioning
HVDC	High Voltage Direct Current
IE	Independent Engineer
LCP	Lower Churchill Project
LITL or LIL	Labrador Island Transmission Link
LTA	Labrador Transmission Asset
MF	Muskrat Falls
NERC	North American Electric Reliability Corporation
OEM	Original Equipment Manufacturer
P&C	Protection and Controls
PSC	Project Completion System
RCC	Roller Compacted Concrete
RFCI	Ready for Commercial Integration
RFI	Ready for Integration
S/W	Software
SC	Synchronous Condensers
SME	Subject Matter Expert
SOP	Soldiers Pond
SP	Shear Pins
TTO	Transition to Operations

Appendix 2

Site Photographs



Photo 1 - SOP Convertor building switchboards



Photo 2 - SOP Synchronous Condensers building



Photo 3 – MF Spillway Hoist Support Structure and Gates



Photo 4 - Four interconnecting lines between the Powerhouse and Converter building



Photo 5 - Intake gate hoist



Photo 6 - Intake gate hoist Motor Control Centre (MCC) detail

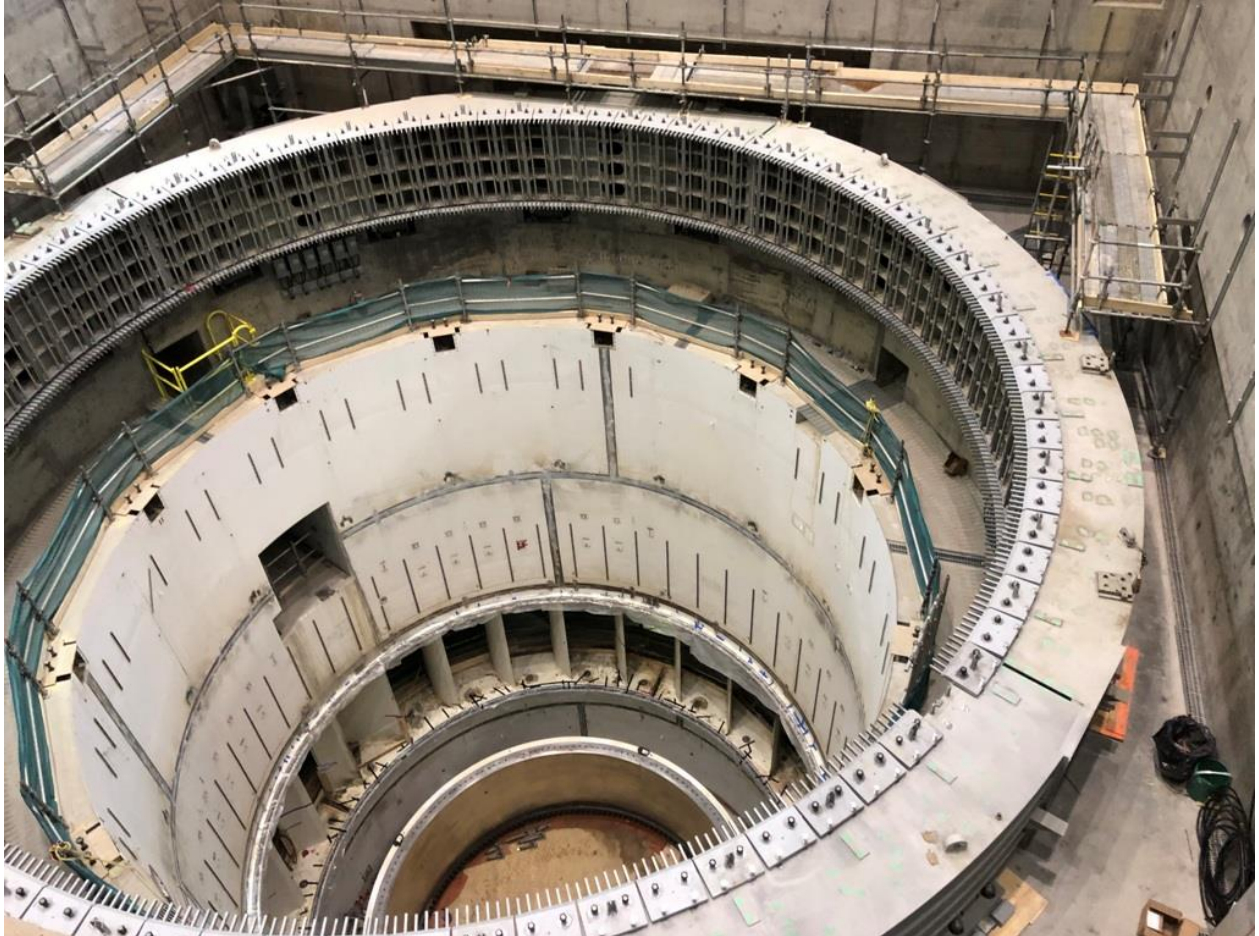


Photo 7 - Unit 3 Generator stator frame complete



Photo 8 - Unit 2 Turbine runner



Photo 9 - Unit 4 Turbine pit and stay ring



Photo 10 – North (RCC) Dam drainage gallery



Photo 11 - North Spur



Photo 12 - Instrumentation detail at North Spur

Appendix 3

NALCOR ENERGY Formal Response to IE comments in Section 7.1



MEMO

To: Nik Argirov

Date: 03 October 2019

From: Rob Henderson

RE: HUMAN MACHINE INTERFACES

We wish to explain the approach taken at Nalcor Energy and Newfoundland and Labrador Hydro with regard to Human Machine Interfaces (HMI) and the risk you have raised in your recent report on your visit to St. John's, as provided below:

"Coordination meetings are held between project delivery team and operation staff. IE were advised that the ECC will develop their own HMI screens and the GE has the responsibility for development of the converter station HMI screens.

IE Comment: Development and the style of the Synchronous Condenser (SC) control HMI and MF generator units / control room has not been discussed. With ABB supplying the SC HMI screens and Andritz being responsible for the MF powerhouse control room screens, 4 different systems, perhaps using different symbols and equipment designations may be implemented. Mr. Henderson suggested that reconciliation and cross references between the systems will be required. In IE opinion, such an approach creates potential for miscommunication and operating errors.

It is a good utility practice to have a single point of responsibility for all the operating information including operating instructions, HMI screen layouts and the operating diagrams. Only one and unique designation is typically used on all station engineering drawings, operating single line diagrams, HMI screens and the equipment nameplates. IE recommends further discussions on this issue. In the event of natural, environmental or complex emergencies, response risk assessment will focus on people and equipment safety."

Nalcor purchases control systems from a variety of vendors which have their unique control design and interfaces. Nalcor generally applies functional specifications when it purchases the control systems. Therefore, the vendors are required to provide the functionality but the specification is not prescriptive in the terminology or control displays. This approach was also applied to the Lower Churchill Project.

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Therefore, it is important that Nalcor, through its vendor supply contracts, include training of Nalcor's operations, maintenance and engineering personnel expected to use the vendor supplied HMIs so that they understand the interface to safely and efficiently operate, and maintain the equipment. This training will be implemented on all facilities being supplied in the Lower Churchill Project.

When it comes to the HMI in the NLSO's Energy Control Centre, the NLSO deploys standardized nomenclature, symbols, single lines and screen layouts so that the ECC operator won't make an error in the execution of controls or interpretation of displays due to differences in vendors. When implementing the controls for the LCP facilities, the NLSO and project engineering team will map the vendor supplied control and data points to NLSO standardized nomenclature. Where the vendor implements a non-standardized control sequence or due to the nature of the vendor supplied equipment, additional controls and data are provided, operating instructions are developed by the NLSO referencing the vendor supplied documentation, and the ECC operators are trained in these prior to the facilities going into operation.

In addition to the ECC HMI's, Hydro applies standardized nomenclature across its engineering drawings, single line diagrams and equipment cabinet nameplates. The system operating diagrams (operating single line drawings) are prepared using a centralized drafting group and a prescribed approval process. This ensures accuracy and consistency in these drawings again to mitigate safety and reliability risks associated with drawing interpretation.

These practices and approaches to different vendors, and their nomenclature have been applied at Hydro and Nalcor Energy for many years which has been necessary as it has a variety of vendor supplied equipment applying a variety of technologies of different vintages. As noted, this requires careful preparation of standard operating instructions at the ECC, standardized operating diagrams and training programs. This approach is also being applied for the LCP.

Regards,



R. X. Henderson
VP Transition to Operations

copy: Gilbert Bennett
Jim Haynes
Jim Meaney
Dawn Layden