MEETINGS IN ST. JOHN'S AND VISIT TO SOLDIERS POND, DECEMBER 3 TO 6, 2018

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 attended project briefings at the Lower Churchill Project Delivery Office in St. John's on December 4, 5 and 6th, 2018 and visited Soldiers Pond HVDC site on Dec. 5th, 2018. NALCOR management and project team representatives accompanied the IE.

IE team: Nik Argirov (IE Team Lead)
Vlad Kahle (IE Electrical SME)
Tim Little (IE Geotechnical SME)

The trip itinerary was as follows:

December 3:

- Arrive in St John's NL.

December 4:

- Orientation meeting and Project Updates in Nalcor's LCP Delivery office.

December 5:

- Project Updates in Nalcor's LCP Delivery office.
- Visit to Soldiers Pond converter building and Synchronous Condenser (SC) building.

December 6:

- Recap Meetings in LCP office.
- Depart St John's for home bases.

2 LCP PROJECT OFFICE MEETINGS ON DECEMBER 4TH, 5TH AND 6TH, 2018

Discussions on Project issues and updates were carried out during the three sessions in the LCP Project office.

2.1 MFA Project briefing:

- Safety update.
- MFA Project risk assessment briefing.
- LTA- LIL Cost Risk Update briefing. HVDC is 99% complete and no new risks were added. Cost and schedule are on target.
- Generation Project details were presented.
- NALCOR and GE are negotiating amendments to commercial agreement. New agreement should identify the next steps.

- All past commercial claims have been settled.
- Focus for 2018/ 2019 will be the Project execution and commercial close-out strategy.
- Current challenges are establishing reliable power transfer, P&C software and SOP synchronous condensers lift pressure system upgrades, oil contamination remediation, bearings reassembly and dynamic commissioning.
- The main risks remaining appear to be safety during energization of new equipment when working around the Pole 1 equipment already in service, Bi-pole P&C development and GE commercial risk.
- GE commercial risk continues to be the focus area for risk mitigation.

2.2 MFA P&C Solutions

Design deviations from the CH0030: Turbines and Generators Design, Supply and Installation Contract (Contract) became apparent during IE Factory Visit to the Contractor's (Andritz) facility on Nov. 6, 2018. Subsequent discussions with NALCOR indicate that as yet unidentified operations group requested several design changes. Design revisions were said to be carried out according to formal Change Orders, the original Contract has not yet been updated. IE are of the opinion that some of the design changes deviate from good utility practice and requested clarification. This subject was discussed with Messrs. Rob Henderson, Frank Gillespie, Paul Adams, Richard Severs and Chad Wiseman. Following Contract articles and sections are identified for consideration:

a) **Articles 4.1, 4.2 and 4.3** state that the design has to be carried out and stamped by P. Eng. and the Contractor is to have specialized knowledge and design the project to good utility practice.

Article 26.1 and 26.4 Company has the right to make a Change at any time and from time to time prior to the Issuance of the Final Completion Certificate by issuing a Change Order. Except to the extent expressly provided in a Change Order, no Changes shall vitiate (impair the legal validity of) or invalidate or be deemed to amend or be deemed to constitute a waiver of any provision of this Agreement. All Changes shall be governed by all the provisions of this Agreement.

IE Comment: *In order to confirm compliance with Articles 4.1, 4.2, 4.3, 26.1 and 26.4, IE requested copies of documents that were issued for the purpose of modifications to the original Contract dated 02-Aug-2102. Change Orders, Change Requests and Engineering Change Notices were provided on December 18, 2018. That list is incomplete. IE request copies of all Protection and Control related Engineering Change Notices, sealed by P. Eng., that resulted in fundamental revisions to the Protection trip sequences detailed below. It appears ethos Change Orders were not generated at the time of implementing the revisions.*

Section 1.2.2.1.2: The station shall be unmanned, and the unit shall have automatic operation with start, stop, and load and voltage control from Company's Energy Control Center. NALCOR confirmed that the station will be gradually de-staffed with the long-term plan (2 to 3 years) to operate MF as an unattended station.

IE Comment: *Protection trip sequences have been modified from the original Contract to require Operator manual intervention in case of either the shear pin (SP) failure(s) or turbine pit flooding alarms. Since both of those occurrences present risk to the plant, plant equipment and personnel, unattended operation of*

MF is not acceptable. IE understand that during the initial period the PH will be attended on part time basis (not a 24/7 operation).

b) **Section 8.3.2.7.2** Breaker failure protection shall send direct trip to 'next in line' breaker.
Section 8.5.3.5 Generator Electrical Protections A and B.
Section 8.5.3.8 Voltage Regulator and Excitation System.
Section 8.5.3.11 Generator Mechanical Protections.
Section 8.5.3.12 Speed Governor.

IE Comment: *Design modifications now specify Intake/head Gate (IG) closure for many of the electrical and mechanical protections covered by these five sections. IE suggest that closing the intake gate for majority of those faults is unwarranted and not in line with good utility practice. Electrical faults will normally be cleared by breaker opening in 100ms, breaker failure trips the next in line breaker in approximately 300ms and turbine wicket gates close in several seconds. Similarly, exciter, governor and overtemperature Protections will disconnect the energy sources long before the intake gates close in 17 minutes. Therefore, the emergency water flow shut-off will not increase the plant security or mitigate consequences of those faults and it may unduly lengthen the duration of outages.*

Another concern associated with such the unnecessary 'overtripping' is exposing the intake gates to increased duty cycle. Review of the gate design is recommended to ensure the IG's are robust enough to withstand the more frequent gate operations caused either by legitimate Protection operations or Protection misoperations and inadvertent personal errors.

In IE opinion, the design should revert to the original Contract specification documented in the section 8.5.3.13 (see below). Specifically, separate trip should be provided to initiate the Intake Gate emergency drop only for (i) sustained overspeed, (ii) a combination of low oil pressure and low Governor System tank level, or (iii) a turbine pit flood detected through the turbine water detection system. This IG drop should also be initiated if the generator fails to stop if the 86F trip relay operates. Intake gate trip should further be provided if the 86S relay operates and if, because of full governor failure or total oil pressure failure, the wicket gates do not fully close, and the generator circuit breaker does not trip via the low forward power interlock.

***IE recommend review of the following trip sequences**:*

- *Original design (table 8.5.3.12) shows that electrical overspeed detector (12E) initiates a non-lockout shutdown at 110% rated speed and mechanical overspeed detector (12M) set at 140% initiates Intake Gate (IG) closure. The electrical overspeed is set well below the anticipated full load rejection overspeed of 139% (see Andritz study AHCM-0130018, rev. 2, LCP number MFA-AH-SD-0010-01) and the mechanical overspeed is set too close to it.*
- *In deviation from the original design, Protection trip matrix MUS-P-1TM_Rev11 Y2017M12-D20 shows the electrical overspeed 12E trips lock-out 86M that in turn initiates IG close. If it remains set at 110%, 12E may initiate unnecessary IG closures.*
- *It is offered for consideration to initiate the intake gate close by 150% electrical overspeed detector and back it up by mechanical overspeed detector set at 160%.*
- *In the original Contract any Shear Pin (SP) Failure initiated a full emergency shutdown with Intake Gate (IG) drop. That sequence was later eliminated in favor of an alarm only that requires the plant Operator to make a decision whether to shut the unit down. The SP Failure alarm now does not*

discriminate between single or multiple SP Failure. IE request the Contractor to provide declaration that the unit can be safely operated with sustained multiple SP Failures. If such declaration is not given, design should revert to the original Contract requirement for emergency shutdown including dropping the head gate. This issue is considered important because there are risks of wiping the guide bearing or runner damage when running the unit with multiple SP failed.

- *To IE knowledge there is no consensus on closing the intake gates for powerhouse flooding. Some Owners consider turbine pit flooding a serious safety issue and provide for automatic shutdown and intake gate close while others apply risk analysis to arrive at a recommendation appropriate to their plant/ fleet. Since the original Contract recommended intake gate close in case of turbine flooding, IE request Change Order and supporting engineering and risk evaluation documentation that lead to revision from the intake gate close and shutdown trip sequence to a mere alarm.*

c) **Section 8.5.3.13** Action Taken by Auxiliary Relays:
The table (under this section) lists outputs from the tripping and lock-out relays. Separate trip shall be provided to initiate the head gate emergency drop for sustained overspeed, a combination of low oil pressure and low Governor System tank level, a broken shear pin or a turbine pit flood detected through the turbine water detection system. This drop shall also be initiated if the generator fails to stop if the 86F trip relay operates. A head gate trip shall be provided if the 86S relay operates and if, because of full governor failure or total oil pressure failure, the wicket gates do not fully close, and the generator circuit breaker does not trip via the low forward power interlock.

IE Comment: *Revisions to detection logic and resulting action for shear pin failures and turbine pit floor are covered in the paragraph above.*

d) **Section 9.3.7.5.1** Emergency Stop. Emergency Intake Gate drop pushbuttons (protected), operating via the protection system through hardwired connections shall be provided at the governor, UCP and the powerhouse control room.
Section 9.8.3.3.4 Intake Gate Control drop is to be hardwired from the protection system only and intake gate lower from the powerhouse control room.

IE Comment: *Usual utility practice for provision of emergency shutdown sequences includes directly wired intake gate close. According to MF-AH-SD-3451-EL-C05-0003-01 trip logic diagram Muskrat Falls intake gates close circuits are wired via 86F lock-out relays. That introduces a single point of failure and unwanted additional link in the circuit. In other words, MF design is less reliable and robust than directly wired signal because it relies on the Protection panel 125VDC supplies and it introduces 86F relays as 'permissive' devices.*

In IE opinion Powerplant emergency flow shut- off (emergency closing functions) should be independent of any other systems. Following is offered for consideration:

(i) Design should be based on two independent emergency hardwired latching close circuits
(ii) Emergency close circuit should use direct connection between the initiating device and emergency close solenoid to the extent practical (interposing relays shall not be used, MFA is not compliant since the emergency close is via Protection 86 lock- out relays)

(iii) Emergency close circuit shall have emergency close solenoid supplied from separate DC circuit (86 relays are powered by a DC supplies that also power up the Primary and Standby generator protection panels)
(iv) Emergency close circuits shall be continuously supervised.

References:
[1] NE-LCP document MFA-AH-SD-3240-EL-C07-0003-01 (or Andritz doc MUSG-EL-ITP-CTL-TEC-001; doc title: "Muskrat Falls – Intake Gates Control System - Functional Description") - p. 8, Section 10.1.9 Emergency Close.
[2] Granite Canal Hydro Station where hardwired circuit for IG emergency closure is implemented as per the GUP followed by Newfoundland Hydro. The Brilliant Expansion Project (in BC) is another more recent example of the same.

Local Manual Emergency Close at the intake gate control panel has not yet been reviewed. Section 9.8.3.3.4 does not appear to cover it in detail.

On recommendation from IE NALCOR will review requirements for gate droop protection.

2.3 MFA P&C Information Request

IE requested additional information on Protection and Control:

- Coordinated Protections Studies / narrative for the MF HVDC Converter, MF Switchyard, MFA Powerhouse and the 315kV transmission lines.
- MFA generation dump design criteria.
- Protections trip / transfer trip interconnections between MF HVDC Converter and MFA Powerhouse.

2.4 LIL P&C Software

Update by LCP protection specialist:

- Version V1.15.1 is currently in service, NALCOR explores the possibility to transfer 100 - 110MW this winter.
- Version 1.16.1 release has been abandoned.
- Version 1.17.1 regression testing has been completed on Nov. 30, 2018 but there are some issues with Lane1 to and from Lane 2. Consequently V 1.17.1 is still under development in Stafford, UK. Due to uncertainties with its reliability and the requirement for approximately 4-week site testing required, V 1.17.1 version will not be released this winter.
- Key point remains the lack of redundancy. That is, at present only Lane 1 system is in service and any Protection or Control failure in that system will result in the HVDC link shutdown.

Going forward:

- Resolving punch list items.
- Operations sequencing has not yet been completed, GE continues with the Pole 1 development.
- Pole 2 and Bi-pole software is expected by end of 2019. Bi-pole software development remains on critical path.
- HMI programming is done by another vendor. At this time IE were not advised on how the programming activities are coordinated between the sites and ECC.

2.5 LCP Operations Update (Meeting at SOP)

IE were briefed on overall assessment and quarterly performance of Transition to Operation (TTO):

- Program completion increased to 67.7% from 59.6% over the last quarter and schedule compliance improved to 96.4% from 93.8% over the same period.
- Schedule threats are posed by people turnover and generation staffing.
- Building the Production Organization (BTPO) is in progress. Gaps were identified and action plans are in progress to complete operator training, close all contracts and import / archive the spare parts inventory.
- Ready for Integration (RFI) overall progress advanced to 97.8%.
- Number of LCP Readiness Items has been completed. Items in progress are operationalizing high frequency preventive maintenance program, complete OM&A service contracts and complete outstanding NLSO operational requirements.
- Overall recruiting activities are on track. 92% transmission O&M, 88% engineering services, 30% of generation O&M, 74% of corporate and 100% of HVDC support service roles have been secured.
- Emergency response readiness (ERR) mock trial for overhead lines has been successfully completed. The exercises identified procedural, process coordination and logistical gaps that are being progressively closed. Additional exercises are planned.

2.6 Synchronous Condenser Contaminated Oil Remediation Update

As previously reported, during static commissioning an issue was identified with lube oil contamination and an inability to achieve required lift of the rotor in accordance with the specifications. To address these issues Units 1 and 3 have commenced dismantling activities. Unit 1 rotor was jacked up and bell housing removed. The bearing housing and shells were removed for inspection and repair. Pressure flushing of Unit 1 lube oil system is expected to commence in the following week. Electrical disconnection has commenced on Unit 2. Current information indicates an updated forecast delay to Q3 2019 for dynamic commissioning completion of all 3 units.

2.7 Intake Bulkhead Gate Operation

The operation of the Intake Bulkhead Gate (IBG) sections is performed by the Trashrack Cleaning Machine (TCM) hoist. Typically, the IBG is lifted under a balance pressure condition. To achieve that the space between the IBG and Intake Gate (IG) is filled with water through a filling valve placed in the top Bulkhead Gate section. Setting the Lifting Beam on the top of the closed Bulkhead Gate opens the valve, filling the water passage with water from the reservoir. Load is applied to the Lifting Beam with the TCM hoist, and when the hydrostatic pressure on the IBG equalizes within 1 m differential head (pressure), the Top Bulkhead Gate section will release and then be removed. There is a vent pipe between the IBG and IG that equalizes air pressure above the water in the water passage.

IE Comment: *IE are not comfortable with this arrangement since the operator does not appear to have a fail-safe way to confirm that the differential head is within 1 meter and there is no torque limiter on the TCM hoist. The safeguard / permission to lift the gate appears to be audio monitoring of 'reduction' of the airflow out of the vent pipe.*

IE request Contractor's (Andritz) opinion on this mode of operation, long term reliability of the apparatus and whether they can guarantee a safe operation of the IBG in an unbalanced condition (assuming that the PTFE coated IBG's seals are designed to open under load).

IE offer suggestion that the industry practice is to operate bulkhead gates only in balanced pressure condition. That is assured by a differential head measurement that sends a permissive signal to the hoist (or alternatively a visual indication to the operator) when the pressure equalizes to a value equivalent to 1 meter or less of differential head.

2.8 Powerhouse

- NALCOR working to complete agreement for Pennecon to take over remaining scope of Astaldi contract (note: agreement successfully concluded on Dec. 06'18).
- Unit 1 was pit-free prior to Astaldi departure and work is still on schedule for first power in late 2019. Pit-free date for Unit 2 was Nov 23, so there is some potential for delay on this unit. Bridge crane rail realignment is the only outstanding work item before Unit 2 can be handed over to Andritz; estimated time for this work is about 2 weeks. Pit free dates for Units 3 and 4 are in early 2019 and may be OK if Pennecon starts work soon.
- Completion of intake works by Andritz is progressing well and watertight conditions in all units should be achieved by February or March 2019.
- Balance of Plant contract was about 48% complete at end of November, is progressing well and has not been impacted by Astaldi departure.
- Tailrace plug was scheduled to be blasted the week of December 16'18.

2.9 Dams and Reservoir

- Drilling and grouting from the top of the north RCC dam are complete. Drilling and grouting from the dam gallery and completion of the gallery concrete floor should be completed in early 2019.
- De-launching and removal of the temporary construction bridge upstream of the spillway intakes was completed in November.
- Spillway rollway concrete is complete in all five bays. Electrical and mechanical works are completed in only 2 of the 5 bays; the other three bays will be completed after spring 2019 flood period.
- Ice cover formed on the reservoir in late November and extends about 10 km upstream. As of December 05, the ice cover on the river downstream was still about 2 to 3 km from the site.
- NALCOR will prepare a Decision Support Plan for reservoir filling in 2019.

IE Comment: *IE require to review the Decision Support Plan when it becomes available, prior to reservoir filling.*

2.10 North Spur

- NALCOR provided an overview of its post-construction assessment of the North Spur. The assessment report has not yet been finalized. A report on the North Spur construction has been completed but is not yet distributed.
- NALCOR's assessment is that site conditions and material properties are generally equal to or better than assumed for the design, and that target stability and performance criteria for the constructed works are achieved.

- A seismograph has been installed on the rock knoll adjacent to the North Spur. The IE requested information on type of seismograph and settings/trigger level.

  IE Comment: IE require to review the construction report and post-construction assessment reports when they become available, prior to reservoir filling.

3 CONCLUSIONS AND COMMENTS

- Software is the main C3 / C4 outstanding item. Final completion has been pushed to October 2019.
- Change Orders, Change Requests and Engineering Change Notices documentation review specific to the Protection tripping matrix has not yet been completed by the IE. IE request copies of the relevant documents.
- Closing of the IG (overtripping) for most of the electrical and mechanical protections potentially lengthens the forced outage times and increases maintenance costs. This design modification should be reviewed and rationalized.
- Removal of the automatic detection and trips in favor of manual intervention by an Operator for shear pin failure and turbine pit flooding should be subject to further risk evaluation. Furthermore, this approach should preclude unattended operation of the facility. Further review, Contractor's opinion and evaluation of the risks to the plant, equipment and personnel are requested.
- Electrical overspeed and mechanical overspeed trip thresholds should be reviewed.
- Emergency Stop circuitry should be by independently supplied direct wire control.
- IBG operation arrangement requires further discussions and comments by the Contractor.
- Draft Tube Stoplog operation (lifting) should follow the same pattern as outlined for IBG under Section 2.7.
- NALCOR together with Andritz will address the IE concerns during upcoming April 2019 meeting in Montreal, QC.