Interconnection Feasibility Study Report

GIP-537-FEAS-R1

Interconnection Request #537

250 MW Hydro (30 MW Increase) Generating Facility

Victoria County (85S Wreck Cove)

2016 08 18

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The interconnection Customer submitted a Network Resource Interconnection Service Interconnection Request to NSPI for a proposed 30 MW addition to the existing 220 MW hydro generation facility interconnected to the NSPI 138kV transmission system at the 85S-Wreck Cove substation. The total output of the proposed generation facility will be 250 MW.

No concern regarding short-circuit or voltage flicker was found for this project on its own, provided that the project design meets NSPI requirements for low-voltage ride-through, reactive power range and voltage control system. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

Proposed increase in generation would overload lines L-6545, L-6549, L-6537 and L-6538 for single contingencies. This overload can be mitigated by uprating the lines L-6545, L-6549 and L-6537 in addition to modifying the existing Special Protection Scheme (Northeast Power Coordinating Council designation #193). The preliminary non-binding estimated cost of facilities required to interconnect this increased generation to the transmission system for this option is $25,245,000 including a contingency of 10%. This non-binding estimate will be further refined in the System Impact Study and the Facility Study.

Alternate option is to design and install a new Special Protection Scheme to detect the overload and reduce the output of Wreck Cove automatically. This scheme would reduce the flow on the lines below the seasonal limits without tripping Wreck Cove generators. It should be noted that new SPS has to be approved by Northeast Power Coordinating Council. The preliminary non-binding estimated cost of facilities required to interconnect this increased generation to the transmission system for this option is $660,000 including a contingency of 10%. This non-binding estimate will be further refined in the System Impact Study and the Facility Study.

The loss factor for this additional 30 MW of generation at the Point Of Interconnection is approximately 27%.

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1 Introduction

The Interconnection Customer submitted an Interconnection Request for Network Resource Interconnection Service (NRIS) to NSPI for a proposed 30 MW addition to the existing 220 MW[1] hydro generation facility interconnected to the NSPI 138kV transmission system at the 85S-Wreck Cove substation in Victoria County. The total output of the proposed generation facility will be 250 MW.

The Interconnection Customer signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system, dated 2016-04-26, and this report is the result of that Study Agreement. This project is listed as Interconnection Request #537 in the NSPI Interconnection Request Queue, and will be referred to as IR #537 throughout this report.

2 Scope

The Interconnection Feasibility Study (FEAS) report consists of a power flow and short circuit analysis. Based on this scope, the FEAS report shall provide the following information:

1. Preliminary identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection;
2. Preliminary identification of any thermal overload or voltage limits violations resulting from the interconnection; and
3. Preliminary description and non-bonding estimated cost of facilities required to interconnect the Generating Facility to the Transmission System, the time to construct such facilities, and to address the identified short circuit and power flow issues.

The Scope of this FEAS includes modeling the power system in normal state (with all transmission elements in service) under anticipated load and generation dispatch conditions.

For Network Resources Integration Service (NRIS), the FEAS will identify any transmission upgrades required as the result of thermal overload, voltage violation, or equipment rating. The FEAS will attempt to provide high level cost estimates for such upgrades and direct interconnection costs.

A more detailed analysis of the technical implications of this development will be included in the System Impact Study (SIS) report. This will include system stability analysis, single contingencies (including contingencies with more than one common element), off-nominal frequency operation, off-nominal voltage operation, low voltage ride through, harmonic current distortion, harmonic voltage distortion, system protection,

[1] Although each generator is rated at 110 MW, the simultaneous plant output is limited to 210 MW due to penstock restrictions. The 4 MW Gisborne generator is not included in this analysis

special protection systems (SPS), automatic generation control (AGC) and islanded operation. The impacts on neighbouring power systems and the requirements set by reliability authorities such as Northeast Power Coordinating Council (NPCC), North American Electric Reliability Corporation (NERC), and NSPI will be addressed at that time. The SIS may identify additional costs and upgrades that were not identified in this FEAS. The SIS may require an appropriate computer model for study of the dynamic performance of the proposed facility.

A separate Facilities Study will follow the SIS in order to ascertain the final cost estimate for interconnection and any transmission upgrade requirements.

3 Assumptions

This FEAS is based on the technical information provided by the Interconnection Customer. The Point of Interconnection (POI) and configuration is studied as follows:

1. Network Resource Interconnection Services.
2. 30 MW increase to the existing 220 MW hydro generating facility consisting of two identical synchronous generators each rated for 125 MW.
3. The generation technology used must meet NSPI requirement for reactive power capability of 0.95 capacitive to 0.95 inductive at the 85S 138kV bus. Each generator is specified for 125 MW at a rated power factor of 0.9. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the generator terminals during and following system disturbances.
4. The Interconnection Customer indicated interconnection at the 138kV bus of 85S substation. Each generator will be connected to the 85S substation by a 138 kV cable and a generator step-up transformer. Unit service will be fed from the low-voltage terminals of the generator step-up transformer.
5. Preliminary data was provided for the generator step-up transformer. Modeling was conducted using a 138kV-13.8kV 125 MVA transformer with a positive sequence impedance of 7.14%. It was indicated that the step-up transformer has a grounded wye-delta winding configuration.

4 Projects with Higher Queue Positions

All in-service generation is included in the FEAS.

As of 2016-06-23 the following projects are higher queued in the Interconnection Request Queue, and have the status indicated.

Interconnection Requests ahead of IR #537 – Included in FEAS

- IR #426 GIA executed
- IR #457 GIA executed
- IR #471 GIA in progress
- IR #510 SIS in progress
- TSR #400 Scheduled in-service in 2017

Electrically Remote Transmission Interconnection Requests ahead of IR #537 – Not included in FEAS

- IR #507 GIA executed
- IR #516 GIA executed
- IR #517 GIA executed

If any of the higher-queued projects included in this FEAS are subsequently withdrawn from the Queue, the results of this FEAS may require to be updated. The re-study cost incurred as a result of the withdrawal of the higher-queued project shall be the responsibility of the Interconnection Customer that has withdrawn the higher queued project.

5 Objective

The objective of this FEAS is to provide a preliminary evaluation of the system impact and cost of interconnecting the 250 MW generating facility to the NSPI transmission system at the designated location. The assessment will identify potential impacts on the loading of transmission elements, which must remain within their thermal limits. Any violations of voltage criteria will be identified and addressed. If the proposed new generation increases the short-circuit duty of any circuit breakers beyond their rated capacity, the circuit breakers must be upgraded. Single contingency criteria[2] are applied for the Network Resource Interconnection Service assessment.

This assessment is based on a power flow and short circuit analysis and does not include a complete determination of facility changes/additions required to increase system transfer capabilities that may be required to the Bulk Power System to meet the design and operating criteria established by the Northeast Power Coordinating Council (NPCC) and/or the North American Reliability Corporation (NERC) or required to maintain system stability. These requirements will be determined by the subsequent interconnection System Impact Study (SIS).

[2] The Single Contingency Criteria is defined by NPCC in its A-7 Document, and may involve more than one transmission element.

6 Short-Circuit Duty

The maximum (design) expected short-circuit level on 138kV systems is 5000 MVA. The short-circuit levels in the area before and after this development are provided in Table 1 below.

Table 1: Short-Circuit Levels. Three-phase MVA [(1)]		
Location	**IR #537 in service**	**IR #537 not in service**
All transmission facilities in service		
85S 138kV (POI)	1433	1350
5S-Glen Tosh 138kV	1339	1302
3S-Gannon Road 138kV	1165	1153
Minimum Conditions		
138kV Interconnection Point	435	435

(1) Classical fault study, flat voltage profile

The maximum short-circuit level at the POI is presently 1350 MVA. After installing IR #537 short-circuit current at the POI will increase to 1433 MVA. Minimum short-circuit case assumes all thermal units in Cape Breton except Point Aconi offline and 138 kV line L-6549 (88S-Lingan to 2S-Victoria Junction) out of service. The short-circuit level for minimum conditions will be approximately 435 MVA at the POI. This translates into maximum equivalent system impedance at the POI of 0.23 per unit on 100 MVA base.

The interrupting capability of 138kV circuit breakers in the vicinity of 85S-Wreck Cove is at least 3500 MVA which will not be exceeded by the addition of IR #537.

7 Voltage Flicker and Harmonics

The generators are conventional synchronous machines with an excitation system and therefore voltage flicker is not expected to be not a concern for this project. The generators are expected to meet IEEE Standard 519 limiting Total Harmonic Distortion (all frequencies) to a maximum of 5%, with no individual harmonic exceeding 1%.

8 Thermal Limits

IR #537 is connected to NSPI transmission system at 85S-Wreck Cove substation. Two 138 kV lines L-6545 and L-6549 connect 85S-Wreck Cove substation to 5S-Glen Tosh. From 5S-Glen Tosh substation power flows out to 2S-Port Hastings through line L-6537 and to 2S-Victoria junction through lines L-6538 & L-6539.

Lines L-6545 and L-6549 have a continuous winter rating of 184 MVA based on an ambient temperature of 5ºC. When IR #537 is operating at 250 MW, loss of either L-6545 or L-6549 would over load the other line to 130% of its winter rating.

Line L-6537 has a continuous winter rating of 184 MVA based on an ambient temperature of 5ºC. When IR #537 is operating at 250 MW, loss of line L-6538 would over load L-6537 to 132% of its winter rating and loss of line L-6539 would over load L-6537 to 115% of its winter rating.

Line L-6538 has a continuous rating of 110 MVA limited by the thermal rating of the steel conductor on the span that crosses Bras D'Or Lake. The rest of the line L-6538 has a winter rating of 165 MVA based on an ambient temperature of 5ºC. Loss of line L-6537 would over load the steel conductor span on L-6538 to 218% and rest of the line (ACSR 556.5 Dove conductor designed for 50ºC) to 130% of its winter rating. However, there is a Special Protection Scheme (SPS) in operation to prevent the steel section of L-6538 from permanent damage. This scheme consists of protective relays at the Glen Tosh substation monitoring power flow on line L-6538. Flow exceeding the arming value (114 MVA) will trip a pre-selected Wreck Cove unit in 6 minutes and line L-6538 in 6.5 minutes if the overload is not relieved. The System Operator is expected to reduce the flow below 85 MVA to prevent tripping of Wreck Cove generator. Due to balancing problems that arise when the existing Wreck Cove units are tripped at full load, it is important that Wreck Cove output is reduced to prevent the trip. The increased power output from IR #537 would require decreasing the time delay for the trips which further reduces the time for operator to reduce Wreck Cove output. It should be noted that this SPS is designed to prevent the permanent damage on the steel conductor at the Bras D'Or Lake crossing but not to prevent rest of the line from sagging and violating the ground clearance. Preliminary calculation indicates that with the addition of IR #537 line L-6538 would reach its design temperature in less than 5 minutes for winter rating conditions. Therefore an automatic action scheme is recommended to relieve the overload rather than rely on manual operator action. This scheme should be designed to detect the overload on L-6538 and decrease the output of Wreck Cove before the permanent conductor damage as well the ground clearance violation. Details of this scheme will be addressed in SIS.

Overloading issues on lines L-6545, L-6549 and L-6537 caused by the addition of IR #537 can be mitigated by uprating the lines to 100ºC maximum operating temperature. All three lines are currently designed to operate for the maximum temperature of 60ºC. Alternatively, a SPS scheme can be designed and installed to detect the overload and reduce the output of Wreck Cove below the line limit. This scheme would consist of combination and measuring relays and a Programmable Logic Controller (PLC) at 5S-Glen Tosh and Tele-communications between Glen Tosh and Wreck Cove. Details of the SPS design would be included in the SIS. It should be noted that any new SPS has to be approved by NPCC.

9 Voltage Limits

This generating facility must be capable of providing both lagging and leading power factor of 0.95, measured at the 138kV terminals of the 85S substation, at all production levels up to the full rated load of 250 MW. The generator must be equipped with a high-speed continuously-acting automatic voltage regulator set to control its 13.8 kV terminals to a value established by the NSPI System Operator. The details of the specific control features, control strategy and settings will be reviewed and addressed in the SIS, as will the dynamic performance of the generator and its excitation.

The NSPI System Operator must have manual and remote control of the voltage set-point and the reactive set-point of this facility to coordinate reactive power dispatch requirements.

This facility must be capable of staying on-line during and following a three-phase fault on the 138kV bus at 85S, cleared in 100ms (6 cycles). The performance of the generator controls to meet this requirement will be studied in detail in the SIS.

With the proposed generator step-up transformer impedance of 7.14% on 125 MVA, and the rated generator power factor of 0.90 measured at the machine 13.8 kV terminals, the net power factor requirements of 0.95 measured at the Point of Interconnection can be achieved.

10 System Security / Stability Limits

The NSPI transmission system has limited east to west transfer capability. Transmission corridors between Sydney and Halifax are often operated to security limits. This project increases flow across the Cape Breton Export, the Onslow Import, and the Onslow South interfaces. Generation rejection Special Protection Systems[3] (SPS's) are utilized to increase system stability limits to maximize east to west power transfers. Depending on the impact of other generation additions ahead of this project in the Interconnection Request Queue, the additional generating capacity that this facility provides may not be integrated into the NSPI system under all dispatch conditions without system upgrades.

Under some dispatch conditions with certain contingencies, transmission corridors become overstressed, which may require Network Upgrades. The SIS will determine if this action solves the stability issues associated with the congested interfaces.

[3] Also known as Remedial Action Schemes, SPS's are defined by NPCC as "A protection system designed to detect abnormal system conditions, and take corrective action other than the isolation of faulted elements." *NPCC Document A7 - Glossary of Terms.*

In general, the SIS will determine the facility changes that are required to permit higher transmission loadings while maintaining compliance with NERC/NPCC standards and in keeping with good utility practice.

11 Expected Facilities Required for Interconnection

The following 2 options of network upgrades are provided to interconnect IR #537:

Network Upgrades/Additions Options

1. Uprate line L-6545, L-6549 and L-6537 to 100ºC maximum operating temperature. All three lines are currently designed to operate for the maximum temperature of 60ºC. Additionally, modify L-6538 Overload Protection SPS (NPCC Designation # 193) to accommodate the increased loading due to additional 30 MW from IR #537.
2. Design and install a SPS scheme to detect the overload on lines L-6545, L-6549, L-6537 & L-6538 and reduce the output of Wreck Cove below the line limit. This scheme would consist of combination and relays and a Programmable Logic Controller (PLC) at 5S-Glen Tosh and Tele-communications between 5S-Glen Tosh and Wreck Cove. This New SPS would enable retiring of the existing L-6538 Overload Protection SPS (NPCC Designation # 193). It should be noted that new SPS has to be approved by NPCC.

Requirements for the Generating Facility

1. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (250 MW) all at the 138kV bus when the voltage at that point is operating between 95 and 105 % of nominal.
2. Centralized controls. These will provide centralized voltage set-point controls to control the 13.8kV bus voltage. Responsive (fast-acting) controls are required. The controls will also include a curtailment scheme which will limit or reduce total output from the facility, upon receipt of a telemetered signal from NSPI's SCADA system. The controller will also limit the load ramp rate of the facility to within limits set by NSPI and/or telemetered from NSPI's SCADA system.
3. NSPI to have control and monitoring of reactive output of this facility, via the centralized controller. This will permit the NSPI Operator to raise or lower the voltage set-point remotely.
4. Low voltage ride-through capability equivalent to FERC Order 661a[4] .
5. Real-time monitoring (RTU's) of the interconnection facilities for NSPI to execute high speed rejection of generation (transfer trip).

[4] FERC Order 661A addresses the requirement for wind-powered generation to ride-through faults in a manner similar to traditional synchronous generator. This reference is meant to indicate that IR #537 must meet the same requirement to remain on-line during and following a fault.

12 NSPI Interconnection Facilities and Network Upgrade Cost Estimate

Estimates for Network Upgrades are included in Table 2.

Table 2: Cost Estimates identified from FEAS scope		
Option #1		
i	Uprate L-6545, L-6549 & L-6537	$22,750,000
ii	Modify SPS# 193	$200,000
iii	Contingency (10%)	$2,295,000
Total		**$25,245,000**
Option #2		
i	Design and build a new SPS	$400,000
ii	Modify SPS# 193	$200,000
iii	Contingency (10%)	$60,000
Total		**$660,000**

13 Issues to be addressed in SIS

The SIS must determine the facilities required to operate this facility at full capacity, withstand the contingencies as defined by NPCC/NERC and identify any restrictions that must be placed on the system following a first contingency loss. The SIS will be conducted in accordance with the GIP with all appropriate higher-queued projects included in the SIS study base case as well as identified Network Upgrades associated with those higher-queued projects.

The SIS will confirm the options and ancillary equipment that the customer must install to control flicker, voltage and ensure that the facility has the required ride-through capability.

The assessment will consider but not be limited to the following. The facility additions/changes required to increase NSPI east to west transfers under system normal conditions (all transmission in) over the range of NSPI loads and with interruptible loads on or off. Some of the constrained interfaces that will be included in the assessment are as follows.

1. Cape Breton Export
2. Onslow Import
3. Onslow South
4. Metro reactive reserve requirements
5. NS – NB export/import

Steady-State Post-contingency Analysis

All elements within acceptable voltage and thermal limits under the following single contingencies, in accordance with NPCC[5] and NERC[6] criteria

1. L-6545
2. L-6549
3. 2S-B61
4. L-8004
5. 79N-T81
6. L-8003
7. L-6537
8. L-6538
9. 3S-T1
10. 2S-B64

System stability for the following faults

Loss of any element without a fault

1. L-8004
2. Hopewell transformer 79N-T81
3. L-8003

Three-phase fault cleared in normal time:

1. L-6518 at 47C-NewPage
2. L-8004 at Woodbine end
3. L-8004 at Hopewell end
4. L-8003 at Onslow end
5. L-8003 at Hopewell end
6. 79N-T81 transformer at 345kV (trip L-8004 + L-8003)
7. L-8001 at import (NS islanded with under-frequency) and export limits

Single-phase to ground fault cleared in backup time (Breaker Failure)

1. L-8003 at Onslow with failure of 79N-803 (lose L-8004)
2. L-8003 at Onslow with failure of 67N-811 (lose 67N-T82)

Single-phase to ground fault on separated circuits of double-circuit tower:

1. L-7003 plus L-7004 at Canso Causeway
2. L-7005 plus L-8004 at Strait of Canso crossing.

Aside from the required change to the Strait Area Overload Protection SPS, any changes to SPS schemes required for operation of this generating facility, in addition to existing

[5] NPCC criteria are set forth in it's Reliability Reference Directory #1 *Design and Operation of the Bulk Power System*

[6] NERC transmission criteria are set forth in *NERC Reliability Standards TPL-001, TPL-002, TPL-003*

generation and facilities that can proceed before this project, will be determined by the SIS as well as any required additional transmission facilities. The determination will be based on NERC and NPCC criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

The SIS will calculate the unit loss factor, which is a measure of the percentage of the net output of IR #537 which is lost through the transmission system.

The SIS will calculate the unit loss factor, which is a measure of the percentage of the net output of IR #537 which is lost through the transmission system. Preliminary value is calculated to be 27% (system losses increase by 8 MW when IR #537 is increased from 220MW to 250 MW.

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