Interconnection Feasibility Study Report

GIP-552-FEAS-R1

System Interconnection Request #552

100.8 MW Wind Generating Facility

Pictou County (L-6511)

2017-03-31

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR#552) for Network Resource Interconnection Service (NRIS) for a proposed 100.8 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2022-12-31. The Point of Interconnection (POI) requested by the customer is on the 138 kV transmission line L-6511, at or near the 93N-Glen Dhu substation. Alternatively, a 50.4 MW wind farm is proposed at the same POI.

The Generation Interconnection Procedures do not confer any rights to receive transmission service, which must follow the procedures of the NSPI Open Access Transmission Service. Preceding IR#552 is a long-term firm transmission service reservation in the amount of 330 MW from Nova Scotia to New Brunswick, as well as two transmission Interconnection Requests ahead of IR#552 which are considered in this study

NRIS service for IR#552 is expected to honour the long term firm reservation for delivery of 330 MW to the NS-NB border, plus delivery of between 172 MW and 220 MW of operating reserve to NB Power in accordance with reserve sharing agreements (Transmission Reservation Margin). This combination can result in a total transfer of 650 MW. This study identified a number of transmission contingencies inside Nova Scotia and New Brunswick which would violate thermal loading, voltage support, and uncontrolled separation criteria. Significant upgrades to the NS-NB interconnection would be necessary to support these levels of transfer, as identified in the *Nova Scotia Power 10 Year System Outlook*.

An alternative assumption was made to address the NS-NB transfer limits. That is, IR#552 displaced an equivalent level of import from the Maritime Link to allow it to operate within the long-term firm reservation amount of 330 MW from NS to the NB border.

The assessment of 100.8 MW on the primary POI on the 138 kV line L-6511 indicated that L-6511 would exceed its normal summer rating even without a contingency and it would be impractical to make the necessary upgrades would be necessary to deliver 100.8 MW without exceeding emergency thermal ratings of equipment. It was proposed that a new 138 kV transmission be built from 50N-Trenton to IR#552 Interconnection Substation. The line must be operated radially, as tying the new line into 93N-Glen Dhu substation would not prevent significant line overloading for a breaker failure contingency at 50N-Trenton. A number of other upgrades would be necessary to accommodate 100.8 MW:

- Uprate 65 km of L-6503 to a conductor operating temperature of 100°C
- Uprate switchgear on L-6503 at 1N-Onslow and 50N-Trenton

To provide for NRIS, upgrades would be necessary for the transmission system were identified:

- The line L-6613 from 1N-Onslow to 74N-Springhill is planned to be built in 2017-2018, but the switchgear was not planned to be changed. IR#552 will require switches at the 1N-Onslow end of L-6613 and the switchgear at the 74N-Springhill end must be uprated.
- To prevent voltage collapse in the Springhill-Amherst area, a 50 Mvar Static Var Compensator.
- Overloads on L-7004 and L-7019 would require thermal uprating of those circuits.

The alternate project size of 50.4 MW connected to L-6511 resulted in the need for the following upgrades:

- Thermal uprating of L-6511
- Uprating of switchgear at the 1N-Onslow end of L-6503

Providing NRIS requires the following additional network upgrades:

- Uprating switchgear at the 50N-Trenton end of L-6503
- Thermal uprating of L-7004 and L-7019 by 5°C.
- Uprating of switchgear of L-6613 at 1N-Onslow and 74N-Springhill

Although normally outside the scope of a feasibility study for the NSPI system, a contingency in New Brunswick (loss of the 345kV line from Memramcook to Salisbury) was found to overload the Memramcook 345 kV transformer in summer. This should be addressed by NB Power in the transmission service request studies under its OATT.

Data provided by the IC indicates that IR#552 should be able to meet this requirement without additional reactive support. Based on the provided rated power factor of the 4.2 MW Enercon E-141 EP4-FT (0.875), and the provided impedances of the transformers, supplementary reactive support probably will not be needed. This will be further investigated in the System Impact Study.

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.

The preliminary value for the unit loss factor is calculated to be 6.4% for 100.4 MW at the POI on the new radial line L-6611 and 8.2% for POI on L-6511 kV, neglecting collector circuit and transformer losses. Losses were found to be sensitive to the generation dispatch at 50N-Trenton.

Minimum short circuit levels were calculated at 875 MVA with all lines in-service and 381 MVA with one line out of service. These values should be communicated to the generator designers for control design. This project does not add enough fault current to affect the fault clearing duty of existing circuit breakers.

Both Points of Interconnection (L-6511 and L-6611) are not considered Bulk Power System (BPS), and therefore the Interconnection Substation does not need to be designed to meet the requirements of NPCC Directory 4 *System Protection Criteria*.

The preliminary non-binding cost estimate for interconnecting 100.8 MW onto the new radial circuit L-6611 would be $17,008,200 interconnection facility cost and an additional $26,125,000 in network upgrades to support incremental transmission export capability for NRIS (total of $43,133,200). For the option of a plant size of 50.4 MW on L-6511, the interconnection cost would be $11,797,500 with an additional $14,100,000 to support NRIS (total $25,897,500). All cost estimates include a contingency of 10% and they will be further refined in the System Impact Study and the Facility Study.

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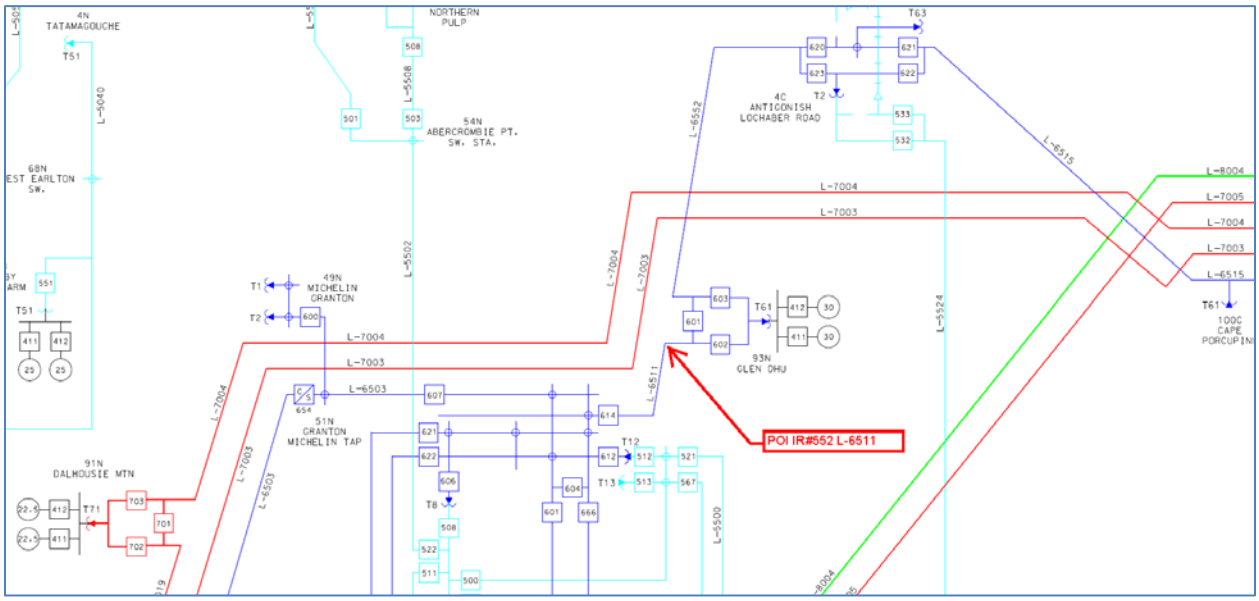
1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR#552) for Network Resource Interconnection Service (NRIS) for a proposed 100.8 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2022-12-31. The Point of Interconnection (POI) requested by the customer is on the 138 kV transmission line L-6511 near the existing 93N-Glen Dhu Wind. Alternatively, a 50.4 MW wind farm is proposed at the same POI. See Figure 1.

The Interconnection Customer (IC) signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2017-03-13, and this report is the result of that Study Agreement. This project is listed as Interconnection Request #552 in the NSPI Interconnection Request Queue, and will be referred to as IR#552 throughout this report.

Figure 1 Point of Interconnection (not to scale)



2 Scope

This Interconnection Feasibility Study (FEAS) 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;
3. Preliminary description and high level non-bonding estimated cost of facilities required to interconnect the Generating Facility to the Transmission System 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.

In accordance with Section 3.2.2.2 of the Standard Generation Interconnection Procedures (SGIP), “the Interconnection Study for NR Interconnection Service shall assure that the Interconnection Customer's Generating Facility meets the requirements for NR Interconnection Service and as a general matter, that such Generating Facility's interconnection is also studied with the Transmission Provider’s Transmission System at peak load, under a variety of severely stressed conditions, to determine whether, with the Generating Facility at full output, the aggregate of generation in the local area can be delivered to the aggregate of load on the Transmission Provider’s Transmission System, consistent with the Transmission Provider’s reliability criteria and procedures”.

A more detailed analysis of the technical implications of this development will be included in the System Impact Study (SIS) report. The SIS includes system stability analysis, power flow analysis such as 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, 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 and will include an assessment of the status of the Interconnection Facility as a Bulk Power System element. The SIS may identify and provide a non-binding estimate of any additional interconnection facilities and/or network upgrades that were not identified in this FEAS.

An Interconnection Facilities Study follows the SIS in order to ascertain the final cost estimate to interconnect the generating facility.

In accordance with Section 2.4 of the SGIP, "Nothing in this GIP shall constitute a request for transmission service or confer upon an Interconnection Customer any right to receive transmission service". Transmission Service is subject to the requirements of the Nova Scotia Power Inc. Open Access Transmission Tariff (OATT).

This study does not examine the effects of increased wind generation on the overall operation and security of the NSPI power system. The most recent Integrated Resource Plan indicated that the maximum amount of wind generation which the NSPI system could accept without significant reinforcement of the ties with other systems was about 600 MW, which has currently been exceeded with the recent Community Feed-In Tariff (COMFIT) Program.

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 Service type per section 3.2 of the SGIP.

2. Commercial Operation date 2022-12-31.

3. The Interconnection Facility consists of 100.8 MW net generation with 24 (alternatively 12) units of 4.2 MW Enercon E-141 EP4-FT Wind Turbines on four (alternatively two) collector circuits. These are classified as Type 4 Wind Energy Conversion Systems using full IGBT inverter technology.

4. The IC indicated that the POI is on the 138 kV transmission line L-6511 near 93N-Glen Dhu substation (UTM coordinates 560,247.71m E 5,048,919.15m N. This study will assume that the Interconnection Facility is adjacent to the existing transmission line and there is negligible transmission circuitry from the POI to the wind farm transformer substation.

5. The generation technology used must meet NSPI requirement for reactive power capability of at least 0.95 capacitive to 0.95 inductive at the HV terminals of the IC Substation Step Up transformer. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the designated voltage control point during and following system disturbances as determined in the subsequent System Impact Study. The designated voltage control point will either be the low voltage terminals of the wind farm transformer, or if the high voltage terminals are used, equipped with droop compensation controls. It is assumed that the generating units are not de-rated in their MW capability when delivering the required reactive power to the system.

6. Preliminary data was provided by the IC for the IC substation step-up transformers. Modeling for the primary interconnection point was conducted with a 138 kV-34.5 kV 66/88/110 MVA Interconnection Facility transformer with a positive sequence impedance of 8.0% and an X/R ratio of 35. The IC indicated that this Interconnection Facility transformer has a grounded wye-delta winding configuration with +/-10% on-load tap changer and a separate grounding transformer; however NSPI indicated in the scoping meeting that the preferred winding arrangement is grounded wye – grounded wye with a delta tertiary and eliminate the need for the grounding transformer. The impedance of generator step-up transformers is assumed to be 6% on 4.8 MVA with an assumed X/R ratio of 7.5. The alternative transformer would be half the rating, with the same winding configuration and impedance.

7. Collector circuit data was not provided, so typical data was assumed with the understanding that the net output of the plant will be impacted by losses through transformers and collector circuits.

8. The FEAS analysis is based on the assumption that IR's higher in the Generation Interconnection Queue and OATT Transmission Service Queue that have completed a System Impact Study, or that have a System Impact Study in progress will proceed, as listed in Section 4 below.

9. The IC indicated that the wind turbines are equipped with a “cold weather option” suitable for delivering full power under expected Nova Scotia winter environmental conditions. The data sheet supplied with the application provided a winter rating based on an ambient temperature of -30°C, which would be considered suitable for Nova Scotia.

10. The IC has indicated that this project is intended for export from Nova Scotia, and as such, there will be no adverse impact on Native Load Customers in the form of out-of-merit dispatch costs, compromised reliability, or any ancillary services outside the requirements of the NSPI OATT.

11. Planning criteria meeting NERC Standard TPL-001-4 *Transmission System Planning Performance Requirements* and NPCC Directory 1 *Design and Operation of the Bulk Power System* as approved for use in Nova Scotia by the Utility and Review Board, are used in evaluation of the impact of any facility on the Bulk Electric System.

12. All committed transmission upgrades associated with the Maritime Link have been completed.

4 Projects with Higher Queue Positions

All in-service generation is included in the FEAS.

As of 2017-03-31 the following projects are higher queued in the Interconnection Request Queue and OATT Transmission Service Queue, and have the status indicated.

Interconnection Requests -Included in FEAS

- All distribution connected generation qualified under the COMFIT program
- IR #426 GIA Executed, in-service
- IR #507 GIA Executed
- IR #516 GIA Executed
- IR #540 GIA in Progress
- IR #542 SIS in Progress

Interconnection Requests –Not Included in FEAS

- IR #514 FEAS complete
- IR #543 Load FAC in progress
- IR #549 FEAS in progress
- IR #550 FEAS in progress
- IR #551 FEAS in progress

OATT Transmission Service Queue– Included in FEAS

- TSR-400 Long Term Firm Point to Point, under construction

OATT Transmission Service Queue– Not included in FEAS

- TSR-401 Point to Point Application Complete
- TSR-402 Network, Application Complete
- TSR-403 Point to Point, Application Complete
- TSR-404 Network, Application Complete
- TSR-405 Network, Application Complete
- TSR-406 Network, Application Complete

Only Transmission Service Request TSR400 and Interconnection Requests IR#426, IR#516 and IR#542 are expected to have an impact on IR#552.

If any of the higher-queued projects included in this FEAS are subsequently withdrawn from the Queue, the results of this SIS may require updating or a re-study may be necessary. 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 withdraws the higher queued project.

5 Objective

The objective of this FEAS is to provide a preliminary evaluation of the system impact and the high-level non-binding cost estimate of interconnecting the 100.8 MW generating facility to the NSPI transmission system at the designated location(s). The assessment will identify potential impacts on the loading of transmission elements, which must remain within their thermal limits. Any potential 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[1] are applied for both NRIS and ERIS assessments.

This FEAS 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 NPCC and NERC or required to maintain system stability. These requirements will be determined by the subsequent interconnection System Impact Study (SIS).

Although this FEAS is not meant to constitute a System Impact Study for Transmission Service under the OATT, it is acknowledged that this project is intended for export from Nova Scotia and will be studied in two ways; the first will assume that the output from IR#552 will not displace any firm transactions and will be incremental to established transfer levels, the second will assume that the anticipated transfer limit between Nova Scotia and New Brunswick in 2022 is honoured.

[1] A Single Contingency is defined by NPCC as "A single event, which may result in the loss of one or more elements".

6 Short-Circuit Duty / Short Circuit Ratio

The maximum (design) expected short-circuit level is 5000 MVA on 138 kV systems. The short-circuit levels in the area before and after this development are provided below in Table 6-1 for the designated POI (L-6511). Because the generator type for IR#552 is Type 4, the fault characteristics are given as only slightly greater than full load current, or X'd = 1.0 per unit.

The maximum short-circuit level at the POI on L-6511 with IR#552 off-line will be 1172 MVA in 2022. With IR #552 on-line the short-circuit level will increase to 1254 MVA at the POI. Similarly, under minimum generation conditions, the short circuit level will be 875 MVA with all lines in-service, and 381 MVA with the line from POI to 50N-Trenton out of service. This translates into minimum Short Circuit Ratio of between 3.8 and 8.8 for the 100.8 MW option and double that for the 50.4 MW alternative.

Table 6-1: Short-Circuit Levels. IR552 on L-6511 Three-phase MVA [(1)]

Location	Without IR #552	With IR #552
All transmission facilities in service		
Point of Interconnection	1172	1254
50N-Trenton 138 kV	2538	2575
4C-Lochaber Rd 138 kV	1109	1147
Minimum Conditions		
Point of Interconnection	381 line out	875 lines in

(1) Classical fault study, flat voltage profile

The interrupting capability of the 138 kV circuit breakers is at least 5000 MVA at 50N-Trenton. There are no circuit breakers at 51N-Michelin tap, and circuit breakers at 4C-Lochaber Rd are rated at least 3500 MVA. As such, the interrupting ratings will not be exceeded by this development on its own. IR#551 does not add appreciable fault duty to local circuit breakers.

7 Voltage Flicker and Harmonics

Due to the lack of flicker coefficient information on the Enercon E-141 Wind Turbines, this study assumes the same flicker data as for the Enercon E-82 machine. Type 4 wind turbines are not expected to result in appreciable voltage flicker at minimum generation conditions. Therefore voltage flicker should not be a concern for this project.

The generator is expected to meet IEEE Standard 519-1992 limiting voltage Total Harmonic Distortion (all frequencies) to a maximum of 1.5%, with no individual harmonic exceeding 1.5% on 138 kV, and a maximum of 1.5% THD and no individual harmonic exceeding 1% on 230 kV.

8 Thermal Limits

This facility is requested to be interconnected via a new substation connected to the existing 138 kV transmission line L-6511 between 50N-Trenton and 93N-Glen Dhu Wind Farm, at or near the 93N-Glen Dhu substation as shown in Figure 1. This line is designed and insulated for 138 kV (insulator strings, phase spacing, conductor height), using 556.5 ACSR Dove conductor. Recently, the line was uprated to an operating temperature of 60°C. Although the conductor now has a thermal rating of 140 MVA in summer and 184 MVA in winter[2], the line is limited to 173 MVA due to full load metering at the 50N-Trenton end.

Table 1

Table 8.1 Local Transmission Element Limits

Line	Conductor	Design Temperature	Limiting Element	Summer Rating Normal/Emergency	Winter Rating Normal/Emergency
L-6515	556.5 Dove	50°C	Conductor/Switches	110/121	143/157
L-6552	556.5 Dove	50°C	Conductor/Switch	110/121	143/157
L-6511	556.5 Dove	60°C	Conductor	140/154	184/202
L-6503	1113 Beaumont	85°C /100°C	Switchgear	287/316	287/316
L-7003	556.5 Dove	70°C	Conductor	271/298	335/368
L-7004	556.5 Dove	60°C	Conductor	233/256	307/338
L-7005	1113 Beaumont	70	Relaying/Metering	398/438	398/438

IR#552 was modeled as a new wind farm interconnected at the 93N-Glen Dhu substation with its own station transformer, collector circuits, and WECS units. This configuration would produce similar loading on existing circuits as if it was connected via a new three-breaker ring bus on L-6511.

IR#552 at 100.8 MW

With the system economically dispatched within present limits, the addition of 100.8 MW at the POI resulted in line L-6511 exceeding its normal summer rating by 13% - 29%, depending on the generation level at Trenton (lower generation produced higher loading on L-6511). These loading levels are without a contingency and are therefore unacceptable. Under contingency, L-6511 was found to exceed its emergency rating by up to 45%. To achieve a rating of 216 MVA, the conductor operating temperature would have to be raised from 60°C to 100°C, meaning every transmission structure would have to be replaced (36.5km). However, raising the rating of L-6511 would not solve overload issues for loss of L-6511 itself. Lines L-6552 (19.7 km) and L-6515 (49.25 km) would need to be uprated to 70°C and 60°C respectively.

To solve the loading issues on the 138 kV lines between 2C-Port Hastings and 50N-Trenton, it is proposed to construct a new radial circuit from 50N-Trenton (50N-B62) to IR#552, approximately 36 km. Under this option, IR#552 would not be connected to

[2]Summer rating is based on an ambient temperature of 25°C; winter rating is based on ambient temperature of 5°C. When ambient temperature exceeds these assumed ambient temperatures, transmission lines may be de-rated.

93N-Glen Dhu substation or the existing Glen Dhu wind farm. Loss of this circuit would isolate IR#552.

An alternative was considered consisting a second 138kV circuit (L-6611) be built between 93N-Glen Dhu and 50N-Trenton and L-6511 be uprated from 60°C to 70°C. However, it would be necessary to ensure that a single contingency did not trip both circuits between 93N and 50N. Although it may be possible to modify the three-breaker ring bus at 93N-Glen Dhu to ensure that L-6611 and L-6511 do not share a common circuit breaker, this is not feasible at 50N-Trenton, which is based on a split-bus configuration subject to failure of the bus tie breaker tripping all lines.

The POI is situated on transmission lines that constitute the transmission interface known as Onslow Import (ONI). Balancing load flow and generation sources in this region can also influence the transmission interface known as Cape Breton Export (CBX). The capability of these interfaces is therefore a function of generation at 50N-Trenton, 91N-Dalhousie Mountain, 93N-Glendhu, and COMFIT distributed generation between Truro and Cape Breton. It must be assumed that when IR#552 is operating at full rated power, then all other wind power generation sources in the local area are also operating at full rated power. Because this Interconnection Request is requested to be NRIS, then IR#552 will be incremental to economically dispatched generation serving native load and committed firm transmission reservations.

There is a long-term firm transmission reservation between Nova Scotia and New Brunswick (Transmission Service Request TSR-400) of 330 MW. Transmission upgrades are underway to permit the NS-NB transfer of 330 MW plus the delivery of between 172 MW and 220 MW of shared Operating Reserve in accordance with the NS-NB Interconnection Agreement for a total capability of between 502 MW and 550 MW.

With 100.8 MW of generation connected to the POI on the new radial line L-6611 in summer conditions (April to October), the following contingencies result in overloaded of L-6503:

- Tripping of L-8003 with or without a fault
- Failure of circuit breaker 67N-811 (L-8003, 67N-T82)
- Tripping of 79N-T81 (L-8003, L-8004, 79N-T81)
- Failure of circuit breaker 79N-803 or 79N-810 (L-8003, L-8004, 79N-T81)

The following contingencies resulted in the overload of L-7004 and L-7019

- Tripping of 79N-T81
- Fault on L-8004 with breaker failure at 79N
- Fault on L-8003 with breaker failure at 79N
- Bus fault or breaker failure on the 138kV bus at 79N

These contingencies activate existing Special Protection Systems (SPS) that will either trip one or two thermal units in Cape Breton, or activate high-speed runback of the

Maritime Link HVdc. The SPSs rely on sufficient generation on-line at Pt. Aconi and Lingan, or sufficient import from Newfoundland and Labrador to be able to reduce CBX and ONI flow by 330 MW within 100 milliseconds. These SPSs have been designated as Type I[3] by NPCC, and any modifications would need to be approved by all committees of NPCC.

It is feasible to uprate L-6503 to emergency ratings of 363/400 MVA (summer/winter) by changing out the switchgear and current transformers at 50N-Trenton and 1N-Onslow and uprating the conductor from 85°C to 100°.

L-7004 can be uprated by raising conductor operating temperature between 91N-Dalhousie Mountain and Little Harbour Road (35 km) by 10°C. L-7019 has recently been uprated to 70°C, and raising it a further 10°C may require a line re-build.

At these high levels of flow it is possible that system stability will be the limiting factor on ONI, rather than thermal loading of equipment. This would be confirmed in the System Impact Study, and it will be determined if there are features of IR#552 design that can extend stability limits.

In addition to the limitations of L-6511, IR#552 adds 100.8 MW (minus losses) to the flow between Onslow and the New Brunswick border, resulting in a total export of between 600 MW and 650 MW, including the firm transmission reservation of 330 MW and the delivery of shared operating reserve to New Brunswick. While exporting high amounts of power from NS, the Export Power Monitor SPS (NPCC Type III) must be armed to quickly reject/runback up to 330 MW of generation in Nova Scotia to avoid overload of the parallel 138kV transmission, maintain synchronism between the NS and NB power systems, and avoid excess over-frequency operation of the NS power system. Loss of L-8001 (designated L-3025 on the New Brunswick side of the border) will activate this SPS for the following contingencies:

- Loss of L-8001/L-3025 for any reason
- Breaker failure of 67N-814 (L-8001, 67N-T81)
- Breaker failure at Memramcook NB (L-3006, L-8001/L-3025, ME-T3)

Loss of L-8001, even with activation of the Export Power Monitor SPS, resulted in L-6613, the new circuit to be constructed this year in association with TSR-400 reservation, to exceed its thermal rating with IR#552 NRIS plus TSR-400 and reserve delivery to NB. L-6613 is designed with the same conductor /characteristics as L-6503. If switchgear at 1N-Onslow and 74N-Springhill is uprated to 2000 A, then the emergency rating of L-6613 can be increased from the planned rating of 287 MVA to an emergency rating of 363/400 MVA (summer/winter).

[3] A Type I designation means that the failure to operate or misoperation SPS can have significant adverse impacts outside the local area, and must be designed to a high level of reliability and redundancy in accordance with NPCC Directory 7 *Special Protection Systems.*

A contingency on the NB side of the border (loss of L-3006) was found to result in exceeding the emergency rating of the Memramcook 345kV – 138kV transformer by 10%. This issue would normally be dealt with if a SIS is conducted by the NB Power System Operator in conjunction with a transmission service request into or through their system, in accordance with the NB Power OATT.

As a sensitivity case to the normal assumptions of an NRIS SIS, it was assumed that IR#552 formed part of the transmission reservation TSR-400 (330 MW firm) with reserve delivery to NB Power of 220 MW. Under this scenario, Maritime Link is dispatched at 374 MW, which still provides SPS run-back capability of 330 MW. It was found that the contingencies resulting in loss of L-8003 with IR#552 at rated load resulted in L-6503 exceeding its summer emergency rating by 10%. However, if L-6503 is uprated to give a summer rating of 320 MVA normal, 353 MVA emergency, this overload would be eliminated. The uprating of L-6503 would require new switchgear at 1N-Onslow and thermal uprating of the conductor to 100°C between the POI and 1N-Onslow. The contingency loss of L-8001 requires SPS rejection/run-back of 330 MW resulting in line L-6613 loading to 100% of its emergency rating MVA, so it would not require switchgear uprating. Loss of L-3006 in New Brunswick brings flow on the Memramcook 345kV transformer to 110% of its summer emergency rating.

Winter peak load conditions were studied with the NS-NB firm export of 330 MW and the assumption that Maritime Link would be operated at no greater than 330 MW. Under these conditions, the reserve sharing commitment to New Brunswick was limited to 172 MW. Addition of IR#552 as NRIS results in a total export of 600 MW. Under these conditions, contingencies involving loss of L-8003 (with SPS action), require uprating of L-6503 by replacement of the switchgear at 50N-Trenton, subject to any stability related limits found in the SIS. Contingencies related to loss of L-8001 result in voltage collapse of the 138 kV intertie and separation from New Brunswick, even with SPS action and thermal uprating of L-6613. Reactive power support in the form of a 0-50 Mvar Static Var Compensator (SVC) would be required on the 138kV bus at 74N-Springhill.

Alternate IR#552 at 50.4 MW

The IC has requested that an alternate project size of 50 MW be considered for the POI on L-5611. This was examined with existing transmission, with the POI at or adjacent to 93N-Glen Dhu as shown in Figure 1.

To provide NRIS, the addition of 50.4 MW at the POI resulted in the following issues:

- Loss of L-7005 resulted in L-6511 reaching 100% of its summer emergency rating
- Loss of the double circuit tower L-7003+L-7004 (Canso Causeway or Trenton bypass) resulted in L-6511 reaching 128% of its summer emergency rating. If the Group 3 SPS is armed, this loading would be reduced to 113% (overloaded by 13% of emergency rating).
- Loss of L-7019 results in L-6511 reaching 102% of its summer emergency rating.

- Loss of L-8004 with SPS run-back of Maritime Link results in L-6511 reaching 116% of its summer emergency rating.
- Loss of 79N-T81 with SPS run-back of Maritime Link results in L-7004 and L-7019 exceeding their summer emergency rating by 3% - 5%.
- Loss of L-8003 with SPS run-back of Maritime Link results in L-6503 overloading by 10% at the 50N-Trenton end and 3% at the 1N-Onslow end.
- Loss of L-8001 results in L-6613 exceeding emergency rating by 4%.

These results suggest that L-6511 would need to be uprated from a conductor temperature of 60°C to 80°C, the switchgear on L-6503 at 1N-Onslow (switch) and 50N-Trenton (breaker and switch) must be uprated from 1200 A to 2000 A. L-7009 and L-7019 would need to be have conductor operating temperature increased by 10°C, subject to a detailed survey.

Loss of the NB Power line L-3006 results in the Memramcook transformer exceeding its summer emergency rating by 8%.

If the assumption is made that IR#552 does not add incremental transfers to the 330 MW firm export reservation, but NS is responsible for delivering 220 MW to New Brunswick, then all contingencies fall within summer limits, assuming that there is at least 330 MW of import from Maritime Link to be run-back by SPS action. If only 300 MW is available for SPS action (two thermal units at Lingan, for example), then L-6613 would require new switchgear at 1N-Onslow (switches only) and 74N-Springhill (breaker and switches). Voltage did not collapse for this option.

9 Voltage Limits

This project, like all new generating facilities must be capable of providing both lagging and leading power factor of 0.95, measured at the HV terminals of the IC Substation Step Up Transformer, at all production levels up to the full rated load of 100.8 MW.

Data provided by the IC indicates that IR#552 would likely meet this requirement without additional reactive support. The data sheet provided was for the 4.2 MW Enercon E-141 EP4-FT WECS which states that the normal power factor range is 0.875 leading and lagging at the machine terminals. Depending on the characteristics of the collector circuits and given the impedances of the transformers, supplementary reactive support may be needed in the form of capacitor banks at the low voltage terminals of the Interconnection Transformer, or a mixture of Enercon model FT and FTQ WECS units. This will be further investigated in the System Impact Study.

A centralized controller will be required which continuously adjusts individual generator reactive power output within the plant capability limits and regulates the voltage at the 34.5 kV bus voltage. The voltage controls must be responsive to voltage deviations at the terminals of the Interconnection Facility substation, be equipped with a voltage set-point control, and also have the ability to slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual generators capabilities. 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. Line drop compensation, voltage droop, control of separate switched capacitor banks must be provided.

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 also have low voltage ride-through capability as per Appendix G of the Standard Generator Interconnection and Operating Agreement (GIA). The SIS will state specific options, controls and additional facilities that are required to achieve this.

The material provided by the IC indicates that the Enercon units are available with a STATCOM Reactive Power mode. It is recommended that the IC obtain an optional quote for this feature, as it may help to support system voltage and stability during high power transfer levels. The need for this feature will be further examined in the SIS.

10 System Security / Bulk Power Analysis

As NRIS this generating facility will increase loading on the Onslow Import interface (flow into Onslow from eastern Nova Scotia) which can be heavily loaded from the supply sources at Lingan, Point Aconi, Wreck Cove, Point Tupper and Trenton as well as imported power from the Maritime Link. This interface supports flow towards the load centre in Halifax and exports to New Brunswick and is therefore often congested, especially with transmission out of service for maintenance. Increased flow on this interface may require increased reactive support at Onslow and in the Halifax area or invoke facility additions that can reduce the reactive support requirements. This will be evaluated in the SIS.

The SIS will determine if any facility changes are required to permit the proposed higher transmission loadings while maintaining compliance with NERC/NPCC standards and in keeping with good utility practice.

As noted in Section 8, the transmission capacity between Nova Scotia and New Brunswick is limited to the long term firm transmission reservation associated with the Maritime Link, including the transmission capacity necessary to deliver reserve to NB Power under the Interconnection Agreement. There is some incremental capacity available, but not enough to support this NRIS application at the locations identified. The *Nova Scotia Power 10 Year System Outlook* is posted on the NSPI OASIS. Section 9.5 of that report discusses the characteristics of the NS-NB and notes “the timing and configuration of an expansion to the provincial intertie has yet to be determined”.

It is important to note that, without a second 345 kV transmission line between Nova Scotia and New Brunswick, export capability is dependent on the availability of sufficient generation in Nova Scotia to be rejected or run-back by SPS action. This means that for NS export up to 330 MW, the Maritime Link must be operating in import mode in excess of 330 MW or two thermal units at Pt. Aconi/Lingan must be operating at full load.

The POI on L-6511 or the proposed new L-6611 would not be considered Bulk Power System (BPS), and therefore the Interconnection Substation does not need to be designed to meet the requirements of NPCC Directory 4 *System Protection Criteria*.

11 Expected Facilities Required for Interconnection

100.8 MW at POI L-6611 (new 138 kV circuit)

The following facility changes are required to interconnect IR #552 sized at 100.8 MW at the proposed POI:

Additions/Changes for POI on the 138 kV circuit L-6611:

1. Build new 138kV transmission line, 36 km, 795 ACSR Drake Conductor designed for 100°C, designated L-6611.
2. Single 138kV circuit breaker with switches and metering at 50N-Trenton and the Interconnection Substation.
3. Uprate the transmission line L-6503 between the 51N-Michelin Tap and the 1N-Onslow substation (57 km) from a conductor operating temperature of 85°C to 100°C by removing insulator disks.
4. Uprate the switches 1N-623A and 1N-623B to 2000 A.
5. Uprate switchgear (breaker and switches) associated with L-6503 at 1N-Onslow and 50N-Trenton to 2000 A.
6. Modification of NSPI protection systems,
7. Control and communications between the wind farm and NSPI SCADA system (to be specified).

Network Upgrades to provide NRIS service.

8. Upgrade switchgear for L-6613 to 2000 A at 1N-Onslow (switches only) and 74N-Springhill (breaker and switches).
9. Uprate L-7004 from 60°C to 70°C conductor temperature, the line section between Little Harbour Road and Dalhousie Mountain (35 km section with 556.5 ACSR Dove conductor). Detailed Lidar survey is required.
10. Uprate L-7019 from 70°C to 80°C conductor operating temperature, requiring a detailed Lidar survey.
11. Install 0-50 Mvar Static Var Compensation at 74N-Springhill 138kV to support high exports in winter.

Alternate Project Size – 50.4 MW at POI on L-6511

The following facility changes are required to interconnect IR #552 at the proposed POI on L-6511:

1. A three-breaker ring bus development adjacent to the right-of-way of L-6511, designed for 138 kV. Circuit breakers must be rated 2000 A. Non-BPS. This assumes that IR#552 cannot share a bus with 91N-Glen Dhu.
2. Uprate line L-6511 from a conductor operating temperature of 60°C to 75°C
3. Uprate L-6503 by changing switches at 1N-Onslow.
4. Control and communications between the wind farm and NSPI SCADA system (to be specified).

Network Upgrades to provide NRIS service.

5. Upgrade switchgear for L-6503 to 2000 A at 1N-Onslow (switches only) and 50N-Trenton (breaker and switches).
6. Uprate L-7004 from 60°C to 65°C conductor temperature, the line section between Little Harbour Road and Dalhousie Mountain (35 km section with 556.5 ACSR Dove conductor). Detailed Lidar survey is required.
7. Uprate L-7019 from 70°C to 75°C conductor operating temperature, requiring a detailed Lidar survey.
8. Uprate L-6613 switches at 1N-Onslow and switchgear (breaker and switches) at 74N-Springhill to 2000A,

Requirements for the Generating Facility

1. It is assumed that the Interconnection Substation is located at the POI. If not, a radial branch line to a new Interconnection Substation would be required. The branch line would be designed for 138 kV and would be fully shielded for 1.0 km out of each substation. The Interconnection Substation would require a circuit breaker at high side of customer power transformer and protections as acceptable to NSPI. An RTU to interface with NSPI's SCADA, with telemetry and controls as required by NSPI.
2. Facilities to provide 0.95 leading and lagging power factor when delivering rated output at the HV terminals of the IC Substation Step Up Transformer when the voltage at that point is operating between 95 and 105 % of nominal. The functionality of Enercon STATCOM Reactive Power mode should be considered.
3. Centralized controls. These will provide centralized voltage set-point controls and are known as Farm Control Units (FCU). The FCU will control the 34.5 kV bus voltage and the reactive output of the machines. 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.

4. 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.
5. Low voltage ride-through capability as per Appendix G to the Standard Generator Interconnection and Operating Agreement (GIA).
6. Real-time monitoring (including a Remote Terminal Unit) of the interconnection facilities. Local wind speed and direction, MW and Mvar, as well as bus voltages are required.
7. Facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined in SIS. The plant may be incorporated into SPS run-back schemes.
8. Synthesized inertial response similar to the features of Enercon IE controls.
9. Automatic Generation Control to assist with tie-line regulation.
10. Operation at ambient temperature of -30°C

12 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 100.8 MW wind energy onto the identified POI on the 138 kV transmission system are included in Table 12-1. Estimates for the alternate size plant of 50.4 MW are included in Table 12-2.

Table 12-1: Cost Estimates identified from FEAS scope 100.8 MW on L6611

	Determined Cost Items	Estimate
NSPI Interconnection Facilities		
i	New 138kV transmission line from 50N-Trenton to POI 36 km	$ 10,080,000
ii	138 kV Single breaker bus primary equipment and control building	$ 1,700,000
iii	138 kV line termination at 50N-Trenton	$ 1,200,000
iv	Uprate L-6503 to 100°C Michelin to Onslow (57 km)	$ 1,482,000
v	Uprate L-6503 switchgear at 1N-Onslow and 50N-Trenton	$500,000
vi	Protection, control	$500,000
vii	Communications	$500,000
	Subtotal	$15,462,000
	Contingency (10%)	$1,546,200
	Total Interconnection Facilities	$17,008,200
Network Upgrades (including increased tie capacity for NRIS)		
viii	Uprate L-7004 (35 km) from 60°C to 70°C	$8,750,000
ix	Uprate L-7019 (29.6 km) 70°C to 80°C	$7,400,000
x	Upgrade switchgear on L-6613 to 2000 A (1N and 74N)	$500,000
xi	50 Mvar SVC at 74N-Springhill	$7,000,000
xii	Protection modifications	$100,000
	Subtotal	$23,750,000
	Contingency (10%)	$2,375,000
	Total Network Upgrades	$26,125,000
Totals		
xiii	Total of Determined Cost Items	$43,133,200
	To be Determined Costs	
xiv	System additions to address potential stability limits	TBD (SIS)
xv	Memramcook transformer loading issue	TBD (NB Power SIS)

The preliminary non-binding cost estimate for interconnecting 100.8 MW at the POI on a new radial line L-6611 would be $17,008,200 including a contingency of 10%, but this would not constitute NRIS service, since it does not extend the NS-NB transmission capacity. The necessary Network Upgrades to provide NRIS would cost an estimated $26,125,000 for a total cost of $43,133,200.

Table 12-2: Cost Estimates identified from FEAS scope 50.4 MW on L6511		
	Determined Cost Items	**Estimate**
NSPI Interconnection Facilities		
i	138 kV 3-breaker ring bus on L-6511, complete	$6,000,000
ii	Uprate conductor temperature L-6511 from 60°C to 75°C	$3,650,000
iii	Uprate L-6503 by changing switches at 1N-Onslow	$75,000
iv	Protection, control	$500,000
v	Communications	$500,000
	Subtotal	$10,725,000
	Contingency (10%)	$1,072,500
	Total Interconnection Facilities	$11,797,500
Network Upgrades (including increased tie capacity for NRIS)		
vi	Uprate L-6503 switchgear at 1N-Onslow and 50N-Trenton	$500,000
vii	Uprate L-7004 (35 km) from 60°C to 65°C	$7,000,000
viii	Uprate L-7019 (29.6 km) 70°C to 75°C	$6,000,000
ix	Upgrade switchgear on L-6613 to 2000 A (1N and 74N)	$500,000
x	Protection modifications	$100,000
	Subtotal	$14,100,000
	Contingency (10%)	$1,410,000
	Total Network Upgrades	$15,510,000
Totals		
xi	Total of Determined Cost Items	$27,307,500
	To be Determined Costs	
xii	System additions to address potential stability limits	TBD (SIS)
xiii	Memramcook transformer loading issue	TBD (NB Power SIS)

The preliminary non-binding cost estimate for interconnecting the alternate plant size of 50.4 MW at the POI on L-6511 would be $11,797,500 including a contingency of 10%, but this would not constitute NRIS service, since it does not extend the NS-NB transmission capacity. The necessary Network Upgrades to provide NRIS would cost an estimated $15,510,000 for a total cost of $27,307,500.

12 Loss Factor

Injection of 100.8 MW of power at the POI, for delivery to NB border will be incremental to transmission system losses serving native load. To assist in the evaluation of the impact of the location of the POI and alternate POI, loss factors from the POI to the NS-NB border were calculated. This calculation does not include any losses from the generators to the POI (generator transformer, collector circuits, Interconnection Substation equipment, or any radial circuit from the Interconnection Substation to the POI):

- 100.8 MW with POI on L-6611, Loss Factor 6.4%
- Alternate size 50.4 MW POI on L-6511, Loss Factor 8.2%

The loss factor for the 50.4 MW option is larger than the 100.8 MW because the POI is on the heavily loaded L-6511 instead of the new radial circuit L-6613.

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#552. The SIS will include a more comprehensive assessment of the technical issues and requirements to interconnect generation as requested. It will include contingency analysis, system stability and ride through and operation following a contingency (N-1 operation). The SIS must determine the facilities required to operate this facility at full capacity, withstand any contingencies (as defined by the criteria appropriate to the location) and identify any restrictions that must be placed on the system following a first contingency loss. 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 SIS will be conducted in accordance with the GIP with the assumption that all appropriate higher-queued projects will proceed and the facilities associated with those projects are installed.

The following outline provides the minimum scope that must be complete in order to assess the impacts. It is recognized the actual scope may deviate, to achieve the primary objectives.

The assessment will consider but not be limited to the following.

i. Facilities that the customer must install to meet the requirements of the GIP
ii. The minimum transmission additions/upgrades that are necessary to permit operation of this Generating Facility, under all dispatch conditions, catering to the first contingencies listed.
iii. Guidelines and restrictions applicable to first contingency operation (curtailments etc.)
iv. Under-frequency load shedding impacts

To complete this assessment the following first contingencies, as a minimum, will be assessed:

- L-8001/3025
- L-3006
- Memramcook 345/138 kV transformer
- L-6613
- L-6514
- L-6535/L-1159
- L-6511/L-1160
- L-8003
- 67N-T82 & L-8003 (common circuit breaker)
- L-8003 & L-8004 (common circuit breaker)
- L-8001 & 67N-T81 (common circuit breaker)
- L-8002 & 67N-T81 (common circuit breaker)

- L-3006 & L-3025 & Memramcook 345/138 kV Tx (common breaker)
- L-3006 & L3017 (common breaker)
- 1N-B61 (bus fault)
- L-6507/L6508 double circuit tower
- L-7003/L7004 double circuit tower
- L7005
- L-1108/1190 Common 138 kV structure
- Loss of 180 MW of load under peak load conditions
- Loss of largest generation source in NS
- Loss of Maritime Link

To complete this assessment the dynamics of the following first contingencies, as a minimum, will be assessed:

- 3 phase fault L-8001/3025 at 67N-Onslow, NS Import SPS operation (islanding)
- 3 phase fault L-8001/3025 at 67N-Onslow, NS Export SPS operation
- 3 phase fault L-3006 at Memramcook, NB SPS/UVLS operation (islanding)
- 3 phase fault L-3006 at Memramcook, NB Export SPS
- 3 phase fault L-3006 at Salisbury, NB SPS/UVLS operation (islanding)
- 3 phase fault L-8003 at 67N-Onslow
- 3 phase fault L-8002 at 67N-Onslow
- SLG L-3017, drops L-3017&L-3006 (common CB), NB SPS/UVLS operation,
- SLG Memramcook T3, drops L-3006 (common CB), NB SPS/UVLS operation
- SLG L-8003 at Onslow, drops 67N-T82, 345kV SPS Operation
- 3 phase fault at 79N-Hopewell, drops L-8003, 8004, bus, SPS operation
- 3 phase fault 1N-Onslow 138 kV bus B61
- 3 phase fault on L7005 at 67N-Onslow

Any changes to SPS schemes required for operation of this generating facility, in addition to existing 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[4] and NPCC[5] criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

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[4] NPCC criteria are set forth in its Reliability Reference Directory #1 *Design and Operation of the Bulk Power System*
[5] NERC transmission criteria are set forth in *NERC Reliability Standards TPL-001, TPL-002, TPL-003*