Interconnection Feasibility Study Report

GIP-549-FEAS-R1

System Interconnection Request #549

124 MW Wind Generating Facility

Colchester County (L-6503)

2017-03-31

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR#549) for Network Resource Interconnection Service (NRIS) for a proposed 124 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2021-10-31. The Point of Interconnection (POI) requested by the customer is on the 138 kV transmission line L-6503, approximately 20 km from the 1N-Onslow substation. An alternative POI identified by the IC is on the 230 kV line L-7005, approximately 19 km from the 67N-Onslow EHV substation.

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#549 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#549 which are considered in this study

NRIS service for IR#549 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 660 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#549 displaced and 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 the primary POI on the 138 kV line L-6503 indicated that upgrades would be necessary to deliver 124 MW without exceeding emergency thermal ratings of equipment. The line section of L-6503 between the POI and 1N-Onslow is limited by the conductor operating temperature of 85°C and the rating of switches at the 1N-Onslow end of the line. The switches at the Onslow end of L-6503 must be uprated to 2000 A, and the conductor uprated to 100°C by removing insulator disks to increase ground clearance. 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#549 will require switches at the 1N-Onslow end of L-6613 and the switchgear at the 74N-Springhill end must be uprated.

The assessment of the system impact with the alternative POI on the 230 kV transmission line L-7003 resulted in lower post-contingency loading on most lines compared with the 138 kV POI, however the 50N-Trenton end of L-6503 was found to exceed the emergency rating of the switchgear and should be uprated. Similar uprating requirements were identified for L-6613.

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#549 may not be able to meet this requirement without additional reactive support. Based on the provided rated power factor of the GE 3.86 MW (normally 0.95, optionally 0.90), and the provided 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. 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 3.14% for POI on L-6503 and 2.0% for POI on L-7004 kV; system losses increased by net 3.8 MW when IR #549 interconnects into L-6503 and 2.5 MW when IR#549 interconnects into L-7005 at the full output of 124 MW, neglecting collector circuit and transformer losses. There may be a concern for low Short Circuit Ratio with minimum short circuit level under line-out conditions, 593 MVA on L-6503 and 562 MVA on L-7005. These values should be communicated to the generator designers.

Both Points of Interconnection (L-6503 and L-7005) are considered Bulk Power System (BPS), and therefore the Interconnection Substation must be designed to meet the requirements of NPCC Directory 4 *System Protection Criteria*.

The preliminary non-binding cost estimate for interconnecting 124 MW onto L-6503 would be $7,397,500 and $8,745,000 on L-7005. Both cost estimates include a contingency of 10% and they will be further refined in the System Impact Study and the Facility Study. Neither of these estimates addresses the transmission reinforcements necessary to provide NRIS and associated incremental firm transmission service between IR#549 and the NS-NB border. The network upgrades necessary for NRIS would add $8,360,000 to each of the estimates for a total of $15,757,500 or $17,105,000 for POI on L-6503 or L-7005 respectively.

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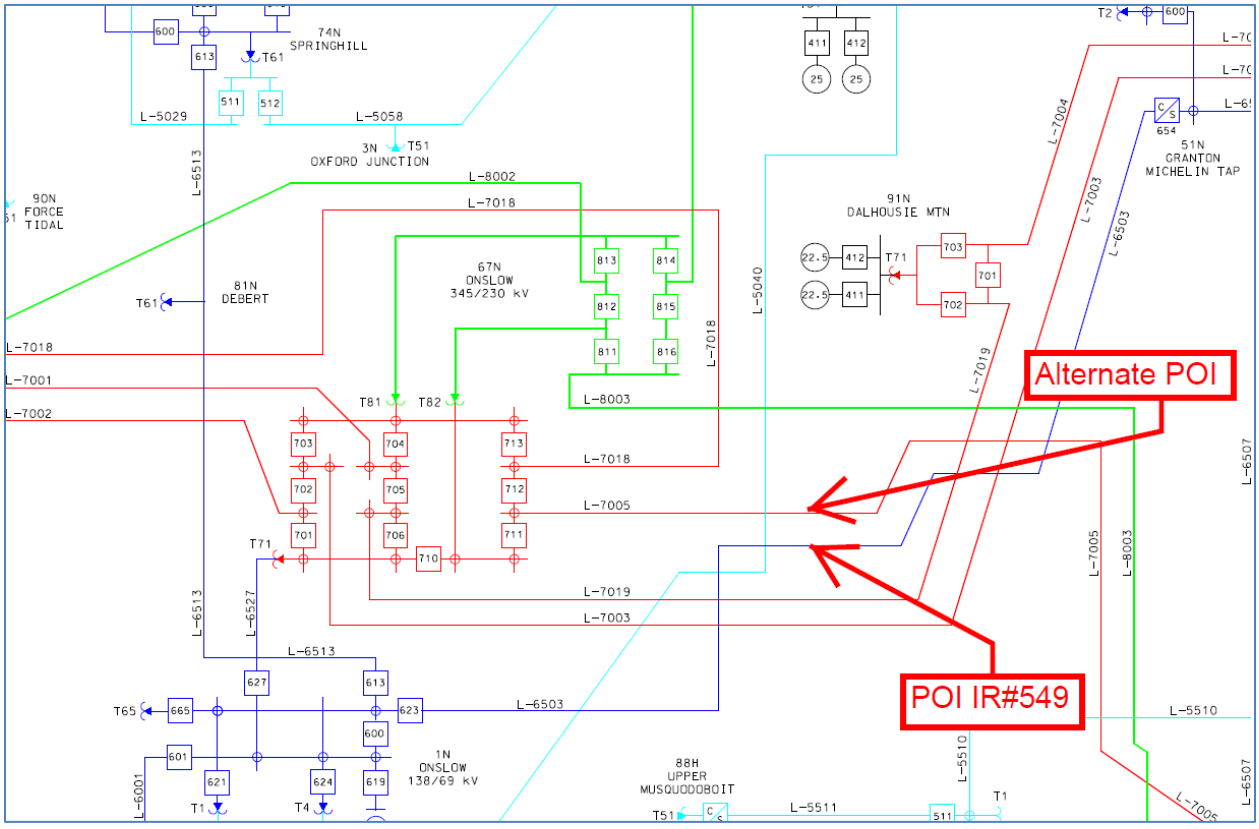
1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR#549) for Network Resource Interconnection Service (NRIS) for a proposed 124 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2021-10-31. The Point of Interconnection (POI) requested by the customer is on the 138 kV transmission line L-6503 approximately 21 km from the 1N-Onslow Substation. An alternative POI identified by the IC is on the 230 kV line L-7005 approximately 20 km from 67N-Onslow EHV Substation. 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 2017-03-09, and this report is the result of that Study Agreement. This project is listed as Interconnection Request #549 in the NSPI Interconnection Request Queue, and will be referred to as IR#549 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 2021-10-31.

3. The Interconnection Facility consists of 124 MW net generation with 32 units of 3.86 MW DFIG DFAG Wind Turbines on four collector circuits. These are classified as Type 3 Wind Energy Conversion Systems using doubly-fed induction generators and partial inverter supply.

4. The IC indicated that the POI is on the 138 kV transmission line L-6503 near Cove or Mungo Road near Kemptown Colchester County, a point which is approximately 21 km from the 138 kV substation 1N-Onslow. The alternative POI identified by the IC is on the 230 kV line L-7005 near Mungo Rd, approximately 20 km from the 67N-Onslow EHV substation. 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 80/106/132 MVA Interconnection Facility transformer with a positive sequence impedance of 8.5% and an assumed X/R ratio of 25. The IC indicated that this Interconnection Facility step-up transformer has a grounded wye-delta-wye winding configuration with +/-5% off-load tap changer. The impedance of generator step-up transformers is assumed to be 6% on 4.0 MVA with an assumed X/R ratio of 7.5. The alternate POI will assume the same transformer data with the exception of a high voltage rating of 230 kV.

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. It is assumed that the wind turbines are equipped with a "cold weather option" suitable for delivering full power under expected Nova Scotia winter environmental conditions.

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

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#549.

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 124 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#549 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 2021 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 and 10000 MVA on 230 kV systems. The short-circuit levels in the area before and after this development are provided below in Table 6-1 for the primary POI (L-6503) and Table 6-2 for the Alternate POI (L-7005). Because the generator type for IR#549 is Type 3, the fault characteristics are given as three times rated current for up to 5 cycles, or X'd = 0.33 per unit.

The maximum short-circuit level at the POI on L-6503 with IR#549 off-line will be 1565 MVA in 2021. With IR #549 on-line the short-circuit level will increase to 1898 MVA at the POI. Similarly, under minimum generation conditions, the short circuit level will be 1290 MVA with all lines in-service, and 859 MVA with the line from POI to 1N-Onslow out of service. This translates into minimum Short Circuit Ratio of between 6.4 and 10.4.

Table 6-1: Short-Circuit Levels. IR549 on L-6503 Three-phase MVA (1)

Location	Without IR #549	With IR #549
All transmission facilities in service		
Point of Interconnection	1565	1898
1N-Onslow 138 kV	2277	2453
51N-Michelin Tap 138 kV	2192	2297
Minimum Conditions		
Point of Interconnection	593 line out	1290

(1) Classical fault study, flat voltage profile

The maximum short-circuit level at the POI on L-7005 with IR#549 off-line will be 2705 MVA in 2021. With IR #549 on-line the short-circuit level will increase to 3038 MVA at the POI. Under minimum generation conditions, the short circuit level will be 1970 MVA with all lines in-service, and 562 MVA with the line from POI to 67N-Onslow out of service. This translates into minimum Short Circuit Ratio of between 4.5 and 15.9.

Table 6-2: Short-Circuit Levels. IR549 on L-7005 Three-phase MVA (1)

Location	Without IR #549	With IR #549
All transmission facilities in service		
Point of Interconnection	2705	3038
67N-Onslow 230 kV	4200	4487
3C-Port Hastings 230 kV	3031	3103
Minimum Conditions		
Point of Interconnection	562 line out	1970

The interrupting capability of the 138 kV circuit breakers is at least 3500 MVA at 1N-Onslow. There are no circuit breakers at 51N-Michelin tap, and circuit breakers at 50N-Trenton that are rated less than 6000 MVA have been identified as requiring replacement. The interrupting capability of the 230 kV circuit breakers at 67N-Onslow and 3C-Port Hastings is at least 10,000 MVA. As such, the interrupting ratings will not be exceeded by this development on its own. Therefore IR#549 will not impact the circuit breakers at these stations.

7 Voltage Flicker and Harmonics

Due to the lack of flicker coefficient information on the GE 3.86 MW DFIG DFAG Wind Turbines, this study assumes the same flicker data as for the GE 1.5SLE machine. Type 3 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-6503 between 50N-Trenton and 1N-Onslow, approximately 21 km from 1N-Onslow as shown in Figure 1. This line is designed and insulated for 230 kV (insulator strings, phase spacing, conductor height) but it is currently operated at 138 kV. The line is built with 1113 kcmil ACSR Beaumont with a design conductor temperature of 85°C. Although the conductor has a thermal rating of 287 MVA in summer and 335 MVA in winter[2], the line section between the POI and 1N-Onslow is limited to 287 MVA due to the rating of switchgear at the 1N-Onslow end.

The Alternate POI is requested to be a new substation on the 230 kV line L-7005 between 67N-Onslow EHV and 3C-Port Hastings, approximately 19 km from the 67N-Onslow end. This transmission line is designed and insulated for 230 kV, with the same conductor, Gulfport structures, and insulation as L-6503; however the conductor design temperature of L-7005 is 70°C. L-7005 is rated 404 MVA in summer and 502 MVA in winter. However the line protection relaying is limited to 398 MVA, and full scale metering is limited to 462 MVA at each end of the line.

Both primary and alternate POI are 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#549 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#549 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.

Primary POI L-6503

With 124 MW of generation connected to the POI on L-6503 in summer conditions (April to October), the following contingencies involving the loss of L-8003 result in the overload of L-6503:

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

[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.

- 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)

These contingencies activate an existing Special Protection System (SPS) that will either trip one or two thermal units in Cape Breton, or activate high-speed runback of the Maritime Link HVdc. The SPS relies 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. The SPS has 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 1N-Onslow and uprating the conductor from 85°C to 100°. However, the post contingency flow on L-6503 was found to be 375 MVA in the summer case, including the off-loading effect of the SPS. The summer rating will be de-rated for ambient temperatures above 25°C, representing about 250 hours per year.

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#549 design that can extend stability limits.

In addition to the limitations of L-6503, IR#549 adds 124 MW to the flow between Onslow and the New Brunswick border, resulting in a total export of between 600 MW and 668 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, resulted in voltage collapse along the 138 kV circuits between Onslow and the NB border. The size of IR#549 was reduced to 100 MW to seek a steady-state solution and it was found that L-6613, the new circuit to be constructed this year in association with TSR-400 reservation,

[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.*

would not have sufficient thermal capacity to carry the NRIS service request of IR#549 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), however the line would still be thermally overloaded, and voltage would not meet criteria. To assist in supporting 138kV voltage, a 50 Mvar Static Var Compensator is proposed for 74N-Springhill.

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 – 138 kV transformer by 25%. 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#549 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 350 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#549 at rated load resulted in L-6503 exceeding its summer emergency rating by 16%. 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 334 MVA, requiring uprating of switchgear at 1N-Onslow and 79N-Springhill. Loss of L-3006 in New Brunswick brings flow on the Memramcook 345kV transformer to 105% 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#549 as NRIS results in a total export of 626 MW. Under these conditions, contingencies involving loss of L-8003 (with SPS action), require uprating of L-6503 by replacement of the switches at 1N-Onslow, and uprating the conductor from 85° to 100°C, 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.

Alternate POI L-7005

The proposed alternate POI is on L-7005 approximately 19 kV from the 67N-Onslow EHV substation (Figure 2). The line is 160 km from 67N-Onslow to 3C-Port Hastings and forms part of the critical interfaces known as Cape Breton Export and Onslow Import. It is assumed that the Interconnection Facility is adjacent to the existing line and does not require a line extension. L-7005 is designed and operated at 230 kV, with all but

1.5 km using wood pole Gulfport structures and 1113 Beaumont ACSR conductor designed for 70°C operating temperature. Presently, L-7005 shares a common double-circuit tower with L-8004 across the Strait of Canso, but it will be moved to a new tower structure before 2021. L-7005 is currently rated 398 MVA summer and winter due to the relaying current transformers at each end. It could be uprated to 404/502 MVA (summer/winter if the current transformers associated with protection and metering are changed). This would provide and emergency rating of 444/552 (summer/winter).

The addition of IR#549 to L-7005 as NRIS would add 124 MW to the committed NS-NB transfers of 330 MW (long term firm reservation associated with TSR-100) plus 172 MW of shared reserve.

Loss of L-7005 between 67N-Onslow and the POI would re-route IR#549 back to Port Hastings, resulting in L-7004 and L-7019 reaching their summer emergency rating. Loss of the double-circuit towers carrying L-7003 plus L-7004 (either Canso Causeway or Trenton by-pass) results in L-7005 exceeding its emergency rating, so the current transformer replacements mentioned above would be required. Loss of L-8003 with SPS runback would result in overload of L-6503 at the 50N-Trenton end. This would require a replacement of one circuit breaker and switches and two switches at 50N-Trenton. L-6503 would not need to be uprated at the 1N-Onslow end.

Loss of L-8001 with 624 MW of export from NS to NB, with SPS runback, resulted in voltage collapse across the Springhill-Amherst 138 kV system, significant overloading of L-6613 and transformer 67N-T71 (230 kV – 138 kV) at 67N-Onslow. Assuming L-6613 is uprated to a normal summer rating of 320 MVA, emergency summer rating of 362 MVA by changing the switchgear at each terminal, the maximum output from IR#549 that can be supported is 80 MW. At that level, the uprated line L-6613 and the transformer 67N-T71 reach their emergency rating. To achieve full NRIS capacity without voltage collapse, a 50 Mvar Static Var Capacitor is proposed for the 138kV bus at 74N-Springhill in addition to the upgrades to L-6613.

Loss of the NB Power line L-3006 results in the Memramcook transformer exceeding its summer emergency rating by 26%.

If the assumption is made that IR#549 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).

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 124 MW.

Data provided by the IC indicates that IR#549 may not be able to meet this requirement without additional reactive support. The data sheet provided was for the GE 1.85-82.5 WECS which states that the normal power factor range is 0.95 leading and lagging at the machine terminals, with the option for 0.90 power factor "with real power de-rating", depending on system voltage conditions. 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. This will be further investigated in the System Impact Study. More information on a potential tap-changer will be required for that analysis.

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 GE units are available with a WindFree 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.

Both Points of Interconnection (L-6503 and L-7005) are considered Bulk Power System (BPS), and therefore the Interconnection Substation must be designed to meet the requirements of NPCC Directory 4 *System Protection Criteria*.

11 Expected Facilities Required for Interconnection

Primary POI L-6503 138 kV circuit.
The following facility changes are required to interconnect IR #549 at the proposed POI:

Additions/Changes for POI on the 138 kV circuit L-6503:

1. A three-breaker ring bus development adjacent to the right-of-way of L-6503, designed for 138 kV. Designed to BPS.
2. Uprate the transmission line L-6503 between the POI and the 1N-Onslow substation from a conductor operating temperature of 85°C to 100°C
3. Uprate the switches 1N-623A and 1N-623B to 2000 A.
4. Upgrade switchgear for L-6613 to 2000 A at 1N-Onslow (switches only) and 74N-Springhill (breaker and switches).
5. Modification of NSPI protection systems,
6. Control and communications between the wind farm and NSPI SCADA system (to be specified).

Alternate POI L-7005 230 kV circuit.
The following facility changes are required to interconnect IR #549 at the proposed alternate POI:

Additions/Changes for POI on the 230 kV circuit L-7005:

1. A three-breaker ring bus development adjacent to the right-of-way of L-7005, designed for 230 kV. Circuit breakers must be rated 2000 A. Designed to BPS.
2. Uprate the switchgear on L-6503 at 50N-Trenton to 2000 A (breaker and switches).
3. Upgrade switchgear for L-6613 to 2000 A at 1N-Onslow (switches only) and 74N-Springhill (breaker and switches).
4. Modification of NSPI protection systems,
5. Control and communications between the wind farm and NSPI SCADA system (to be specified).

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 or 230 kV (depending on POI) and would be fully shielded. 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 GE WindFree 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 GE WindINERTIA 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 124 MW wind energy onto the preferred POI on the 138 kV line L-6503 are included in Table 12-1. Estimates for the Alternate POI are included in Table 12-2.

Table 12-1: Cost Estimates identified from FEAS scope Primary POI		
	Determined Cost Items	**Estimate**
NSPI Interconnection Facilities		
i	Site preparation for new BPS substation at POI on L6503	$ 1,000,000
ii	138 kV 3-breaker ring bus primary equipment and control building	$ 4,000,000
iii	Up-rate L-6503 (20 km) to 100°C	$650,000
iv	Up-rate line terminals of L-6503 (switches at 1N)	$75,000
v	Protection, control	$500,000
vi	Communications	$500,000
	Subtotal	$6,725,000
	Contingency (10%)	$672,500
	Total Interconnection Facilities	$7,397,500
Network Upgrades (including increased tie capacity for NRIS)		
vii	Upgrade switchgear on L-6613 to 2000 A (1N and 74N)	$500,000
viii	Protection modifications	$100,000
ix	50 Mvar SVC at 74N-Springhill	$7,000,000
	Subtotal	$7,600,000
	Contingency (10%)	$760,000
	Total Network Upgrades	$8,360,000
Totals		
x	Total of Determined Cost Items	$15,757,500
	To be Determined Costs	
xi	System additions to address potential stability limits	TBD (SIS)
xii	Memramcook transformer loading issue	TBD (NB Power SIS)

The preliminary non-binding cost estimate for interconnecting 124 MW at the preferred POI on L-6503 would be $7,397,500 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 $8,360,000 for a total cost of $15,757,500.

Table 12-2: Cost Estimates identified from FEAS scope Alternate POI		
	Determined Cost Items	**Estimate**
NSPI Interconnection Facilities		
i	Site preparation for new BPS substation at POI on L-7005	$ 1,500,000
ii	230 kV 3-breaker ring bus primary equipment and control building	$ 4,500,000
iii	Upgrade line terminals of L-6503 (breaker and switches at 50N)	$450,000
iv	Protection, control	$1,000,000
	Communications	$500,000
	Subtotal	$7,950,000
	Contingency (10%)	$795,000
	Total Interconnection Facilities	$8,745,000
Network Upgrades (including increased tie capacity for NRIS)		
v	Upgrade switchgear on L-6613 to 2000 A (1N and 74N)	$500,000
vi	Protection modifications	$100,000
vii	50 Mvar SVC at 74N-Springhill	$7,000,000
	Subtotal	$7,600,000
	Contingency (10%)	$760,000
	Total Network Upgrades	$8,360,000
Totals		
ix	Total of Determined Cost Items	$17,105,000
	To be Determined Costs	
xi	System additions to address potential stability limits	TBD (SIS)
xii	Memramcook transformer loading issue	TBD (NB Power SIS)

The preliminary non-binding cost estimate for interconnecting 124 MW at the alternate POI on L-7005 would be $8,745,000 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 $8,360,000 for a total cost of $17,105,000.

13 Loss Factor

Injection of 124 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):

- POI on L-6503, Loss Factor 3.14%
- Alternate POI on L-7005, Loss Factor 2.0%

This means, for example, if output of IR#549 was raised from 0 MW to 122 MW at the POI, the amount of power received at the NS-NB border would be 118.2 MW for the primary POI and 119.6 MW for the alternate POI.

14 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#549. 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-6503/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-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*