Interconnection Feasibility Study Report

GIP-556-FEAS-R1

System Interconnection Request #556

150 MW Wind Generating Facility

Cumberland County (L-6513)

2017-04-28

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR#556) for Network Resource Interconnection Service (NRIS) and an alternate Energy Resource Interconnection Service (ERIS) for a proposed 150 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2019-09-01. The Point of Interconnection (POI) requested by the IC is on the 138 kV transmission line L-6513, approximately 46 km from the 74N-Springhill substation. This line will be a surplus radial circuit by 2019, replaced by a new higher capacity circuit L-6613 between the same substations as L-6513. The IC requested that an alternate POI on L-6613 be studied as well.

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#556 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#556 which are considered in this study

NRIS service for IR#556 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 – 690 MW. This study identified transmission contingencies inside Nova Scotia which would violate thermal loading criteria and estimated the cost of necessary upgrades to allow for full NRIS operation with increased export capability from Nova Scotia.

The alternative study request of ERIS assumes that IR#556 displaces an equivalent level of import from the Maritime Link to allow IR#556 to operate within the long-term firm reservation amount of 330 MW from NS to the NB border, plus the delivery of Operating Reserve to NB.

The assessment of the POI on the 138 kV line L-6513 indicated that upgrades would be necessary to deliver NRIS of 150 MW without exceeding emergency thermal ratings of equipment. The line section of L-6513 between the POI and 1N-Onslow is limited by the conductor operating temperature and must be uprated to 70°C to accommodate IR#556. Because a new circuit (L-6613) will be built in 2017-2018 to replace L-6513, L-6513 will not be in use in the year 2019 and will not have switchgear installed at the 74N-Springhill end. To use L-6513 to supply IR#556, two new circuit breakers will be required at 74N-Springhill in a ring configuration to allow L-6513 and IR#556 to bypass 74N during bus outages.

The IC indicated that a new 14 km branch line will be required to connect IR#556 to the POI on either L-6513 or L-6613. If IR#556 is connected to L-6513, a single 138kV switch is required at the POI. However, if L-6613 is used as the POI, a three-breaker ring bus or four-breaker ring bus is required, depending on ERIS vs. NRIS.

To allow for increased export capability from Nova Scotia to New Brunswick beyond the long term firm reservation of 330 MW and the Transmission Reliability Margin to deliver up to 220 MW of reserve to NB Power, thermal uprating of L-6514 is required, and switches at the 30N-Maccan end must be uprated. If the alternate POI L-6613 is used, the circuit breakers and

switches at the 74N-Springhill end of L-6613 would need to be uprated to 2000A, and a new 138kV circuit should be built between the POI and 74N-Springhill. The metering on L-6536 would need to be uprated.

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#556 should be able to meet the reactive power requirements without additional reactive support, although provision for two 15 Mvar capacitor banks are shown on the preliminary one-line diagrams provided by the IC. This will be further investigated in the System Impact Study.

No concern regarding high short-circuit level 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. Short Circuit Ratio may be an issue for inverter-based generation controls. For the option of the POI on L-6513, the minimum short circuit level at IC substation is 395 MVA with all lines in service, and 331 MVA with one line out of service. For the alternate POI on L-6613, the minimum short circuit levels at the IC stubstation would be 860 MVA with all lines in-service and 352 MVA with one line open. The generator supplier should be advised of this situation.

IR#556 is not part of the Bulk Power System if the POI is selected as L-6513, but would be considered Bulk Power if the POI is selected as L-6613.

The preliminary value for the unit loss factor is calculated to be 4.3% for NRIS or 4.2% for ERIS with POI on L-6513. The loss factor including the spur line to the wind farm would be 4.6% / 4.5% (NRIS / ERIS). For the alternate POI on L-6516, the loss factor was calculated to be 2.2% for NRIS and 1.5% for ERIS measured at the POI, or 2.6%/1.8% (NRIS/ERIS) if measured at the wind farm 138kV substation.

The preliminary non-binding cost estimate for interconnecting 150 MW onto L-6513 would be $12,177,000, and an additional $935,000 to extend NS-NB intertie capacity as necessary for NRIS for a total of $13,112,000. The alternate POI on L-6613 would incur an interconnection cost of $13,827,000 plus an additional $26,213,000 of network upgrades to support NRIS, for a total of $40,040,000. All estimates include a 10% contingency margin and assume that NSPI will build the radial spur line from the POI to the IC facility. These estimates will be further refined in the System Impact Study and the Facility Study.

Table of Contents

Page

1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR#556) for Network Resource Interconnection Service (NRIS) for a proposed 150 MW wind generation facility interconnected to the NSPI transmission system, , with a Commercial Operation Date of 2019-09-01. The Point of Interconnection (POI) requested by the customer is on the 138 kV transmission line L-6513 approximately 46 km from the 74N-Springhill Substation. Figure 1 shows the present configuration of line L-6513.

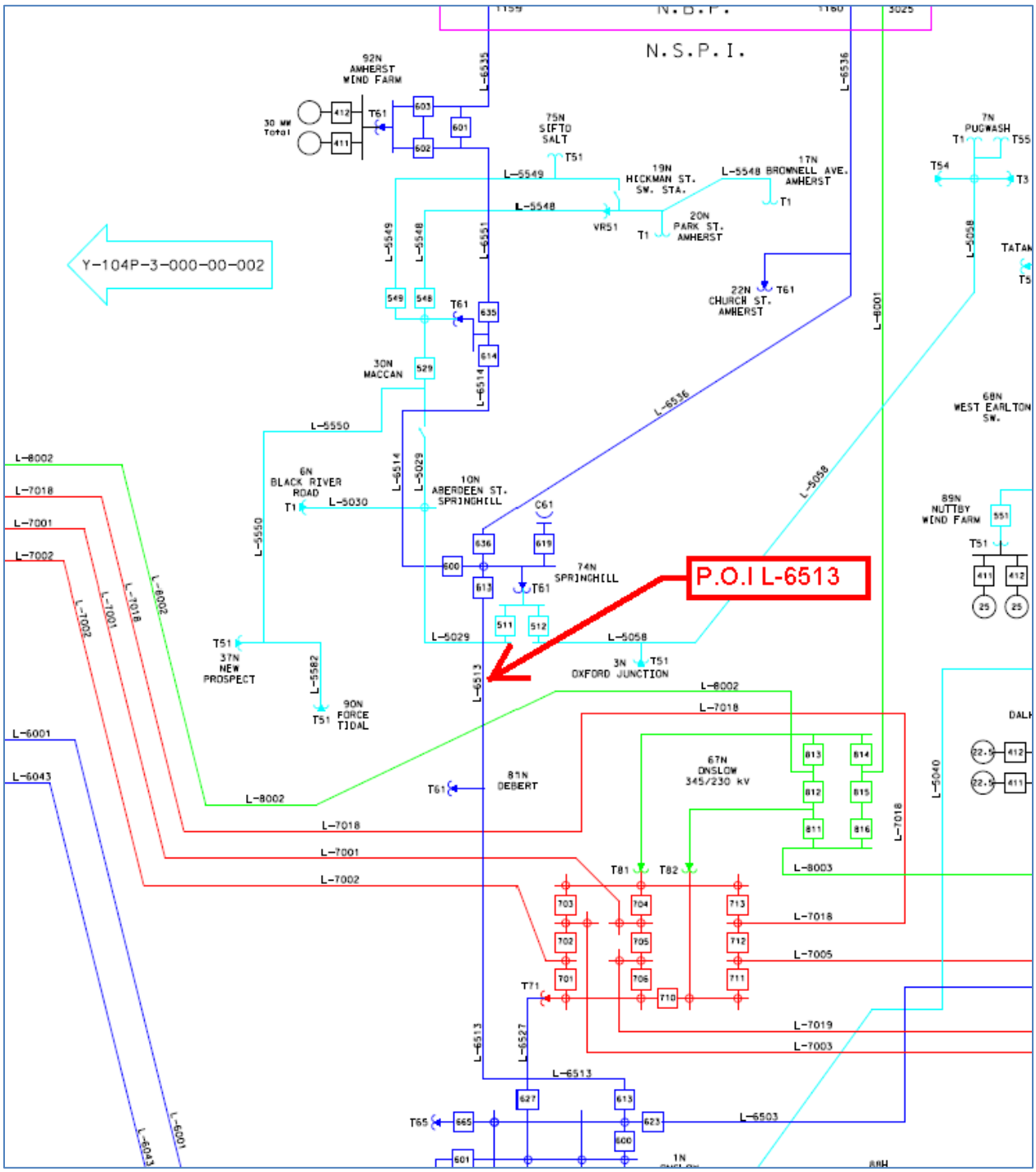
This configuration will change in 2018. A new 138 kV transmission line designated L-6613 will be built parallel to L-6513 and will be connected into 1N-Onslow and 74N-Springhill using the existing switchgear. L-6513 can be used as a radial circuit from 74N-Springhill to the POI with the addition of new switchgear at 74N-Springhill.

The IC requested the following alternate considerations for the Feasibility Study:

- Energy Resource Interconnection Service (ERIS) instead of NRIS,
- POI on the new L-6613 transmission line at approximately the same physical location as L-6513.

The Interconnection Customer (IC) signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2017-04-07, and this report is the result of that Study Agreement. This project is listed as Interconnection Request #556 in the NSPI Interconnection Request Queue, and will be referred to as IR#556 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”.

In accordance with Section 3.2.1.2 of Standard Generation Interconnection Procedures (GIP), as approved by the UARB on February 10, 2010, the FEAS for ERIS consists of short circuit/fault duty, steady state (thermal and voltage) analyses. The short circuit/fault duty analysis would identify direct Interconnection Facilities required and the Network Upgrades necessary to address short circuit issues associated with the Interconnection Facilities. The steady state studies would identify necessary upgrades to allow full output of the proposed Generating Facility and would also identify the maximum allowed output, at the time the study is performed, of the interconnecting Generating Facility without requiring additional Network Upgrades. It is therefore assumed that transmission interfaces limits will not be exceeded to avoid system upgrades in an ERIS study.

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, with an alternate request to study Energy Resource Interconnection Service type, per section 3.2 of the SGIP

2. Commercial Operation date 2019-09-01.

3. The Interconnection Facility consists of 150 MW net generation with 42 units of 3.6 MW Vestas V-136 GridStreamer Wind Turbines on five collector circuits. These are classified as Type 4 Wind Energy Conversion Systems using full IGBT inverter technology. Although the nameplate rating of the units is 151.2 MW, the plant output will be capped at 150.0 MW.

4. The IC indicated that the primary POI is on the 138 kV transmission line L-6513 approximately 46 km south of the 138 kV substation 74N-Springhill. L-6513 will be operated as a radial circuit by 2019. The alternate POI is on the new 138 kV line L-6613 which will run between 1N-Onslow and 94N-Springhil. The alternate POI will also be approximately 46 km south of 74N-Springhill. The IC has indicated that the Interconnection Facility substation will be connected to the POI via a new 138kV circuit, approximately 14 km in length and built using a twin-bundle 954 kcmil Cardinal ACSR conductor. It should be noted that this is a non-standard conductor in Nova Scotia.

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 one 138 kV-34.5 kV transformer rated 95/120/160 MVA. An Interconnection Facility transformer was modeled with a positive sequence impedance of 8.5% and an assumed X/R ratio of 45. The IC indicated that this Interconnection Facility step-up transformer has a grounded wye-delta winding configuration with +/-10% on-load tap changer in 32 steps. The preferred winding configuration to provide grounding on the 34.5 kV system is wye-grounded to wye-grounded with a delta tertiary.

7. The impedance of generator step-up transformers is assumed to be 6% on 3.2 MVA with an assumed X/R ratio of 7.5.

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

9. 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.

10. 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. The data sheet supplied with the application provided a winter rating based on an ambient temperature of -15°C, which would not be considered suitable for Nova Scotia.

11. 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.

12. 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.

13. 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
- IR #552 FEAS in progress
- IR #555 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 TSR-400 and Interconnection Requests IR#516 and IR#542 are expected to have an impact on IR#556.

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 150 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#556 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 2019 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 POI on L-6513 and Table 6-2 for the POI on L-6613. Because the generator type for IR#556 is Type 4, the fault current contribution is only slightly greater than full load current, (Ik"=1.05 pu).

The maximum short-circuit level at the POI on L-6513 with IR#556 off-line will be 481 MVA in 2019. With IR #556 on-line the short-circuit level will increase to 600 MVA at the POI. The maximum short-circuit level at the IC 138kV substation will be 431 MVA without IR#556 and 553 MVA with IR#556. Similarly, under minimum generation conditions, the short circuit level at the POI will be 436 MVA with all lines in-service, and 359 MVA with the line from 74N-Springhill to 1N-Onslow out of service. This translates into minimum Short Circuit Ratio of between 2.4 and 2.9. The SCR at the IC substation can be as low as 2.2 and may require special consideration by Vestas in designing plant controls. If 74N-Springhill bus is out of service and L-6513 is by-passed to 30N-Maccan via L-6514, the minimum SCR drops to 1.88 at the IC substation.

Table 6-1: Short-Circuit Levels. IR556 on L-6513 Three-phase MVA (1)

Location	Without IR #556	With IR #556
All transmission facilities in service		
IC substation (138kV)	431	553
Point of Interconnection	481	600
74N-Springhill 138 kV	1236	1340
Minimum Conditions		
IC substation (138kV)	331 (1 line out)	395 (all lines in)
Point of Interconnection	359 (1 line out)	436 (all lines in)

(1) Classical fault study, flat voltage profile

Table 6-2: Short-Circuit Levels. IR556 on L-6613 Three-phase MVA (1)

Location	Without IR #556	With IR #556
All transmission facilities in service		
IC substation (138kV)	1076	1199
Point of Interconnection	1450	1570
74N-Springhill 138 kV	1236	1263
Minimum Conditions		
IC substation (138kV)	352 (1 line out)	860 (all lines in)
Point of Interconnection	385 (1 line out)	1083 (all lines in)

The maximum short-circuit level at the alternate POI on L-6613 with IR#556 off-line will be 1450 MVA in 2019. With IR #556 on-line the short-circuit level will increase to 1570 MVA at the POI. The maximum short-circuit level at the IC 138kV substation will be 1076 MVA without IR#556 and 1199 MVA with IR#556. Similarly, under minimum generation conditions, the short circuit level at the POI will be 1083 MVA with all lines in-service, and 385 MVA with the line from the POI to 1N-Onslow out of service. This translates into minimum Short Circuit Ratio of between 2.6 and 7.2. The SCR at the IC substation can be as low as 2.3 with a line out of service, which may have implications for the design of wind farm controllers.

The interrupting capability of the 138 kV circuit breakers is at least 5000 MVA at 74-Springhill and 1N-Onslow. As such, the interrupting ratings will not be exceeded by this development on its own. Therefore IR#556 will not impact the circuit breakers at these stations.

7 Voltage Flicker and Harmonics

Due to the lack of flicker coefficient information on the Vestas V-136 Wind Turbines, this study assumes the same flicker data as for other Type 4 machines. 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.

8 Thermal Limits

This facility is requested to be interconnected connected to the existing 138 kV transmission line L-6513 about 46 km south of 74N-Springhill as shown in Figure 1. A new radial 138kV circuit, approximately 14 km in length, from the POI to the IC substation. The existing L-6513 is designed, insulated and operated at 138 kV (insulator strings, phase spacing, conductor height), using 556.5 kcmil ACSR Dove conductor with a design conductor temperature of 50°C. Although the conductor has a thermal design rating of 110 MVA in summer and 165 MVA in winter[2], a recent Lidar survey has indicated that ground clearance has deteriorated over time, and it must be upgraded to meet the original design rating of 110 MVA. To provide capability for 150 MW, it must be further uprated to 70°C. In the proposed configuration, L-6513 would be a radial circuit from the POI to 74N-Springhill. The design of the new 138kV radial circuit from the POI to the wind farm substation, as proposed by the IC, is based on a twin-bundle conductor design using 954.5 ACSR Cardinal conductor.

The alternate POI is on the new circuit L-6613, 46 km south of 74N-Springhill. This line is designed and operated at 138kV using a single conductor 1113 kcmil ACSR Beaumont designed for operation at up to 100°C. Since the switchgear at each end of L-6613 is not planned to be changed, L-6613 will be limited by the switchgear ratings. The wind farm substation would be connected to the POI via the new twin-bundle 954 Cardinal design and 14 km length used in the primary POI option.

The rating of transmission lines in the area are summarized in Table 8-1.

Table 8-1 Local Transmission Element Limits

Line	Conductor	Design Temperature	Limiting Element	Summer Rating Normal/Emergency	Winter Rating Normal/Emergency
L-6535	556.5 Dove	100°C	Conductor	214/234	242/266
L-6536	556.5 Dove	100°C	Metering	173/190	173/190
L-6514	556.5 Dove	60°C	Conductor/Metering	140/154	143/157
L-6613	1113 Beaumont	100°C	Switchgear	287/316	287/316
L-6513	556.5 Dove	50°C	Conductor	110/121	165/181
L-6551	556.5 Dove	100°C	Switch	143/157	143/157
L-1159	NB Power Equipment 80°C /100°C			175/213	215/222
L-1160	NB Power Equipment 80°C /100°C			175/213	215/246

IR#556 would feed into the Nova Scotia – New Brunswick Interface and has the potential to impact NS export and import limits. It must be assumed that when IR#556 is operating at full rated power, then all other wind power generation sources in the local area are also operating at full rated power. When this Interconnection Request is studied as NRIS, then IR#556 will be incremental to economically dispatched generation serving native load

[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.

and committed firm transmission reservations. The alternate request for ERIS will honour existing transfer limits.

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 556 MW.

NRIS Study Results, POI on L-6513

As NRIS, IR#556 adds 150 MW to the flow across the Nova Scotia - New Brunswick border, resulting in a total export of between 650 MW and 700 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 overload of L-6514 of 3% if generation at 90N-Force Tidal and 92N-Amherst Wind is operating at full load; L-6514 would exceed its summer emergency rating by 26% if generation at 90N and 92N is off-line. Loss of L-6536 under the latter conditions would result in L-6514 exceeding its thermal emergency rating by 6%.

L-6514 is limited to 140 MVA by the 60°C design temperature of its 556.5 ACSR Dove conductor, the rating of the switches at 30N-Maccan (143 MVA), and the full scale metering (173 MVA). To achieve the required emergency rating, the conductor operating temperature must be raised from 60°C to 80°C, and the switches at 30N-Maccan uprated to 1200 A. Similarly, L-6551 has a summer conductor rating of 215 MVA, but a switch at the 30N-Maccan end is rated at 143 MVA and must also be uprated along with L-6514.

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 345 kV – 138 kV transformer by 15%. 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.

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#556 as NRIS results in a total export of 650 MW. Under these conditions, the only contingencies of concern are those that involve the loss of L-8001 and activation of the Export Power Monitor SPS to runback 330 MW of Maritime Link import (or equivalent amount of thermal generation at Lingan and Pt. Aconi); the result being a 10% overload of L-6514, and 5% overload of L-6551. Uprating of the switches at the 30N-Maccan end of L-6514 and L-6551 to 1200 A and uprating full-scale metering on both ends of the line will remedy this overload.

NRIS Study Results, POI on L-6613

With IR#556 interconnected at the alternate POI on L-6613, delivery of incremental 150 MW to the 330 MW of firm export transmission service and 220 MW of shared reserve delivery to NB Power would increase the flow at the 74N-Springhill end of L-6613 from 127 MW to 184 MW, or 66% of its continuous summer rating. This means that 60% of the incremental 150 MW is diverted through Onslow to the 345 kV link to the NS-NB border. Contingency loss of L-6536 would not result in overload of L-6514.

With generation at 90N-FORCE and 92N-Amherst on-line, the loss of L-8001 with SPS run-back would result in transmission lines exceeding their emergency summer ratings by the following amounts:

- L-6514 by 8%
- L-6551 by 9%
- L-6536 by 21%
- L-6613 (between POI and 74N-Springhill) by 35%

To accommodate these overloads, the following upgrades would be necessary:

- Conductor on L-6514 uprated from 60°C to 80°C
- Switchgear at 30N-Maccan (L-6514 and L-6551) uprated from 600 A to 1200 A
- Switchgear for L-6514 at 74N-Springhill uprated from 600 A to 1200 A
- Switchgear for L-6613 at 74N-Springhill uprated from 1200 A to 2000 A
- Full scale metering on L-6536 increased from 172 MVA to 287 MVA

Conductor rating of L-6613 (summer) from POI to 74N-Springhill (46 km) increased to 1650 A (emergency rating 1800 A). As this has been determined to be impractical, a new line from the POI to 74N would be required. L-6513 would not be suitable for this second circuit because it would need to be uprated to a summer rating of 200 MVA. A new line is therefore proposed.

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#556 as NRIS results in a total export of 650 MW. Under these conditions, the only contingencies of concern are those that involve the loss of L-8001 and activation of the Export Power Monitor SPS to runback 330 MW of Maritime Link import (or equivalent amount of thermal generation at Lingan and Pt. Aconi); the result

being a 17% overload of L-6514 and L-6551. Uprating of the switches at the 30N-Maccan end of L-6514 and L-6551 to 1200 A and uprating full-scale metering on both ends of the line will remedy this overload. Due to the full-scale metering on L-6536, this line would also be overloaded by 15% The section of L-6613 between the POI and 74N-Springhill would be overloaded by 45% due to the switchgear at 74N-Springhill, which would need to be uprated to 2000 A. Voltage support in the Springhill/Maccan/Amherst are would be challenged under these conditions, therefore an SVC in the range of 50 – 100 Mvar would be required.

In the event that generation at 90N-Force and 92N-Amherst is off-line, L-6514 would be overloaded by 27%, L-6551 would be overloaded by 17%, L-6536 would be overloaded by 23% and L-6613 would be overloaded by 56%.

ERIS Study Results

Under the conditions of ERIS, it was assumed that IR#556 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. With NS-NB total export of 556 MW, there were no loading issues found.

Impact on NS Import

Because IR#556 is located between Onslow and the NB Border, the impact of the project on import from NB must be considered. Importing more than 100 MW from NB is possible with the Import Power Monitor SPS, which provides a controlled separation of Nova Scotia from New Brunswick if line L-3006 and/or L-8001 is lost. It was found that, after the building of line L-6613, the impact of IR#556 on the Import Power Monitor setting of 100 MW would be negligible. However at higher import values, voltage collapse would be experienced for the simultaneous loss of L-8001 and L-3006 (as would be the case for a breaker failure at Memramcook 345kV). The Import Power Monitor setting of 100 MW will remain if IR#556 is installed.

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 150 MW. This translates into a required reactive delivery of 49 Mvar leading and lagging.

Data provided by the IC indicates that IR#556 should be able to meet this requirement without additional reactive support, although the one-line diagram provided by the IC indicates provision for two 15 Mvar switchable capacitor banks on the 34.5 kV bus. The data sheet indicated that the Vestas V136 GridStreamer 3.6 MW WECS will be used, and that unit has a rated power factor of 0.902 capacitive to 0.918 inductive. Depending on the characteristics of the collector circuits and given the impedances of the transformers, supplementary reactive support in the form of capacitor banks at the low voltage terminals of the Interconnection Transformer may be advantageous. 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.

It is unknown if Vestas offers an optional STATCOM feature which provides reactive power and voltage control down to zero real power operation (low wind). If this is the case, 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 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 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.

The POI on L-6513 radially connected to 74N-Springhill is not considered Bulk Power System (BPS), however the alternate POI on L-6613 would be considered BPS. Therefore the Interconnection Substation would need to be designed to meet the requirements of NPCC Directory 4 *System Protection Criteria* if the POI is L-6613.

11 Expected Facilities Required for Interconnection

Additions/Changes for POI on the 138 kV circuit L-6513:

1. A single 138kV switch on L-6513, connecting the new 14 km radial circuit to the IC substation.
2. Proposed new 138 kV transmission line from the POI to IR#556 facility meeting NSPI design standards. Line-end circuit breaker at the IC facility.
3. Uprate the transmission line L-6513 between the POI and the 74N-Springhill substation from a conductor operating temperature of 50°C to 70°C.
4. Two new 138kV circuit breakers at 74N-Springhill.
5. Modification of NSPI protection systems,
6. Control and communications between the wind farm and NSPI SCADA system (to be specified).

Additions/Changes for Alternate POI on the 138 kV circuit L-6613:

1. A three-breaker ring bus development adjacent to the right-of-way of L-6613, connecting the new radial transmission from the POI to the IC substation. Protection designed for Bulk Power System standards.
2. Proposed new 138 kV transmission line from the POI to IR#556 facility meeting NSPI design standards. Line-end circuit breaker at the IC facility.
3. Modification of NSPI protection systems,
4. Control and communications between the wind farm and NSPI SCADA system (to be specified).

Network Upgrades to provide NRIS with POI on the 138 kV circuit L-6513:

The following additional network upgrades are required to provide NRIS service for export.

1. Uprate line L-6514 from 60°C to 80°C conductor operating temperature.
2. Uprate the switches on L-6514 and L-6551 at 30N-Maccan to 1200 A. Increase full load metering of L-6514 and L-6536.
3. Potential re-rating of 345kV – 138kV transformer at Memramcook (to be verified in NB Power Transmission Service Request).

Network Upgrades to provide NRIS with alternate POI on the 138 kV circuit L-6613:

The following additional network upgrades are required to provide NRIS service for export.

1. Uprate line L-6514 from 60°C to 80°C conductor operating temperature.

2. Uprate the switches on L-6514 and L-6551 at 30N-Maccan to 1200 A. Increase full load metering of L-6514 and L-6536 to 287 MVA.
3. Uprate switchgear for L-6613 at 74N-Onslow from 1200A to 2000A.
4. New 138kV line between POI and 74N-Springhill (46 km). This would be terminated with two new circuit breakers at 74N-Springhill and one new circuit breaker at the POI (making it a four-breaker ring bus).
5. Install a Static Var Compensator rated 50 Mvar at 74N-Springhill.
6. Potential re-rating of 345kV – 138kV transformer at Memramcook (to be verified in NB Power Transmission Service Request).

Network Upgrades to provide ERIS with POI on either L-6513 or L-6613:

There are no additional transmission network upgrades necessary to prove ERIS.

Requirements for the Generating Facility

1. Because IR#556 will be located 14 km from the POI, a new 138kV circuit is required. This line would be designed and constructed to NSPI standards and would be shielded for 1 km out of the Interconnection Substation. The Interconnection Substation would require circuit breakers at high side of each of the customer power transformer and protection as acceptable to NSPI. A Remote Terminal Unit (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 potential availability of STATCOM mode for the Vestas GridStreamer technology 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 an RTU) 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 controls to slow frequency decline in the event of a sudden separation of the Nova Scotia power system from the interconnected grid.
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 150 MW wind energy at the POI on the 138 kV line L-6513 are included in Table 12-1.

Table 12-1: Cost Estimates identified from FEAS scope POI L-6513

	Determined Cost Items	Estimate
NSPI Interconnection Facilities		
i	138 kV switch on L-6513	$200,000
ii	Uprate L-6513 (30 km) to 70°C	$2,300,000
iii	Site expansion, terminal equipment, at 74N-Springhill	$1,900,000
iv	Remote end protection modifications	$300,000
v	Protection, control	$500,000
vi	Communications	$250,000
vii	New radial circuit from POI to IR#556 (14 km)	$3,920,000
viii	138 kV Single breaker bus primary equipment and control building at IR#556 site.	$1,700,000
	Subtotal without increased export capability	$11,070,000
	Contingency (10%)	$1,107,000
	Total	$12,177,000
Network Upgrades for NRIS (increased export capability) with POI on L-6513		
ix	Up-rate L-6514 (20 km) to 80°C	$600,000
x	Upgrade line terminals of L-6514 and L-6551 (switches at 30N)	$150,000
xi	Protection, metering modifications	$100,000
	Subtotal	$850,000
	Contingency	$85,000
	Total	$935,000
Totals		
xi	Contingency (10%)	$1,192,000
xii	Total of Determined Cost Items	$13,112,000
	To be Determined Costs	
xiii	System additions to address potential stability limits	TBD (SIS)
xiv	Memramcook transformer loading issue	TBD (NB Power SIS)

Cost estimates for interconnecting IR#556 at the alternate POI on L-6613 are summarized in Table 12-2.

Table 12-2: Cost Estimates identified from FEAS scope Alternate POI L-6613		
	Determined Cost Items	**Estimate**
NSPI Interconnection Facilities		
i	Three-breaker ring bus development at POI on L-6613 BPS	$6,200,000
v	Protection, control	$500,000
vi	Communications	$250,000
vii	New radial circuit from POI to IR#556 (14 km)	$3,920,000
viii	138 kV Single breaker bus primary equipment and control building at IR#556 site.	$1,700,000
	Subtotal without increased export capability	$12,570,000
	Contingency (10%)	$1,257,000
	Total	$13,827,000
Network Upgrades for NRIS (increased export capability) with POI on L-6513		
ix	Up-rate L-6514 (20 km) to 80°C	$600,000
x	Upgrade line terminals of L-6514 and L-6551 (switches at 30N)	$150,000
xi	Protection, metering modifications	$100,000
	Upgrade switchgear on L-6613 at 74N-Springhill to 2000A	$500,000
	Build new 138kV circuit between POI and 74N-Springhill 46 km	$12,880,000
	Site preparation and new circuit breaker at 74N-Springhill	$1,700,000
	Fourth circuit breaker added to ring bus at POI	$900,000
	50 Mvar SVC at 74N-Springhill	$7,000,000
	Subtotal	$23,830,000
	Contingency	$2,383,000
	Total	$26,213,000
Totals		
xi	Contingency (10%)	$3,640,000
xii	Total of Determined Cost Items	$40,040,000
	To be Determined Costs	
xiii	System additions to address potential stability limits	TBD (SIS)
xiv	Memramcook transformer loading issue	TBD (NB Power SIS)

The preliminary non-binding cost estimate for interconnecting 150 MW at the POI on L-6513 would be $12,177,000 including a contingency of 10%. This figure assumes that

NSPI builds the new 14 km line extension from the POI to the IC facility using its standard line configuration for 138 kV (single Drake conductor per phase), but would be higher if the proposed twin bundle Cardinal conductor is used. This configuration would be sufficient for ERIS but would not be sufficient for NRIS, since it does not extend the NS-NB transmission capacity. Including the Network Upgrades necessary to accommodate NRIS by extending the NS-NB transmission capacity would add $935,000 to the total determined cost, for a total of $13,112,000.

For the alternate POI on L-6613, the preliminary non-binding cost estimate for interconnecting 150 MW at the POI on L-6613 would be $13,827,000 including a contingency of 10%, and the assumption that the radial line extension would be based on a single Drake conductor design. This would be sufficient for ERIS, but the required network upgrades necessary for NRIS would add $26,213,000 to the cost for a total of $40,040,000 including 10% contingency.

12 Loss Factor

Injection of 150 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 and are presented in Table 12-1. These calculations do not include any losses internal to the wind generation facility (generator transformer, collector circuits, Interconnection Substation transformer), and separate the losses on the radial circuit from the Interconnection Substation to the POI. Any revenue class metering that is installed at the IC facility would be compensated for losses to reflect energy delivered at the POI, based on the as-built line impedance.

Table 12-1 Transmission Loss Factors for IR#556 measured at the NB Border

Service	POI	L.F. from Facility	L.F. from POI
NRIS	L-6513	4.6%	4.3%
NRIS	Alternate L-6613	2.6%	2.2%
ERIS	L-6513	4.5%	4.2%
ERIS	Alternate L-6613	1.8%	1.5%

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#556. 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-6513/L-1160
- 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

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[3] and NPCC[4] criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

Nova Scotia Power
Transmission System Operations
2017-04-28

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