Interconnection Feasibility Study Report
GIP-IR644-FEAS-R1

Generator Interconnection Request 644
102.6 MW Wind Generation Facility
Inverness County, NS

2022-04-21

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted a Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS) Interconnection Request for a 102.6 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2023-01-21. The Point of Interconnection (POI) requested by the customer is the 138kV line L-6537, approximately 6.9 km from 2C-Port Hastings substation.

There are five transmission and three distribution Interconnection Requests in the Advanced Stage Transmission and Distribution Queue that must be included in the study models for IR#644. In addition, there is a long-term firm Transmission Service Reservation (TSR) that must be accounted for: 550 MW from New Brunswick to Nova Scotia (TSR-411). The TSR is expected to be in service in 2025 and a system study is currently underway to determine the associated upgrades to the Nova Scotia transmission system. These upgrades are expected to materially alter the configuration of the transmission system in Nova Scotia. As a result, the following notice was posted to the OASIS site at https://www.nspower.ca/oasis/generation-interconnection-procedures:

> *Effective January 19th, 2021, please be advised that the completion of advanced-stage Interconnection Studies under the Standard Generator Interconnection Procedures (GIP) may be delayed pending the outcome of the Transmission Service Request (TSR) 411 System Impact Study, which is expected to identify significant changes to the NSPI transmission system. The revised expected completion date for the study is February 28, 2022. Feasibility Studies initiated prior to the completion of the TSR System Impact Study will be performed based on the current system configuration.*

This study assumes that the addition of generation from IR#644 will displace coal-fired generation in eastern Nova Scotia for both NRIS and ERIS.

Since L-6537 is classified as Bulk Power System, interconnection with that line will require a three-breaker 138kV ring bus substation. This new substation will be categorized Bulk Electric System under NERC criteria and Bulk Power System determination will be performed in the System Impact Study (SIS) report. As IR#644 has dispersed generation with an aggregate more than 75 MVA, the generators and elements in Interconnection Customer substation (including collector bus and substation step-up transformer) are categorized as BES and subject to the applicable NERC Reliability Criteria.

The assessment of the L-6537 POI shows thermal loading violations under system normal conditions, requiring 6.9 km of line rebuild between the POI and 2C-Hastings. Several post-contingency thermal loading violations would occur due to IR#644, notably on transmission lines L-6537, L-6515, L-6538, and L-6539 and transformer 3C-T71. As an alternative to uprating the affected transmission facilities, the following upgrades are proposed:

- Modifications reducing arming/limit levels of existing Remedial Action Schemes (RAS) be applied to alleviate L-6515 overloads. The alternative is an uprate of L-6515, for approximately 50.7 km.
- Re-design of an existing RAS or a new RAS be applied, to alleviate L-6538 and L-6539 overloads, subject to NPCC approval. IR#644 may be included in the RAS logic and should

be designed appropriately to receive the trip signals. L-6538 includes a water crossing that will require an engineering study to more accurately determine the extent of cost and work required.

- Installation of a new RAS for 3C-T71 transformer overloads, subject to NPCC approval. IR#644 may be included in the RAS logic and should be designed appropriately to receive the trip signals.

If, during the SIS, it is determined that modifying existing or addition of a RAS does not provide an acceptable solution, then an uprate of these lines and/or transformer replacement will be required.

No violations of voltage criteria were found for IR#644.

Data provided by the IC indicates that IR#644 will be utilizing the Nordex N149 5.7 MW Double-Fed Induction Generator (DFIG) wind turbines. Based on supplied interconnection data and assumptions, IR#644 may not meet the net power factor requirement of +0.95 at the high voltage side of Interconnection Facility. The adequacy of reactive power supply will be further investigated in the System Impact Study as specific details of the collector circuits become available. It is noted that the proposed Nordex N149 DFIG wind turbine models will meet the requirement to produce full MVAr capability down to zero MW output.

IR#644 was not found to adversely impact the short-circuit capabilities of existing circuit breakers. The short circuit level at the Interconnection Facility 138kV bus is 1,134 MVA with all lines in service and IR#644 off-line, resulting in a 11.1 Short Circuit Ratio (SCR). This falls to 202 MVA with L-6537 open at 2C-Port Hastings, resulting in a very low SCR of 2.0. These conditions should be discussed with the wind turbine manufacturer to determine if the equipment can operate, or if modifications are required.

The calculated voltage flicker Pst of 0.529 for continuous operation exceeds NS Power's required limit with L-6537 open at 2C end concurrent with low system generation. This will be examined in the System Impact Study (SIS), as more detail is provided. It is assumed that the project design meets NSPI requirements for low-voltage ride-through and voltage control. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

The preliminary value for the unit loss factor is calculated as +9.8% at the POI on L-6537, net of any losses on the IC facilities up to the POI.

To connect IR#644 as NRIS, the preliminary non-binding cost estimate for interconnecting 102.6 MW to the L-6537 POI is $16,247,000. This cost estimate includes:

- A 3 breaker ring bus substation at the POI.
- Protection upgrades at 2C-Port Hastings, 5S-Glen Tosh.
- 6.9 km of L-6537 line rebuild plus a 10 km spur line from the POI to the Interconnection Customer's Interconnection Facility (ICIF).
- Modifications to arming/limit values of existing Group 3, Group 5, and Group 6 RAS.
- Redesign/modifications to the existing Wreck Cove RAS and is subject to NPCC approval.
- A new RAS for 3C-T71 overload and is subject to NPCC approval.

This cost estimate assumes the modifications to existing RAS and the new RAS will be approved by NPCC and includes a 10% contingency. In this estimate, $9,460,000 (plus 10% contingency) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP. The remainder of the costs are fully funded by the Interconnection Customer.

If transmission upgrades, instead of RAS modifications and additions, were found to be necessary to address the forementioned thermal overloads, the total cost of Network Upgrades would increase by an estimated $41,480,000 for the upgrades of L-6515, L-6538, L-6539 and 3C-T71. This cost estimate does not include any contingency. Note L-6538 includes a water crossing that will require an engineering study to more accurately determine the extent of cost and work required.

To connection IR#644 as ERIS, while limited to 27 MW, the preliminary non-binding cost estimate for interconnecting at the POI is $12,936,000, including a 10% contingency. This estimate includes:

- A 3 breaker ring bus substation at the POI.
- Protection upgrades at 2C-Port Hastings, 5S-Glen Tosh.
- 10 km spur line from the POI to the Interconnection Customer's Interconnection Facility (ICIF).
- Redesign/modifications to the existing Wreck Cove RAS and is subject to NPCC approval.

In this estimate, $6,450,000 (plus 10% contingency) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP.

If transmission upgrades, instead of RAS modifications, were found to be necessary to address the forementioned thermal overloads, the total cost of Network Upgrades would increase by an estimated $2,760,000 for the L-6537 upgrades.

The preliminary cost estimate does not include any supplemental reactive power devices that are potentially required to meet the NSPI power factor requirements. It also does not include TBD costs to address any stability issues identified at the SIS stage based on dynamic analysis, and it assumes that RAS additions are approved by NPCC.

The estimated time to construct the Transmission Providers Interconnection Facilities and any Network Upgrades is 18-24 months after receipt of funds and cleared right of way from the customer. These estimates will be further refined in the System Impact Study and the Facility Study.

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1 Introduction

The Interconnection Customer (IC) submitted a Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS) Interconnection Request for a 102.6 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2023-01-21. The Point of Interconnection (POI) requested by the customer is the 138kV line L-6537, approximately 6.9 km from 2C-Port Hastings substation.

The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2021-12-22, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 644 in the NSPI Interconnection Request Queue and will be referred to as IR#644 throughout this report.

Figure 1 shows the proposed geographic location of IR#644 in relation to the NSPI transmission system.

Figure 1 IR#644 Site Location

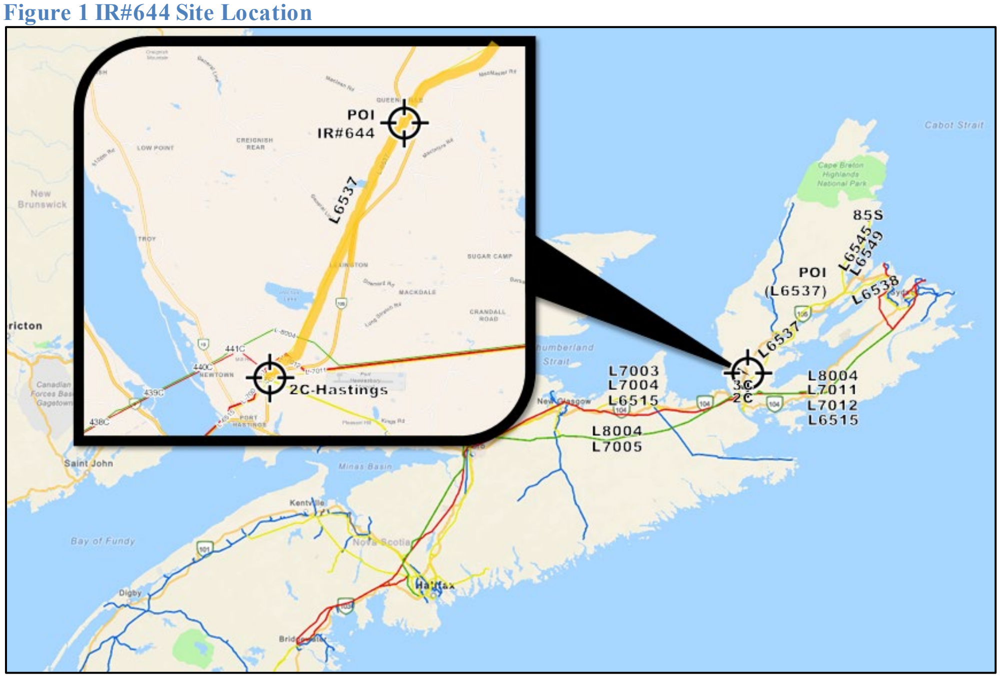


Figure 2 is a simplified one-line diagram of the transmission system configuration in the area of the POI. Figure 3 shows the circuit breaker configuration of transmission lines in the vicinity of the POI.

Figure 2 Point of Interconnection (not to scale)

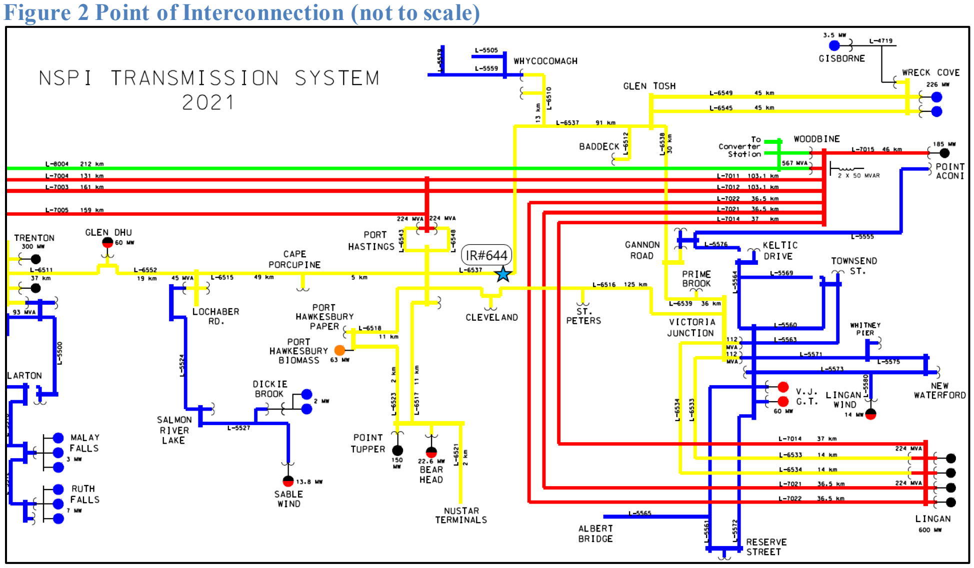
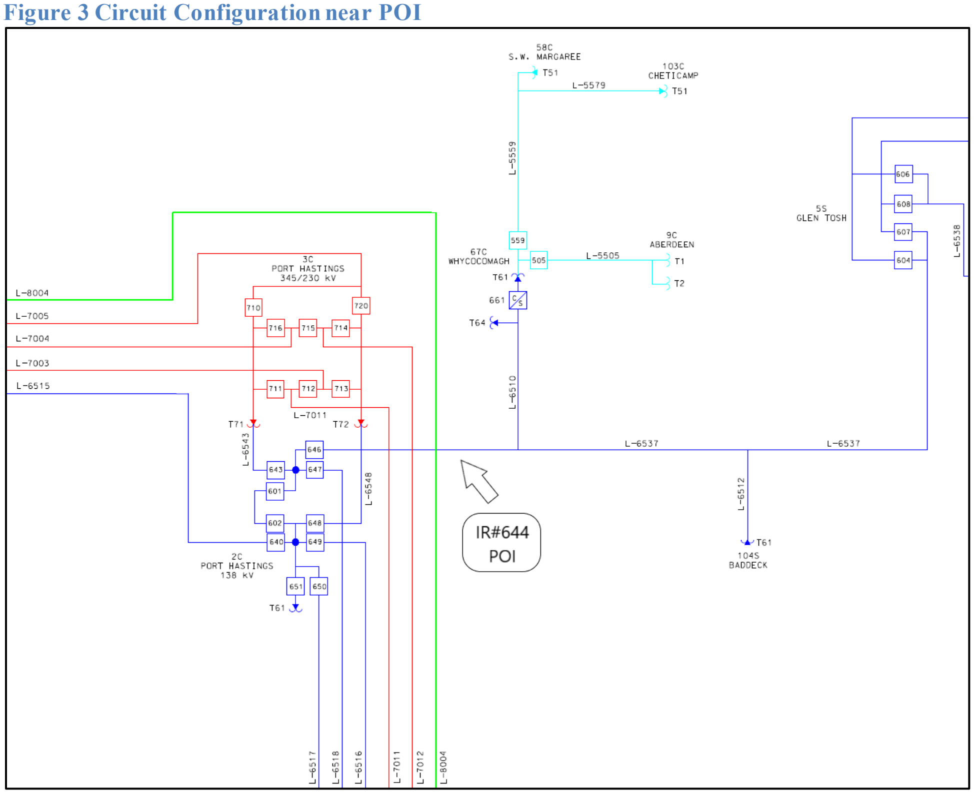


Figure 3 Circuit Configuration near POI



2 Scope

The objective of this Interconnection Feasibility Study (FEAS) is to provide a preliminary evaluation of system impacts from interconnecting the proposed generation facility to the NSPI transmission system at the requested location. The assessment will identify potential impacts on transmission element loading, which must remain within their thermal limits. Any potential violations of voltage criteria will be identified and addressed. If the proposed generation increases the short-circuit duty of any existing circuit breakers beyond their rated capacity, the circuit breakers must be upgraded. Single contingency criteria are applied.

The scope of the FEAS includes the modelling of the power system in normal state (with all transmission elements in service) under anticipated load and generation dispatch conditions. A power flow and short circuit analysis will be performed to provide the following information:

- Preliminary identification of any circuit breaker short circuit capability limits exceeded because of the interconnection, and any network upgrades necessary to address the short circuit issues associated with the IR. Expected minimum short circuit capability will also be identified for the purposes of Short Circuit Ratio analysis.

- Preliminary identification of any thermal overload or voltage limit violations resulting from the interconnection and identification of the necessary network upgrades to allow full output of the proposed facility. Thermal limits are applied to the seasonal (summer/winter) emergency ratings of transmission elements. Voltage violations occur when the post-contingency transmission bus voltage is outside the range of +/-10% of nominal voltage.

- Preliminary analysis of the ability of the proposed Interconnection Facility to meet the reactive power, power quality and cold-weather capability requirements of the NSPI *Transmission System Interconnection Requirements*[1].

- Preliminary description and high-level non-binding estimated cost and time to construct the facilities required to interconnect the generating facility to the transmission system.

- For comparative purposes, the impact of IR#644 on incremental system losses under standardized operating conditions is examined.

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 the system transfer capabilities that may be required to meet the design and operating criteria established by NSPI, the Northeast Power Coordinating Council (NPCC), and the North

[1] transmission-system-interconnection-requirements (nspower.ca)

American Electric Reliability Corporation (NERC). These requirements will be determined by a more detailed analysis in the subsequent interconnection System Impact Study (SIS). An Interconnection Facilities Study (FAC) follows the SIS to ascertain the final cost estimate to the interconnect the generating facility.

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. NRIS and ERIS per section 3.2 of the Generator Interconnection procedures (GIP).

2. Commercial Operation date 2023-01-21.

3. The Interconnection Customer Interconnection Facility (ICIF) consists of up to 18 Wind Energy Converter System (WECS) units; Nordex N149 5.7 MW Double-Fed Induction Generator (DFIG) wind turbines, 750V, Type 3, for a total of 102.6 MW, connected to collector circuits operating at the 34.5kV voltage level.

4. The POI on L-6537 is categorized Bulk Power System and will therefore require three-breaker ring bus in accordance with Table 8 of the NSPI *Transmission System Interconnection Requirements.*

5. The ICIF will require the construction of a 6.18 km 138 kV transmission spur line from the POI to the IC 138kV/34.5kV transformers. The IC will be responsible for providing the Right-of-Way for the lines. Detailed line data was not provided, so typical data was assumed based on 556.5 Dove conductor and 60°C.

6. The generation technology used must meet NSPI requirements 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.

7. Preliminary data was provided by the IC for the IC substation interconnection facility. The transformer was rated at 90/115 MVA and modeled with a positive-sequence impedance of 13% on 100 MVA with an X/R ratio of 37. The IC indicated this interconnection facility transformer has a wye-delta winding configuration with +/- 15% on-load tap changer. The impedance of each generator step-up transformer was modeled as 9.9% on 6.35 MVA with an assumed X/R ratio of 12.14.

8. Detailed collector circuit data was not provided, so typical data (R+jX = 0.01+j0.04 p.u. on system base 100 MVA) 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. 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.

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. The rating of transmission facilities in the vicinity of IR#644 are shown in Table 2 and Table 3.

Table 2 Local Transmission Element Ratings

Line	Conductor	Design Temp	Limiting Element	Summer Rating Normal/Emergency	Winter Rating Normal/Emergency
L-6503	1113 Beaumont	85°C	Switchgear	287/315 MVA	287/315 MVA
L-6511	556.5 Dove	60°C	Conductor	140/154 MVA	184/202 MVA
L-6552	556.5 Dove	50°C	Conductor	110/121 MVA	143/157 MVA
L-6515	556.5 Dove	50°C	Conductor	110/121 MVA	143/157 MVA
L-6537	556.5 Dove	60°C	Conductor	140/154 MVA	184/202 MVA
L-6538	Spec. Galv. Steel/ 556.5 Dove	50°C	Conductor	110/121 MVA	114/125 MVA
L-6539	555.5 Dove	100°C	Switchgear	191/210 MVA	191/210 MVA
L-7003	556.5 Dove	70°C[2]	Conductor	273/303 MVA	345/379 MVA
L-7004	556.5 Dove	60°C	Conductor	233/246 MVA	307/338 MVA
L-7005	1113 Beaumont	70°C	CT Ratio	398/438 MVA	398/438 MVA

Table 3 Transformer Ratings

Transformer	Normal Rating / 15 min Emergency Summer/Winter
3C-T71	225/236 MVA
3C-T72	225/236 MVA

[2] L-7003 is currently being uprated from a design temperature of 60°C to 70°C. This study assumed that the upgrade is complete before IR#644 is in service.

4 Projects with Higher Queue Positions

All in-service generation is included in the FEAS, except for Lingan Unit 2, which is assumed to be retired.

As of 2021/10/15, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are committed to the study base cases:

- IR426: GIA executed
- IR516: GIA executed
- IR540: GIA executed
- IR542: GIA executed
- IR557: SIS complete
- IR569: GIA executed
- IR568: GIA executed
- IR566: GIA executed
- IR574: FAC complete
- IR595: SIS complete

The following projects have been submitted to the Transmission Service Request (TSR) Queue:

- TSR411: SIS in progress
- TSR412: Withdrawn

TSR-411 is a long-term firm point-to-point transmission service reservation in the amount of 550 MW from New Brunswick to Nova Scotia; The TSR is expected to be in service in 2025 and a system study is currently underway to determine the required upgrades to the Nova Scotia transmission system. As a result, the following notice has been posted to the OASIS site at https://www.nspower.ca/oasis/generation-interconnection-procedures:

> *Effective January 19th, 2021, please be advised that the completion of advanced-stage Interconnection Studies under the Standard Generator Interconnection Procedures (GIP) may be delayed pending the outcome of the Transmission Service Request (TSR) 411 System Impact Study, which is expected to identify significant changes to the NSPI transmission system. The revised expected completion date for the study is February 28, 2022. Feasibility Studies initiated prior to the completion of the TSR System Impact Study will be performed based on the current system configuration.*

5 Short-Circuit Duty / Short Circuit Ratio

The maximum expected (design) short-circuit level is 5,000 MVA (21 kA) on 138kV systems and 10,000 MVA (25 kA) on 230kV system. The fault current characteristic for this Nordex N149 5.7 MW DFIG wind turbines is given as 3.13 times rated current, or X'd = 0.319 per unit on machine base MVA.

Short circuit analysis was performed using PSS®E for a classical fault study, 3LG and flat voltage profile at 1.0 p.u. V. The short-circuit levels in the area before and after this development are provided below in Table 4.

Table 4: Short-Circuit Levels. IR#644 on L-6537 Three-phase MVA (1)		
Location	Without IR#644	With IR#644
All transmission facilities in service		
POI on L-6537 (138kV)	2,051	2,244
Interconnection Facility (138kV)	2,047	2,240
3C-Port Hastings (230kV)	3,282	3,385
2C-Port Hastings (138kV)	2,813	2,986
5S-Glen Tosh (138kV)	1,312	1,323
Minimum Conditions (TC3, LG1, ML In-Service)		
Interconnection Facility (138kV kV), all lines in-service	1,134	1,327
Interconnection Facility (138kV), L-6537 open at 2C	202	395
Interconnection Facility (138kV), L-6537 open at 5S	1,076	1,269

(1) Classical fault study, flat voltage profile

The interrupting capability of the 230 kV circuit breakers at 3C-Port Hastings and 67N-Onslow is at least 10,000 MVA. The interrupting capability of the 138 kV circuit breakers at 2C-Port Hastings, 5S-Glen Tosh is at least 3,500 MVA. As such, the interrupting rating at these substations will not be exceeded by this development on its own.

Inverter-based generation installations often have a minimum Short Circuit Ratio (SCR) for proper operation of converters and control circuits. Based on the calculated short circuit levels, a POI on 138 kV L-6537, and a 102.6 MW installation consisting of 18 Nordex N149 WECS units, the short circuit ratio would be 11.1 at the 138kV Interconnection Facility of the IR#644 substation with all lines in service and IR#644 offline. This falls to 2.0 with L-6537 open at 2C-Port Hastings end, and 10.5 if L-6537 opens at 5S-Glen Tosh end.

The system short circuit level could be an issue for the wind turbines during minimal generation conditions with L-6537 open at 2C end. These conditions should be discussed with the wind turbine manufacturer to determine if the wind turbines can operate, or if modifications are required.

6 Voltage Flicker and Harmonics

The voltage flicker calculations use IEC Standard 61400-21 based on estimated data provided by Nordex N149 5.7 MW DFIG wind turbines (4.0 flicker coefficient c(ψk, va) at 85° system angle). The flicker step factor Kf (ψk) for switching operations at a system angle of 85° is given as 0.02 for start-up at both cut-in wind speed and rated wind speed. The maximum number of switching operations within a 10-minute period N_{10m} is given as 1. The voltage flicker Pst and Plt levels are calculated at the Interconnection Facility for various system conditions and are shown in Table 5 below.

Table 5: Calculated Voltage Flicker

System Conditions	Flicker at 138 kV Bus IR#644 18 Machines	
	Pst=Plt Continuous	Switching, at cut-in speed and rated speed
Maximum Generation		
All Transmission in Service	0.052	0.023
Minimum Conditions (TC3, LG1, ML In-Service)		
All Transmission in Service	0.094	0.041
L-6537 open at 2C	0.529	0.231
L-6537 open at 5S	0.099	0.043

NS Power's required limits are 0.25 for Pst and 0.35 for Plt. IR#644 may not be able to meet the flicker requirement in minimal generation conditions with L-6537 open at the 2C-Hastings end. This will be further evaluated in the SIS.

The generator is expected to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion (all frequencies) to a maximum of 2.5%, with no individual harmonic exceeding 1.5% on 138 kV.

7 Load Flow Analysis

The load flow analysis was completed for generation dispatches under system summer peak load and winter peak load conditions which are expected to stress the east-west corridor across the transmission interfaces Cape Breton Export (CBX) and Onslow Import (ONI). Generation dispatch was also chosen to represent import and export scenarios that consider expected flows from the existing transmission service reservation associated with the Maritime Link, and scenarios where Maritime Link imports displace NS thermal generation.

The major transmission interfaces/corridors relating to the IR#644 are shown in Figure 4. The nominal interface thermal limits are summarized in Table 6. NSPI relies on Remedial Action Schemes (RAS[3]), approved by NPCC, to maintain system stability. These RAS are armed by system conditions and flows across the respective interfaces and react to pre-determined contingencies to rapidly reduce flow by either tripping generation in Cape Breton or running-back Maritime Link HVdc import.

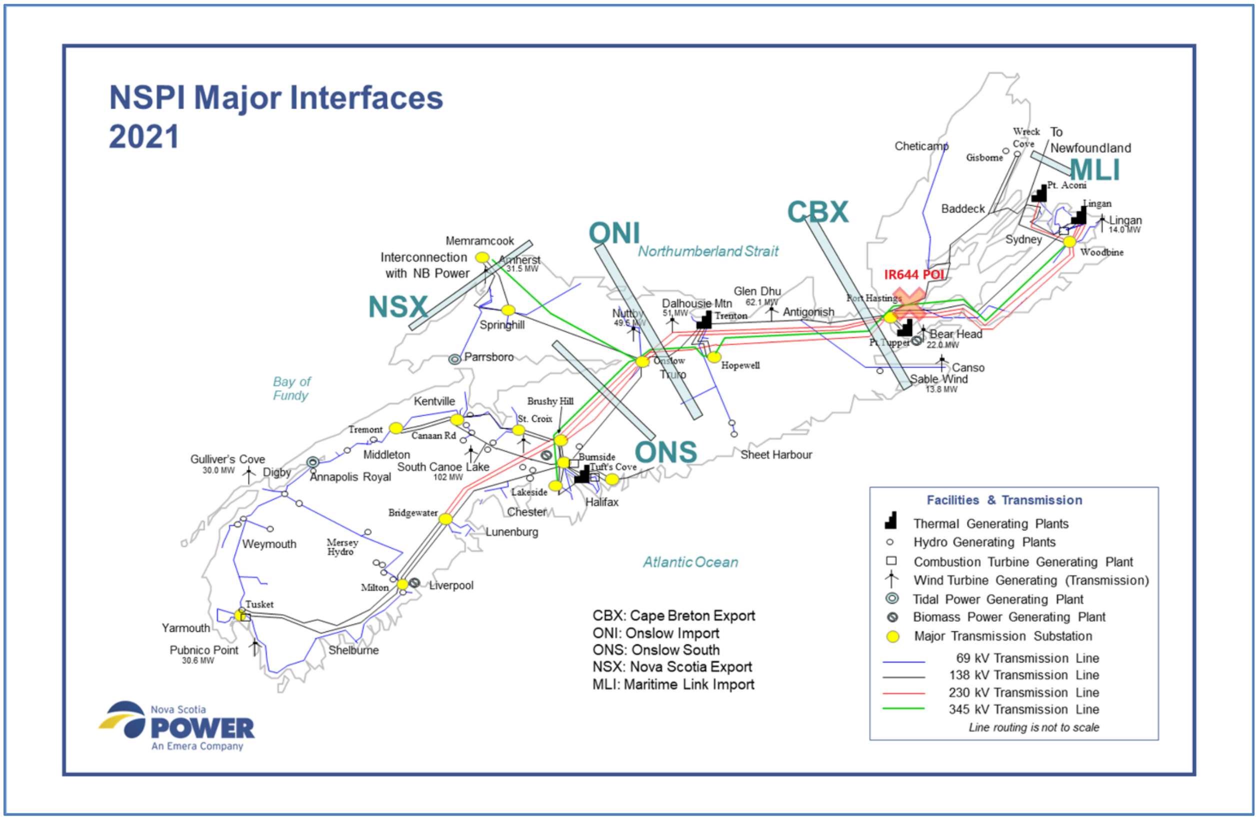


Figure 4 Major Transmission Interfaces

Table 6 Transmission Interface Limits						
Interface	MLI (1)	NSX (2)	NSI (3)	CBX (4)	ONI	ONS (5)
Summer	475	500	Up to 300	875-1075	1075-1275	600-850
Winter	475	500	Up to 300	950-1150	1275	600-975

(1) MLI is limited by simultaneous New Brunswick Import
(2) NS Export to NB (NSX) is dependant on Maritime Link runback RAS
(3) NS import from NB (NSI) is dependant on conditions in NB and PEI
(4) Dependant on generation at Trenton and Point Tupper
(5) Dependant on reactive power reserve in Metro

[3] Also referred to as Special Protection Scheme (SPS),

The cases and dispatch scenarios considered are shown in Table 7. Generation was dispatched to stress local and adjacent corridors. Transmission connected wind generation facilities were typically dispatched at approximately 40%, except in the vicinity of IR#644. There is high correlation between wind plants in the Central Region close to Port Hastings, so it is reasonable to expect that these other wind plants would be near full output when IR#644 is at rated output.

Table 7: Base Case Dispatch (MW) IR#644 On-Line									
Case	MLI	NS-NB	CBX	ONI	ONS	LIN	TRE	WC	RAS (2)
SP01	475	331	969	1,004	570	269	160	0	79NG6 67NG5
SP02	475	0	844	886	785	221	160	121	79NG5
SP03	475	330	869	822	429	0 (1)	0	150	79NG6
SP04	475	0	767	822	724	221	160	200	79NG5
SP05	475	0	725	773	673	221	160	170	-
SP06	475	0	757	804	703	198	160	90	79NG5
WP01	320	149	911	1,119	790	383	324	212	67NG5
WP02	320	149	996	1,116	788	383	324	212	67NG5
WP03	320	0	833	962	785	383	324	212	-
WP04	320	0	992	1,008	706	383	165	200	79NG5 67NG5
S - Summer Peak W - Winter Peak LIN – Lingan Gen TRE – Trenton Gen WC – Wreck Cove Gen									
(1) IR644 displaces 84 MW of Lingan plus 30 MW of Point Aconi **(2) Based on present RAS arming levels**									

For NRIS and ERIS analysis, this FEAS added IR#644 and displaced coal-fired generation in Cape Breton, maintaining Cape Breton Export (CBX) transfers and Onslow Import (ONI) transfers. Single contingencies were applied at the 345 kV, 230 kV, and 138 kV voltage levels for the above system conditions with IR#644 interconnected to the POI on L-6537. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 8.

Table 8 Contingency List			
Transmission Line	**Transformer / Bus**	**Circuit Breaker Failure**	**Double Circuit Tower**
L-7014, L-7021, L-7022	88S: T71, T72	88S: 710, 711, 713, 690, 721, 722, 723*	L-6534 + L-7021
L-7011, L-7012, L-7015, L-8004*	101S: T81, T82	101S: 701, 702, 703, 704, 705, 706, 711, 712, 713, 811, 812*, 813*, 814, 816	
L-6515, L-6516, L-6537*	2C: B61, B62	4C: 620, 621, 622, 623	
L-7003, L-7004, L-7005, L-7019	3C-T71, 3C-T72	3C: 710, 712, 713, 715, 716, 711, 714	L-7003+L-7004* Canso Causeway
L-6503, L-6613	1N: B61, B62	1N: 600, 613	
L-8001*, L-8002	67N: T71, T81	67N: 701, 702, 7-3, 705, 711, 712, 713, 811*, 812, 813, 814*, 815*	L-7003+L7004 Trenton area
L-6507, L-6508, L-8003*	79N: T81*	79N: 601*, 606*, 803*, 810*	
L-6537, L-6538*, L-6539, L-6516	91N: B71	91N: 701, 702, 703 5S: 606, 607	

*Indicates contingency was studied with/without RAS action

NRIS Results

With the interconnection of IR#644 as NRIS, the study shows up to 139% overload on L-6537 between 2C-Port Hastings and IR#644 POI under system normal conditions during summer, as well as under various contingency conditions. The highest overload for the section of L-6537 between 2C and IR#644 POI is only listed for system normal conditions in Table 9.

Several contingencies resulted in thermal overloads on:

- Line L-6515 (2C-Hastings/100C-Cape Porcupine/4C-Lochaber Rd)
- Line L-6537 (2C-Hastings/104S-Baddeck/5S-Glen Tosh)
- Lines L-6538 (5S-Glen Tosh/3S-Gannon Rd)/L-6539 (3S-Gannon Rd/111S-Prime Brook/2S-Victoria Junction)
- Transformer 3C-T71

No contingencies resulted in a violation of voltage limit criteria.

Table 9 shows the highest thermal overloads found, but other conditions were found which also violated thermal loading criteria, but to a lesser degree.

Table 9 Contingencies Resulting in Highest Line Overload				
Line	**Line segment**	**Highest Overload (% of Normal Rating)**	**Case**	**Condition**
L-6537	2C-Hastings/ IR#644	Summer: 139%	SP04	System Normal
Line	**Segment**	**Highest Overload (% of Emergency Rating)**	**Case**	**Contingency**
L-6515	2C-Hastings / 4C-Lochaber Rd	Winter: 105%	WP02	101S-813 or L-8004
L-6538	5S-Glentosh / 3S-Gannon Rd	Summer: 230%	SP04	L-6537 (2C to IR#644) or 2C_B61
L-6539	3S-Gannon Rd/ 2S-Victoria Junction	Summer: 120%	SP04	L-6537 (2C to IR#644) or 2C_B61
3C-T71	3C- Hastings	Winter: 125%	WP02	2C_B62

For the overload on L-6537 between 2C and IR#644 POI under system normal conditions, L-6537 line rebuild is required for at least 6.9 km at a cost of $2,760,000.

For the contingencies resulting in the thermal overloads on L-6515, the options examined include:

1. Thermal uprating of L-6515, approximately 50.7 km, at a cost of $7,500,000.
2. Reduce arming values for existing Group 3, Group 5, and Group 6 RAS, estimated at $50,000, if no functional changes are required.

For the contingencies resulting in the thermal overloads on L-6538 and L-6539, the options examined include:

1. Thermal uprating of these lines at a total cost of approximately $27,880,000. Note that L-6538 includes a water crossing and requires a more detailed engineering study to more accurately determine the cost.
2. Modification of the existing Wreck Cove Overload RAS, which IR#644 may be included in. This is estimated to cost $200,000 and is subject to NPCC approval.

For the contingencies resulting in the thermal overloads on 3C-T71, the options examined include:

1. Transformer replacement of 3C-T71 at a cost of $6,100,000.
2. Design and installation of a new RAS, which IR#644 may be included in, estimated at $200,000 and is subject to NPCC approval.

If, during the System Impact Study, it is determined that modifying the existing RAS or addition of one does not provide an acceptable solution, then the respective transmission line uprate or transformer replacement will be required.

The proposed upgrades for NRIS, including alternatives to uprating the affected transmission lines L-6515, L-6538, L-6539 and to the replacement of 3C-T71, are:

1. L-6537 line rebuild between IR#644 POI and 2C for approximately 6.9 km.
2. Modifications to existing Remedial Action Schemes (RAS) arming/limit values. to mitigate overloads on L-6515.

3. Redesign or modification to the Wreck Cove Overload SPS to mitigate thermal overloads on L-6538 and L-6539.
4. Installation of a new RAS to mitigate thermal overloads on 3C-T71.

ERIS Results

With the interconnection of IR#644 as ERIS, the facility must be capped at 27 MW due to the constraints on L-6537 (during system normal and post-contingency conditions) and the 3C-T71 transformer for the 2C-B62 contingency. However, the redesign or modification to the Wreck Cove Overload SPS is still required to mitigate thermal overloads on L-6537, L-6538 and L-6539, subject to NPCC approval.

Re-design of an RAS, or the addition of a new RAS, is subject to the approval of NPCC. If, during the System Impact Study, it is determined that modifying the existing RAS does not provide an acceptable solution, then uprate will be required.

If transmission upgrades were found to be necessary to address the forementioned thermal overloads, the total cost of Network Upgrades would increase by an estimated $30,640,000:

- $2,760,000 for the upgrades of L-6537
- $27,880,000 for L-6538 and L-6539. Note that L-6538 includes a water crossing and requires a more detailed engineering study to more accurately determine the cost.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR#644 must be capable of delivering reactive power for a net power factor of at least +/- 0.95 of rated capacity to the high side of the plant interconnection transformer(s). Reactive power can be provided by the asynchronous generator or by continually acting auxiliary devices such as STATCOM, DSTATCOM or synchronous condenser, supplied by the Interconnection Customer.

The information provided by IC indicates that the Nordex N149 5.7 MW DFIG WECS have a rated power factor of 0.9 lagging and leading (+/- 2.761 Mvar per WECS) at the machine terminal voltage of 0.96-1.06 p.u. The provided Q-P diagram (Figure 5) shows a similar Nordex 5.9 MW WECS, and indicates that the Nordex N149 DFIG will meet the NSPI Transmission System Interconnection Requirements (Section 7.6.2) for rated reactive power being available through the full range of real power output of the Generating Facility, from zero to full power.

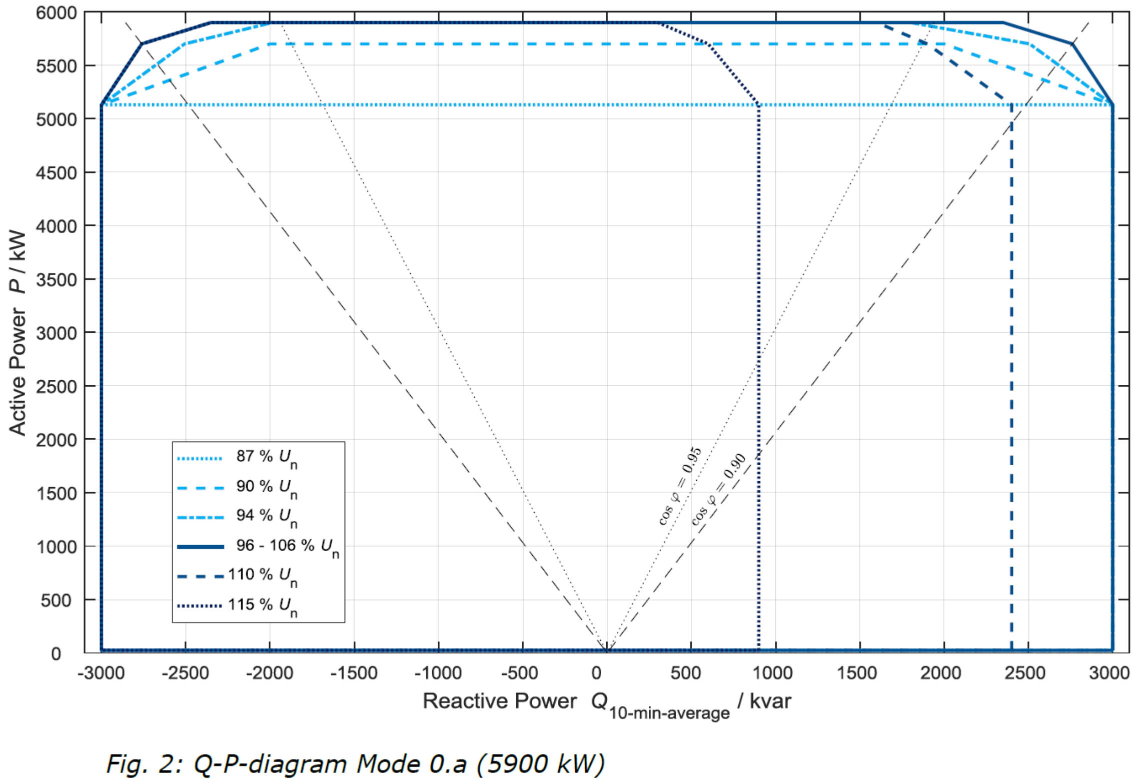


Figure 5 Model Nordex 5.9 MW PQ Curve and Reactive Capability

Analysis shown in Figure 6 indicates that IR#644 may not be able to meet the full-load reactive power requirement. The model shows that with 18 WECS units (Nordex N149 5.7 MW) operating at a total 102.6 MW and 49.7 Mvar, the delivered power to the high side of the ICIF transformers is 100.3 MW and 19.9 Mvar, corresponding to a 0.98 power factor with WECS terminal voltage at 1.06 p.u. Additional reactive power equipment may be required and would be supplied by the Interconnection Customer if this is determined to be the case in the SIS..

This configuration would be able to meet the leading power factor requirement of -0.95 at the high side of ICIF transformer The model shows that with 18 units of WECS operating at a total of 102.6 MW and -9.4 Mar, the delivered power to the high side of the ICIF transformers is 100.3 MW and -39.9 Mvar, corresponding to a -0.95 a power factor with WECS terminal voltage at 1.0 p.u.

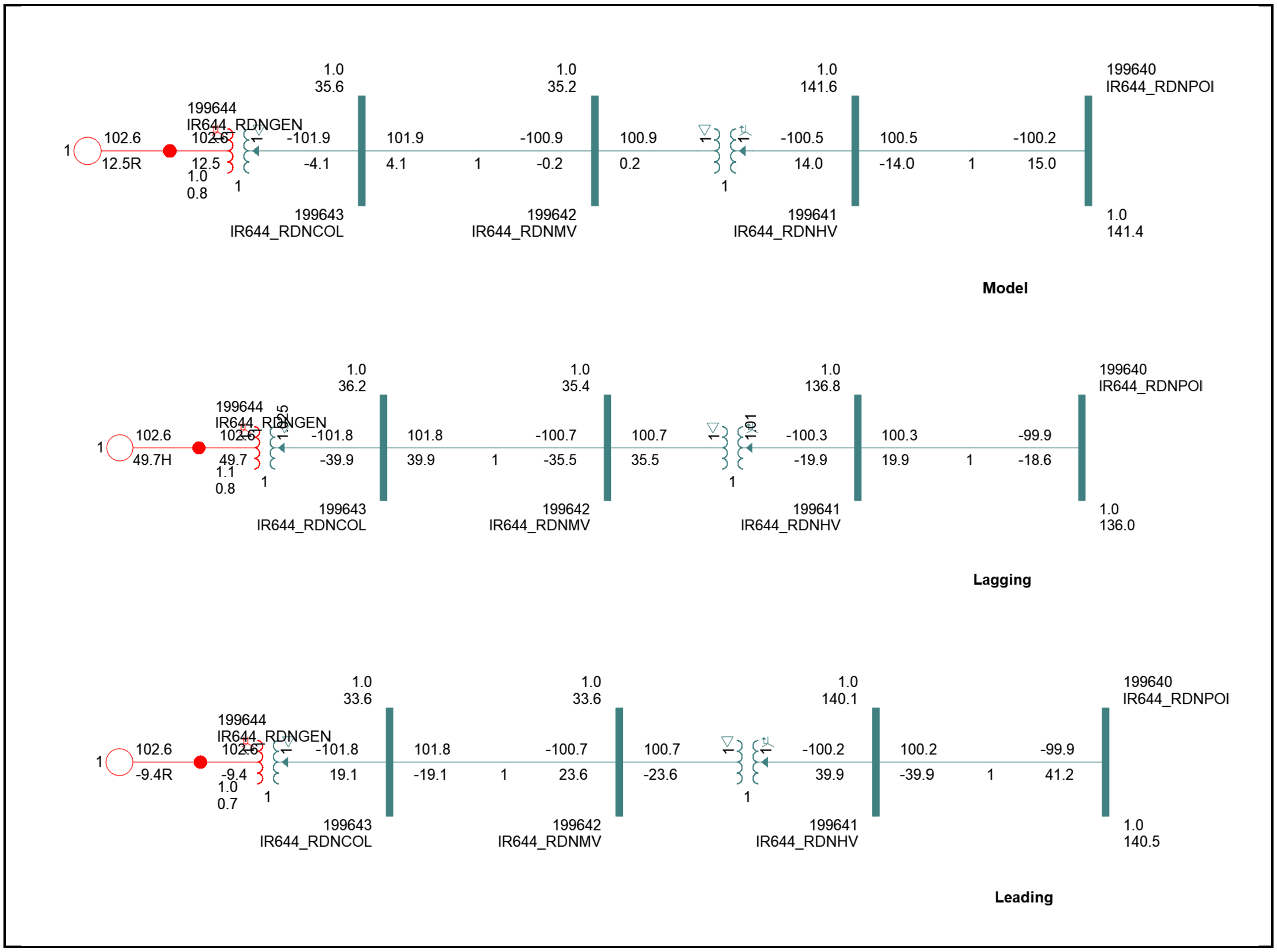


Figure 6 Power Factor Analysis

Because this analysis is based on preliminary transformer data and assumed collector circuit models, reactive capability will be confirmed in the SIS when detailed design is submitted.

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 can slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual generator 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.

Settings for the ICIF on-load tap-changer must be coordinated with plant voltage controller for long-term reactive power and voltage management at the POI.

9 System Security / Bulk Power Analysis

Interconnection with that line will require a three-breaker 138kV ring bus since L-6537 is categorized as Bulk Power System. This new substation will be categorized Bulk Electric System under NERC criteria with final Bulk Power System determination performed in the System Impact Study.

As IR#644 has dispersed generation with an aggregate more than 75 MVA, the generators and elements in Interconnection Customer substation (including collector bus and substation step-up transformer), are also categorized as BES, subject to the applicable NERC Reliability Criteria.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR#644 to the NSPI transmission system at a POI on L-6537:

1a. Required Network Upgrades under NRIS:

- Install a new 138kV substation complete with 3 breaker ring bus at the L-6537 POI with control and protection. A Remote Terminal Unit (RTU) to interface with NSPI's SCADA, with telemetry and controls as required by NSPI.
- Modification of NSPI protection systems at 2C-Port Hastings and 5S- Glen Tosh.
- Rebuild L-6537 section between 2C-Port Hastings and IR#644 POI, approximately 6.9 km.
- Changes to existing NSPI RAS (Group 3, Group 5, and Group 6) arming/limit values.
- Redesign or modification to the existing Wreck Cove Overload SPS and is subject to NPCC approval.
- A new RAS for 3C-Port Hastings transformer 3C-T71 overload and is subject to NPCC approval.

1b. Required Network Upgrades under ERIS (capped at 27 MW):

- Install a new 138kV substation complete with 3 breaker ring bus at the L-6537 POI with control and protection. A Remote Terminal Unit (RTU) to interface with NSPI's SCADA, with telemetry and controls as required by NSPI.
- Modification of NSPI protection systems at 2C-Port Hastings and 5S-Glen Tosh.
- Redesign or modification to the existing Wreck Cove Overload SPS and is subject to NPCC approval.

2 Required Transmission Provider's Interconnection Facilities (TPIF):

- Construct a 10 km transmission spur line between the L-6537 POI and the Interconnection Customer's Interconnection Facility. This line would be built to 138kV standards.
- Add control and communications between the solar plant and NSPI SCADA system (to be specified).

3 Required Interconnection Customer's Interconnection Facilities (ICIF)

The NSPI Transmission System Interconnection Requirements has a detailed description of ICIF requirements, including:

- 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. This study shows that Nordex N149 DFIG wind turbines would not meet the 0.95 lagging power factor requirement but will meet the requirement that rated reactive power be delivered from zero to full rated real power.
- 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.
- NSPI will 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.
- Low voltage ride-through capability per Section 7.4.1 of the Nova Scotia Power Transmission System Interconnection Requirements (TSIR).
- 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.

- Facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined in SIS. The plant may be incorporated into RAS run-back schemes.
- Synthesized inertial response controls within the WECS.
- Automatic Generation Control to assist with tie-line regulation.
- Operation at ambient temperature of -30°C.

11 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

NRIS Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 102.6 MW wind energy at the L-6537 POI are included in Table 10 for NRIS.

Table 10 Cost Estimate for NRIS @ L-6537 POI		
Item	**Network Upgrades**	**Estimate**
1	Three breaker ring bus 138 kV substation complete with P&C at NSPI POI substation and connection to L-6537, including P&C modifications at 2C-Port Hastings and 5S-Glen Tosh	$6,250,000
2	Rebuild L-6537 (6.9 km)	$2,760,000
3	Modifications to Group 3, Group 5, and Group 6 RAS arming/limit settings	$50,000
4	Redesign or modifications to Wreck Cove Overload RAS and is subject to NPCC approval	$200,000
5	New RAS for 3C-T71 transformer overload and is subject to NPCC approval	$200,000
	Sub-total for Network Upgrades	$9,460,000
Item	**TPIF Upgrades**	**Estimate**
1	Build 10 km 138kV spur line from TPIF to ICIF, with IC responsible for providing Right-Of-Way	$5,000,000
2	NSPI P&C relaying equipment	$100,000
3	NSPI supplied RTU	$60,000
4	Tele-protection and SCADA communications	$150,000
	Sub-total for TPIF Upgrades	$5,310,000
	Total Upgrades	**Estimate**
	Network Upgrades + TPIF Upgrades	$14,770,000
	Contingency (10%)	$1,477,000
	Total (Incl. 10% contingency and Excl. HST)	$16,247,000

The preliminary non-binding cost estimate for interconnecting 102.6 MW at the POI on L-6537 under NRIS is $16,247,000 including a 10% contingency. In this estimate, $9,460,000 (plus 10% contingency) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP.

The preliminary cost estimate does not include any reactive power devices that are potentially required to meet the NSPI power factor requirements. It also does not include TBD costs to address any stability issues identified at the SIS stage based on dynamic analysis, and it assumes that RAS additions are approved by NPCC.

The estimated time to construct the Transmission Providers Interconnection Facilities is 18-24 months after receipt of funds and cleared right of way from the IC.

The estimated time to construct the Network Upgrades is 24-36 months after receipt of funds from the IC.

ERIS Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting IR#644 capped at 27 MW for ERIS at the 138 kV POI on L-6537 are included in Table 11.

Table 11 Cost Estimate for ERIS @ L-6537 POI (capped at 27MW)		
Item	**Network Upgrades**	**Estimate**
1	Three breaker ring bus 138 kV substation complete with P&C at NSPI POI substation and connection to L-6537, including P&C modifications at 2C-Port Hastings and 5S-Glen Tosh	$6,250,000
2	Redesign or modifications to Wreck Cove Overload RAS and is subject to NPCC approval	$200,000
	Sub-total for Network Upgrades	$6,450,000
Item	**TPIF Upgrades**	**Estimate**
1	Build 10 km 138kV spur line from TPIF to ICIF, with IC responsible for providing Right-Of-Way	$5,000,000
2	NSPI P&C relaying equipment	$100,000
3	NSPI supplied RTU	$60,000
4	Tele-protection and SCADA communications	$150,000
	Sub-total for TPIF Upgrades	$5,310,000
	Total Upgrades	**Estimate**
	Network Upgrades + TPIF Upgrades	$11,760,000
	Contingency (10%)	$1,176,000
	Total (Incl. 10% contingency and Excl. HST)	$12,936,000

The preliminary non-binding cost estimate for interconnecting 27 MW at the POI on L-6537 under ERIS is $12,936,000 including a 10% contingency. In this estimate, $6,450,000 (plus 10% contingency) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP.

The preliminary cost estimate does not include any reactive power devices that are potentially required to meet the NSPI power factor requirements. It also does not include TBD costs to address any stability issues identified at the SIS stage based on dynamic analysis, and it assumes that RAS additions are approved by NPCC.

The estimated time to construct the Transmission Providers Interconnection Facilities is 18-24 months after receipt of funds and cleared right of way from the IC.

The estimated time to construct the Network Upgrades is 24-36 months after receipt of funds from the IC.

12 Loss Factor

Loss factor is calculated by running the winter peak load flow case with and without the new facility in service while keeping 91H-Tufts Cove as the Nova Scotia Area Interchange bus. This methodology reflects the load centre in and around Metro.

Without IR#644 in service, losses in the winter peak case total 86.4 MW. With IR#644 in service at the L-6537 POI, displacing generation at 91H, and not including losses associated with the IR#644 Generation Facilities or TPIF Interconnection Facilities, system losses total 96.2 MW, an increase of 9.8 MW. The power delivered to the POI is 100.3 MW, therefore the loss factor is calculated as 9.8/100.3 = +9.8%.

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#644.

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, 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, frequency response, active power 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 proceed, and the facilities associated with those projects are installed.

The following outline provides the minimum scope that must be complete 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:

- Facilities that the customer must install to meet the requirements of the GIP and the *Transmission System Interconnection Requirements*.
- The minimum transmission additions/upgrades that are necessary to permit operation of this Generating Facility, under all dispatch conditions, catering to NERC, NPCC, and NSPI design and operation criteria.
- Guidelines and restrictions applicable to first contingency operation (curtailments etc.).
- Under-frequency load shedding impacts.

The SIS will assess system contingencies such that the system performance will meet the following criteria:

- Table 1 "Planning Design Criteria" of NPCC Directory 1.
- Table 1 "Steady State & Stability Performance Planning Events" of NERC TPL-001-4.
- NSPI System Design Criteria, report number NSPI-TPR-003-4.

Additionally, electromagnetic transient study may be required to account for IR#644's control system to coordinate with other facilities in the transmission system and to ensure fault ride through.

Any changes to RAS 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.

Nova Scotia Power
Transmission System Operations
2022-04-21

[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 Standard TPL-001-4*