Interconnection Feasibility Study Report
GIP-IR618-FEAS-R1

Generator Interconnection Request 618
130.2 MW Wind Generating Facility
Pictou County, NS

2022-02-06

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 (IR#618) for a proposed 130.2 MW wind generation facility interconnected to the NSPI Transmission System, with a Commercial Operation Date of 2025-01-01. The Point of Interconnection (POI) requested by the customer is the 230kV line L-7003, approximately 5.8 km from 3C-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#618. In addition, there is a long-term firm Transmission Service Reservation (TSR) that must be accounted for: 800 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#618 will displace coal-fired generation in eastern Nova Scotia for both NRIS and ERIS.

Interconnection on L-7003 will require a three-breaker 230kV ring bus since L-7003 is classified as Bulk Power System. This new substation will be classified as Bulk Power System under NPCC criteria and Bulk Electric System under NERC criteria. As IR#618 has dispersed generation totalling more than 75 MVA, each generator will be classified as a NERC Bulk Electric System (BES) element. The IR#618 Interconnection Customer substation is also classified as part of the BES, subject to the applicable NERC Reliability Criteria.

The assessment of the POI on the 230 kV line L-7003 indicated that several thermal loading violations would occur due to IR#618, notably on L-7004, L-7019 and L-6515. As an alternative to uprating the affected transmission lines, it is proposed that modifications to the setting of existing Remedial Action Schemes (RAS) be applied to alleviate most of these overloads; the situation of the POI on L-7003 also requires a new RAS to accommodate a double-circuit contingency near Trenton affecting L-7004 plus L-7003. This new RAS is subject to approval by NPCC.

No violations of voltage criteria were found for IR#618.

Data provided by the IC indicates that IR#618 will be utilizing the E-138 EP3 E2 -FTQ version of the Enercon E-138 EP3 E2 4.2 MW wind turbines. Based on the provided impedances of the transformers and typical collector circuit impedances, IR#618 should be able to meet the net power factor of +0.95 to -0.95 at each high side of the IC's the Interconnection Facility's two substation step up transformer buses (ICIF). The adequacy of reactive power supply will be further investigated in the System Impact Study as specific collector circuit details become available. It is noted that the proposed Enercon models do not meet the requirement to produce full Mvar capability down to zero MW output.

IR#618 was not found to adversely impact the short-circuit capabilities of existing circuit breakers. Although flicker coefficients were not provided for the proposed generator, voltage flicker is not expected to be a concern for this project on its own. 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 minimum short circuit level at the Interconnection Facility 230kV bus is 1,554 MVA with all lines in service and IR#618 off-line, resulting in a 11.9 Short-Circuit Ratio; and 516 MVA with L-7003 open between the POI and 3C-Port Hastings, with a 4.0 Short-Circuit Ratio.

The preliminary value for the unit loss factor is calculated as +9.2% at the L-7003 POI, net of any losses on the IC facilities up to the POI.

The preliminary non-binding cost estimate for interconnecting 130.2 MW to the POI at L-7003, including the cost of the three breakers for line connection and protection upgrades at each end of L-7003 plus three spur lines (POI to ICIF, ICIF to Englands Lake, and ICIF to Long Lake) totalling 24.3 km is $27,191,450 under the assumption that the proposed new Limited Impact RAS is approved by NPCC. The cost estimate includes a contingency of 10%, and this estimate will be further refined in the System Impact Study and the Facility Study. In this estimate, $8,250,000 (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.

This cost estimate is the same for NRIS and ERIS due to the interdependencies between IR#618's output, the Cape Breton generation displacement, and Cape Breton Export RAS arming.

If transmission upgrades were found to be necessary to address these thermal overloads, the total cost of Network Upgrades would increase by an estimated $18,850,000 for the uprate of L-7004, L-7019 and L-6515 as well as the elimination of the double circuit contingency L-7004 plus L-7003 at Trenton. The elimination of the double circuit contingency (as an alternative to the development of a new RAS) is estimated to increase the Network Upgrade cost by at least $2,000,000. These cost estimates do not include any contingency. Network upgrades are funded by the IC and are eligible for refund under the terms of the GIP.

The estimated time to construct the Transmission Providers Interconnection Facilities is 18-24 months, and the Network Upgrades are estimated to be completed 24-36 months after receipt of funds and cleared right of way from the customer.

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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 proposed 130.2 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2025-01-01. The Point of Interconnection (POI) requested by the customer is the 230kV line L-7003, approximately 5.8 km from 3C-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 2021-08-18, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 618 in the NSPI Interconnection Request Queue and will be referred to as IR#618 throughout this report.

Figure 1 shows the proposed geographic location of IR#618 in relation to the NSPI transmission system.

Figure 1 IR#618 Site Location

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

Figure 2 Point of Interconnection (not to scale)

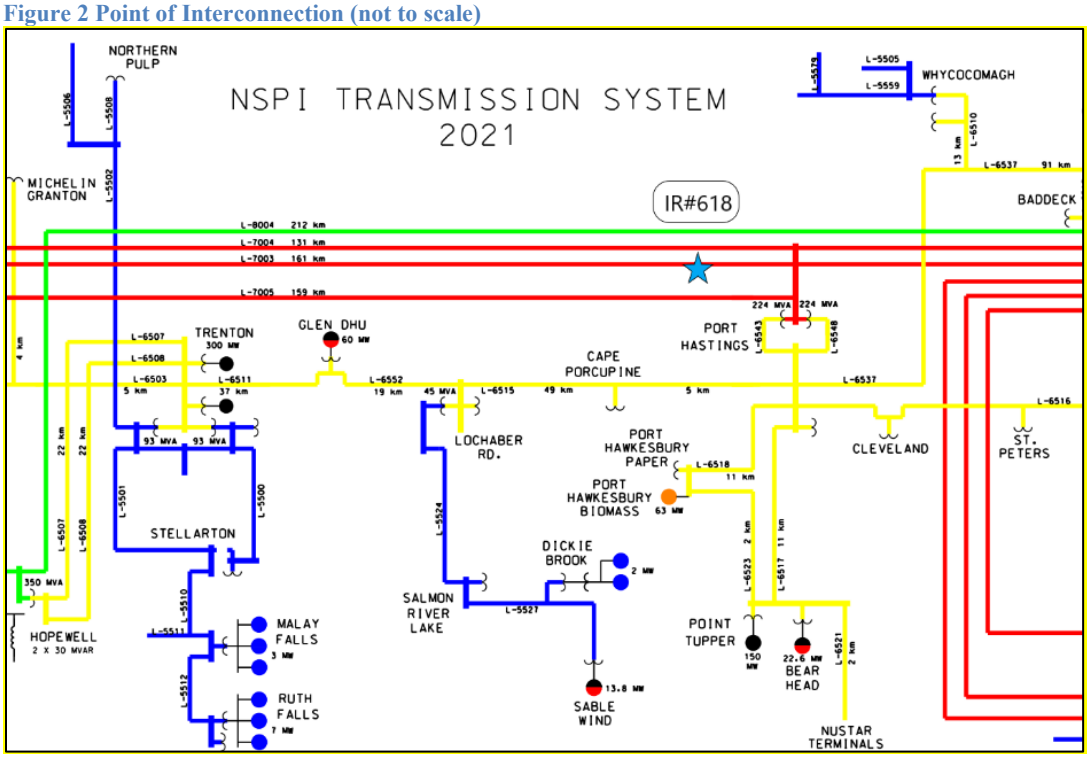
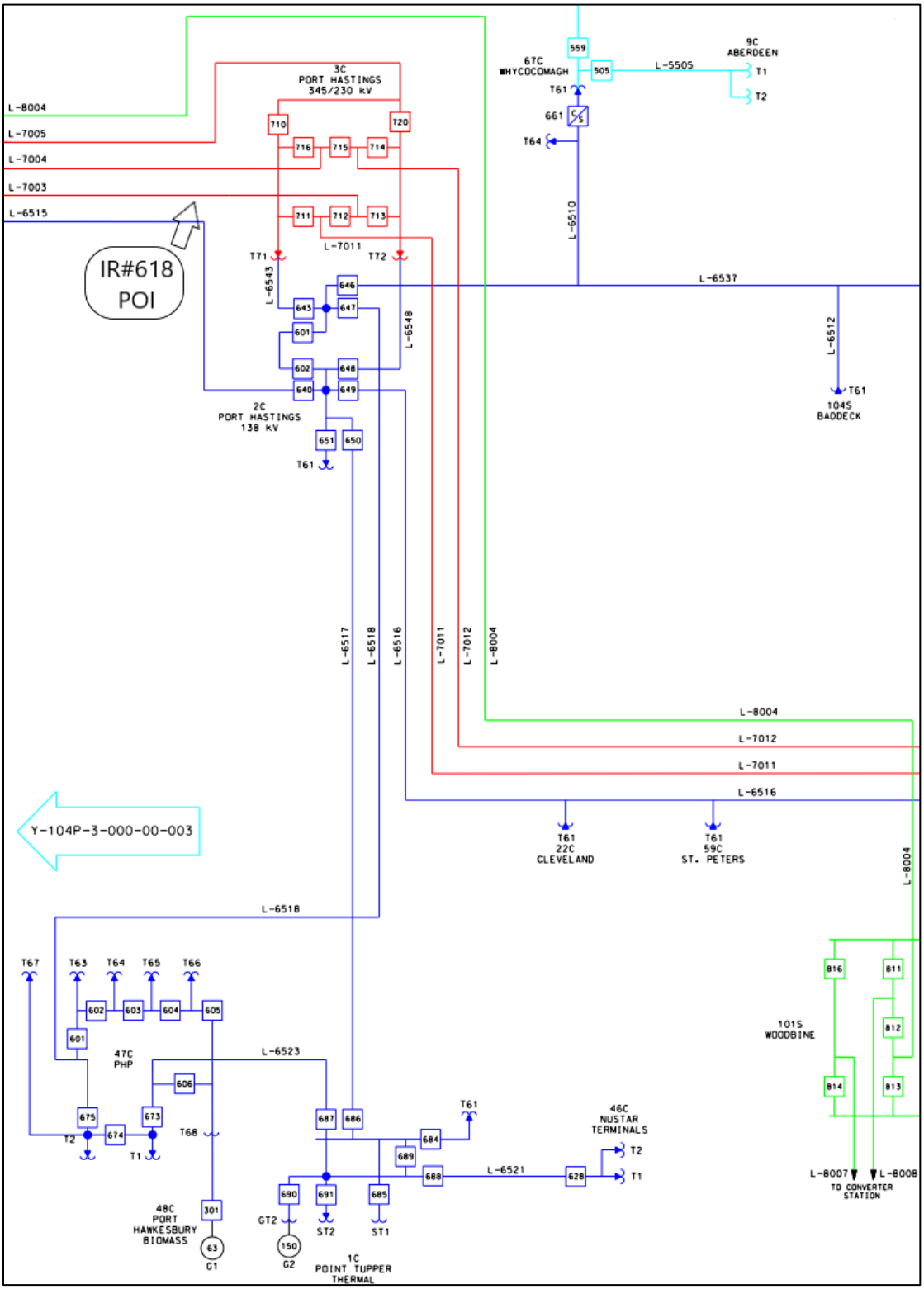


Figure 3 Circuit Configuration near POI



2 Scope

This Interconnection Feasibility Study (FEAS) objective 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#618 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 2025-01-01.

3. The Interconnection Customer Interconnection Facility (ICIF) consists of 31 Wind Energy Converter System (WECS) units; Enercon E-138 EP3 E2 4.2 MW wind turbines, 630V, Type 4 (full converter), equipped with the FTQ reactive power option, capped at a total of 130.2 MW.

4. The WECS are distributed among the Englands Lake and Long Lake sites; The Englands Lake site has 18 WECS while Long Lake site has 13 WECS distributed among three collector circuits each.

5. The POI on L-7003 is considered Bulk Power System facilities and will therefore require three-breaker ring bus in accordance with Table 8 of the NSPI *Transmission System Interconnection Requirements.* The IC is responsible for providing the land for and access road to the interconnection substation at the POI.

6. The ICIF will require the construction of a 9.13 km 230 kV transmission spur line from the POI to the IC Interconnection Facility at Pirate Bay and continues with two overhead transmission lines (7.48 km and 7.73km) to the IC 230kV/34.5kV transformers located at Long Lake and Englands Lake respectively. 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.

7. 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.

8. Preliminary data provided by the IC for the IC Interconnection Facility has two 230kV/34.5kV station transformers both rated at 71.5/79.5 MVA. One transformer at Long Lake connected to the collector circuit with 13 WECS units, the other transformer at English Lake connected to the collector circuit with 18 WECS units. Both transformers were modeled with a positive-sequence impedance of 16% on 100 MVA with an X/R ratio of 34. The IC indicated that these interconnection facility transformers have a grounded wye-delta winding configuration with +/-10% on-load tap changer in 32 steps. The impedance of each generator step-up transformer was not provided by the IC and is assumed as 9.9% on 5.15 MVA with an X/R ratio of 12.14.

9. 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.

10. The FEAS analysis assumes 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.

11. 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.

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. L-7003 is a 230kV circuit between 3C-Port Hastings and 67N-Onslow and is comprised of multiple sections with various conductors and structure designs as shown in Table 1. The POI for IR#618 is located on the line section between Trenton and Canso Causeway which uses 556.5 kcmil Dove ACSR with H frame wood pole structures, and is limited to an operating temperature of 60°C. L-7003 is currently being uprated from the operating temperature of 60°C to 70°C. This study assumed that the upgrade is complete before IR#618 is in service.

Table 1 L-7003 Construction

Section	Length (km)	Conductor	Size	Type	Structure
Onslow End (Gulfport)	0.83	Drake	795.0	ACSR	Gulfport
Onslow to Hwy#4	23.44	Dove	556.5	ACSR	H frame
Str#124 Hwy#4 to Trenton	33.56	Dove	556.5	ACSR	H frame
Trenton Area (DC Steel Tower)	1.45	Special C	626.7	ASCR	DC Four Leg
Trenton to Causeway	98.47	Dove	556.5	ACSR	H frame
Canso Causeway Towers	1.48	Special C	626.7	ASCR	DC Four Leg
Causeway to Pt. Hastings 3C	1.37	Drake	795.0	ACSR	DC Four Leg

14. The rating of transmission lines in the vicinity of IR#618 are shown in Table 2.

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-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-7019	555.5 Dove	70°C	Conductor	273/303 MVA	345/379 MVA
L-7005	1113 Beaumont	70°C	CT Ratio	398/438 MVA	398/438 MVA

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 800 MW from New Brunswick to Nova Scotia; The TSR is expected to be in service in

[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#618 is in service.

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 Enercon E-138 EP3 E2 4.2 MW wind turbines Type 4 fully converted units is given as 1.045 times rated current, or X'd = 0.957 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 3.

Table 3: Short-Circuit Levels. IR#618 (Type 4) on L-7003 Three-phase MVA (1)

Location	Without IR#618	With IR#618
All transmission facilities in service		
POI on L-7003 (230kV)	2904	3029
Interconnection Facility (230kV)	2902	3027
3C-Port Hastings (230kV)	3282	3402
2C-Port Hastings (138kV)	2813	2866
67N-Onslow (230kV)	4300	4340
Minimum Conditions (TC3, LG1, ML In-Service)		
Interconnection Facility (230kV kV), all lines in-service	1554	1679
Interconnection Facility (230kV), L-7003 open at 3C	516	640
Interconnection Facility (230kV), L-7003 open at 67N	1424	1550

(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 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 assumed and supplied data and calculated short circuit levels, the SCR is 11.9 at the 230kV bus of IR#618 ICIF with all lines in service and IR#618 offline. This falls to 4.0 with L-7003 open at 3C-Port Hastings, and 10.9 if L-7003 is open at 67N-Onslow.

6 Voltage Flicker and Harmonics

Flicker coefficient information was not provided for the Enercon E-138 EP3 E2 4.2 MW Wind Turbines, however, it is known that Type 4 wind turbines typically have a flicker coefficient of 2.0 - 2.4 at angle of 85°, which is about half that of Type 3 machines. Type 4 wind turbines are not expected to result in appreciable voltage flicker at minimum generation conditions. Voltage flicker will be further examined when data for the 4.2 MW Enercon E-138 machine is made available for the SIS.

The generator is expected to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion (all frequencies) to a maximum of 1.5%, with no individual harmonic exceeding 1.5% on 230 kV.

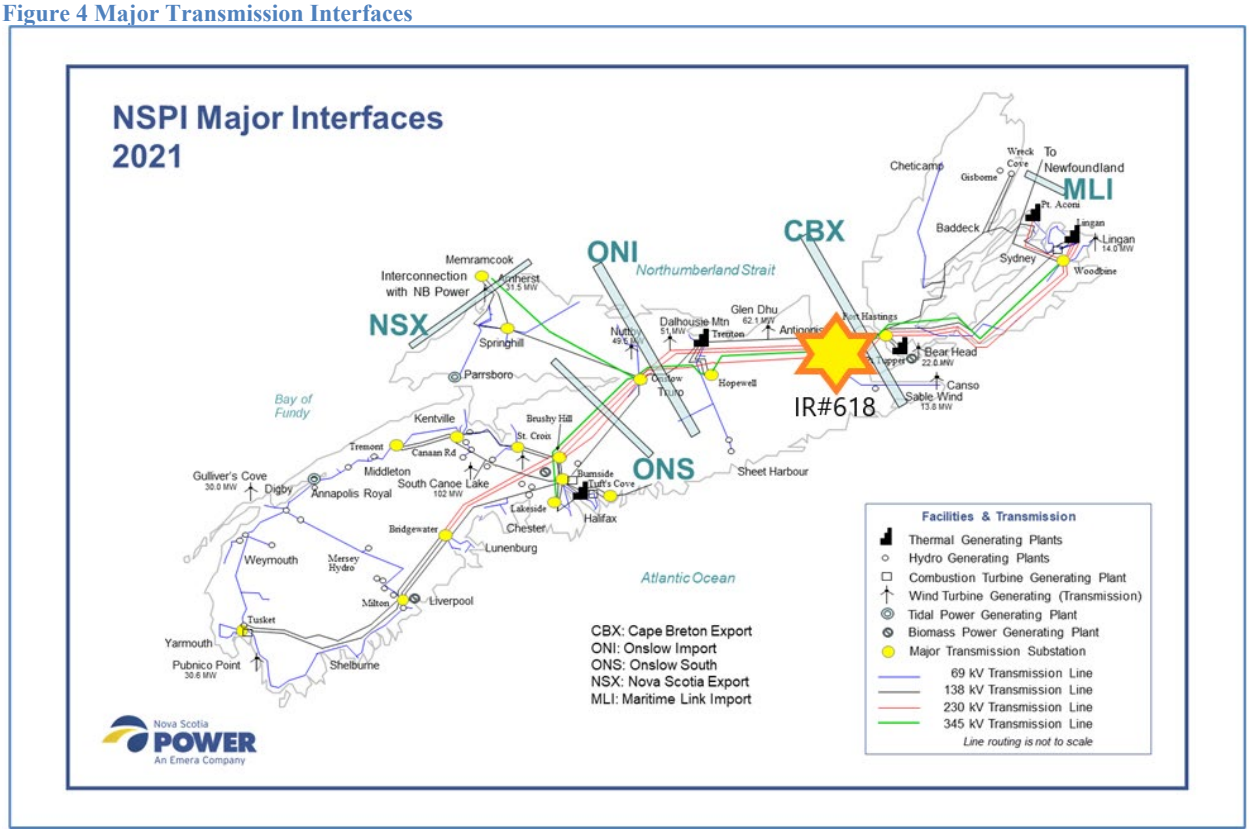
7 Load Flow Analysis

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#618 are shown in Figure 4. The nominal interface thermal limits are summarized in Table 4. NSPI relies on Remedial Action Schemes (RAS[3]) approved by NPCC to maintain interface limits. These RAS are armed by system conditions and flow 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.

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

Figure 4 Major Transmission Interfaces



Note: IR#618 does not directly contribute to the CBX corridor measurement as the CBX corridor is measured from 3C-Port Hastings.

Table 4 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, capped at 38% of NS load.
(4) Dependant on generation at Trenton and Point Tupper
(5) Dependant on reactive power reserve in Metro

Transmission connected wind generation facilities were typically dispatched at approximately 40%, except in the vicinity of IR#618. There is high co-relation between wind plants in the Central Region between Port Hastings and Onslow, so it is reasonable to expect that these other wind plants would be near full output when IR#618 is at rated output. The cases and dispatch scenarios considered are shown in Table 5.

Table 5: Base Case Dispatch (MW) IR#618 On-Line									
Case	MLI	NS-NB	CBX	ONI	ONS	LIN	TRE	Wind	RAS (3)
SP01	475	333	852	980	580	172	78	340	79NG5
SP02	475	0	713	886	782	188	160	252	-
SP03	475	330	749	855	472	0 (1)	0	504	79NG5
SP04	475	0	620	886	820	189	165	380	-
SP05	475	170	947	1132	857	267	156 (2)	258	79NG5 67NG5
SP06	475	170	753	812	538	70	0	291	79NG5
SP07	-100	-264	16	288	462	70	160	397	-
SP08	475	170	847	1036	765	155	156 (2)	258	67NG5
WP01	320	150	815	1,165	870	350	324	363	67NG6
WP02	475	150	1020	1,210	920	350	165	348	79NG5 67NG6
WP03	320	150	724	1,063	792	353	324	365	67NG5
WP04	475	2	1,014	1,110	930	343	165	205	79NG5 67NG5
WP07	-100	-169	137	507	555	100	324	542	-

S - Summer Peak W - Winter Peak LIN – Lingan Gen TRE – Trenton Gen

(1) IR618 displaces 90 MW of Lingan plus 40 MW of Point Aconi

(2) Two Trenton units at near minimum load

(3) Based on present RAS arming levels

For both NRIS and ERIS analysis, this FEAS added IR#618 and displaced coal-fired generation in Cape Breton, reducing Cape Breton Export (CBX) transfers while maintaining 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#618 interconnected to the POI at L-7003. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 6.

Table 6 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	

Table 6 Contingency List			
Transmission Line	**Transformer / Bus**	**Circuit Breaker Failure**	**Double Circuit Tower**
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: 710, 712, 713, 715, 716	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, 703, 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*	
Line segments either side of POI	91N: B71	91N: 701, 702, 703	

*Indicates contingency was studied with/without RAS action

Results

Several contingencies resulted in thermal overloads based on the current function and settings of RAS. In most cases, the overloads can be resolved by lowering the arming levels of these RAS without modification of the RAS design. This will increase the probability of a RAS operating and causing a run-back of the Maritime Link or tripping of a thermal unit at Lingan or Point Aconi. Re-design of an RAS, or the addition of a new RAS, is subject to the approval of NPCC.

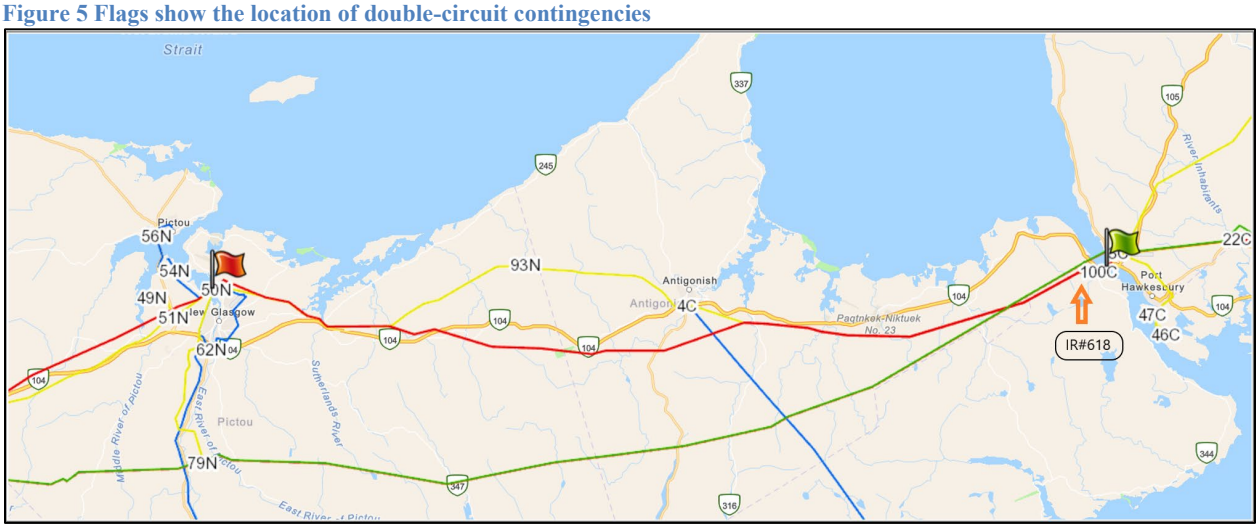
No contingencies resulted in a violation of voltage limit criteria. Table 7 shows the highest thermal overloads found, but other conditions were found which also violated thermal loading criteria, but to a lesser degree.

Table 7 Contingencies Resulting in Highest Line Overload				
Line	**Line segment**	**Highest Overload (% of Emergency Rating)**	**Case**	**Contingency**
L-6515	2C-Hastings / 4C-Lochaber	Summer: 117%	SP05	101S-813 or L-8004
L-7004	91N-Dalhousie / 3C-Hastings	Summer: 106%	SP08	79N-803, 79N-810, 79N-T81, 79N-B81 or 79N-B63
L-7019	91N-Dalhousie / 67N-Onslow	Summer: 104%	SP08	79N-803, 79N-810, 79N-T81, 79N-B81 or 79N-B63
L-6515	2C-Hastings / 4C-Lochaber Rd	Summer: 110%	SP05	Trenton Double Circuit Tower

As shown in Figure 5 and outlined in Table 1, L-7003 has two locations where it shares a common tower with L-7004 (Canso Causeway and Trenton Bypass). NERC and NPCC considers simultaneous loss of two circuits on a multi-circuit tower to be a normal (single) contingency for which voltage, stability, and thermal loading criteria must be met. There is currently a RAS (Group 3) which will operate for loss of these two circuits if the faults are at either location. However, the existing RAS monitoring Hastings substation will not

function for the double-circuit contingency at the Trenton Bypass because IR#618 POI will split L-7003 between Port Hastings and the Trenton area.

Figure 5 Flags show the location of double-circuit contingencies



The following options were examined for the Trenton Bypass double-circuit contingency and associated overloads (classified as Network Upgrades funded by the IC but eligible for refund under the GIP):

1. Uprate L-6515 from 50°C to 60°C. This line uses a Dove 556.5 kcmil ACSR from 2C-Port Hastings to 4C-Lochaber Rd, a distance of 48 km (not including the Canso Causeway which has a larger conductor). This would increase its summer thermal rating by 27%, however switches at the 4C end would need to be replaced. The estimated cost is $7,500,000; or
2. Build a new single circuit line section to separate L-7004 from L-7003 at the Trenton Bypass. This would require a new right-of-way and would involve a 500m river crossing at Greens Point. It is estimated to cost at least $2,000,000 (excluding river crossing structures); or
3. Design and build a new RAS to detect the Trenton Bypass double-circuit contingency and potentially targeting the IR and/or Maritime Link. This is estimated to cost $200,000 with the assumption that it will be approved by NPCC.

For the other contingencies resulting in the thermal overloads on L-6515, L-7019 and L7004, the options examined include:

1. Thermal uprating of the following line sections (total of $17,100,000):
    a. Uprate L-6515 as above at a cost of $7,500,000 (this would also eliminate the Trenton DCT issue as well as other contingencies that are not covered by the other options);
    b. Uprate L-7004 between Little Harbour Road and 91N-Dalhousie from 60°C to 70°C, 35 km of Dove 556.5 kcmil ACSR on 138kV-style H-frame, estimated at $5,250,000;
    c. Uprate L-7019 from 70°C to 80°C, 29 km of Dove 556.5 kcmil ACSR on 138kV-style H-frame, estimated at $4,350,000; or

2. Reduce arming values for existing Group 5 and Group 6 RAS, and potentially for Group 3 RAS, estimated at $50,000 if no functional changes are required.

As an alternative to uprating the affected transmission lines, it is proposed that:

1. Modifications to the setting of existing Remedial Action Schemes (RAS) be applied to alleviate most of these overloads.
2. A new RAS to accommodate a double-circuit contingency near Trenton affecting L-7004 plus L-7003 with the IR#618 POI on L-7003.

Due to the interdependency between IR#618, Cape Breton generation displacement, and Cape Breton Export RAS arming, the upgrades for NRIS and ERIS are the same.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR#618 must be capable of delivering reactive power at 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 (Figure 6) provided by Enercon indicates that the Enercon E-138 EP3 E2 -FTQ 4.2 MW WECS have a rated power factor of 0.85 lagging and leading (+/- 2.65 Mvar per WECS) at the machine terminal voltage of 1.0 p.u. or above, from 10% to 100% of rated power. However, the NSPI Transmission System Interconnection Requirements (Section 7.6.2) requires that rated reactive power shall be available through the full range of real power output of the Generating Facility, from zero to full power.

Figure 6: Model E-FTQ WECS Reactive Capability

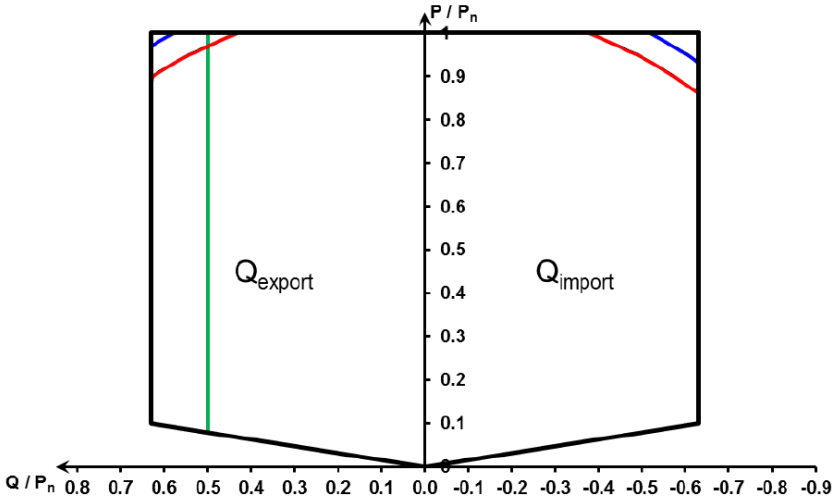


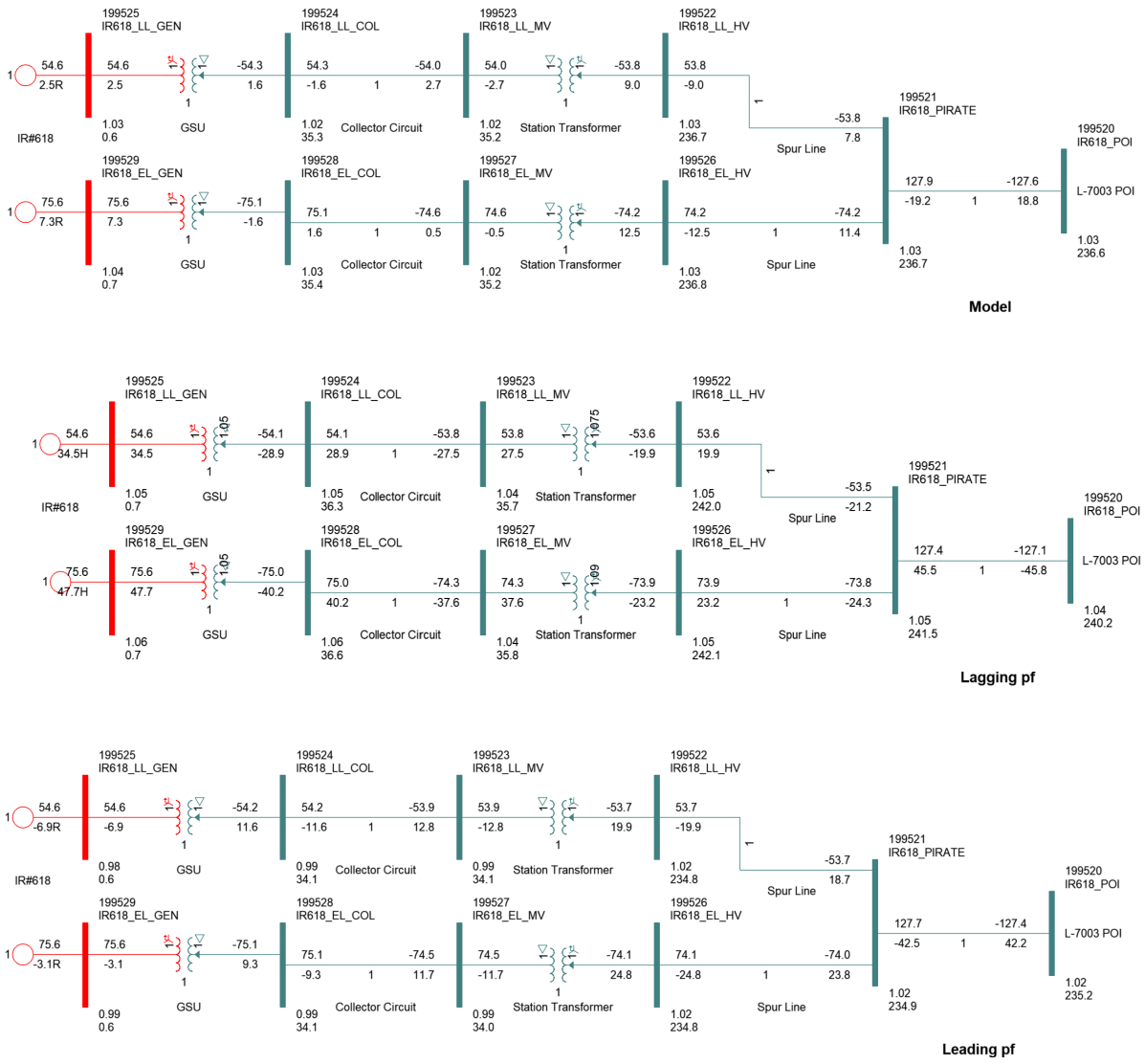
Fig. 1: Reactive power range as determined by the active power and grid voltage

	90 % U_n
	95 % U_n
	≥100 % U_n
	≥115 % U_n

Analysis shown in Figure 7 indicates that IR#618 may be able to meet the full-load reactive power requirement without additional reactive support. The model shows that with 31 WECS units (E2-FTQ version) operating at a total 130.2 MW and 82.2 Mvar, the delivered power to the high side of the ICIF transformers at Long Lake is 53.6 MW and 19.9 Mvar, or a power factor of 0.937 with WECS terminal voltage at 1.05 p.u, and the delivered power to the high side of the ICIF transformers at Englands Lake is 73.9 MW and 23.2 Mvar, or a power factor of 0.954 with WECS terminal voltage at 1.06 p.u. The delivered power to the L-7003 POI is 127.1 MW and 45.8 Mvar, or a power factor of 0.941.

This configuration would be able to meet the leading power factor requirement of -0.95 at the high side of both ICIF transformers at Long Lake and Englands Lake while the WECS are operating at a total of 130.2 MW and -10.0 Mvar at a terminal voltage of 0.98-0.99 p.u.

Figure 7: 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.

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 generator's 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

The 230kV buses at the 67N-Onslow substation and the 3C-Port Hastings substation as well as line L-7003 are part of the Nova Scotia Bulk Power System (BPS). As such, all protection systems associated with the new three-breaker ring bus at the POI must comply with NPCC Directory 4 *System Protection Criteria*.

Since the 67N-Onslow substation and 3C-Port Hastings substations are currently classified as part of the NERC Bulk Electric System (BES), they are also subject to the applicable NERC Reliability Criteria. As IR#618 has dispersed generation totalling more than 75 MVA, Inclusion I4 of the NERC BES Definition applies; each generator and systems designed for delivering that aggregate capacity to the POI classified are categorized as BES elements.

Line L-7003 presently has RAS installed (Group 3 and Group 4) which will be impacted by the installation of a Transmission Provider Interconnection Facility (TPIF) substation on this circuit. Modifications will be required to account for the fact that the TPIF would create two separate circuits. Complete RAS categorization will be determined further in the GIP process and the modifications will require NPCC approval.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR#618 to the NSPI transmission system at a POI on L-7003 under NRIS and ERIS:

a. Required Network Upgrades

- Modification of NSPI protection systems at 67N-Onslow and 3C-Port Hastings.
- Install a new 230kV substation complete with 3 breaker ring bus at the POI at L-7003 with control and protection. A Remote Terminal Unit (RTU) to interface with NSPI's SCADA system, with telemetry and controls as required by NSPI.
- Changes to existing NSPI RAS (Group 3, Group 5 and Group 6) plus a new RAS, likely Limited Impact, for the Trenton Bypass double-circuit tower, pending NPCC approval.

b. Required Transmission Provider's Interconnection Facilities (TPIF):

- Construct transmission lines totalling 24.3 km, between the L-7003 POI and the ICIF and lines between the ICIF and Englands Lake and Long Lake sites. These lines would be built to NSPI's 230kV standards.
- Supervisory, control, and communications between the wind farm and NSPI SCADA system (to be specified).

c. Required Interconnection Customer's Interconnection Facilities (ICIF)

- 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 assumed that Enercon model E3-FTQ would meet this requirement, however the data provided did not 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

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 130.2 MW wind energy at the 230kV POI on L-7003 are included in Table 7.

Table 7 Cost Estimate NRIS & ERIS @ POI L-7003

Item	Network Upgrades	Estimate
1	Three breaker ring bus 230 kV substation complete with P&C at NSPI POI substation and connection to L-7003, including P&C modifications at 3C-Port Hastings and 67N-Onslow. The IC is also responsible for providing the substation site and access road.	$8,000,000
2	Modifications to RAS settings Group 3, Group 5, Group 6	$50,000
3	New RAS for Trenton Bypass	$200,000
	Sub-total for Network Upgrades	$8,250,000
Item	**TPIF Upgrades**	**Estimate**
1	Build 24.3 km 230kV spur line from TPIF to ICIF, with IC responsible to provide right-of-way	$16,159,500
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	$16,469,500
	Total Upgrades	**Estimate**

	Network Upgrades + TPIF Upgrades	$24,719,500
	Contingency (10%)	$2,471,950
	Total (Incl. 10% contingency and Excl. HST)	$27,191,450

The preliminary non-binding cost estimate for interconnecting 130.2 MW at the POI at L-7003 under both NRIS and ERIS is $27,191,450 including a contingency of 10%. In this estimate, $8,250,000 (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. This 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#618 in service, losses in the winter peak case total 86.2 MW. With IR#618 in service at the POI of L-7003, displacing generation at 91H, and not including losses associated with the IR#618 Generation Facilities or TPIF Interconnection Facilities, system losses total 97.9 MW, an increase of 11.7 MW. The power delivered to the POI is 127.6 MW, therefore the loss factor is calculated as 11.7/127.6 = +9.2%.

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#618. 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.

i. Facilities that the customer must install to meet the requirements of the GIP and the *Transmission System Interconnection Requirements*.
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
- L-8004
- L-8003
- Transformer 79N-T81
- L-7003 either side of IR#618
- L-7019 with 91N generation
- L-8004 & 79N-T81 (common circuit breaker)
- L-8004 & 101S-T81 (common circuit breaker)
- 1N-B61 (bus fault)
- L-7004 & 3C-T71 (common circuit breaker)
- L-7004 & L-7012 (common circuit breaker)
- L-7005
- Loss L-7003 & L-7004 (double circuit tower) at Canso Causeway and Trenton Bypass
- 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-8004 at 101S-Woodbine, CBX and ONI, RAS armed
- 3 phase fault L-8003 at 67N-Onslow, ONI RAS armed

- 3 phase fault L-8001 with high NS import from NB (islanding)
- 3 phase fault L-8002 at 67N-Onslow
- Simultaneous SLG on L-7003 and L-7004 double circuit tower at 3C-Port Hastings
- SLG L-8003 at Onslow, drops 67N-T82, 345kV RAS Operation
- 3 phase fault at 79N-Hopewell, drops L-8003, 8004, bus, RAS operation
- 3 phase fault 1N-Onslow 138 kV bus B61

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. The SIS will also determine the contingencies for which this facility must be curtailed.

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