Interconnection Feasibility Study Report
GIP-IR633-FEAS-R2

Generator Interconnection Request 633
100 MW Solar Generation Facility
Inverness County, NS

2022-03-17

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted a Network Resource Interconnection Service (NRIS) Interconnection Request for a proposed 100 MW solar generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2023-07-01. The Point of Interconnection (POI) requested by the customer is the 138kV bus B62 at 2C-Port Hastings substation, approximately 3.14 km from the IC 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#633. 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#633 will displace coal-fired generation in eastern Nova Scotia for NRIS.

Interconnection with 2C-Port Hastings 138 kV bus will require a new 138kV breaker and associated equipment. The 3C & 2C-Port Hastings substations are categorized Bulk Power System under NPCC criteria and Bulk Electric System under NERC criteria. As IR#633 has dispersed generation totalling more than 75 MVA, each generator will be classified as a NERC Bulk Electric System (BES) element. The IR#633 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 2C-Port Hastings 138 kV bus B62 indicated that several thermal loading violations would occur due to IR#633, notably on L-6515. As an alternative to uprating the affected transmission line, it is proposed that modifications to the arming/limit values of existing Remedial Action Schemes (RAS) be applied to alleviate most of these overloads.

No violations of voltage criteria were found for IR#633.

Data provided by the IC indicates that IR#633 will be utilizing the Delta M250HV solar PV inverters. Based on the inverters, typical impedances of the transformers, IC provided collector circuit length, and typical collector circuit impedances, IR#633 will not meet the net power factor of +0.95 to -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 circuit are supplied. It is noted that the proposed Delta M250HV models do not meet the requirement to produce full MVAr capability down to zero MW output.

IR#633 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 138kV bus is 1353 MVA with all lines in service and IR#633 off-line, resulting in a 13.5 short-circuit ratio; and 1181 MVA with 3C-T71 out of service, resulting in a 11.8 short-circuit ratio.

The preliminary unit loss factor is calculated as +9.3% at the POI on 2C-B62, net of any losses on the IC facilities up to the POI.

The preliminary non-binding cost estimate for interconnecting 100 MW to the POI at 2C-B62 bus, including the cost of the new breaker for line connection and protection upgrades at 3C & 2C-Port Hastings plus a total of 3.14 km spur lines from the POI to the IC's Interconnection Facility is $3,993,000. The cost estimate includes a 10% contingency, and this estimate will be further refined in the System Impact Study and the Facility Study. In this estimate, $250,000 (plus 10% contingency) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but eligible for refund under the terms of the GIP. The remainder of the costs are fully funded by the IC.

If transmission upgrades are found to be necessary to address these thermal overloads instead of modifying the RAS arming/limit values, the total cost of Network Upgrades would increase by an estimated $7,500,000 for the uprate of L-6515. This cost estimate does 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 and Network Upgrades is 18-24 months after receipt of funds and cleared right of way from the IC.

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1 Introduction

The Interconnection Customer (IC) submitted a Network Resource Interconnection Service (NRIS) Interconnection Request for a proposed 100 MW solar generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2023-07-01. The Point of Interconnection (POI) requested by the customer is the 2C-Port Hastings substation 138kV bus, approximately 3.1 km from the IC station.

The 2C-Port Hastings substation 138kV bus was studied, instead of the primary POI (L-6537), after preliminary work on the study identified the need for new and modifications to Remedial Action Schemes (RAS).

The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2021-09-27, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 633 in the NSPI Interconnection Request Queue and will be referred to as IR#633 throughout this report.

Figure 1 shows the proposed geographic location of IR#633 in relation to the NSPI transmission system.

Figure 1 IR#633 Site Location

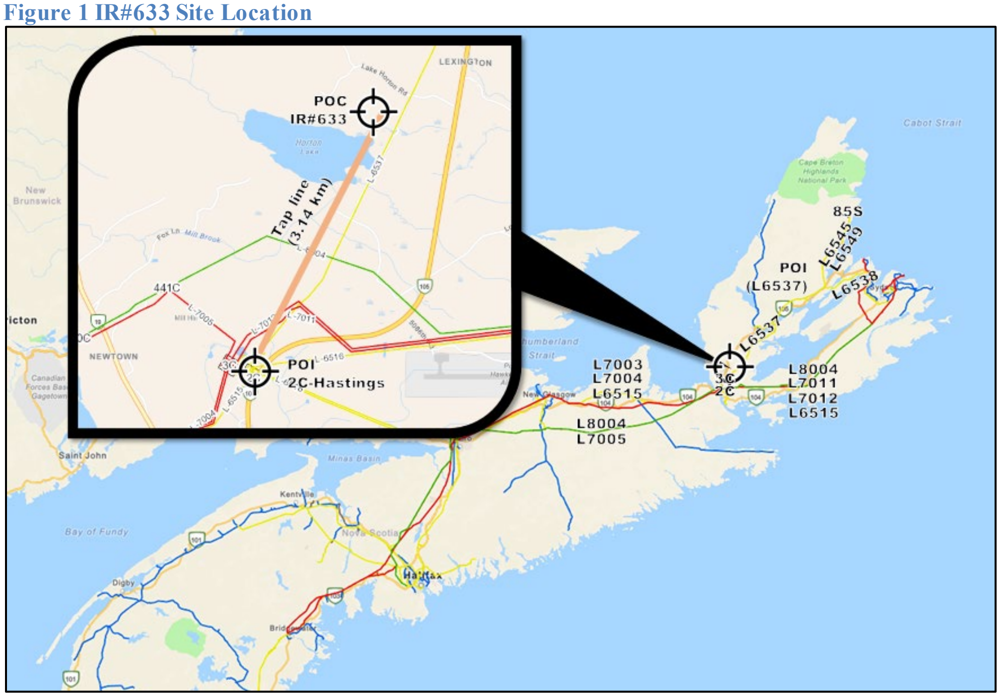


Figure 2 is a simplified one-line diagram of the transmission system configuration in central NS. Figure 3 shows the circuit breaker configuration of transmission lines in the vicinity of the POI.

Figure 2 Point of Interconnection (not to scale)

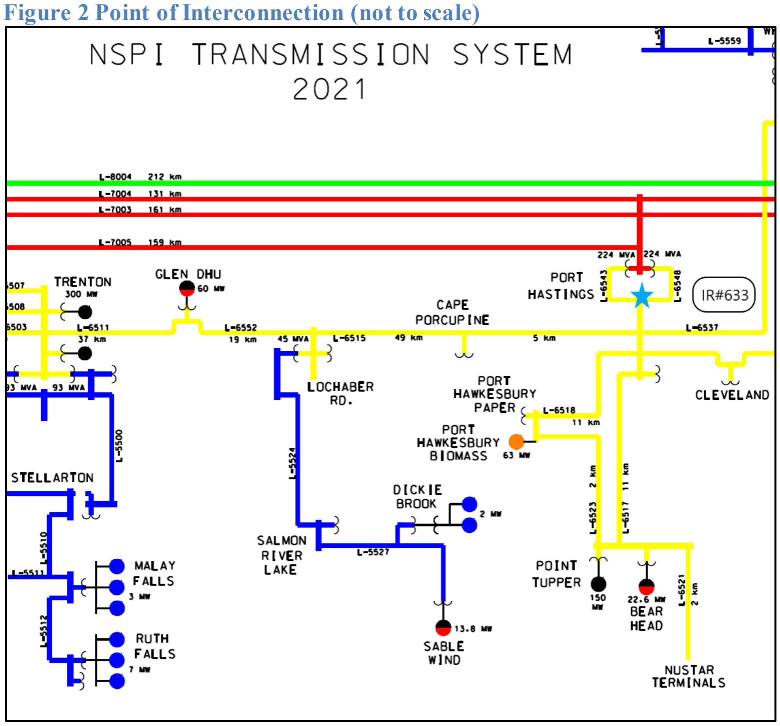
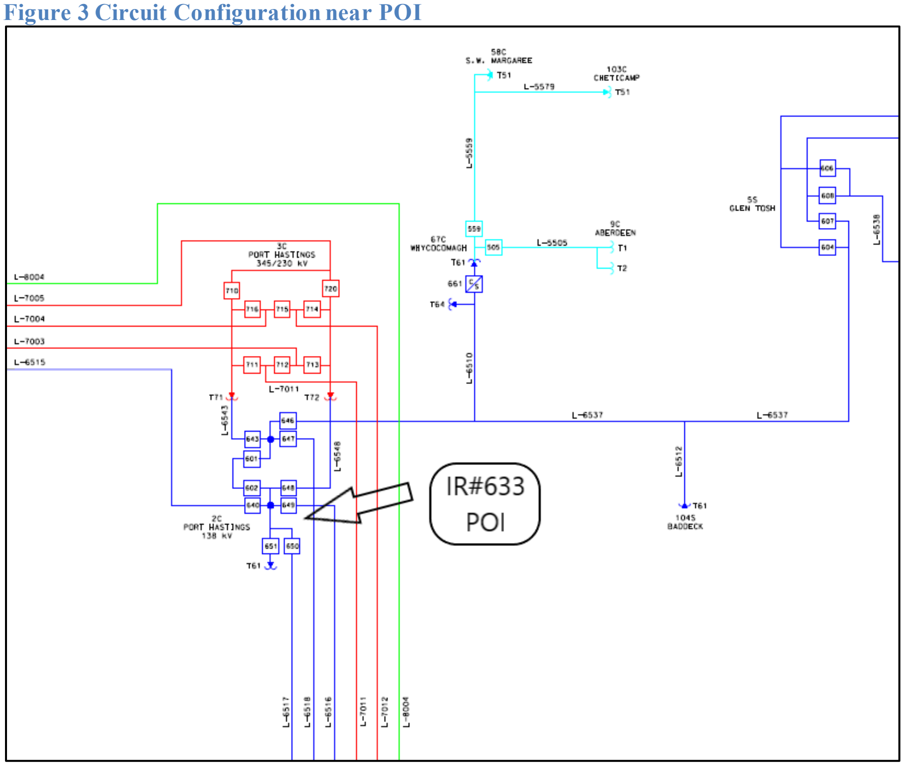


Figure 3 Circuit Configuration near POI



2 Scope

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#633 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 per section 3.2 of the Generator Interconnection Procedures (GIP).

2. Commercial Operation date 2023-07-01.

3. The Interconnection Customer Interconnection Facility (ICIF) consists of up to 400 Delta M250HV solar PV inverters units, each rated at 0.25 MW AC; capped at a total of 100 MW, connected to collector circuits operating at a voltage of 34.5kV.

4. The POI onto 2C-Port Hastings 138 kV bus B62 is categorized Bulk Power System and will require one 138 kV breaker and associated equipment.

5. The ICIF will require the construction of a 3.14 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 solar 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. Typical impedance data was assumed for the 138kV/34.5kV station transformers. The transformer was rated at 67/89/111 MVA and modeled with a positive-sequence impedance of 9.0% on 100 MVA with an X/R ratio of 45. The IC indicated that these interconnection facility transformers have a wye-delta winding configuration with +/-5% on-load tap changer. The impedance of each generator step-up transformer was not provided by the IC and is assumed as 7% on 4 MVA with an X/R ratio of 11.4.

8. Collector circuit length was estimated based on the SLD provided by the IC. Detailed collector circuit data was not provided, so typical data was assumed and calculated at 0.0053+j0.0038 based on the WECC Equivalent Circuit Calculation method[2]. The understanding is that the net real and reactive power output of the plant will be impacted by losses through transformers and collector circuits.

9. The FEAS analysis 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.

10. It is assumed that the solar inverters 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#633 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[3]	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] https://www.wecc.org/Reliability/WECCPVPlantPowerFlowModelingGuide.pdf

[3] 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#633 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 Delta M250HV solar PV inverters is assumed as 1.0 times rated current, or X'd = 1.0 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#633 on 2C B62 Three-phase MVA (1)		
Location	Without IR#633	With IR#633
All transmission facilities in service		
POI on 2C- Hastings (138kV)	2813	2896
Interconnection Facility (138kV)	2810	2893
3C-Port Hastings (230kV)	3282	3332
67N-Onslow (230 kV)	4300	4317
1C- Tupper (138kV)	2296	2342
47C- PHP (138 kV)	2273	2319
Minimum Conditions (TC3, LG1, ML In-Service)		
Interconnection Facility (138kV kV), all lines in-service	1353	1436
Interconnection Facility (138kV), 3C-T71 OOS	1181	1262
Interconnection Facility (138kV), 2C 138 kV B63 open	1247	1330

(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, 1C-Tupper and 47C-PHP 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 minimum calculated short circuit levels in Table 4 and information supplied by the IC, the minimum SCR would be 13.5 at the 138kV Interconnection Facility of the IR#633 substation with all lines in service and IR#633 offline. This falls to 11.8 with 3C-T71 out of service at 3C-Port Hastings, and 12.5 if 2C- Port Hastings 138 kV bus B63 is open.

6 Voltage Flicker and Harmonics

Flicker coefficient information was not provided for the Delta M250HV 0.25 MW solar PV inverters. Voltage flicker will be further examined when data for the machine is made available for the SIS.

Total harmonic distortion (THD) for the Delta M250HV solar PV inverters is indicated less than 3% at nominal apparent power. However, 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 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#633 are shown in Figure 4. The nominal interface thermal limits are summarized in Table 5. NSPI relies on Remedial Action Schemes (RAS[4]) 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.

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

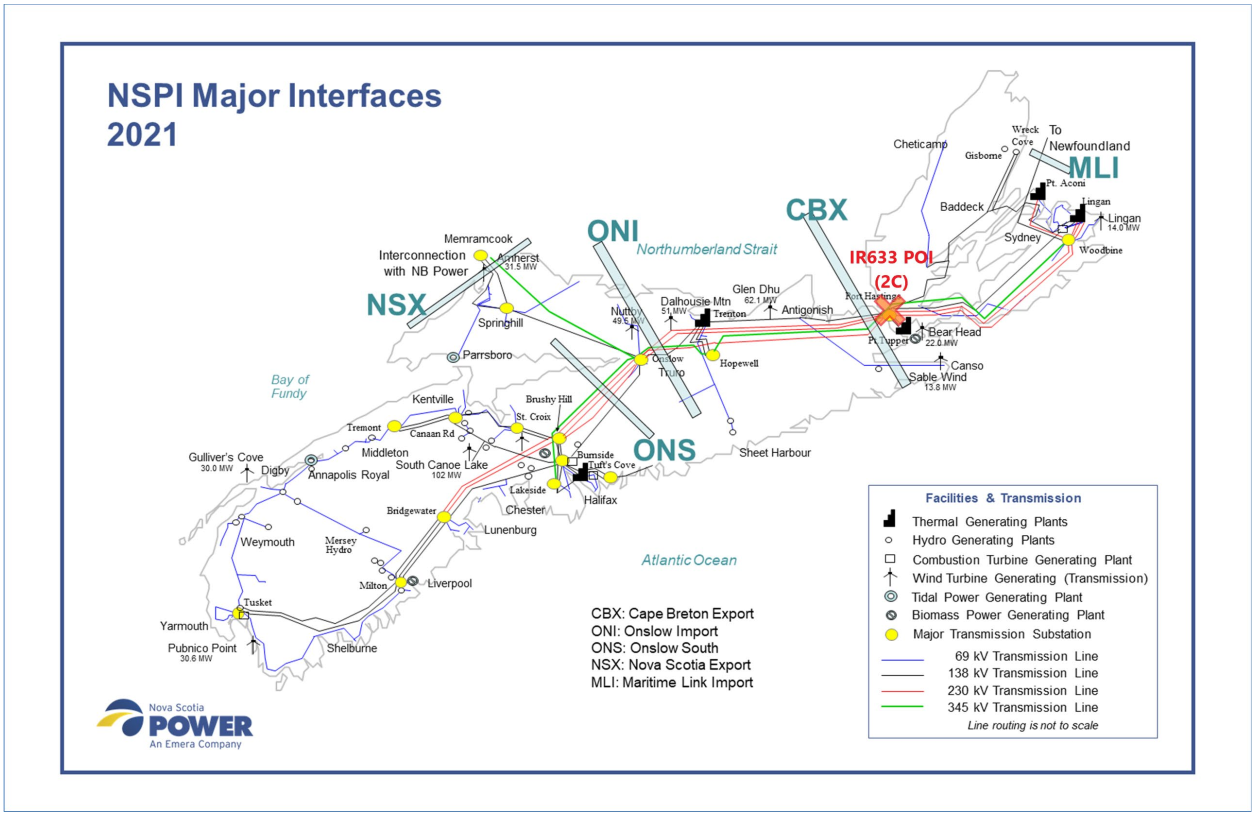


Figure 4 Major Transmission Interfaces

Table 5 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

The cases and dispatch scenarios considered are shown in Table 6. Generation was dispatched to stress local and adjacent corridors as there are no transmission-connected or higher-queued solar PV plants in the area around IR#633.

Table 6: Base Case Dispatch (MW) IR#633 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	79NG5
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	-
WP01	320	149	911	1,119	790	383	324	212	79NG5 67NG5
WP02	320	149	996	1,116	788	383	324	212	79NG5 67NG5
WP03	320	0	833	962	785	383	324	212	-
WP04	320	0	992	1,008	706	383	165	200	79NG6 67NG5
S - Summer Peak W - Winter Peak LIN – Lingan Gen TRE – Trenton Gen WC – Wreck Cove Gen									
(1) IR633 assumed to displace 84 MW of Lingan plus 28 MW of Point Aconi under these dispatches **(2) Based on present RAS arming levels**									

For NRIS analysis, this FEAS added IR#633 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#633 interconnected to the POI at 2C 138 kV bus B62. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 7.

Table 7 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

Table 7 Contingency List			
Transmission Line	**Transformer / Bus**	**Circuit Breaker Failure**	**Double Circuit Tower**
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

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, causing a run-back of the Maritime Link or tripping a Lingan or Point Aconi thermal unit. Changes to the arming levels of existing RAS' do not require NPCC approval as it is not considered a functional modification.

No contingencies resulted in a violation of voltage limit criteria. Table 8 shows the highest thermal overloads found, but other conditions were found which also violated thermal loading criteria, but to a lesser degree.

Table 8 Contingencies Resulting in Highest Line Overload				
Line	**Line segment**	**Highest Overload (% of Emergency Rating)**	**Case**	**Contingency**
L-6515	2C-Hastings / 4C-Lochaber Rd	Summer: 102%	SP03	101S-813 or L-8004
L-6515	2C-Hastings / 4C-Lochaber Rd	Summer: 102%	SP01	7003/7004 Double Circuit Tower

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

1. Thermal uprating of L-6515 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.

As an alternative to uprating the affected transmission lines, for IR#633 it is proposed that reducing existing Remedial Action Schemes (RAS) arming/limit levels be applied to alleviate most of these overloads.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR#633 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 5) provided by IC indicates that the Delta M250HV solar inverters have a rated power factor of 0.857 lagging and leading (+/- 0.15 Mvar per solar inverter) at the machine terminal voltage of 1.0 p.u. or above, from 10% to 80% of rated power. The range of reactive power output is decreased as the solar inverter's real power output increases beyond 80% of rated power. When the solar inverter operates at full real power output, the reactive power output is zero. 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.

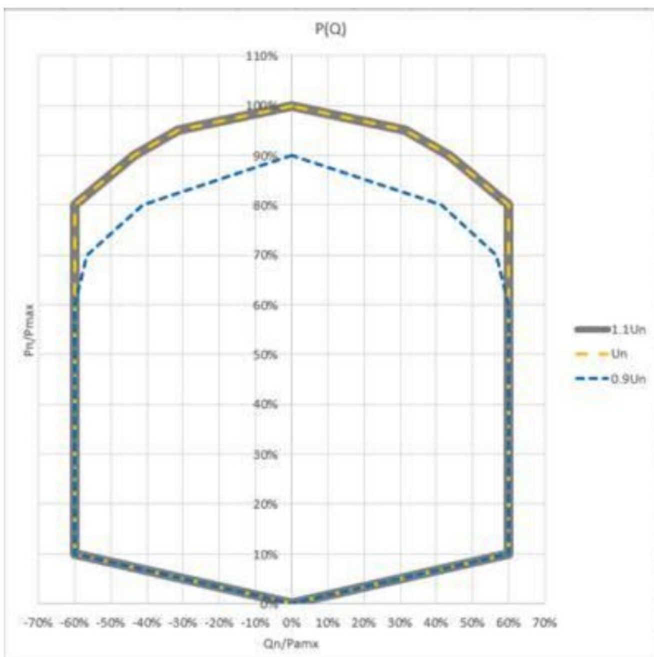


Figure 5 Model Delta M250HV PQ Curve and Reactive Capability

Analysis shown in Figure 6 indicates that IR#633 may not be able to meet the full-load reactive power requirement and may require additional reactive support device such as STATCOM, DSTATCOM or synchronous condenser, supplied by the Interconnection Customer.

The model shows that with 400 solar inverter units operating at a total of 100 MW and 0 Mvar, the delivered power to the high side of the ICIF transformers is 98.4 MW and -15 Mvar, or a power factor of -0.989 with solar inverter terminal voltage at 1.0 p.u.

This configuration would not be able to meet the lagging power factor requirement of 0.95 or leading power factor requirement of -0.95 at the high side of ICIF transformer. The IC is responsible for meeting this requirement by providing power factor correction as described in the Nova Scotia Power Transmission System Interconnection Requirements (TSIR). It is assumed that the reactive power device is installed at 34.5 kV collector system, and the study showed the minimum range of +45/-15 MVAr is required.

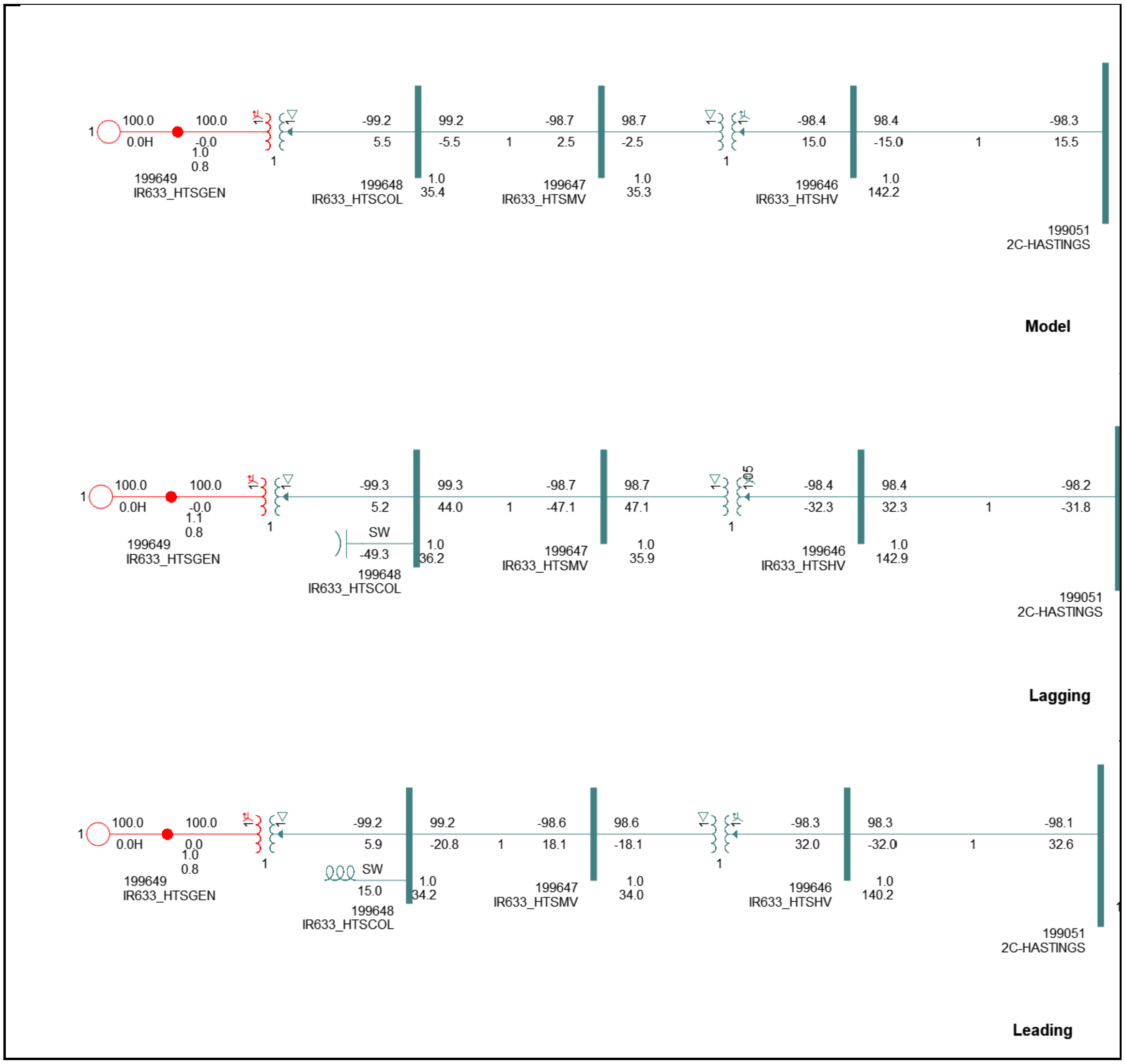


Figure 6 Power Factor Analysis

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

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

The 138kV buses at the 2C-Port Hastings substation are part of the Nova Scotia Bulk Power System (BPS). As such, all protection systems associated with the new breaker at the POI must comply with NPCC Directory 4 *System Protection Criteria*. Complete BPS categorization for IR#633 will occur in the System Impact Study (SIS).

The 3C-Port Hastings substations (230 kV) and 2C- Port Hastings (138 kV) are currently categorized as NERC Bulk Electric System (BES) and are subject to the applicable NERC Reliability Criteria. As IR#633 has dispersed generation totalling more than 75 MVA, Inclusion I4 of the NERC BES Definition applies, and each generator would be classified as a BES element. Also categorized as BES elements are the 138kV IC lines, the IR#633 138kV bus, the 34.5kV bus, and the 138kV - 34.5 kV interconnection transformer.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR#633 to the NSPI transmission system at a POI on 2C- Port Hastings bus B62 under NRIS:

a. Required Network Upgrades

- Modification of NSPI protection systems at 3C & 2C-Port Hastings.
- Changes to existing NSPI RAS (Group 3, Group 5 and Group 6) arming/limit values.

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

- Install a new 138 kV breaker and associated equipment at the 2C-Port Hastings POI, 138 kV bus B62, with protection and control.
- Construct a total of 3.14 km transmission spur line between the POI on 2C bus B62 and the Interconnection Customer's Interconnection Facility. This line would be built to NSPI's 138kV standards.
- Add control and communications between the solar plant 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. The data provided for this study showed the Delta M250HV solar inverters did not meet this power factor requirement and it 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) and control of the interconnection facility, with telemetry including local solar plant MW and Mvar, as well as bus voltages.
- 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.
- 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 100 MW solar energy at the 138kV POI on 2C- Port Hastings B62 are included in Table 9.

Table 9 Cost Estimate NRIS @ POI 2C-B62		
Item	**Network Upgrades**	**Estimate**
1	P&C modifications at 3C and 2C-Port Hastings	$200,000
2	Modifications to Group 3, Group 5, and Group 6 RAS arming/limit values	$50,000
	Sub-total for Network Upgrades	$250,000
Item	**TPIF Upgrades**	**Estimate**
1	Build 3.14 km 138kV spur line from POI to ICIF, with IC responsible for providing Right-Of-Way	$1,570,000
2	One 138 kV breaker and associated equipment at 2C-Port Hastings 138 kV bus B62	$1,500,000
3	NSPI P&C relaying equipment	$100,000
4	NSPI supplied RTU	$60,000
5	Tele-protection and SCADA communications	$150,000
	Sub-total for TPIF Upgrades	$3,380,000
	Total Upgrades	**Estimate**
	Network Upgrades + TPIF Upgrades	$3,630,000
	Contingency (10%)	$363,000
	Total (Incl. 10% contingency and Excl. HST)	$3,993,000

The preliminary non-binding cost estimate for interconnecting 100 MW at the POI on 2C B62 under NRIS is $3,993,000 including a 10% contingency. In this estimate, $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 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 18-24 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#633 in service, losses in the winter peak case total 86.2 MW. With IR#633 in service at the POI of 2C- Port Hastings 138 kV bus B62, displacing generation at 91H, and not including losses associated with the IR#633 Generation Facilities or TPIF Interconnection Facilities, system losses total 95.3 MW, an increase of 9.1 MW. The power delivered to the POI is 98.2 MW, therefore the loss factor is calculated as 9.1/98.2=+9.3%.

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#633.

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
- L-7004
- 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-7011 & 3C-T71 (common circuit breaker)
- L-7012 & 3C-T72 (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
- 3 phase fault 2C-Port Hastings 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 RAS as well as any required additional transmission facilities. The determination will be based on NERC[5] and NPCC[6] criteria as well as NSPI guidelines and good utility practice.

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