Interconnection Feasibility Study Report
GIP-IR635-FEAS-R2

Generator Interconnection Request 635
100 MW Solar Generating Facility
Yarmouth County, NS

2022-04-01

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR#635) for Network Resource Interconnection Service (NRIS) for a proposed net 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 9W-Tusket substation. The Interconnection Customer's Interconnection Facility (ICIF) is approximately 13 km from the POI, and therefore a radial spur line will be required. Because there is no 138kV bus at 9W-Tusket, the POI will be line L-6024 as it enters 9W-Tusket substation.

There are four transmission and three distribution Interconnection Requests currently in the Advanced Stage Transmission and Distribution Queue that must be included in the study models for IR#635. In addition, there is one long-term firm transmission service reservation in the amount of 550 MW from New Brunswick to Nova Scotia (TSR-411). This transmission service request is expected to be in service in 2025 and system studies are 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 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.*

This study assumes that the addition of generation from IR#635 will displace coal-fired generation in eastern Nova Scotia for NRIS.

Because IR#635 is a dispersed generation facility in excess of 75 MVA, Inclusion I4 of the NERC BES Definition would apply, and each inverter would be classified as a Bulk Electric System element, as would the 34.5kV bus and the station transformer. There is the potential for an exclusion from BES to be granted for the high side (138kV) bus based on further analysis per the NS BES Exception Procedure.

The data provided for the Delta M250HV inverters indicates that the reactive power capability at full rated output (100 MW) is very limited, and will not be able to meet the requirement to deliver a power factor of 0.95 at the high voltage terminals of the station transformer. IR#635 will, however be able to meet the capacitive power factor requirement when operating below 90 MW, and the reactive power factor when operating below 95 MW. The plant will not be able to deliver reactive power down to zero MW.

Flicker data for the Delta M250HV inverters was not provided, so the impact of voltage flicker on other customers will be evaluated in the System Impact Study phase. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

No concern regarding high short-circuit level due to the addition of IR#635. The minimum short circuit level at the Interconnection Facility 138kV bus is 333 MVA with all lines in service, and 263 MVA with L-6024 open between the POI and 9W-Tusket. The calculated minimum Short Circuit Ratio at the high voltage terminals of the Interconnection transformer was found to be 3.8 with all transmission elements in service, and 2.2 with the Tusket transformer 9W-T63 out of service. As SCR can affect inverter performance, this information should be shared with the vendor.

The preliminary value for the unit loss factor is calculated as -1.3% at the POI at 9W-Tusket 138kV. Losses associated with the IC facilities (spur line, collector circuits, transformers) are excluded from this calculation.

Since 9W-Tusket and L-6024 are not classified as Bulk Power System and given that a 13 km spur line interconnects IR#635 substation with L-6024, a three-breaker ring line tap will be required. The assessment of the POI at 9W-Tusket 138kV indicated that under certain operating conditions, multiple transmission lines and transformers could exceed emergency operating limit for contingencies at 99W-Bridgewater and 50W-Milton. The recommended Network Upgrades include:

- Install 138kV three-breaker ring bus at the POI designed for single-failure redundancy.
- Move the 99W-Bridgewater terminals of L-6006 and L-6002 from bus 99W-B61 to bus 99W-B62.
- Uprate switches, metering, and protection for line L-5026
- Install three-terminal protection for line L-6024 with transfer trips.

The preliminary non-binding cost estimate for interconnecting net 100 MW to the POI at 9W-Tusket 138kV as NRIS, including the cost of a 13 km 138kV spur line is $14,313,750. In this estimate, $8,360,000 represents Network Upgrade costs which are funded by the IC, but which are eligible for refund under the terms of the GIP. The remainder of the costs are fully funded by the IC. 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 customer, and the estimated time to construct the Network Upgrades is 24-36 months after receipt of funds from the IC.

These cost estimates include a contingency of 10%, and the 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 an Interconnection Request for Network Resource Interconnection Service (NRIS) 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 substation 9W-Tusket. The proposed Interconnection Customer's Interconnection Facility (ICIF) is given to be 13.0 km from the POI, requiring a new 138kV radial spur line.

Lines L-6024 and L-6021 run between 50W-Milton and 9W-Tusket. L-6024 is a direct circuit and L-6021 is tapped at 30W-Souriquois with a 138kV-69kV transformer. The section between 30W-Souriquois and 30W-Milton is designated L-6020. There is no 138kV bus or 138kV circuit breaker at 9W-Tusket, the transmission lines L-6024 and L-6021 terminate in individual 138kV-69kV transformers with 69kV circuit breakers on the low voltage side of the transformers. Because there is no 138kV bus at 9W-Tusket, the POI will be line L-6024 as it enters 9W-Tusket substation.

Figure 1 shows the proposed geographic location of IR#635 in relation to the NSPI transmission system.

Figure 1 IR#635 Tusket Solar Site Location

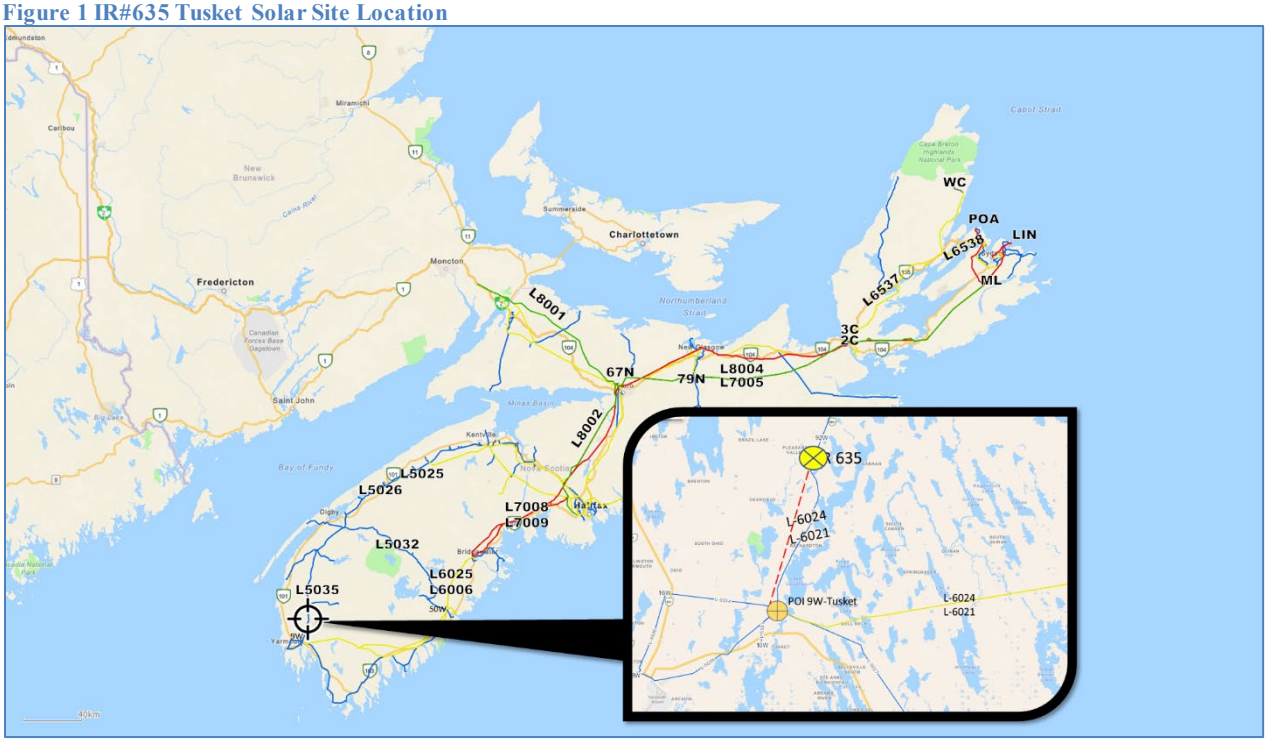


Figure 2 is a simplified one-line diagram of the transmission system configuration near the proposed POI. Figure 3 shows the circuit breaker configuration of transmission lines in the vicinity of the POI.

Figure 2 Point of Interconnection (not to scale)

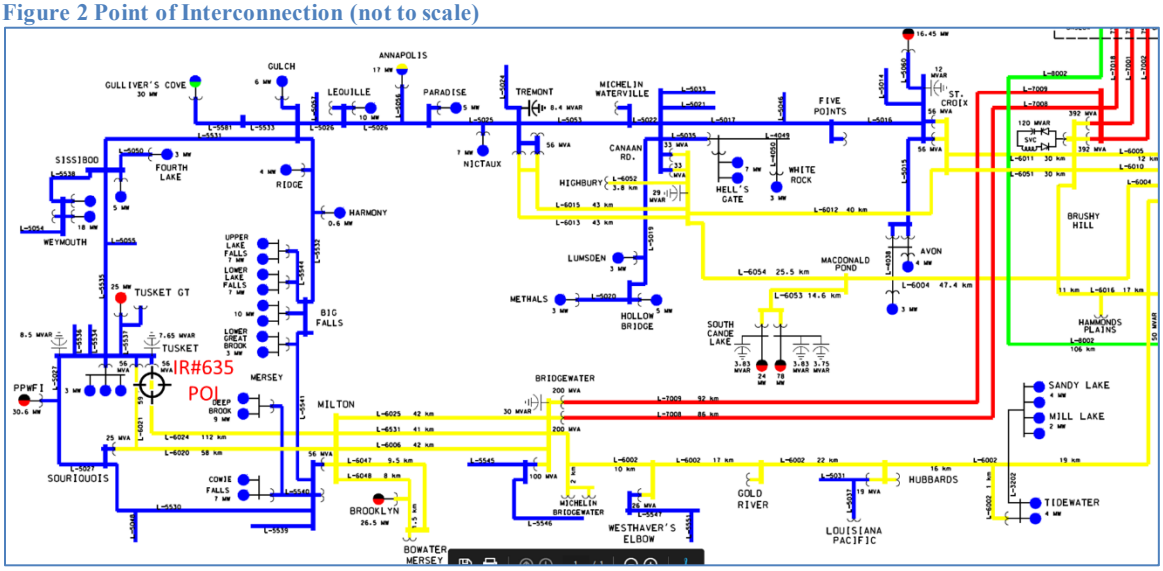
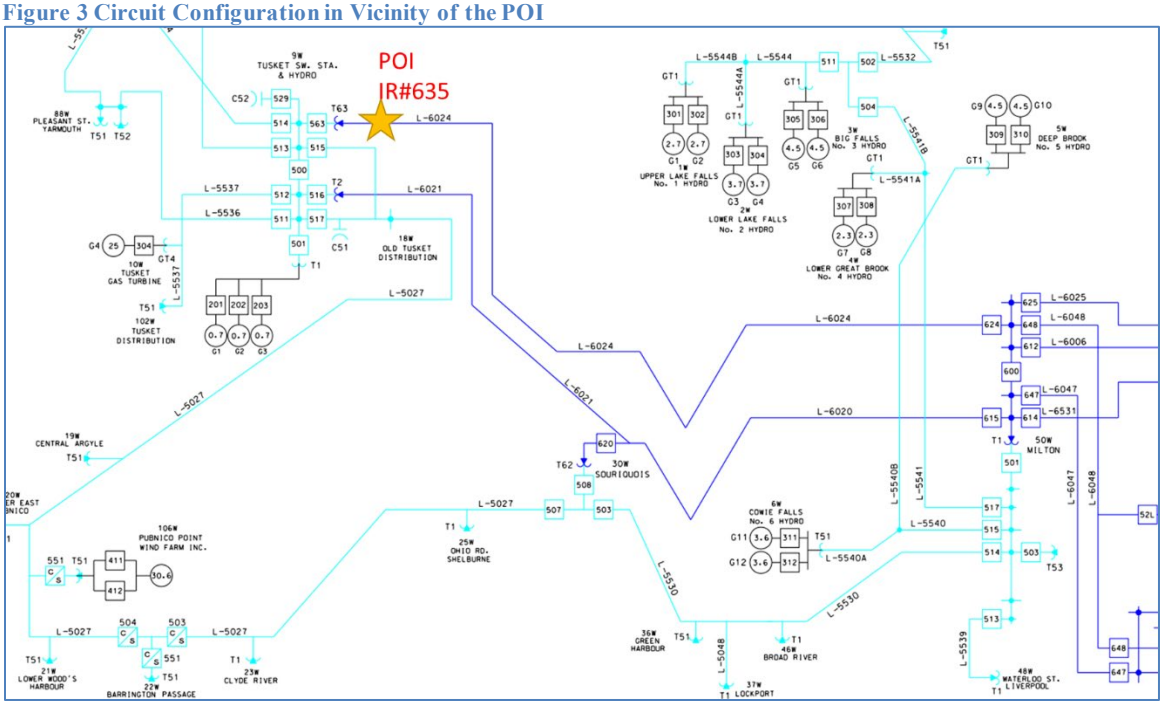


Figure 3 Circuit Configuration in Vicinity of the POI



The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2021-10-05, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 635 in the NSPI Interconnection Request Queue and will be referred to as IR#635 throughout this report.

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 is performed to provide the following information:

- Preliminary identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection, and any network upgrades necessary to address the short circuit issues associated with IR#635. 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] (TSIR).

- 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.

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

- For comparative purposes, the impact of IR#635 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 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 interconnect the generating facility.

3 Assumptions

This FEAS is based on the technical information provided by the IC. The Point of Interconnection (POI) and configuration is studied as follows:

1. NRIS per section 3.2 of the GIP.

2. Commercial Operation date 2023-07-01.

3. The Interconnection Customer Interconnection Facility (ICIF) consists of 400 Delta M250HV solar inverter units, each rated 250 W (100 MW total). connected to five collector circuits operating at a voltage of 34.5kV.

4. 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.

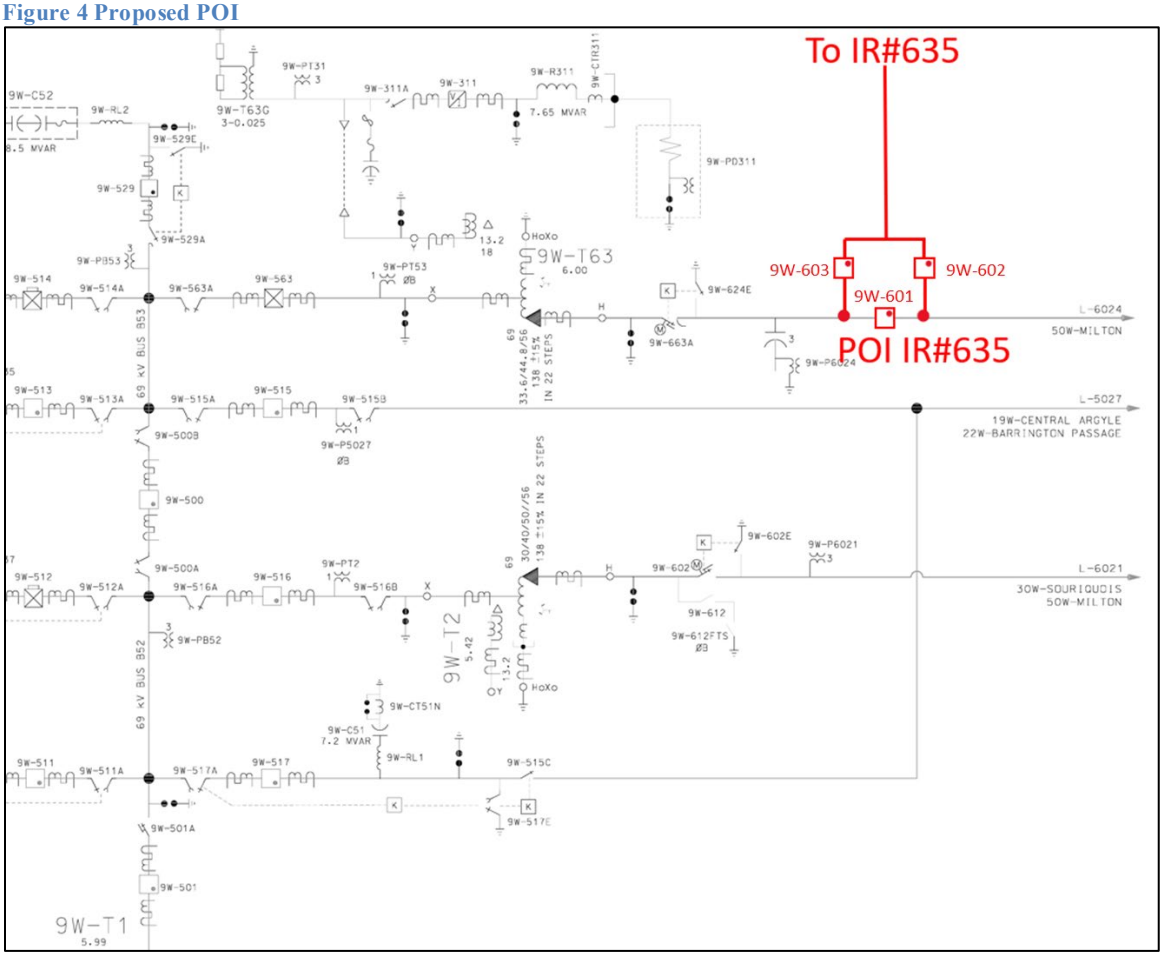
5. Detailed data was not provided by the IC for the ICIF substation step-up transformer, so typical model data was used. The model includes one 138kV-34.5kV 67/89/111 MVA station transformer with a positive-sequence impedance of 7.5% on 67 MVA with an X/R ratio of 40. The information supplied indicates that the station transformer has a grounded wye-delta winding configuration with +/-5% off-load taps. The equivalent impedance of each of the 25 inverter step-up transformers was assumed to be 10% on 4.0 MVA with an X/R ratio of 11.

6. An equivalent 34.5kV collector circuit model was provided with a positive sequence impedance of 0.0027 +j0.00379, B=0.0154 (per unit on 100 MVA).

7. The FEAS analysis is based on the assumption that IR's higher in the Generation Interconnection Queue and OATT Transmission Service Queue that have completed a System Impact Study, or that have a System Impact Study in progress will proceed, as listed in Section 4 below.

8. The proposed POI at 9W-Tusket 138kV is considered non - Bulk Power System facilities. Given that there is no 138kV bus at 9W-Tusket, and a 13.0 km spur line is required between the ICIF and the POI, and since the spur line length is greater than 5 km, a three-breaker ring-bus on line L-6024 as it enters 9W-Tusket will be used in accordance with Table 8 of the NSPI *Transmission System Interconnection Requirements*. The proposed configuration of the POI is shown in Figure 4.

Figure 4 Proposed POI



9. 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.

10. The rating of transmission elements in the vicinity of IR#635 are shown in Table 1.

Table 1 Local Transmission Element Ratings

Line	Conductor	Design Temp	Limiting Element	Summer Rating Normal/Emergency	Winter Rating Normal/Emergency
L-7008	1113 Beaumont	70°C	CT Ratio	398/438 MVA	398/438 MVA
L-7009	795 Drake	50°C	Conductor	223/245 MVA	340/374 MVA
L-6002	556.5 Dove	50°C	Cond/Switch	110/121 MVA	143/157 MVA
L-6006	795 Drake	50°C	Conductor	135/149 MVA	205/225 MVA
L-6025	1113 Beaumont	70°C	CT Ratio	200/220 MVA	200/220 MVA
L-6531	556.5 Dove	50°C	Conductor	110/121 MVA	165/181 MVA
L-6021	336.4 Linnet	50°C	Switch (1)	72/79 MVA	72/79 MVA
L-6020	336.4 Linnet	50°C	Conductor	82/90 MVA	121/133 MVA
L-6024	795 Drake	50°C	Switch (2)	72/79 MVA	72/79 MVA
L-5535	2/0 Quail	50°C	Conductor	23/25 MVA	34/37 MVA
L-5532	4/0 Penguin Quail	50°C	Conductor	23/25 MVA	34/37 MVA
9W-T63	138kV-69kV	65°C rise	Top Rating	56 MVA	56 MVA
9W-T2	138kV-69kV	65°C rise	Top Rating	56 MVA	56 MVA

(1) Switch at 9W end only, conductor rating is 82 MVA summer, 121 MVA winter.
(2) Switch/breaker at 9W end only, CT/Metering limit 173 MVA, conductor rating 203 MVA summer, 251 MVA winter.

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 2021-10-25, 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
- IR574: GIA in progress
- IR598: FAC in progress

The following project has been submitted to the Transmission Service Request (TSR) Queue:

- TSR411: SIS in progress

Preceding IR#635 are six transmission and three distribution Interconnection Requests with GIA's executed. A long-term firm point-to-point transmission service reservation in the amount of 550 MW from New Brunswick to Nova Scotia (TSR-411). This transmission service request is expected to be in service in 2025 and system studies are 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:

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5 Short-Circuit Duty / Short Circuit Ratio

The maximum (design) expected short-circuit level is 5,000 MVA (21 kA) on 138kV systems and 10,000 MVA (25 kA) on 230kV systems. The fault current characteristic for the Delta M250HV inverters is assumed to be 1.0 times rated current, or X'd = 1 per unit.

Table 2: Short-Circuit Levels. IR#635 at 9W-Tusket POI Three-phase MVA (1)

Location	Without IR#635	With IR#635
All transmission facilities in service		
Interconnection Facility (138kV)	404	485
50W-Milton (138kV)	1255	1299
9W-Tusket POI (138kV)	465	544
9W-Tusket (69kV)	548	584
Minimum Conditions (PA1, LG1, ML In-Service)		
Interconnection Facility (138kV), all lines in-service	286	366
Interconnection Facility (138kV), L-6025 open at 50W-Milton	275	357
Interconnection Facility (138kV), L-7009 open at 9W-Tusket	219	301

(1) Classical fault study, flat voltage profile

Short circuit analysis was performed using PSS®E for a classical fault study, 3LG and flat voltage profile at 1.0 p.u. The short-circuit levels in the area before and after this development are provided below in Table 2.

The interrupting capability of the 138kV circuit breakers is at least 3500 MVA at 50W and the 69kV breakers at 9W are rated at least 2000 MVA. As such, the interrupting ratings at these substations will not be exceeded by this development on its own.

Based on the calculated short circuit levels, a POI at 9W-Tusket 138kV, and a 100 MW installation consisting of 400 inverters each rated 0.25 MW, the minimum Short Circuit Ratio (SCR) would be 3.2 at the HV terminals of the IR#635 substation with all lines in service and IR#635 off line. This falls to 2.2 with L-6024 open at 9W-Tusket, and 2.8 if L-6025 is open at 50W-Milton. Note that IR#635 is not permitted to operate with L-6024 open at 50W-Milton because the maximum rating of the 9W-Tusket line-end transformer 9W-T63 is 56 MVA.

6 Load Flow Analysis

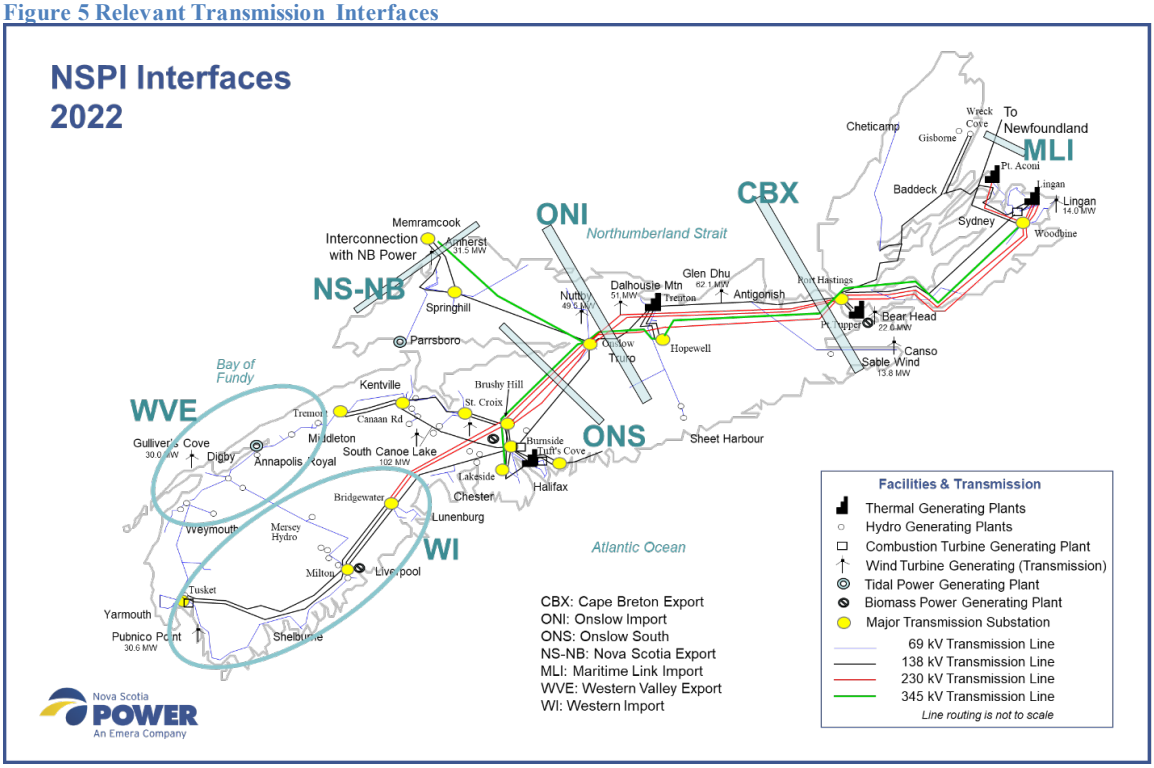
The load flow analysis was completed for generation dispatches under winter peak load conditions, summer low-hydro and spring high-hydro load conditions expected to stress transfers in western NS and Annapolis Valley. Figure 5 shows the relevant interfaces on the NSPI transmission system.

The Western region of Nova Scotia is sensitive to the balance between existing local load and hydro/wind generation. Hydro plants are likely to be a full load during spring run-off conditions and are less likely to be at high load during the dry summer and fall months. The 10W-Tusket Gas Turbine plays an important role in ten-minute operating reserve which can be called upon at any time, so transmission capacity in the vicinity of IR#635 takes this into consideration.

Base cases were selected to reflect the unique nature of solar generation. The lightest loads in NS are experienced at night in summer, so conditions were studied with expected seasonal maximum solar conditions. Case SP01 represented noon hours at the end of June, when western hydro is low and solar generation is at its highest production. Case SP10 represents the beginning of May when hydro generation is at full rated output due to spring run-off and solar capacity is slightly de-rated (assumed at 90% of nameplate). Winter conditions were not considered to be an issue in western NS because of the combined effect of higher local load, higher transmission line ratings, and reduced available solar energy.

For NRIS analysis, this FEAS added IR#635 and displaced an equivalent amount of coal-fired generation in Cape Breton. Model conditions are summarized in Table 3.

Figure 5 Relevant Transmission Interfaces



The cases and dispatch scenarios considered are shown in Table 3.

Table 3: Base Case Dispatch (MW)

Case	NS-NB	LOAD	HYDRO	ONS	WVE	WI	MER	IR#635	Wind
SP01-1	0	900	24	370	9	33	9	0	134
SP01-2	0	900	24	275	9	-62	9	90	134
SP02-1	150	1050	143	337	50	7	43	0	131
SP02-2	150	1050	143	244	50	-86	43	100	131

S – Summer/Spring W - Winter Peak; MER – Mersey Hydro; LOAD – Excludes PHP

With IR#635 connected to the 9W-Tusket POI with a three-circuit breaker ring, IR#635 would be connected to 9W-Tusket via the transformer 9W-T63 and connected to 50W-Milton via line L-6024. If the transformer 9W-T63 is out of service (breakers 9W-601 and 9W-603 open in Figure 4), IR#635 would continue to operate, since the rating of L-6024 is based on the 186 MVA protection current transformer (CT) at breaker 50W-624; if this CT is uprated, this line section would be limited by its conductor emergency rating, 253 MVA summer and 276 MVA winter. However, if L-6024 is open (breakers 9W-601 and 9W-602), output of IR#635 could overload transformers 9W-T63, 9W-T2, and line L-6021.

For this reason, any operation of breaker 50W-624 will transfer-trip the spur line to IR#635 at the POI.

Single contingencies were applied at the 230kV, 138kV, and 69 kV voltage levels for the above system conditions with IR#635 interconnected to the POI at 9W-Tusket 138kV. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 4.

Table 4 Contingency List

Transmission Line	Transformer / Bus	Circuit Breaker Failure	Double Circuit Tower
L-7008, L-7009	120H: T71, T72	120H: 715, 716, 712, 713	L-7008 + L-7009
L-6025, L-6006, L-6531	99W: B61, B62		
L-6024, L-6020, L-6021	50W: B2, B3, B4, T1		
L-5035	9W: B52 B53		
L-5025, L-5026	51V: B51, B62		

NRIS Results

With IR#635 connected to the POI with a three-breaker ring, several contingencies resulted in thermal overloads of transmission lines:

1. Loss of 138kV bus 99W-B61 causes lines L-6025 and L-6006 to open at 99W-Bridgewater, leaving L-6531 loaded to 107%[2] of its emergency rating in case SP10-2 (high hydro dispatch). This same condition would exist for tripping of the transformer 99W-T61 or several breaker-failure contingencies at 99W-Bridgewater: 99W-501, 99W-601, 99W-606.
2. Loss of 138kV bus 50W-B4 causes lines L-6048, L-6025, L-6006 and L-6024 to open at 50W-Milton, with IR#635 radially connected to 9W-Tusket via 9W-T63. This results in the following overloads, depending on the base case:
    a. 9W-T63: 180%
    b. 9W-T2: 140% - 205%
    c. L-6021: 145%
    d. L-6020: 112%
    e. L-5535: 115% - 144%
    f. L-5026: 117%
    g. L-6531: 114%
3. Loss of 138kVbus 50W-B3 causes lines L-6531, L-6020, L-6047 and transformer 50W-T1 to open at 50W-Milton, resulting in L-5026 to load to 115% - 127% of seasonal emergency rating.

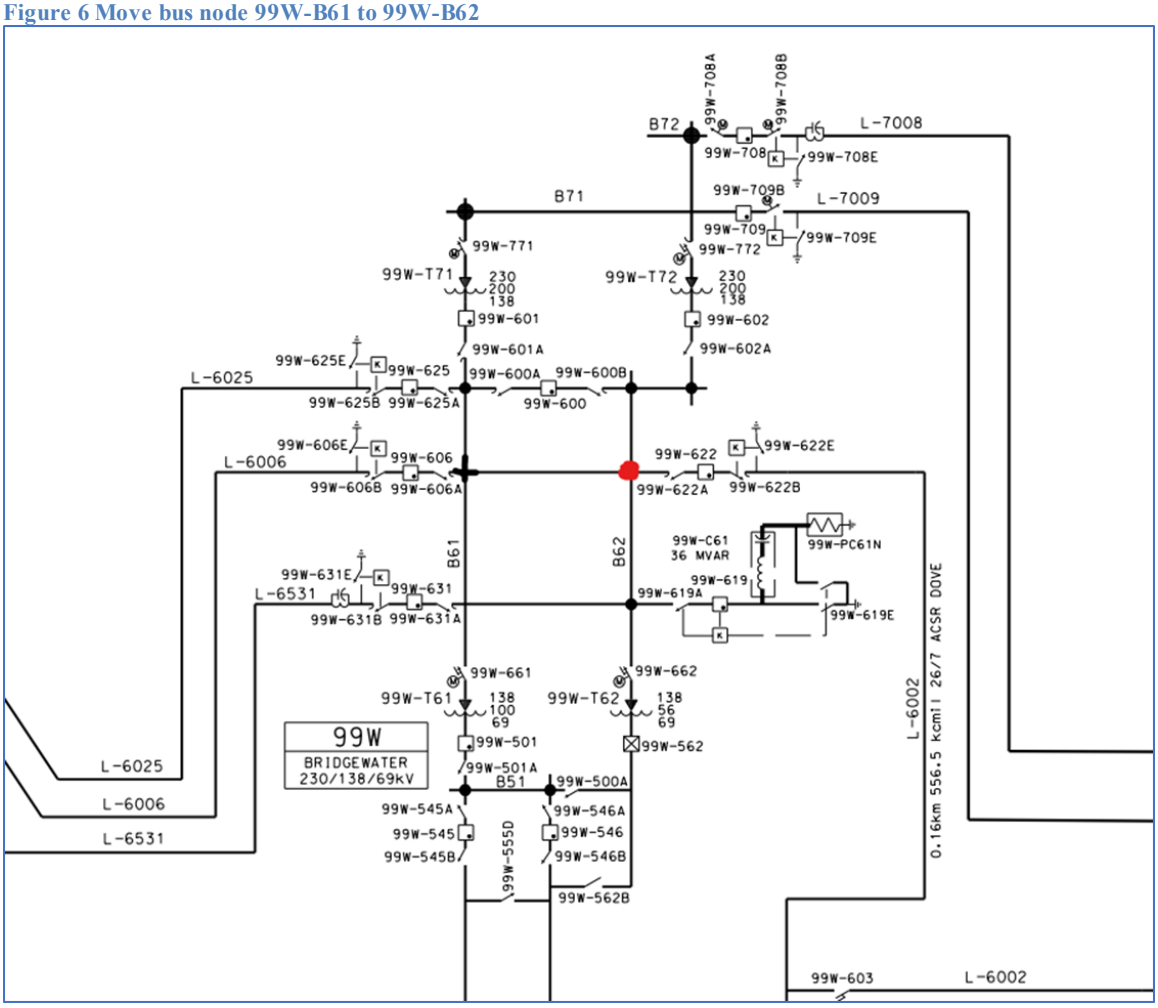
The following options were examined:

1. Increase the operating temperature of L-6531 from 50°C to 60°C at an estimated cost of $6,150,000 plus 10% contingency.

[2] 123% of its emergency rating if 10W-Tusket gas turbine generation is required for reserve.

2. Uprate line L-5026 by replacing 69kV switches, CT's and metering at 13V, 12V, 70V, and 11V, estimated at $500,000.
3. As an alternative to (1), move L-6006 to from bus 99W-B61 to 99W-B62 as shown in Figure 5. This would involve protection and control changes at 99W-Bridgewater and is estimated at $100,000.
4. The overloads associated with loss of the 138kV bus 50W-B4 can mitigated by ensuring that the three-breaker ring at the POI is designed for single-failure redundancy including dual trip coils, redundant station battery, and redundant telecommunications. A transfer-trip signal must be sent to the POI to isolate IR#635 at the POI for any operation (manual or automatic) of breaker 50W-624.

Figure 6 Move bus node 99W-B61 to 99W-B62



The recommended actions are (2), (3) and (4). For a loss of bus 99W-B61, L-6025 will open but L-6006 and L-6531 will remain in-service, eliminating the overload of L-6531. For loss of bus 50W-B4, IR#635 will be isolated by the transfer-trip protection scheme,

preventing the identified thermal overloads and voltage violations without the need to move L-6006 to bus 50W-B3, or the need to uprate L-6021.

7 Voltage Flicker and Harmonics

Flicker coefficient information was not provided for the Delta M250HV inverters. Voltage flicker will be further examined when data 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 2.5%, with no individual harmonic exceeding 1.5% on 138kV.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR#635 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. 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. Rated reactive power shall be available through the full range of real power output of the Generating Facility, from zero to full power. Based on the plant rating of 100 MW, this translates into a reactive capability of 33 Mvar leading and lagging.

The information provided by the IC indicates that the Delta M250HV inverters have a rated reactive power capability of approximately +/- 10 Mvar at 100 MW at a terminal voltage of 1.0 – 1.1 per unit. When the plant is operating below 80 MW, the reactive power capability range is +/-60 Mvar. Figure 7 shows how reactive capability varies with voltage and real power output. It is noted that this unit is not capable of reactive power control down to zero MW.

Analysis shown in Figure 8 shows that IR#635 would not be able to meet this requirement without additional reactive support at full rated power. The model shows that IR#635 operating at a total 100 MW and 10 Mvar at terminal voltage of 1.04 p.u., the delivered power to the high side of the ICIF transformer is 98.9 MW and 6.9 Mvar, or a power factor of 0.997. IR635 can meet the lagging power factor requirement of 0.95 when it is operating at or below 90 MW and can meet the leading power factor of 0.95 when it is operating at or below 95 MW.

Figure 7: Inverter Reactive Capability

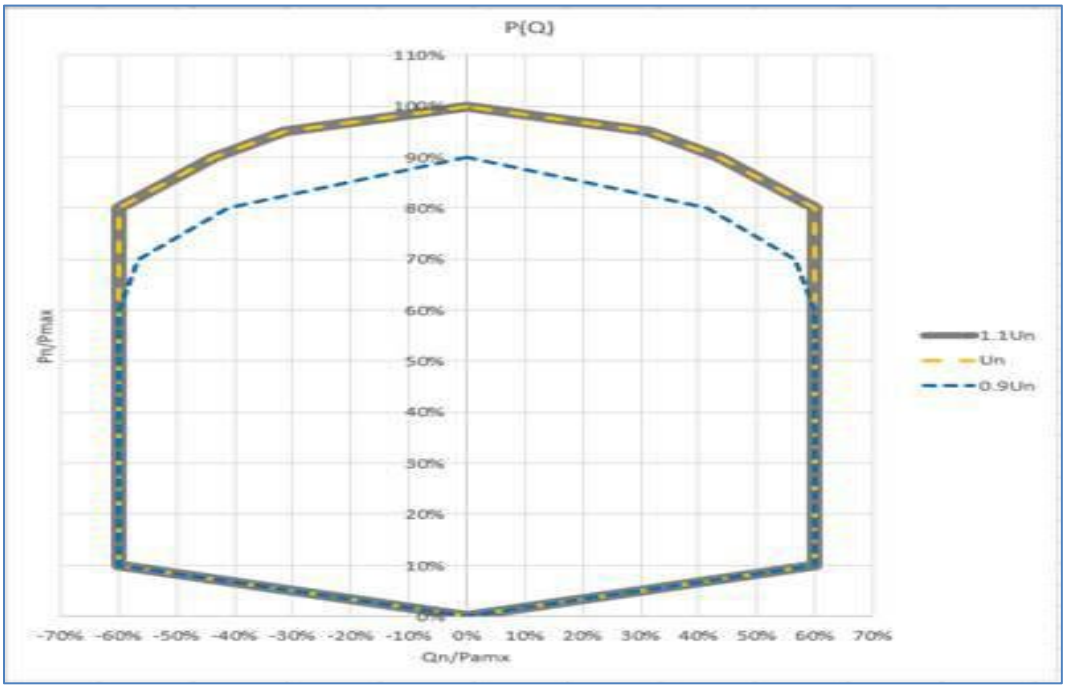
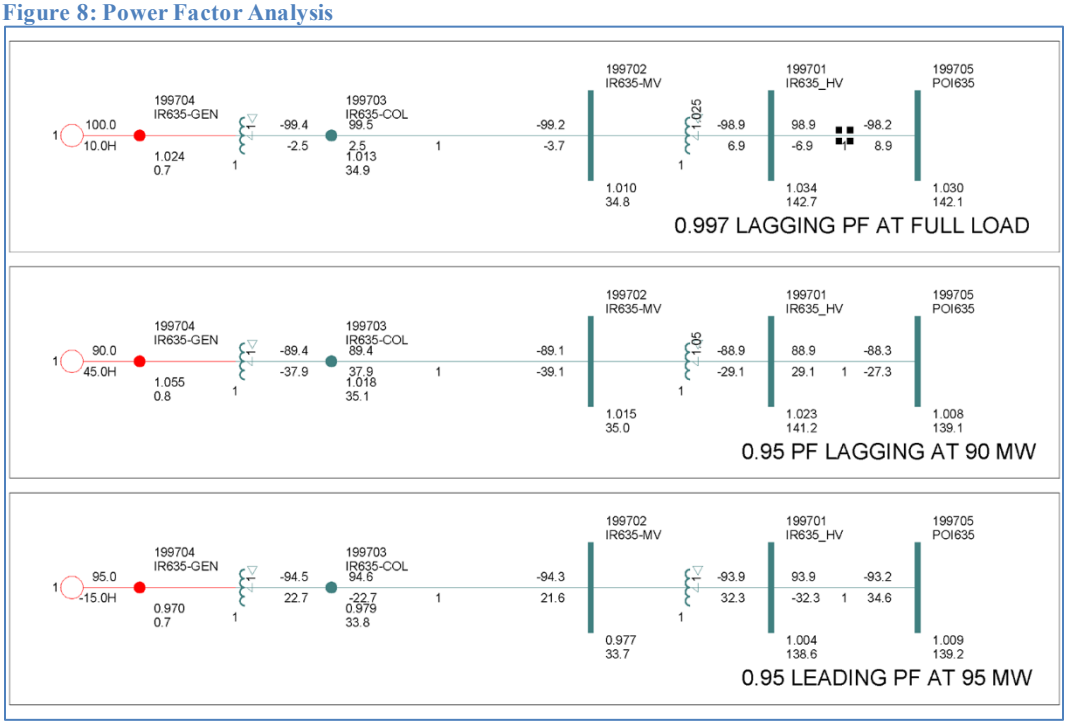


Figure 8: Power Factor Analysis



A centralized controller will be required which continuously adjusts individual generator reactive power output within the plant capability limits and regulates the voltage at the 34.5 kV bus voltage. The voltage controls must be responsive to voltage deviations at the

terminals of the Interconnection Facility substation; be equipped with a voltage set-point control; and also have the ability to slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual 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

Presently the 138kV buses at the 50W-Milton and the 9W-Tusket substations are not part of the Nova Scotia Bulk Power System (BPS) and will be further evaluated in the SIS phase. However, since IR#635 has dispersed generation totalling more than 75 MVA, Inclusion I4 of the NERC BES Definition would apply, and each inverter would be classified as a BES element. The IR#635 138kV bus would be classified as a BES element, including the 138kV – 34.5kV transformer and the 34.5kV bus.

There is the potential for an exclusion from BES to be granted for the high side (138kV) bus based on further analysis per the NS BES Exception Procedure. This analysis will be initiated as part of the System Impact Study (SIS) and exclusion from BES will only be granted upon subsequent approval by the Nova Scotia Utility and Review Board.

10 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#635 in service, losses in the winter peak case total 86.2 MW. With IR#635 in service at the POI at 9W-Tusket 138kV, displacing generation at 91H, and not including losses associated with the IR#635 Generation Facilities or TPIF Interconnection Facilities,

system losses total 84.9 MW, a decrease of 1.3 MW. The model shows power delivered to the POI is 98.9 MW, therefore the loss factor is calculated as -1.3/98.9 = -1.3%.

11 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR#635 to the NSPI transmission system at a POI at 9W-Tusket 138kV:

11.1 NRIS Requirements:

a. Required Network Upgrades

- Addition of a 138kV three-breaker ring bus at the POI on the high-voltage side of transformer 9W-T63 and L-6024, designed for single-failure redundancy including dual trip coils, redundant station battery, and redundant telecommunications.
- Modification of NSPI protection systems on L-6024 at 9W-Tusket and 50W-Milton to provide three-terminal protection scheme. This may require a change to differential protection scheme. Ensure that any operation of breaker 50W-624 transfer-trips to the POI breakers for the spur line to IR#635.
- Relocation of the terminal drop-leads of L-6006 and L-6002 from bus 99W-B61 to bus 99W-B62 at 99W-Bridgewater with associated protection modifications.
- Uprating L-5026 switches, CT's and metering at 13V, 12V, 70V, and 11V to match conductor maximum rating of L-5026.

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

- Add control and communications between the solar farm and NSPI SCADA system (to be specified).
- Build a spur line between the POI and IR#635, 13.0 km built to current NSPI standards. The IC is responsible for acquiring the right-of-way including environmental permitting for this spur line.

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 FEAS analysis confirmed the proposal that a 6 Mvar switched capacitor on the 34.5kV

bus would provide this capability, subject to further analysis with detailed collector circuit and transformer data.

- Centralized controls. These will provide centralized voltage set-point controls to control the 34.5 kV bus voltage and the reactive output of the inverters. 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.
- Real-time monitoring (including an RTU) of the interconnection facilities. Local solar conditions, 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.
- Automatic Generation Control to assist with tie-line regulation.

12 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting net 100 MW solar energy at the 138kV POI at 9W-Tusket 138kV are included in Table 5.

Table 5 Cost Estimate NRIS @ POI 9W-Tusket 138kV		
Item	**Network Upgrades**	**Estimate**
1	Install 138kV three-breaker ring bus at POI on L-6024 designed for single-failure redundancy	$6,250,000
2	P&C modifications to L-6024 at 50W-Milton and 9W-Tusket to redundant three-terminal protection	$750,000
3	Move termination of L-6006 and L-6002 at 99W-Bridgewater from bus 99W-B61 to 99W-B62	$100,000
4	Uprate L-5026 to meet conductor rating	$500,000
	Sub-total for Network Upgrades	$7,600,000
Item	**TPIF Upgrades**	
1	13 km 138kV spur line from POI to ICIF. The IC is responsible for providing ROW and environmental permits	$5,102,500
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	$5,412,500
	Total Upgrades NRIS	**Estimate**
	Network Upgrades + TPIF Upgrades	$13,012,500
	Contingency (10%)	$1,301,250
	Total (Incl. 10% contingency and Excl. HST)	$14,313,750

The preliminary non-binding cost estimate for interconnecting 100 MW at the POI at 9W-Tusket 138kV under NRIS is $14,313,750 including a contingency of 10%. Of this amount, $8,360,000. is for Network Upgrades, which are funded by the IC, but are eligible for refund under the terms of the GIA. The remainder of the costs are fully funded by the IC.

These estimates do not include costs to address any stability issues that may be identified at the SIS stage based on dynamic analysis.

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.

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR#635. 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 in order to assess the impacts. It is recognized the actual scope may deviate, to achieve the primary objectives.

The assessment will consider but not be limited to the following.

i. Facilities that the customer must install to meet the requirements of the GIP and the NSPI *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-8002
- L-7008
- L-7009
- Simultaneous loss of L-7008 + L-7009
- Buses at 50W and 99W
- Loss of largest generation source in NS

- Loss of Maritime Link

To complete this assessment the dynamics of the following first contingencies, as a minimum, will be assessed:

- 3 phase fault L-8001 with high NS import from NB (islanding)
- 3 phase fault L-8002 at 67N-Onslow
- Simultaneous SLG on L-7008 & L-7009 double circuit tower at 120H-Brushy Hill
- SLG fault on breaker 99W-600 or 50W-600, with load loss
- 3 phase fault on buses 99W-B61, 99W-B62, 50W-B2, 50W-B4

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

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