



Interconnection Feasibility Study Report GIP-IR608-FEAS-R2

**Generator Interconnection Request 608
79.8 MW Wind Generating Facility
Shelburne County, NS**

2022-03-31

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR#608) for Network Resource Interconnection Service (NRIS) or Energy Resource Interconnection Service (ERIS) for a proposed net 79.8 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2023-12-01. The Point of Interconnection (POI) requested by the customer is the 138kV line L-6020, with an alternate POI at the 138kV substation 30W-Souriquois. The proposed primary POI is approximately 2 km from 30W-Souriquois, 55 km from 50W-Milton. The alternate POI would be considered if unexpected results not contemplated in the Scoping Meeting are found with the primary POI. The Interconnection Customer's Interconnection Facility (ICIF) is adjacent to the POI, and therefore a 138kV radial spur line will not be required.

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#608. 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#608 will displace coal-fired generation in eastern Nova Scotia for both NRIS and ERIS.

Since L-6020 is not classified as Bulk Power System and given that the ICIF is adjacent to the POI, then a direct line tap with protection would meet the NSPI Transmission System Interconnection Requirements Table 8.

The load flow assessment of the POI indicated that under certain operating conditions multiple transmission lines and transformers could exceed emergency operating limit for contingencies at 99W-Bridgewater, 50W-Milton, and 9W-Tusket. The recommended Network Upgrades include:

- Install a line-tap 138kV circuit breaker with single-failure redundancy as TPIF at the POI.
- Move the 99W-Bridgewater terminals of L-6006 and L-6002 from bus B61 to bus B62.
- Move the 50W-Milton terminal of L-6006 from 50W-B4 to 50W-B3.
- Uprate the operating temperature of L-6020 (section from POI to 50W-Milton) from 50°C to 70°C, and metering at 50W-Milton end to match the conductor rating.
- Install three-terminal protection for line L-6020/L-6021 with transfer trips and interlocks.

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If ERIS is selected, IR#608 shall be limited to a maximum of 65 MW with restrictions to zero MW under certain load/generation patterns, expected to occur 40 hours per year.

Because IR#608 is a dispersed generation facility in excess of 75 MVA, Inclusion I4 of the NERC BES Definition would apply, and each generator 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.

Based on the rated power factor of the Nordex N149 5.7 MW wind turbines, the impedances of the transformers and a typical equivalent collector circuit model, the requirement to meet a net power factor of +0.95 to -0.95 at the Interconnection Facility 138kV bus may require a 12 Mvar capacitor bank to be installed on the 34.5 kV bus. This is to be confirmed in the SIS stage.

No issues regarding high short-circuit level impacting the interrupting capability of existing circuit breakers was found for this project on its own. The minimum short circuit level at the Interconnection Facility 138kV bus is 407 MVA with all lines in service, 368 MVA with L-6021 open at 9W-Tusket, and 364 MVA with L-7009 open at 99W-Bridgewater. The calculated minimum Short Circuit Ratio (SCR) at the high voltage terminals of the Interconnection transformer was found to be 4.6.

The Nordex N149 5.7 MW wind turbines are classified as Type 3, Doubly Fed Induction Generators, and therefore voltage flicker can be a concern with low SCR. Based on the flicker coefficient data provided, the calculated value $P_{st} = P_{lt} = 0.26$ does not exceed NSPI's requirement of $P_{st} = 0.35$ and slightly exceeds the requirement of $P_{lt} = 0.25$. IR#608 would not be permitted to operate in series with 30W-T62 due to low short circuit level and excessive voltage flicker.

The preliminary value for the unit loss factor is calculated as -1.5% at the POI on L-6020. Losses associated with the IC facilities (spur line, collector circuits, transformers) are excluded from this calculation.

It was noted that the proposed winding configuration of the ICIF station transformer is grounded wye / delta rather than the more commonly used grounded wye / grounded wye with delta tertiary.

The preliminary non-binding cost estimate for interconnecting net 79.8 MW to the POI on L-6021 as NRIS, including a 138kV line-tap with circuit breaker incorporating transfer-trip for L-6020/L-6021 is \$13,912,800. 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, \$11,701,800 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.

The estimated cost for interconnection of IR#608 under ERIS is \$1,661,000 including 10% contingency. Of this amount, Network Upgrade costs of \$770,000 for conversion of L-6020/L-

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6021 line protection to three-terminal protection scheme, and is funded by the IC but eligible for a refund under the terms of the GIP. The remainder of the costs are fully funded by the IC. Under ERIS, IR#608 shall be limited to a maximum of 65 MW with a restriction to zero MW during certain dispatch and load conditions, expected to occur 40 hours per year.

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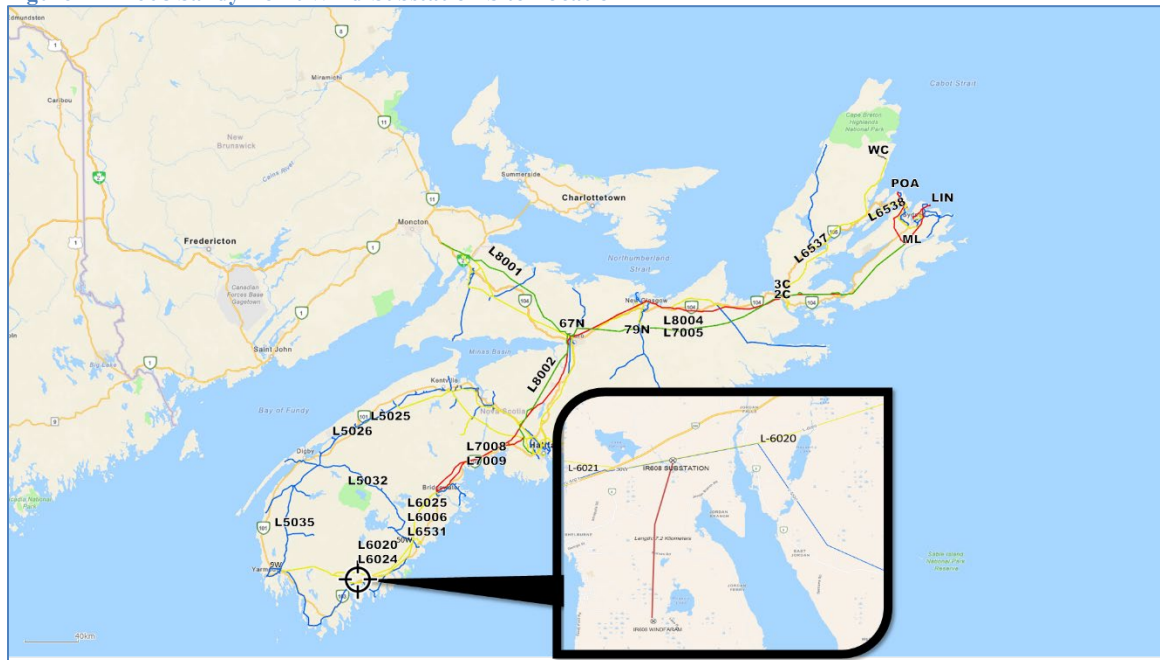
1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request for Network Resource Interconnection Service (NRIS) or Energy Resource Interconnection Service (ERIS) for a proposed 79.8 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2023-12-01. The Point of Interconnection (POI) requested by the customer is the 138kV circuit L-6020, with an alternate POI at the 138kV substation 30W-Souriquois. 30W-Souriquois is currently T-tapped on L-6020/L-6021, with the line designated as L-6021 to the west and L-6020 to the east of 30W-Souriquois. There is a 138kV – 69kV transformer at 30W-Souriquois with a top rating of 25 MVA. The proposed Interconnection Customer’s Interconnection Facility (ICIF) is located on the south side of the right-of-way for L-6020, approximately two kilometers east of 30W-Souriquois. The primary POI would be near structure L-6020-273 approximately 55 km from the 50W-Milton 138kV substation and 61 km from the 9W-Tusket substation.

There are no 138kV buses or 138kV circuit breakers 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. The transformers have a top rating of 56 MVA.

Figure 1 shows the proposed geographic location of IR#608 in relation to the NSPI transmission system.

Figure 1 IR#608 Sandy Point Wind Substation Site Location



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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)

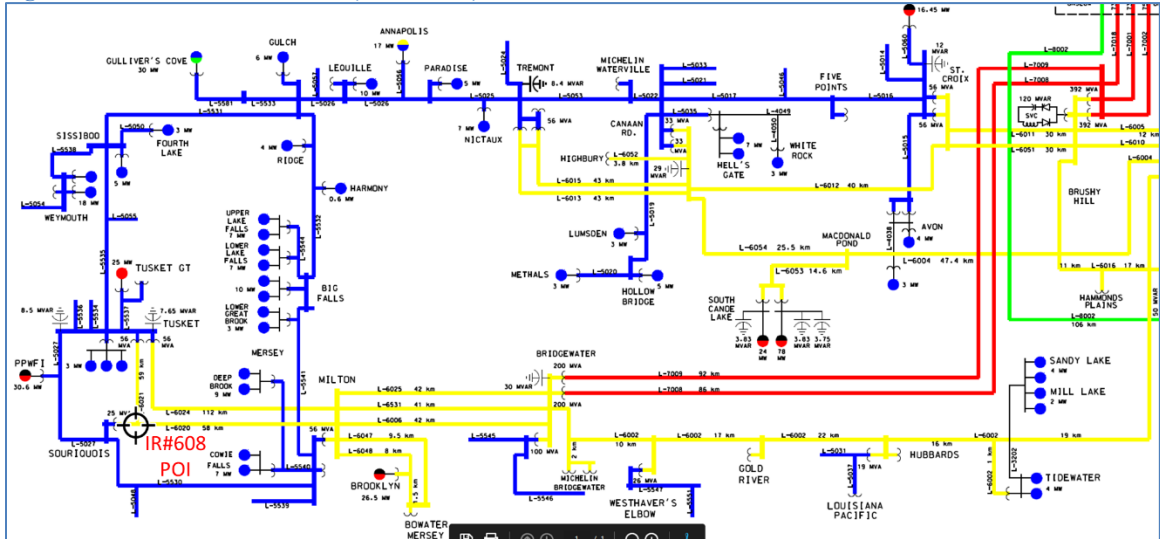
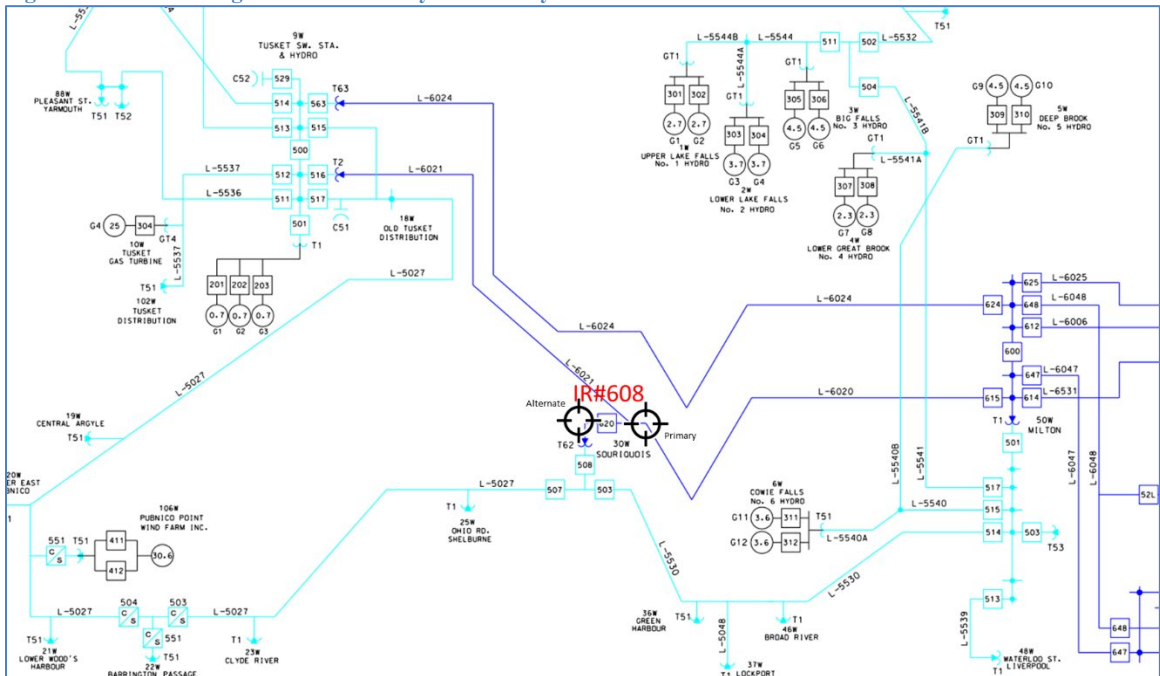


Figure 3 Circuit Configuration in Vicinity of Primary and Alternate POI



The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2021-12-22, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 608 in the NSPI Interconnection Request Queue and will be referred to as IR#608 throughout this report. The study is to include ERIS as well as NRIS.

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.

In accordance with Section 6.1 of the Generator Interconnection procedures (GIP), the alternate POI is only studied if the FEAS uncovers unexpected results not contemplated during the Scoping Meeting.

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#608. 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).

¹ [transmission-system-interconnection-requirements \(nspower.ca\)](https://www.nspower.ca/transmission-system-interconnection-requirements)

- 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#608 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.

The ERIS study identifies necessary upgrades to allow full output of the proposed Generating Facility and the maximum allowed output, at the time the study is performed, of the interconnecting Generating Facility without requiring additional Network Upgrades.

The alternate POI will only be assessed if issues arise with the primary PO which were unforeseen in the scoping meeting.

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 and ERIS per section 3.2 of the GIP.
2. Commercial Operation date 2023-12-01.
3. The Interconnection Customer Interconnection Facility (ICIF) consists of 14 Wind Energy Converter System (WECS) units, Nordex N149 5.7 MW, 750V, Type 3 (DFIG: Doubly-Fed Induction Generator), connected to four collector circuits operating at a voltage of 34.5kV. The total plant rating is 79.8 MW.
4. The proposed POI on L-6020 is considered non - Bulk Power System network line. Given that the ICIF substation is close to the POI, direct line tap with protection would be used in accordance with Table 8 of the TSIR.
5. 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.

6. Preliminary data was provided by the IC for the IC substation transformer, consisting of one 138kV-34.5kV 75/90 MVA transformer. The substation transformer was modeled with a positive-sequence impedance of 12.5% on 75 MVA with an assumed X/R ratio of 20. The IC indicated that this Interconnection Facility step-up transformer has a grounded wye-delta winding configuration with +/-15% on-load tap changer in 19 steps. The impedance of each generator step-up transformer was not provided, and therefore typical data was assumed ($Z_+ = 10\%$ on 6.5 MVA with an X/R ratio of 11). Section 7.6.1 of the TSIR states “The winding configuration for a Generating Facility with medium voltage collector circuit and multiple generators is *generally* grounded-wye on the high side and grounded-wye on the low side, with a delta tertiary winding”, however, the proposed grounded wye – delta configuration will be considered subject to system protection requirements.
7. A detailed equivalent collector circuit model was not provided so an estimated model based on 600 mm² conductors was used, with a positive sequence impedance of 0.013 +j0.065 (per unit on 100 MVA).
8. 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.
9. Rated operating temperature for the WECS was not provided, so it is assumed they are suitable for delivering full power under expected Nova Scotia winter environmental conditions of -30°C as per the NSPI TSIR.
10. 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.
11. The rating of transmission elements in the vicinity of IR#608 are shown in Table 1.

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#608 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

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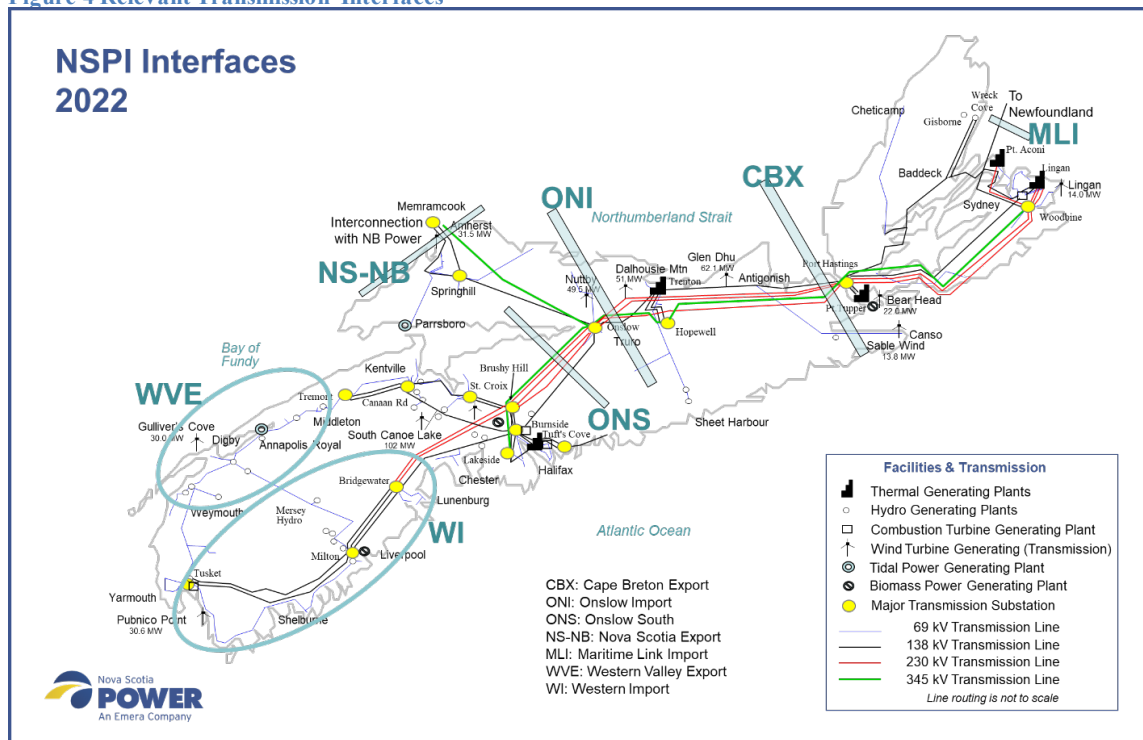
service request is expected to be in service in 2025 and system studies are currently underway to determine the required upgrades to the Nova Scotia transmission system. As a result, the following notice has been posted to the OASIS site at <https://www.nspower.ca/oasis/generation-interconnection-procedures>:

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5 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 4 shows the relevant interfaces on the NSPI transmission system.

Figure 4 Relevant Transmission Interfaces



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Transmission connected wind generation facilities were typically dispatched at approximately 40%, except in the vicinity of IR#608. There is high co-relation between wind plants in western NS between Digby, Yarmouth and Halifax, so it is reasonable to expect that these other wind plants would be near full output when IR#608 is at rated output.

The Western region of Nova Scotia is sensitive to the balance between 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#608 takes this into consideration.

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#608	Wind
SP01-1	335	1350	20	513	-9	71	9	0	231
SP01-2	335	1350	20	433	-9	-6	9	79.8	311
SP02-1	0	890	140	327	56	13	43	0	161
SP02-2	0	890	140	248	56	-61	43	79.8	241
SP03-1	330	1350	20	523	-9	40	9	0	229
SP03-2	330	1350	20	443	-9	-37	9	79.8	309
SP04-1	330	1350	20	391	-9	73	9	0	356
SP04-2	330	1350	20	311	-9	-4	9	79.8	436
WP01-1	170	2200	124	840	-17	121	20	0	323
WP01-2	170	2200	124	769	-17	42	20	79.8	403
WP02-1	0	2200	68	860	-23	105	18	0	328
WP02-2	0	2200	68	770	-23	27	18	79.8	408

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

Line L-6020/L-6021 from the POI to 9W-Tusket is limited by the 72 MVA switch and the 56 MVA top rating of the transformer 9W-T2. Line L-6020 between the POI and 50W-Milton is limited by the sag rating of the conductor to 82 MVA in summer, with an emergency rating of 90 MVA. The winter rating is 115 MVA based the metering at 50W-Milton which, if uprated would provide a winter rating of 121 MVA continuous, 133 MVA emergency based on the conductor design.

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For both NRIS and ERIS analysis, this FEAS added IR#608 and displaced an equivalent amount of coal-fired generation in Cape Breton. Single contingencies were applied at the 230kV, 138kV, and 69 kV voltage levels for the above system conditions with IR#608 interconnected to the POI on L-6020. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 4. It should be noted that some contingencies can result in the separation of the western transmission system, unrelated to IR#608.

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#608 connected to L-6020 via a line tap, several contingencies resulted in thermal overloads of transmission elements:

1. Loss of bus 99W-B61 causes lines L-6025 and L-6006 to open at 99W-Bridgewater, leaving L-6531 loaded up to 112% of its emergency rating in case SP02-2 (high hydro dispatch with 10W-Tusket CT delivering reserve). This same condition would exist for tripping of the transformer 99W-T61.
2. Loss of bus 50W-B4 causes lines L-6048, L-6025, L-6006 and L-6024 to open at 50W-Milton resulting in L-6020 at 108% and L-6531 at 109% of their respective emergency ratings.
3. Loss of bus 50W-B3 causes lines L-6531, L-6020, L-6047 and transformer 50W-T-1 to open at 50W-Milton, resulting in multiple significantly overloaded elements:
 - a. L-6021: 107%
 - b. 9W-T2: 151%
 - c. 9W-T63: 189%
 - d. L-6024: 134%
 - e. L-5532: 117%
 - f. L-5026: 130%
 - g. Voltage < 90% in the Tusket area
4. Opening of breaker 50W-501 results in L-6020 at 103% - 112%
5. Opening of breaker 50W-615 results in overloaded transformers: 9W-T63 at 105% - 134%, 30W-T62 at 144% - 164% and 50W-T1 at 116% - 126%.

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. Develop a 138kV split bus at 9W-Tusket with three 138kV breakers and associated switches. This will require uprating L-6020 and L-6021 from 50°C to 70°C. Estimated cost is \$23,700,000 plus 10% contingency.
3. As an alternative to (1), move L-6006 to bus 99W-B62 and bus 50W-B3 as shown in Figures 5 and 6. This would involve protection and control changes at 99W-Bridgewater and re-routing of L-6006 around bus 50W-B4 to bus 50W-B3 and is estimated at \$1,600,000.
4. As an alternative to (2):
 - a. For the section of L-6020 between the POI and 50W-Milton, uprate the conductor from 50°C to 70°C and change the metering CT ratio at the 50W-Milton end of L-6020 to 600:5. Estimated cost is \$8,338,000.
 - b. Install transfer-trip protection to the new breaker at the POI. This circuit breaker will be designated as TPIF and shall be designed for single-failure redundancy including dual trip coils, redundant station battery, and redundant telecommunications. Any operation (manual or protection) of breaker 50W-615, including bus protection at 50W-B3 transfer-trips to the POI of IR#608. Estimated cost is \$700,000.

The recommended actions are (3), and (4). For a loss of 138 kV buses 30W-B4 or 99W-B61, L-6025 will open but L-6006 and L-6531 will remain in-service, eliminating the overload of L-6531. For opening of 50W-615 for any reason including loss of bus 50W-B3 or 50W-T1, IR#608 will be isolated by the transfer-trip protection scheme, preventing the identified thermal overloads and voltage violations. For loss of 50W-B4, L-6024, 9W-T63, or bus 9W-B53, uprating line L-6020 will eliminate the identified overload.

ERIS Results

To avoid the thermal limit violations encountered in the NRIS analysis, IR#608 could operate under ERIS at up to 65 MW without the need for transmission limit upgrades, except for spring run-off hydro conditions, where IR#608 would be limited to zero MW. This latter condition is expected to occur 40 hours per year.

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Figure 5 Move L-6006 and L-6002 to 99W-B62

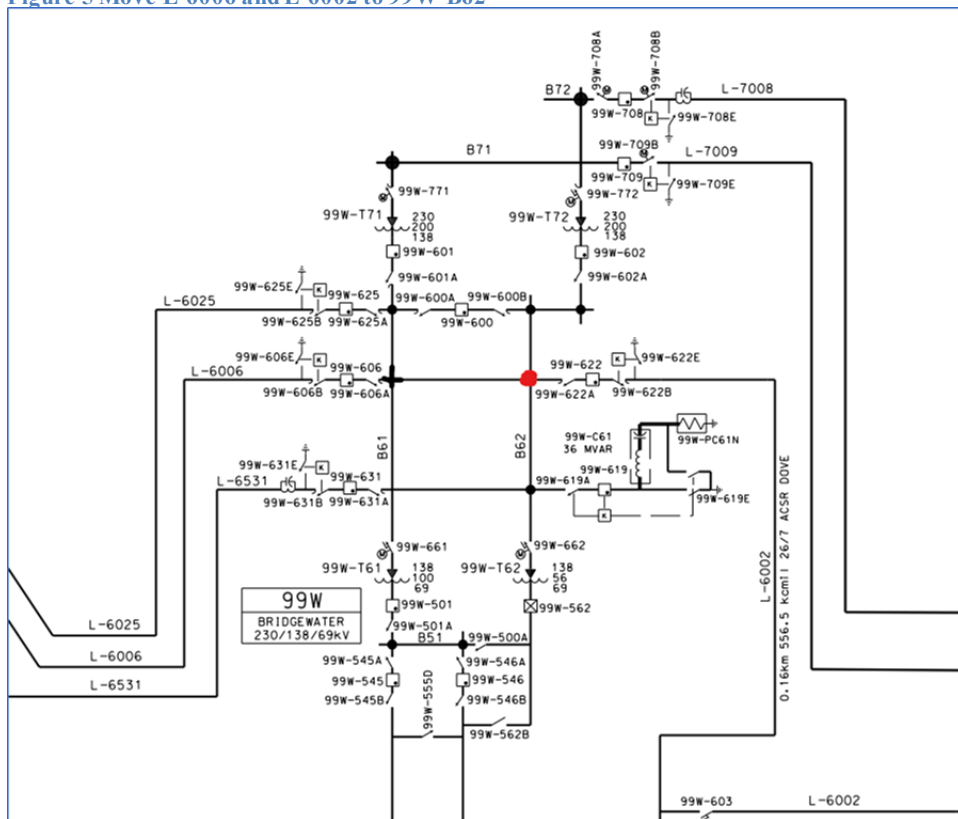
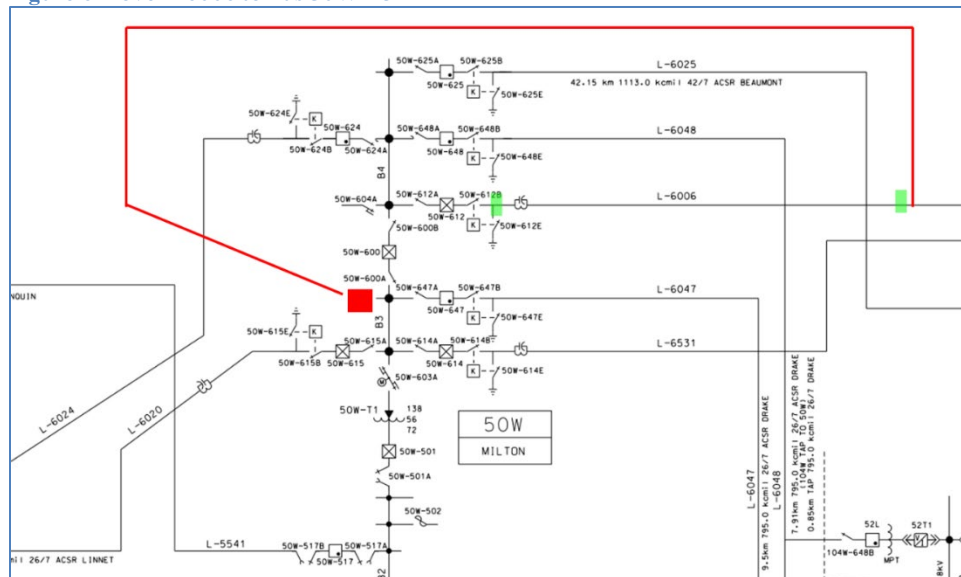


Figure 6 Move L-6006 to Bus 50W-B3



6 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 equivalent short circuit characteristics for the Nordex N149 5.7 MW DFIG units are provided as $X'd = 0.319$ per unit and $X''d = 0.245$ per unit.

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.

Table 2: Short-Circuit Levels. IR#608 @ L-6020 Three-phase MVA ⁽¹⁾		
Location	Without IR#608	With IR#608
All transmission facilities in service		
Interconnection Facility (138kV)	585	726
50W-Milton (138kV)	1255	1354
30W-Souriquois (138kV)	579	713
Minimum Conditions (PA1, LG1, ML In-Service)		
Interconnection Facility (138kV), all lines in-service	407	563
Interconnection Facility (138kV), L-6021 open at 9W-Tusket	368	524
Interconnection Facility (138kV), L-7009 open	364	521

(1) Classical fault study, flat voltage profile

The interrupting capability of the 138kV circuit breakers is at least 3500 MVA at 50W-Milton and the 138kV breaker at 30W-Souriquois is rated at 4500 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 on 30W-B61, and a 79.8 MW installation consisting of 14 units each 5.7 MW, the minimum SCR would be 5.1 at the HV terminals of the IR#608 transformer with all lines in service and IR#608 off line. This falls to 4.6 with L-6021 open at 9W-Tusket, and 4.6 if L-7009 is open at 99W-Bridgewater.

The equivalent system phase angle at the high voltage terminals of the ICIF is 77° at minimum and maximum short circuit levels.

7 Voltage Flicker and Harmonics

Type 3 (DFIG) machine which are known to have higher flicker coefficient than Type 4 wind turbines and therefore voltage flicker was examined in detail. The Nordex N149 5.7 MW WECS flicker parameters are shown in Table 5.

Table 5 Parameters for Flicker Calculations	
Parameter Description	Value
Number of turbines	14
Effective power (MW)	5.7
Flicker Coefficient $c_i(\Psi_k, v_a)$ $\Psi_k=77^\circ$	4.0
Flicker Step Factor $k_f(\Psi_k)$	0.2
Switching Operation, 10-min N_{10}	1
Switching Operation, 120-min N_{120}	12
Minimum short circuit level 138kV (MVA)	364
Minimum short circuit level 34.5kV (MVA)	226

Table 6 Flicker Values at 138kV bus	
<i>Continuous Operation</i>	
$P_{st} = P_{lt}$	0.26
<i>Switching Operation</i>	
P_{st}	0.12
P_{lt}	0.12

The calculated flicker values shown in Table 6 show that IR#608 does not exceed NSPI's requirement of $P_{st} = 0.35$ and slightly exceeds the requirement of $P_{lt} = 0.25$. There may be operational limits with L-6021 open at 9W-Tusket.

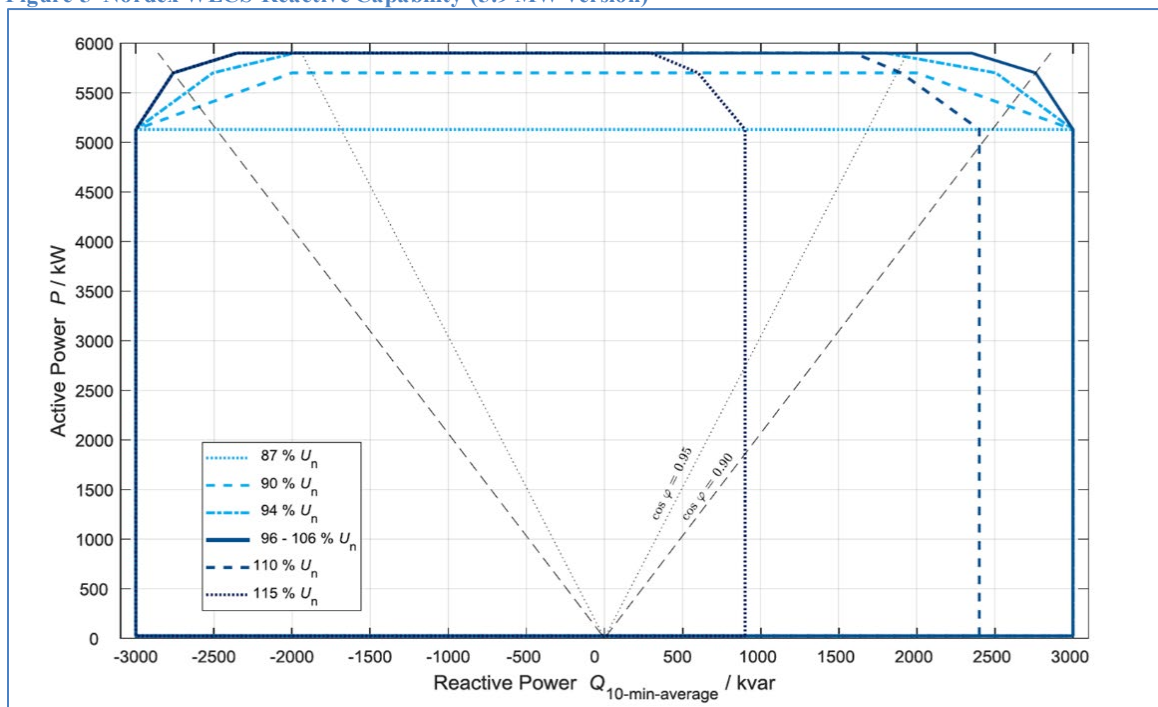
The generator is expected to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion (all frequencies) to a maximum of 1.5%, with no individual harmonic exceeding 1.5% on 138kV.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR#608 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 IC. 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 79.8 MW, this translates into a reactive capability of 31 Mvar leading and lagging.

The information provided by the IC indicates that the Nordex N149 5.7 MW WECS have a rated power factor of 0.90 lagging and 0.90 leading at a terminal voltage of 0.95 - 1.05 p.u. Based on the plant capability of 79.8 MW, this translates into a gross reactive power range of -38 Mvar to +38 Mvar. Figure 8 shows how reactive capability varies with voltage and real power output.

Figure 5 Nordex WECS Reactive Capability (5.9 MW version)



Analysis shown in Figure 9 shows that IR#608 may not be able to meet this requirement without additional reactive support. The model shows that with 14 WECS units operating at a total 79.8 MW and 38 Mvar at terminal voltage of 1.045 p.u., the delivered power to the high side of the ICIF transformer is 77.6 MW and 13.7 Mvar, or a power factor of 0.985. To meet the requirement of 0.95, a fixed capacitor bank rated at 12 Mvar installed on the low voltage side of the ICIF transformer is suggested.

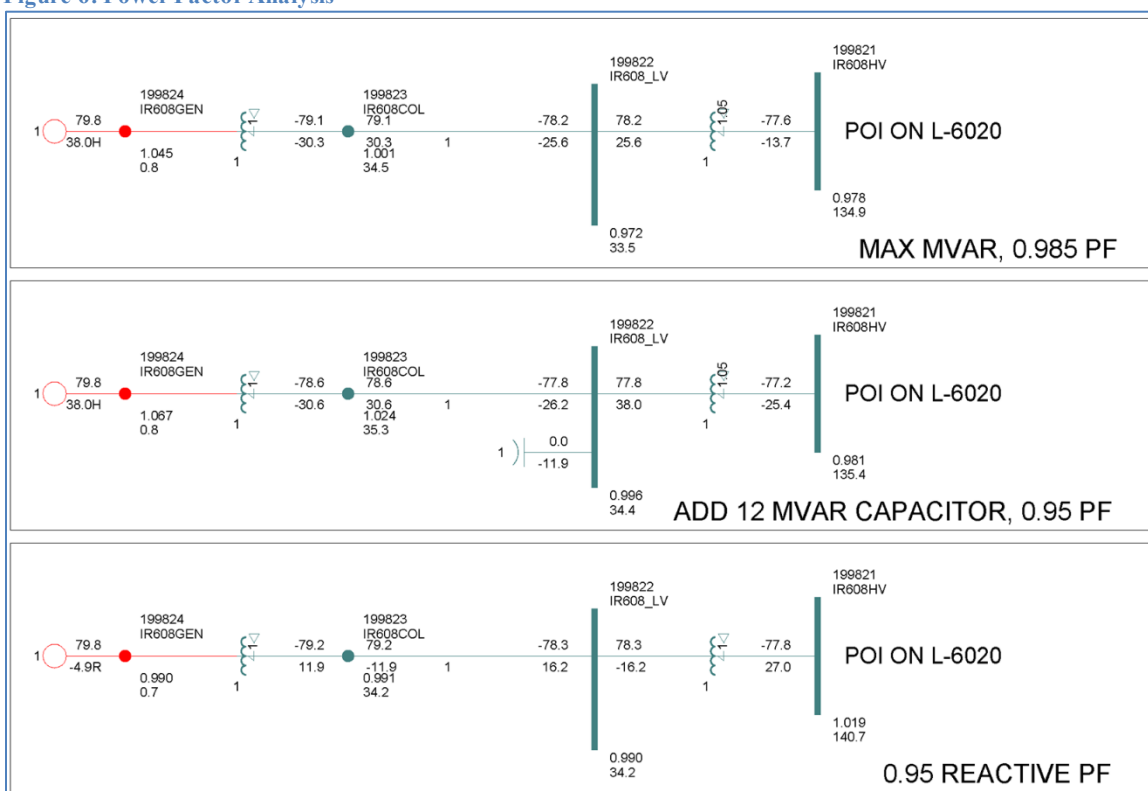
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This configuration would be able to meet the leading power factor requirement while WECS are operating at 79.8 MW and -4.9 Mvar with the capacitor bank switched off.

Reactive power capabilities will be reviewed in the SIS stage when the full collector circuit impedance data is available.

Figure 8 indicates that the full reactive power range extends to standstill (zero MW). Nordex documentation indicates that this feature is a STATCOM option for model N149/5.7. Section 7.6.2 of the NS TSIR requires this feature to be provided.

Figure 6: 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 30W-Souriquois, 50W-Milton and 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#608 has dispersed generation totalling more than 75 MVA, Inclusion I4 of the NERC BES Definition would apply, and each generator would be classified as a BES element. The IR#608 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#608 in service, losses in the winter peak case total 86.2 MW. With IR#608 in service at the POI of L-6020, displacing generation at 91H, and not including losses associated with the IR#608 Generation Facilities or TPIF Interconnection Facilities, system losses total 84.9 MW, a decrease of 1.2 MW. The model shows power delivered to the POI is 77.6 MW, therefore the loss factor is calculated as $-1.2/77.6 = -1.5\%$.

11 Expected Facilities Required for Interconnection

The alternate POI at 30W-Souriquois was not considered as there were no unforeseen issues with the primary POI.

The following facility changes will be required to connect IR#608 to the NSPI transmission system at a POI on L-6020:

11.1 NRIS Requirements:

a. Required Network Upgrades

- Modification of NSPI protection systems on L-6020/L-6021 at 50W-Milton and 9W-Tusket to provide three-terminal protection scheme. This may require a change to differential protection scheme. Provide an interlock scheme that will prevent IR#608 from operating while connected to the transformer 30W-T62 with breakers 50W-615 and 9W-563 open to limit load on 30W-T62 and limit voltage flicker.
- Add a transfer-trip scheme that will trip the 138kV circuit breaker at the POI for any operation (manual or automatic) of breaker 50W-615.
- 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.
- Re-route the western end of L-6006 around bus 50W-B4 to terminate on bus 50W-B3, with appropriate changes to protection.
- Upgrade the conductor sagrating of L-6020 from the POI to 50W-Milton from 50°C to 70°C, with a change in the CT ratio at 50W-Milton to match the conductor rating.

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

- Install a 138kV line tap with single breaker at the POI on L-6020. The IC is required to provide the necessary land and the access road.
- Add 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 FEAS analysis identified that a 12 Mvar capacitor bank 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 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.
- 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 (fast frequency response) controls within the WECS.
- Automatic Generation Control to assist with tie-line regulation.
- A cold-weather package permitting the WECS and associated equipment to operate to -30°C.
- Nordex STATCOM option for model N149/5.7 to permit full reactive power from standstill (zero MW) to full load.

11.2 ERIS Requirements:

To avoid the Network Upgrades identified for NRIS, IR#608 will always be restricted to a maximum of 65 MW, with a limit of zero MW during certain load and generation conditions, estimated to occur approximately 40 hours per year. The TPIF will not include a 138kV line-tap circuit breaker if the ICIF includes a circuit breaker or circuit switcher suitable for energizing and de-energizing the ICIF station transformer with L-6020 energized, and is suitable for incorporation into the three-terminal line protection for L-6020/L-6021. The other requirements of the TPIF and ICIF noted in 11.1 apply to ERIS as well.

12 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnection Facilities and Network Upgrades for interconnecting net 79.8 MW wind energy at the 138kV POI at L-6020 are included in Table 5 (NRIS) and Table 6 (ERIS).

Table 5 Cost Estimate NRIS @ POI L-6020		
Item	Network Upgrades	Estimate
1	P&C modifications to L-6020/L-6021 at 50W-Milton and 9W-Tusket to three-terminal protection, designed for single-failure redundancy. Transfer trip to line tap circuit breaker at POI for any operation of 50W-615	\$700,000
2	Move termination of L-6006 and L-6002 at 99W-Bridgewater from bus 99W-B61 to 99W-B62	\$100,000
3	Route L-6006 from bus 50W-B4 to 50W-B3	\$1,500,000
4	Uprate L-6020 between POI and 50W-Milton from 50°C to 70°C and change metering CT ratio at 50W to meet conductor rating	\$8,338,000
	Sub-total for Network Upgrades	\$10,638,000
Item	TPIF Upgrades	Estimate
1	Install 138kV line tap with single circuit breaker at POI on L-6020	\$1,700,000
2	NSPI P&C relaying equipment	\$100,000
3	NSPI supplied RTU	\$60,000
4	Tele-protection and SCADA communications	\$150,000
	Sub-total for TPIF Upgrades	\$2,010,000
Total Upgrades NRIS		Estimate
	Network Upgrades + TPIF Upgrades	\$12,648,000
	Contingency (10%)	\$1,264,800
	Total (Incl. 10% contingency and Excl. HST)	\$13,912,800

Table 6 Cost Estimate ERIS @ POI L-6020		
Item	Network Upgrades	Estimate
1	P&C modifications to L-6020/6021 at POI, 50W-Milton and 9W-Tusket to three-terminal protection	\$700,000
	Sub-total for Network Upgrades	\$700,000
Item	TPIF Upgrades	Estimate
1	Direct line tap L-6020, conditional on IC providing high-side ICIF circuit breaker for transfer-trip	\$500,000
2	NSPI P&C relaying equipment	\$100,000
3	NSPI supplied RTU	\$60,000
4	Tele-protection and SCADA communications	\$150,000
	Sub-total for TPIF Upgrades	\$810,000
	Total Upgrades ERIS	Estimate
	Network Upgrades + TPIF Upgrades	\$1,510,000
	Contingency (10%)	\$151,000
	Total (Incl. 10% contingency and Excl. HST)	\$1,661,000

The preliminary non-binding cost estimate for interconnecting 79.8 MW at the POI at L-6020 under NRIS is \$13,912,800 including a contingency of 10%. Of this amount, \$11,701,800 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.

The preliminary non-binding cost estimate for interconnecting 79.8 MW at the POI at L-6020 under ERIS is \$1,661,000 including a contingency of 10%. Of this amount, \$770,000 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. Under ERIS, IR#608 shall be limited to a maximum of 65 MW, with a restriction to zero MW during certain dispatch and load conditions, expected to occur 40 hours per year.

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#608. 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

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- Simultaneous SLG on L-7008 & L-7009 double circuit tower at 120H-Brushy Hill
- 3 phase fault on buses 99W-B61, 99W-B62, 50W-B2, 50W-B2, 50W-B4, 9W-B52, and 9W-B53.

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 NERC² and NPCC³ 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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² NPCC criteria are set forth in its Reliability Reference Directory #1 *Design and Operation of the Bulk Power System*

³ NERC transmission criteria are set forth in *NERC Reliability Standard TPL-001-4*