Interconnection Feasibility Study Report
GIP-IR628-FEAS-R1

Generator Interconnection Request 628
80 MW Wind Generating Facility
Yarmouth County, NS

2022-03-30

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR#628) for Network Resource Interconnection Service (NRIS) for a proposed net 80 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2024-03-31. The Point of Interconnection (POI) requested by the customer is the 138kV line L-6021, with an alternate POI at the 69kV line L-5536. The proposed primary POI is adjacent to the 9W-Tusket substation, and the alternate POI is approximately 7 km from 9W-Tusket The Interconnection Customer's Interconnection Facility (ICIF) is approximately 20 km from the primary POI on L-6021, requiring a 138kV radial spur line. The ICIF is approximately 11 km from the alternate POI on L-5536, and therefore a 69kV radial spur line would 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#628. 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#628 will displace coal-fired generation in eastern Nova Scotia for NRIS.

Preliminary analysis of the primary POI on L-6021 determined that the conductor is insufficiently rated for IR#628 plus existing Tusket area generation, and the entire length of L-6021 and L-6020 (116 km) would need to be thermally uprated from an operating temperature of 50°C to 70°C in addition to other identified transmission changes.

Analysis of the alternate POI on the 69kV Tusket system concluded that, since IR#628 would add 80 MW to the existing 66 MW of generation on that system, the existing transformers at 9W-Tusket would be significantly overloaded for a number of contingencies, and the substation would need re-design and expansion, in addition to the re-conductoring of L-5536 between the POI and 9W-Tusket and other transmission upgrades.

In accordance with Section 6.1 of the GIP, the Transmission Provider proposed a substitute POI on the line L-6024 adjacent to the 9W-Tusket substation. This was accepted by the IC.

Since L-6024 is not classified as a Bulk Power System and given that the spur line is greater than 10% of the length of L-6024, a three-breaker ring bus would be required in accordance with the NSPI Transmission System Interconnection Requirements.

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

- Move the 99W-Bridgewater terminals of L-6006 and L-6002 from bus B61 to bus B62.
- Install three-terminal protection for line L-6024 with transfer trips and interlocks to prevent IR#628 from overloading Tusket transformers. Ensure the three-breaker ring bus at the POI is built for single failure redundancy.
- Uprate line L-5026 by replacing 69kV switches, CT's and metering at 13V, 12V, 70V, and 11V.

Because IR#628 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 GE 130-3.8 MW wind turbines, with the enhanced power factor option and the impedances of the transformers and typical equivalent collector circuit, the requirement to meet a net power factor of +0.95 to -0.95 at the Interconnection Facility 138kV bus may be achievable. Further analysis will be conducted with detailed models in the System Impact Study. It was noted that the GE WindFREE option would be required to meet the full range availability of reactive power as required by the NS Transmission System Interconnection Requirements.

No issues regarding high short-circuit level impacting the interrupting capability of existing circuit breakers were found for this project on its own. The minimum short circuit level at the Interconnection Facility 34.5kV bus is 189 MVA with all lines in service, 173 MVA with L-6021 open at 9W-Tusket, and 157 MVA with L-6024 open at 9W-Tusket. The calculated minimum Short Circuit Ratio (SCR) at the low voltage terminals of the Interconnection transformer was found to be 2.4 with all lines in service, and as low as 2.0 with L-6024 open at 9W-Tusket. As this is below the recommended SCR of 2.5, this should be discussed with GE.

The GE 130-3.8 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 $P_{st} = P_{lt} = 0.225$ does not exceed NSPI's requirement of $P_{st} = 0.35$ or $P_{lt} = 0.25$. There may be operational restrictions with L-6024 open at 9W-Tusket since P_{lt} was calculated at 0.27 under that condition.

The preliminary value for the unit loss factor is calculated as -2.5% at the POI on L-6024. Losses associated with the IC facilities (spur line, collector circuits, transformers) are excluded from this calculation.

The preliminary non-binding cost estimate for interconnecting net 80 MW to the POI L-6024 as NRIS, including the cost of a 20 km 138kV spur line (excluding right-of-way) and three-terminal line protection incorporating transfer-trip is $17,336,000. The cost estimate includes a contingency of 10%, and this estimate will be further refined in the System Impact Study and the Facility Study. In this estimate, $8,360,000 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.

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1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request for Network Resource Interconnection Service (NRIS) for a proposed 80 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2024-03-31. The Point of Interconnection (POI) requested by the customer is the 138kV line L-6021, with an alternate POI on the 69kV circuit L-5536. The primary POI on L-6021 is assumed to be close to the 9W-Tusket substation, requiring the construction of a 138kV spur line to the Interconnection Customer's Interconnection Facility (ICIF), approximately 20 km in length. The proposed ICIF is approximately 11 km from the alternate POI on L-5536, requiring a 69kV spur line. L-5536 normally operates as a radial circuit from 9W-Tusket bus 9W-B52 to 88W-Pleasant St. bus 88W-B53. The alternate POI is approximately 7 km from 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 each. The total amount of existing generation on the Tusket 69kV system is 66 MW, whereas the total load ranges from 30 MW to 65 MW.

Figure 1 shows the proposed geographic location of IR#628 in relation to the NSPI transmission system.

Figure 1 IR#628 Wedgeport Wind 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)

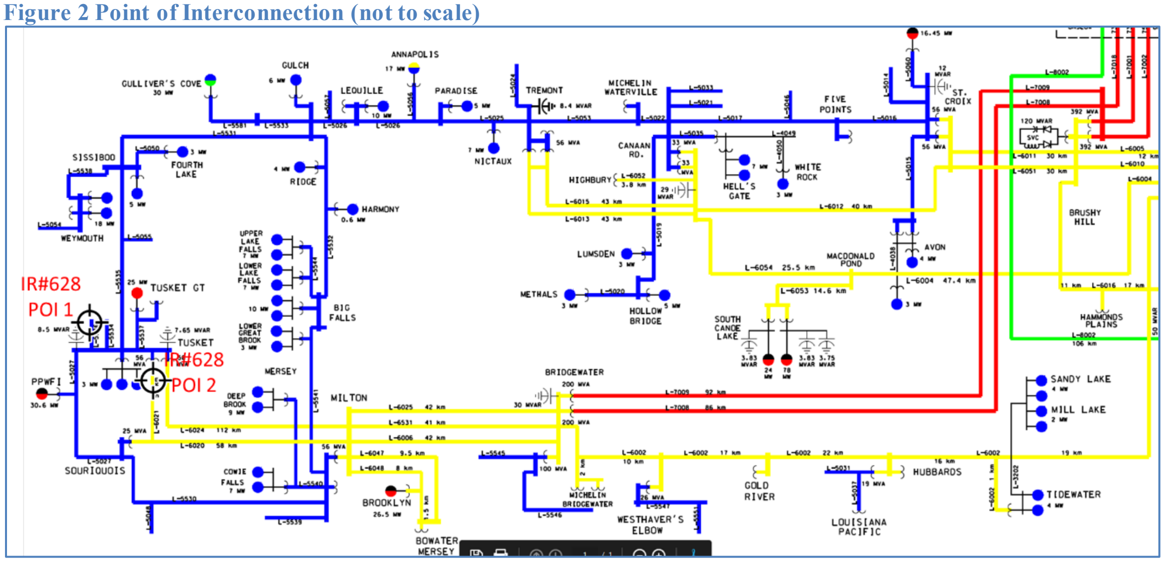
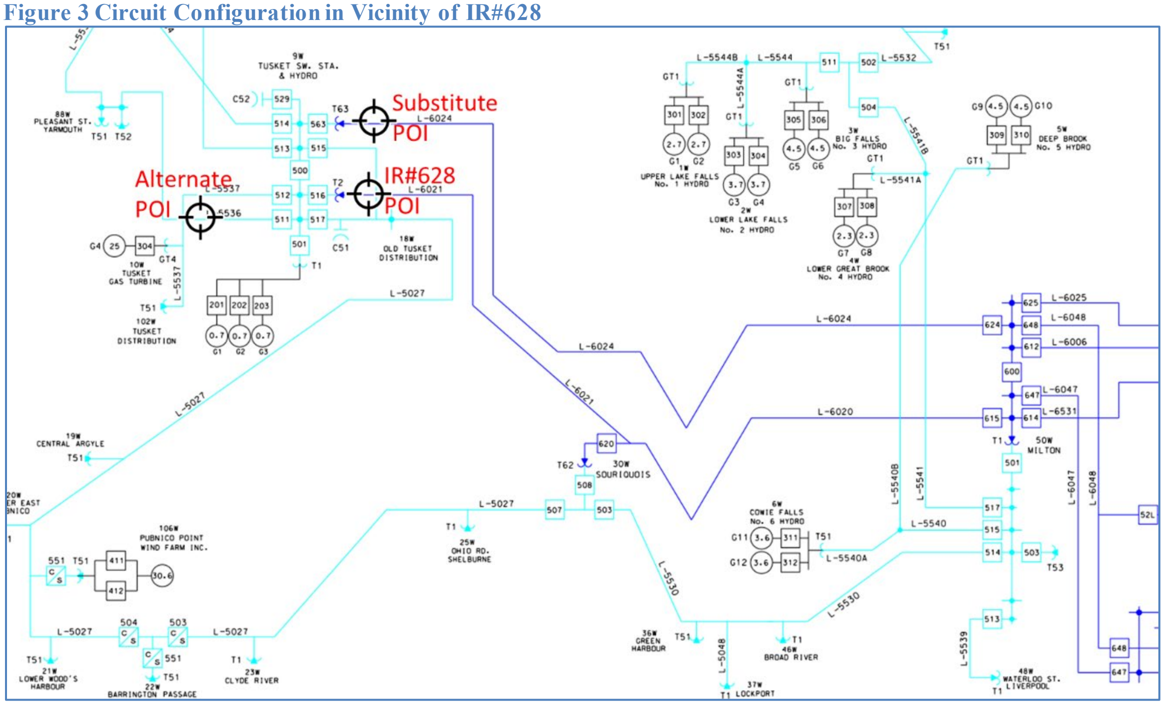


Figure 3 Circuit Configuration in Vicinity of IR#628



The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2021-10-21 and this report is the result of that Study Agreement. This project is listed as Interconnection Request 628 in the NSPI Interconnection Request Queue and will be referred to as IR#628 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#628. 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#628 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 the 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 2024-03-31.

3. The Interconnection Customer Interconnection Facility (ICIF) consists of 21 Wind Energy Converter System (WECS) units, GE 130-3.8 (3.8 MW), 690V, Type 3 (DFIG: Doubly-Fed Induction Generator), for a total plant rating is 80 MW.

4. Preliminary data was provided by the IC for the IC substation transformer, consisting of two 25/33/42 MVA transformers in parallel. The substation transformer was modeled as an equivalent single transformer with a positive-sequence impedance of 8.33% on a base rating of 50 MVA with a given X/R ratio of 20. The IC indicated that this Interconnection Facility step-up transformer has a grounded wye – grounded wye with delta tertiary winding configuration with +/- 5% off-load tap changer in 5 equal steps. The impedance of each generator step-up transformer was provided as Z_{+}=5.75% on 4.5 MVA with an assumed X/R ratio of 11. There will be a total of four 34.5 kV collector circuits, two per substation transformer. Depending on which POI is used, the transformers will be either 138kV – 34.5kV or 69kV – 34.5kV.

5. The proposed primary POI on L-6021 is considered non-BPS network line which would require a three-breaker ring bus in accordance with Table 8 of the TSIR since the 20 km 138kV spur line is greater than 10% of the main line being tapped (combination length of L-6020/L-6021 is 116 km).

6. The proposed alternate POI on L-5536 is considered non - Bulk Power System (BPS) radial line. Given that an 11 km spur line is required between the ICIF and the POI, a single-breaker line tap would be required in accordance with Table 8 of the TSIR.

7. The generation technology used must meet NSPI requirements for reactive power capability of at least 0.95 capacitive to 0.95 inductive at the HV terminals of the IC substation step up transformers. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the designated voltage control point during and following system disturbances as determined in the subsequent System Impact Study. The designated voltage control point will either be the low voltage terminals of the wind farm transformer, or if the high voltage terminals are used, equipped with droop compensation controls. It is assumed that the generating units are not de-rated in their MW capability when delivering the required reactive power to the system.

8. An equivalent collector circuit model was not provided, so a typical model was used with a positive sequence impedance of 0.0027 +j0.00379, B=0.0154 (per unit on 100 MVA).

9. 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.

10. Rated operating temperature for the WECS was given as -15°C on the Interconnection request, which does not meet the requirement of -30°C as per the NSPI TSIR, so it is assumed that the IC will specify the Cold Weather option listed in the GE documentation.

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 elements in the vicinity of IR#628 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
L-5536	2/0 Quail	50°C	Conductor	23/25 MVA	34/37 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#628 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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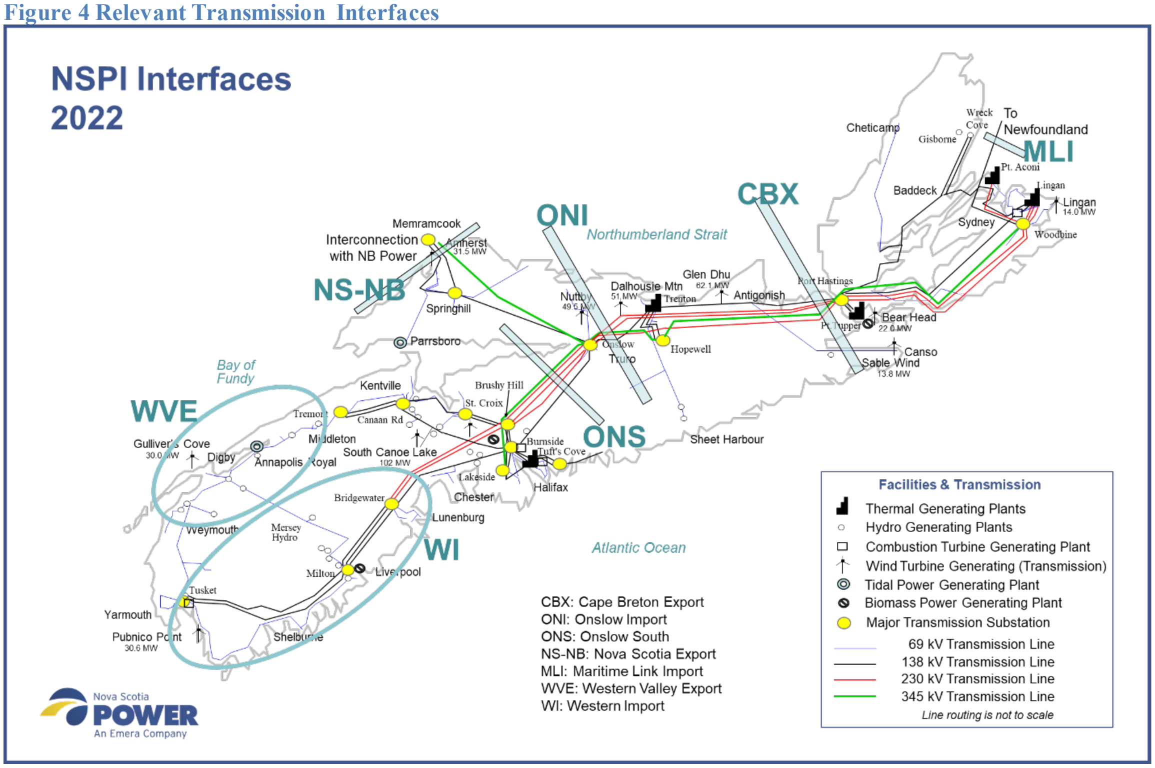
5 Load Flow Analysis

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



Transmission connected wind generation facilities are typically dispatched at approximately 40%, except in the vicinity of IR#628. 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#628 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#628 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#628	Wind
SP01-1	335	1350	20	513	-9	71	9	0	231
SP01-2	335	1350	20	433	-9	-6	9	80	311
SP02-1	0	890	140	327	56	13	43	0	161
SP02-2	0	890	140	248	56	-61	43	80	241
SP03-1	330	1350	20	523	-9	40	9	0	229
SP03-2	330	1350	20	443	-9	-37	9	80	309
SP04-1	330	1350	20	391	-9	73	9	0	356
SP04-2	330	1350	20	311	-9	-4	9	80	436
WP01-1	170	2200	124	840	-17	121	20	0	323
WP01-2	170	2200	124	769	-17	42	20	80	403
WP02-1	0	2200	68	860	-23	105	18	0	328
WP02-2	0	2200	68	770	-23	27	18	80	408

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

Line L-6021 from the primary POI to 9W-Tusket is limited by the 72 MVA switch and the 56 MVA top rating of the transformer 9W-T2. Line L-6021 from the POI to 50W-Milton (the line section between 30W-Souriquois and 50W-Milton is designated L-6020) 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.

Because the spur line to IR#628 is greater than 10% of the length of L-6021/L-6020, the POI would be a three-breaker ring bus.

Preliminary analysis of the primary POI on L-6021 indicated the need for a thermal uprating of the L-6021/L-6020 conductor from 50°C to 70°C for several contingencies. Uprating 116 km of 138kV line is estimated to cost approximately $19,140,000.

The alternate POI on L-5536 has a 2/0 Quail ACSR conductor with a summer normal limit of 21 MVA at maximum conductor temperature of 50°C. In order to handle the 84 MVA rating (80 MW at power factor of 0.95) of IR#628, the 7 km line section would need to be uprated to a 556 Dove conductor at an operating temperature of 75°C. Given that the right-of-way of L-5536 is designed for a single-pole structure, the line section between the alternate POI and 9W-Tusket would need to be rebuilt with a non-standard design.

As mentioned in Section 1 above, the total existing generation on the Tusket 69kV system is currently 66 MW. The addition of IR#628 would bring this total to 146 MW. With the current range of load on the 69kV system (30 MW to 65 MW), generation can exceed load by 81 to 116 MW. Given that the rating of each of the two 138kV-69kV transformers at 9W-Tusket is 56 MVA, loss of one of these transformers can significantly overload the other transformer. A total of eight contingencies including transmission lines and remote buses were found to fail design criteria.

Increasing transformer capacity would involve replacing 9W-T2 and 9W-T63 with units twice their size, or the addition of two additional transformers in parallel. This would require the development of new 138kV bus and re-development of the existing 69kV buses. It is unlikely that there would be room at 9W-Tusket for such a development. This would not address the overloading on transmission lines in the area that was also found: L-6020, L-6021, L-6031 and L-5026.

Having identified the limitations of the primary POI on L-6021 and the alternate POI on L-5536, a third alternative was considered. Adjacent to L-6021 at the entrance of 9W-Tusket is L-6024, which would not require a thermal uprate if it was selected as the POI.

Section 6.1 of the GIP provides for the TP to propose a substitute POI based on results not contemplated in the Scoping Meeting, which was discussed with the IC on 2022-03-29. On this basis, the proposed POI will be a three-breaker ring on L-6024 near 9W-Tusket.

For NRIS analysis, this FEAS added IR#628 and displaced an equivalent amount of coal-fired generation in Cape Breton. Single contingencies were applied at the 230kV, 138kV, and 69kV voltage levels for the above system conditions with IR#628 interconnected to the POI on L-6021. 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#628.

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

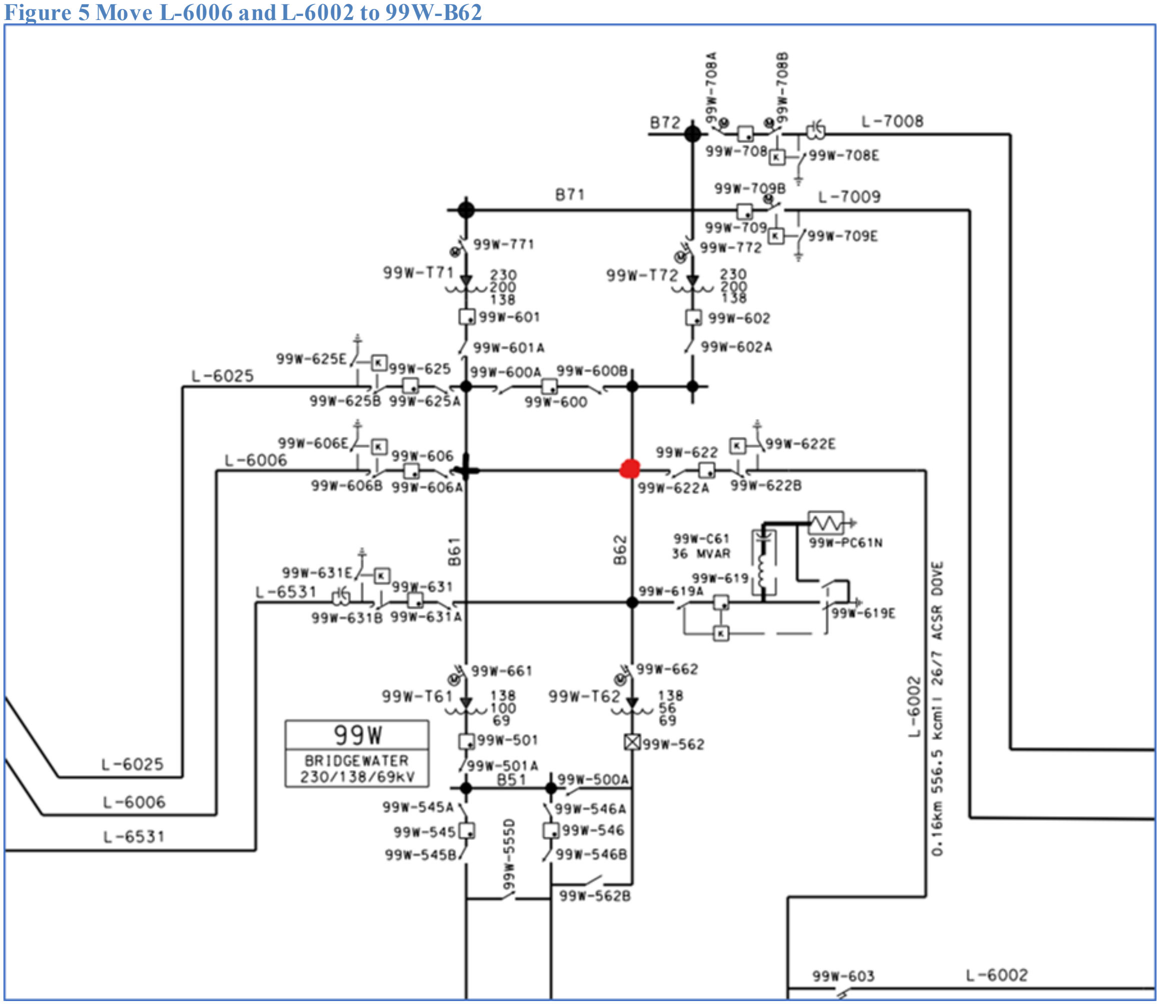
With IR#628 radially connected to a three-breaker on L-6024 at 9W-Tusket, the following contingencies resulted in thermal overloads of transmission elements:

1. Loss of 138kV bus 99W-B61 causes lines L-6025 and L-6006 to open at 99W-Bridgewater, leaving L-6531 loaded up to 109% 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 138kV bus 50W-B3 causes lines L-6531, L-6020, L-6047 and transformer 50W-T1 to open at 50W-Milton, causing L-5026 to load to 112% to 124% of its summer emergency rating.
3. Loss of the 138kV bus 50W-B4, or the opening of breaker 50W-624 for any reason results in overloaded elements: 9W-T63 at 145%, 9W-T2 at 153%-182%, L-6021 at 108%-129%.

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 80°C. Estimated cost is $23,700,000 plus 10% contingency.
3. Uprate line L-5026 by replacing 69kV switches, CT's and metering at 13V, 12V, 70V, and 11V, estimated at $500,000.
4. 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. With IR#628 POI on L-6024, there is no need to move the 50W terminals of L-6006.
5. As an alternative to (2), design the three-breaker ring at the POI for single-failure redundancy including dual trip coils, redundant station battery, and redundant telecommunications. This will ensure that any operation (manual or protection) of breaker 50W-624 transfer-trips to the spur line to IR#628.

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



The recommended actions are (3), (4) and (5). 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#628 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.

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 GE 130-3.8 MW DFIG units are provided as X’d = 0.333 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#628 @ L-6024 Three-phase MVA (1)

Location	Without IR#628	With IR#628
All transmission facilities in service		
Interconnection Facility (138kV)	378	553
50W-Milton (138kV)	1255	1331
9W-Tusket (138kV)	467	620
9W-Tusket (69kV)	547	613
Minimum Conditions (PA1, LG1, ML In-Service)		
Interconnection Facility (34.5kV), all lines in-service	189	421
Interconnection Facility (34.5kV), L-6021 open at 9W-Tusket	173	405
Interconnection Facility (34.5kV), L-6024 open at 9W-Tusket	157	389

(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 69kV breakers at 9W-Tusket are rated at least 2000 MVA. As such, the interrupting ratings at these substations will not be exceeded by this development on its own.

GE technical bulletin states "the 3MW Platform wind turbine is designed to operate with a composite short circuit ratio (CSCR) above 2.5 (on a MW base) at the medium voltage side of the turbine transformer". Based on the calculated short circuit levels, a POI on L-6024, and an 80 MW installation consisting of 21 units each 3.8 MW, the minimum CSCR would be 2.4 at the LV terminals of the IR#628 transformer with all lines in service and IR#628 off line. This falls to 2.2 with L-6021 open at 9W-Tusket, and 2.0 if L-6024 is open at 9W-Tusket. These results should be discussed with GE, as further study may be required.

The equivalent system phase angle at the low voltage terminals of the ICIF is 85° at minimum and maximum short circuit levels.

7 Voltage Flicker and Harmonics

The GE 130-3.8 MW WECS flicker parameters are shown in Table 5.

Table 5 Parameters for Flicker Calculations	
Parameter Description	Value
Number of turbines	21
Effective power (MW)	3.8
Flicker Coefficient c_i (Ψ_k, v_a) Ψ_k=85°	2.2
Flicker Step Factor $k_f(\Psi_k)$	0.06
Switching Operation, 10-min N_{10}	1.2
Switching Operation, 120-min N_{120}	14
Minimum short circuit level 34.5kV (MVA) all lines in	189
Minimum short circuit level 34.5kV (MVA) L-6024 open 9W	157

Table 6 Flicker Values at 138kV bus	
Continuous Operation	
$P_{st} = P_{lt}$	0.225
Switching Operation	
P_{st}	0.055
P_{lt}	0.055

The calculated flicker values shown in Table 6 show that IR#628 does not exceed NSPI's requirement of P_{st} = 0.35 or the requirement of P_{lt} = 0.25 with all lines in service. The value of P_{lt} with L-6024 open at 9W-Tusket is 0.27, which exceed NSPI's requirement and operational restrictions may be necessary under those conditions.

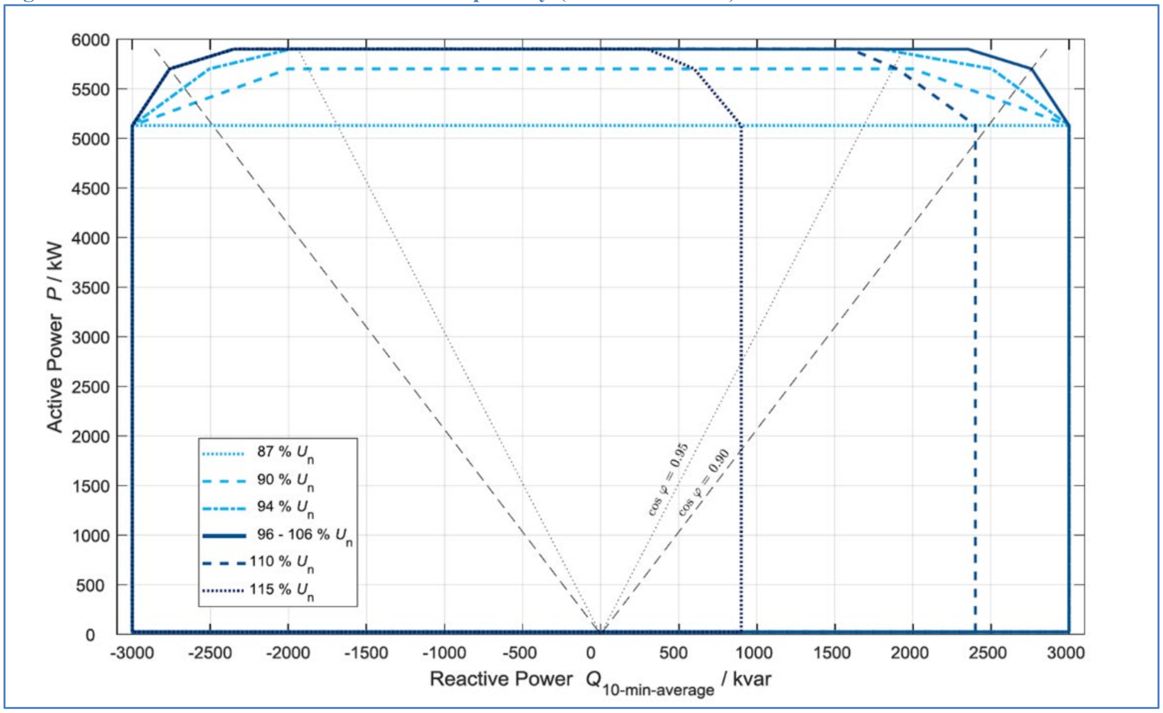
The generator is expected to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion (all frequencies) to a maximum of 1.5%, with no individual harmonic exceeding 1.5% on 138kV.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR#628 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 80 MW, this translates into a reactive capability of 31 Mvar leading and lagging.

The information provided by the IC indicates that the GE 130-3.8 WECS are equipped with the enhanced power factor option and 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 80 MW, this translates into a gross reactive power range of -39 Mvar to +39 Mvar. Figure 6 shows how reactive capability varies with voltage and real power output.

Figure 6 GE 130-3.8 MW WECS Reactive Capability (5.9 MW version)

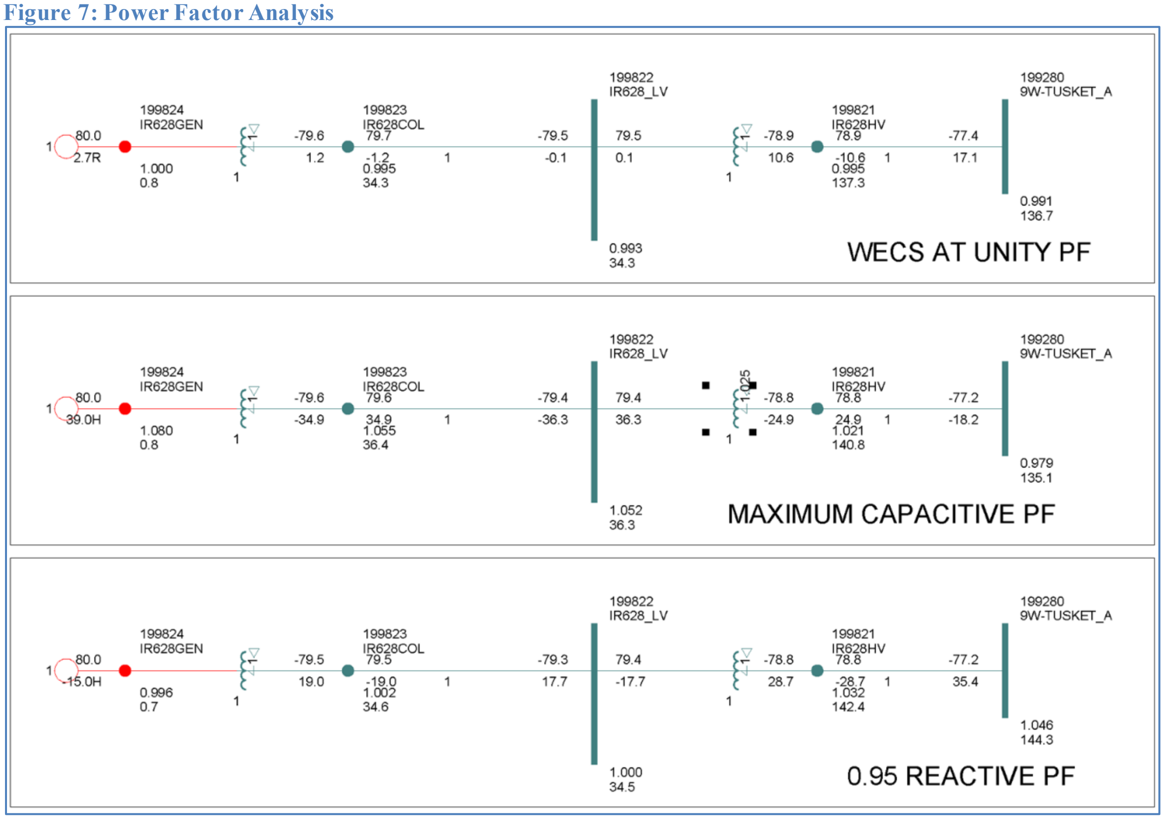


Analysis shown in Figure 7 shows that IR#628 may be able to meet this requirement without additional reactive support. The model shows that with 21 WECS units operating at a total 80 MW and 38 Mvar at terminal voltage of 1.08 p.u., the delivered power to the high side of the ICIF transformer is 78.8 MW and 24.9 Mvar, or a lagging power factor of 0.953. This is very close to the required power factor of 0.95 and will be further evaluated when an accurate model of the collector circuits and transformers is available.

This configuration would be able to meet the leading power factor requirement while WECS are operating at 80 MW and -15 Mvar.

Figure 6 indicates that the full reactive power range extends to standstill (zero MW). GE documentation indicates that this feature is available as the WindFREE Reactive Power option for model GE 130-3.8 MW. Section 7.6.2 of the NS TSIR requires this feature to be provided.

Figure 7: 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 generators 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.

9 System Security / Bulk Power Analysis

Presently the 138kV buses at the 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#628 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#628 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#628 in service, losses in the winter peak case total 86.2 MW. With IR#628 in service at the POI of L-6024, displacing generation at 91H, and not including losses associated with the IR#628 Generation Facilities or TPIF Interconnection Facilities, system losses total 84.3 MW, a decrease of 1.9 MW. The model shows power delivered to the POI is 77.4 MW, therefore the loss factor is calculated as -1.9/77.4 = -2.5%.

11 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR#628 to the NSPI transmission system at a POI on L-6024 at 9W-Tusket.

11.1 NRIS Requirements:

a. Required Network Upgrades

- Addition of a 138kV three-breaker ring bus on L-6024 at or near 9W-Tusket substation designed for single-failure redundancy including dual trip coils, redundant station battery, and redundant telecommunications. The IC is responsible for acquiring necessary land and access roads for the POI ring bus.
- 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 (manual or automatic) of breaker 50W-624 transfer-trips to the spur line at the POI for IR#628.
- 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 wind farm and NSPI SCADA system (to be specified).
- Build a 138kV spur line approximately 20 km in length between the POI and IR#628, 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 identified the proposed enhanced power factor version of the Vestas 130-3.8 may 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.
- GE WindFREE Reactive Power option to permit full reactive power from standstill (zero MW) to full load.

12 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnection Facilities and Network Upgrades for interconnecting net 80 MW wind energy at the 138kV POI at L-6024 are included in Table 5.

The preliminary non-binding cost estimate for interconnecting 80 MW at the POI at L-6024 under NRIS is $17,336,000 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.

Table 5 Cost Estimate NRIS POI @ L-6024		
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, designed for single-failure redundancy. Transfer trip to POI for any operation of circuit breaker 50W-624	$750,000
3	Move termination of L-6006 and L-6002 at 99W-Bridgewater from bus 99W-B61 to 99W-B62	$100,000
5	Uprate L-5026 to meet conductor rating	$500,000
	Sub-total for Network Upgrades	$7,600,000
Item	**TPIF Upgrades**	**Estimate**
1	20 km 138kV spur line from POI to ICIF excluding right-of-way and environmental assessment	$7,850,000
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	$8,160,000
	Total Upgrades NRIS	**Estimate**
	Network Upgrades + TPIF Upgrades	$15,760,000
	Contingency (10%)	$1,576,000
	Total (Incl. 10% contingency and Excl. HST)	$17,336,000

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#628. 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
- 3-phase faults 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 NERC[2] and NPCC[3] 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*