Interconnection Feasibility Study Report
GIP-IR737-FEAS-R2

Generator Interconnection Request 737
147 MW Wind Generation Facility
Hants County, NS

2024-06-14
Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (*IC*) submitted a Network Resource Interconnection Service (*NRIS*) Interconnection Request for a proposed 147 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2026/08/31. The Point of Interconnection (*POI*) requested by the customer is the 138kV line L6012, approximately 10.3 km from the 17V- St. Croix substation and 30 km from the 43V-Canaan Road substation.

There are twenty-two transmission and sixteen distribution higher-queued Interconnection Requests in the Advanced Stage Transmission and Distribution Queue included in this study. IR686 is a higher queued transmission-connected generation IR with its SIS in progress, however it was not included in this study as the IR686 SIS was not complete when IR737 was initiated .

In addition, there is a long-term firm Transmission Service Reservation *(TSR)* that must be accounted for: 550 MW from New Brunswick to Nova Scotia *(TSR411)*.

TSR411 is a long-term firm point-to-point Transmission Service Reservation and a Facilities Study is currently underway to determine the associated upgrades to the Nova Scotia transmission system. These upgrades are expected to materially alter the configuration of the transmission system in Nova Scotia. As a result, the following notice was posted to the OASIS site at https://www.nspower.ca/oasis/generation-interconnection-procedures:

> *Due to ongoing development discussions and engineering studies, the Transmission System Network Upgrades identified as part of Transmission Service Request #411 will not be included in the System Impact Study (SIS) Analysis for Generator Interconnection Procedures (GIP) Study Groups #32 to #35. GIP Study Group #32 to #35 analysis will be limited to the 2024 Transmission System configuration plus any material Network Upgrades identified in higher queued projects.*

This study assumes that the addition of generation from IR737 will displace coal-fired generation in eastern Nova Scotia for NRIS.

IR737's interconnection with L6012 is proposed with a three-breaker 138kV ring bus via a 15 km spur line from the IC substation. IR737's NPCC BPS categorization will be determined in the subsequent System Impact Study *(SIS)*. IR737 will be subject to the applicable NERC Reliability Criteria as its aggregate rated output is greater than 75 MVA. This new substation will be categorized BES under NERC criteria. The generators and elements in Interconnection Customer substation (*including collector bus and substation step-up transformer*), are also categorized as BES.

IR737's assessment indicated five thermal overloads[1] that must be addressed to connect the 147 MW as NRIS and nine pre-existing conditions that are not its responsibility. Solutions for the five overloads that must be addressed are:

1. Replacing 17V-T63 33.6/44.8/56 MVA transformer with a 39/52/65 MVA transformer.
2. Reconductoring L6004 (between 90H and 110W), 47.4 km and upgrading associated 90H breakers, switches, and metering.

[1] Overloads in this report are calculated from emergency ratings, which are already 110% of normal limits

3. Reconductoring L6012 (between 17V and IR737 POI), 10.3 km and upgrading associated 17V breakers, switches, associated equipment, relaying, and metering.
4. Reconductoring L5016 (between 17V and 20V), 18 km.
5. Reconductoring L5017 (between 20Vand 43V), 18 km and upgrading associated 20V and 43V metering.
6. Uprating L5017 (between 20V and 43V), 18.18 km.

The following overloads are not IR724's responsibility:

1. 17V-T2 *(at 100% emergency limit[2])*
2. L7009 (120H /99W) *(pre-existing)*
3. L6003 (91H/ 90H) *(pre-existing)*
4. L6010 (120H / 90H) *(pre-existing)*
5. L6009 (101H / 90H) *(pre-existing)*
6. L6006 (99W / 50W) *(pre-existing)*
7. L6025 (99W / IR739) *(pre-existing)*
8. L6531 (99W / 50W) *(pre-existing)*
9. L5535 (9W / 15V) *(pre-existing)*

Data provided by the IC indicates IR737 will utilize Enercon E-138 EP3 E3 full converter WECS *(Wind Energy Conversion Systems)* with FTS *(FACTS Transmission with STATCOM)* option. Based on the inverters, typical impedances of the transformers, IC provided collector circuit length, and typical collector circuit impedances, IR737 may not meet the net power factor requirement of +0.95 at the high voltage side of Interconnection Facility.

The adequacy of reactive power supply will be further investigated in the System Impact Study as specific details of the collector circuits become available. It is noted that the proposed Enercon E-138 EP3 E3 wind turbine models will meet the requirement to produce full MVAr capability down to zero MW output using the FTS (*STATCOM*) option.

IR737 was not found to adversely impact the short-circuit capabilities of existing circuit breakers. However, this study shows that the minimum short circuit level at the Interconnection Facility 34.5 kV bus is 419 MVA with all lines in service and IR737 off-line. This falls to 254 MVA with L6012 open at 17V-St. Croix, resulting in a very low short-circuit ratio (*SCR*) of 1.7. There are three other IBR based generation sites in relatively close proximity, further reducing the effective SCR level.

The IC should consult Enercon to determine if any support can be provided for IR737's WECS under these low SCR conditions or if other modifications are required. The impact of the low SCR will be further examined when detailed data for the project is made available for the SIS.

IR737 meets NS Power's required short term and long-term voltage flicker requirements based off the supplied data. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519. It is assumed that the project design meets NSPI requirements for low-voltage ride-through and voltage control.

[2] Transmission line and equipment loadings must be within normal limits for pre-disturbance conditions and within 110% of normal limits post-contingency.

The preliminary value for the unit loss factor is calculated as -0.4% at the POI on L6012, net of any losses on the IC facilities up to the POI.

NS Power notes that NERC standard PRC-029-1 is currently in development. As proposed, this standard will impose performance requirements for voltage and frequency ride through behaviour on inverter-based generating resources. It is anticipated that this standard will be applicable to the project currently under study. The Interconnection Customer is advised to consider the requirements of PRC-029-1 in their project design to ensure that their project can conform to these requirements. Conformance will be validated at the System Impact Study stage.

To connect IR737 as NRIS, the preliminary non-binding cost estimate for interconnecting its 147 MW to the L6012 POI, including the Network Upgrade costs of 17V-T63, L6004, L6012, L5016, L5017, the three-breaker ring bus 138 kV substation, and associated upgrades is $120,690,000 including a 25% contingency. In this estimate, $81,240,000 *(plus 25% contingency)* of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP.

The preliminary cost estimate does not include any reactive power devices that are potentially required to meet the NSPI power factor requirements. It also does not include TBD costs to address any stability issues identified at the SIS stage based on dynamic and EMT analysis.

The estimated time to construct the Transmission Providers Interconnection Facilities and any Network Upgrades is 24-36 months after receipt of funds and cleared right of way from the customer. These estimates will be further refined in the System Impact Study and the Facility Study.

Table of Contents

1 Introduction

The Interconnection Customer (*IC*) submitted a Network Resource Interconnection Service (*NRIS*) Interconnection Request for a proposed 147 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2026-08-31. The Point of Interconnection (*POI*) requested by the customer is the 138kV line L6012, approximately 10.3 km from the 17V- St. Croix substation and 30 km from the 43V-Canaan Road substation.

The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2023-11-30, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 737 in the NSPI Interconnection Request Queue and will be referred to as IR737 throughout this report.

Figure 1 shows the proposed geographic location of IR737 in relation to the NSPI transmission system.

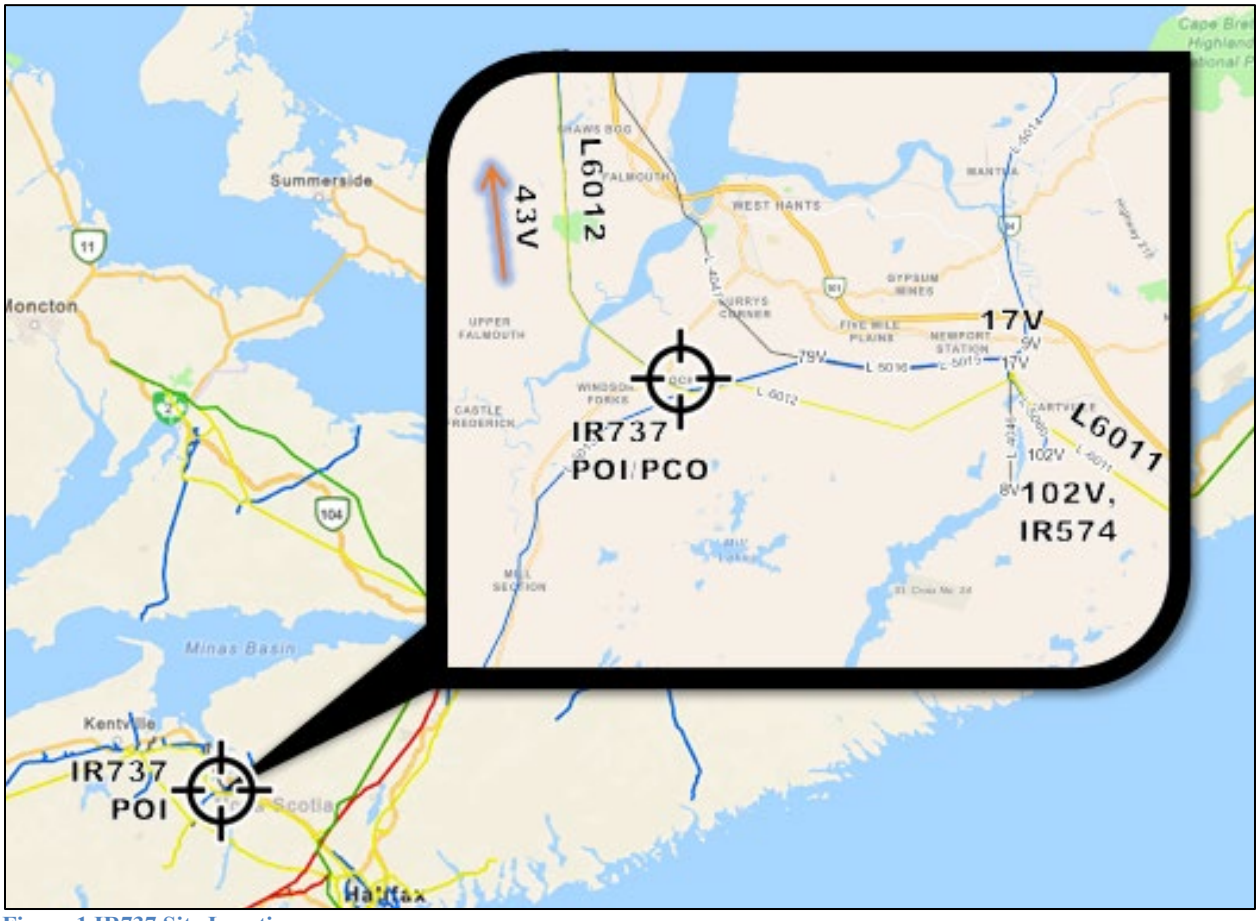

Figure 1 IR737 Site Location

Figure 2 is a simplified one-line diagram of the transmission system configuration in NS.

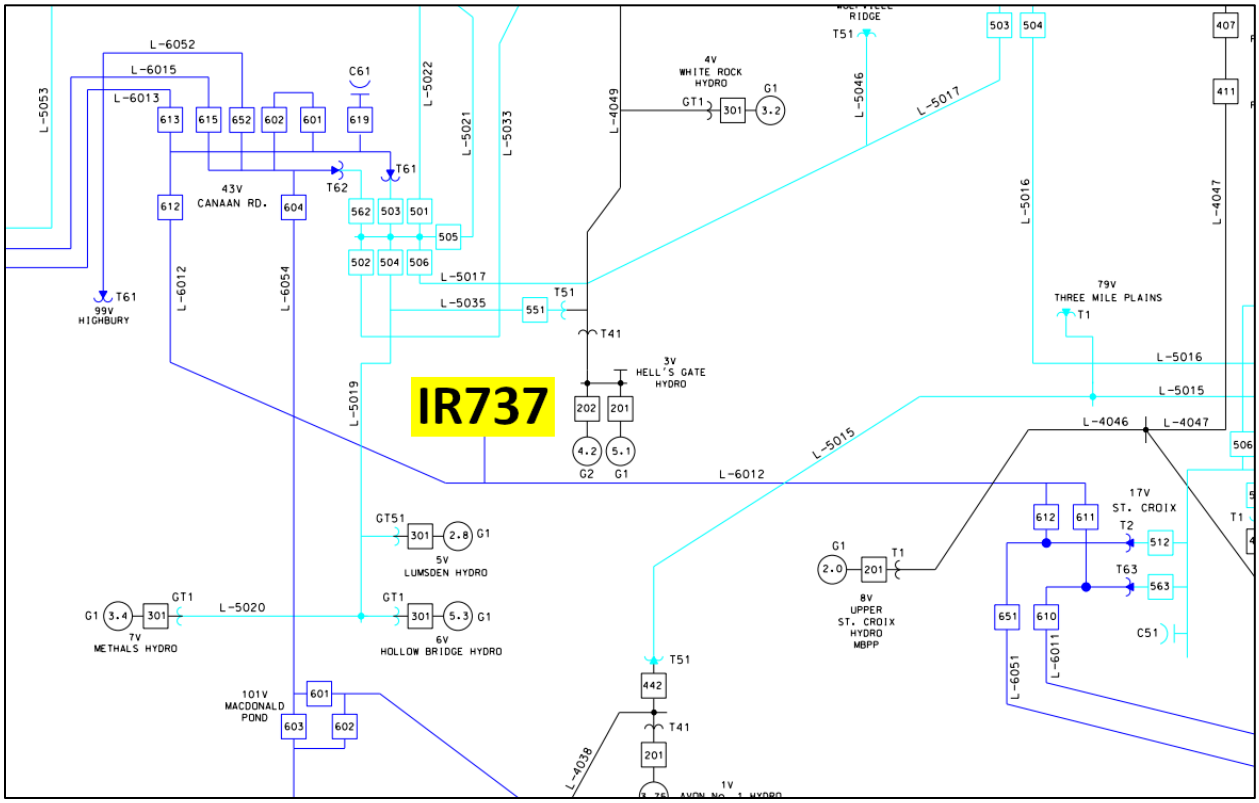

Figure 2: IR737 POI (*not to scale*)

2 Scope

The objective of this Interconnection Feasibility Study (*FEAS*) is to provide a preliminary evaluation of system impacts from interconnecting the proposed generation facility to the NSPI transmission system at the requested location. The assessment will identify potential impacts on transmission element loading, which must remain within their thermal limits. Any potential violations of voltage criteria will be identified and addressed. If the proposed generation increases the short-circuit duty of any existing circuit breakers beyond their rated capacity, the circuit breakers must be upgraded. Single contingency criteria are applied.

The scope of the FEAS includes the modelling of the power system in normal state (*with all transmission elements in service*) under anticipated load and generation dispatch conditions. A power flow and short circuit analysis will be performed to provide the following information:

- Preliminary identification of any circuit breaker short circuit capability limits exceeded because of the interconnection, and any network upgrades necessary to address the short circuit issues associated with the IR. Expected minimum short circuit capability will also be identified for the purposes of Short Circuit Ratio analysis.
- Preliminary identification of any thermal overload or voltage limit violations resulting from the interconnection and identification of the necessary network upgrades to allow

full output of the proposed facility. Thermal limits are applied to the seasonal (*summer/winter*) emergency ratings of transmission elements. Voltage violations occur when the post-contingency transmission bus voltage is outside the range of +/-10% of nominal voltage.

- Preliminary analysis of the ability of the proposed Interconnection Facility to meet the reactive power, power quality and cold-weather capability requirements of the NSPI *Transmission System Interconnection Requirements*[3].
- 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 IR737 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 Interconnection Customer. The Point of Interconnection (*POI*) and configuration is studied as follows:

1. NRIS per section 3.2 of the Generator Interconnection procedures (*GIP*).
2. Commercial Operation date 2026-08-31.
3. The Interconnection Customer Interconnection Facility (*ICIF*) consists of thirty-five Wind Energy Converter System (*WECS*) units; Enercon E-138 EP3 E3 FTS option 4.26 MW wind turbines, Type 4 (*full converter*), a total capacity of 147 MW.
   3.1. The generator terminals are at 750V.
   3.2. Connected to five collector circuits operating at a voltage of 34.5kV. Each collector circuit connected to 7 WECS units.
4. The ICIF will require the construction of a 15 km 138 kV transmission spur line from the POI to the IC 138kV/34.5kV transformers. The IC will be responsible for providing the Right-of-Way for the lines. Detailed line data was not provided, so typical data was assumed based on 556.5 Dove conductor and 100°C.

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

5. IR737 will be connected to L6012 via a three-breaker ring bus in accordance with Table 8 of the NSPI *Transmission System Interconnection Requirements.*
6. The generation technology used must meet NSPI requirements for reactive power capability of at least 0.95 capacitive to 0.95 inductive at the HV terminals of the IC substation step up transformer. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the designated voltage control point during and following system disturbances as determined in the subsequent System Impact Study. The designated voltage control point will either be the low voltage terminals of the 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.
7. Preliminary data was provided by the IC for the IC substation interconnection facility.
    7.1. The IC indicated that the interconnection facility transformer was rated at 96/128/160 MVA and modeled with a positive-sequence impedance of 8.5% on 100 MVA with an assumed X/R ratio of 32.5.
    7.2. The transformer have a wye-delta-wye winding configuration with de-energized tap changers with ±10% taps and 5 equal steps.
    7.3. The impedance of each generator step-up transformer was modeled as 6.5% on 4.7 MVA with an assumed X/R ratio of 12.5.
    7.4. Collector circuit impedance (*Z=0.008+j0.027 p.u and B=0.004 p.u*) was calculated based on the conductor sizes and circuit lengths provided in the IC's SLDs with typical conductor impedance. The net real and reactive power output of the plant will be impacted by losses through transformers and collector circuits.
8. Generation Interconnection Queue and OATT Transmission Service Queue projects 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. It is assumed that the wind turbines are equipped with a "cold weather option" suitable for operating as specified in the TSIR, section 7.6.9 Low Ambient Temperature Requirements - Asynchronous.
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. Transmission facilities rating in the vicinity of IR737 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
L6054*	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA
L6011	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA
L6051	795 Drake	100°C	Conductor	268/295 MVA	287/316 MVA
L6004*	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA
L6013	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA
L6012	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA

*L6054 and L6004 currently use Dove 556.5 kcmil ACSR conductors with a design temperature of 75°C, it's assumed that L6054 and L6004 would be uprated to a design temperature of 100°C for Dove 556.5 kcmil ACSR due to higher queued projects.

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 2024/01/25, 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
- IR517: GIA in progress
- IR574: GIA executed
- IR598: GIA executed
- IR597: GIA executed
- IR647: GIA in progress
- IR664: FAC complete
- IR662: FAC complete
- IR670: FAC complete
- IR671: FAC in progress
- IR669: FAC complete
- IR668: FAC complete
- IR618: FAC complete
- IR673: FAC complete
- IR675: FAC complete
- IR677: SIS in progress
- IR697: SIS in progress
- IR739: SIS in progress

- IR742: SIS in progress

The power system base cases for the feasibility study includes all transmission connected IRs in the GIP queue up to and including IR742 with the exception of IR686, as the IR686 SIS was not completed when IR737 was initiated.

The following projects have been submitted to the Transmission Service Request *(TSR)* Queue:

- TSR411: SIS in progress
- TSR412: Withdrawn

TSR411 is a long-term firm point-to-point Transmission Service Reservation and a Facilities Study is currently underway to determine the associated 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:

> *Due to ongoing development discussions and engineering studies, the Transmission System Network Upgrades identified as part of Transmission Service Request #411 will not be included in the System Impact Study (SIS) Analysis for Generator Interconnection Procedures (GIP) Study Groups #32 to #35. GIP Study Group #32 to #35 analysis will be limited to the 2024 Transmission System configuration plus any material Network Upgrades identified in higher queued projects.*

5 Short-Circuit Duty / Short Circuit Ratio

The NS Power design criteria for maximum system fault capability (*3-phase, symmetrical*) is 5,000 MVA at the 138 kV voltage levels and 3,500 MVA at the 69 kV voltage levels. The fault current characteristic for this Enercon E-138 EP3 E3 wind turbines is given as 1.05 times rated current, or X'd = 0.9524 per unit on machine base MVA.

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

Table 2: Short-Circuit Levels[4]

Location	Without IR737	With IR737
All transmission facilities in service		
POI on L6012 (*138kV*)	1,528	1,657
Interconnection Facility (*138kV*)	969	1,104
17V-St. Croix (*138kV*)	1,961	2,067
43V-Canaan Rd (*138kV*)	1,318	1,362
17V-St. Croix (*69kV*)	869	886
43V-Canaan Rd (*69kV*)	824	838
Minimum Conditions (*TC3, LG1, ML In-Service*)		

[4] Classical fault study, flat voltage profile.

Interconnection Facility (*138kV*), all lines in-service	665	800
IR737 34.5 kV, all lines in-service	419	574
Minimum Conditions (*TC3, LG1, ML in-service*) , L6012 open at 17V		
Interconnection Facility (*138kV*)	327	462
IR737 34.5 kV	254	408

The interrupting capability of the 138 kV circuit breakers is at least 5,000 MVA at 17V-St. Croix and is at least 6,000 MVA at 43V-Canaan Road. The interrupting capability of the 69 kV circuit breakers is at least 1,600 MVA at 17V-St. Croix and is at least 1,000 MVA at 43V-Canaan Road. As such, the breaker interrupting ratings at these substations will not be exceeded by this development on its own.

Inverter-based generation installations often have a minimum Short Circuit Ratio (*SCR*) for proper operation of converters and control circuits. The technical data received from Enercon requires an SCR of at least 3.0 at the medium voltage terminals of the WECS transformer.

Based on the calculated short circuit levels, IR737's specified performance is at risk during minimum load conditions, even with all elements in service. In these conditions, the short circuit ratio can be 2.9 (*419 MVA/147 MW*) at the 34.5 kV bus of the IC substation transformer with all lines in service and IR737 offline. This falls to 1.7 with L6012 open at 17V-St. Croix end, and 2.7 if L6012 opens at 43V-Canaan Rd. end. SCR is further reduced at the high side of the generator step-up transformers due to the collector circuit impedance.

More detailed EMT analysis is required if IR737 proceeds to the SIS stage, as the standard SCR screening methodology becomes less definitive due to the three sites *(IR723, 102V, and 103V)* in relatively close proximity; within 12 km of each other.

- 102V-Ellershouse 1 *(IR461)* & 2 *(IR540)*: 30.55 MW total
- 103V-Ellershouse 3 *(IR574)*: 58.8 MW

The 43V terminal also hosts a BESS site, IR697: White Rock *(50MW)*, approximately 30 km away from IR737.

The IC should consult Enercon to determine if any modifications for lower SCR conditions are required. The impact of the low SCR will be further examined when detailed data for the machine is made available for the SIS. Note that the minimum short circuit level on the 34.5kV bus will also be greatly impacted by the impedance of the Interconnection Facility transformer.

Note that Section 7.4.15 of NSPI's TSIR states:

> *System short circuit level may decline over time with changes to transmission configuration and generation mix. The Generating Facility shall be able to accommodate these changes.*

6 Voltage Flicker and Harmonics

The voltage flicker calculations use IEC Standard 61400-21 based on estimated data provided by Enercon Wind Energy Converter E-138 EP3 E3 (*flicker coefficient c(ψk, va) of 2.5 at system angle of 85°*). The voltage flicker Pst and Plt levels are calculated at the Interconnection Facility for various system conditions and are shown in Table 3 below.

Table 3: Calculated Voltage Flicker

System Conditions	Flicker at 138 kV bus IR737 35 Machines
	Pst=Plt Continuous
Maximum Generation	
All Transmission in Service	0.065
Minimum Conditions (*TC3, LG1, ML In-Service*)	
All Transmission in Service	0.095
L6012 open at 17V	0.193
L6012 open at 43V	0.103

NS Power's required limits are 0.35 for P_{st} and 0.25 for P_{lt}. IR737 meets NS Power's required short term and long-term voltage flicker requirements based off the supplied data.

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 138 kV.

7 Load Flow Analysis

The load flow analysis was completed for generation dispatches under system summer peak, spring light load, shoulder season, and winter peak load conditions which stress the Western and Valley interfaces. Generation dispatch was also selected to represent import and export scenarios that consider expected flows from the existing transmission service reservation associated with the Maritime Link, and scenarios where Maritime Link imports displace NS thermal generation.

For these cases, transmission connected wind generation facilities were dispatched between 19% and 100% of their rated capability. There is high correlation between wind plants in the valley area, so it is reasonable to expect these wind plants would be near full output when IR737 is at rated output. All interface limits were respected for base cases.

Two scenarios were examined for each of the Light Load (*LL*), Shoulder Season (*SH)*, Summer Peak *(SP)*, and Winter Peak (*WP*) cases:

- Pre-IR737 cases ending with "-1": IR737 off.
- Post-IR737 cases ending with "-2": IR737 dispatched at 147 MW under NRIS designation.

The cases and dispatch scenarios considered are shown in Table 4.

Table 4: Base Cases for IR737

Case	NS Load	IR737	System Wind generation	West wind	NS/NB	ML	CBX	ONS	ONI	Valley import	Western import	Valley export	West Valley import
-	-	-	-	-	-		L8004, L7003, L7004, L7005, L6515)	*(L8002, L7001, L7002, L7018, L6001)*	*(L8003, L7003, L7019, L7005, L6503)*	*(L6054, L6011, L6051)*	*(L7008, L7009)*	*(L5532, L5535, L5025)*	*(L5022, L5532, L5535, L6013, L6015)*
c_ll01-1-1	871	0	547	409	330	-475	345	42	367	54	19	-13	32
c_ll01-1-2	863	147	694	556	330	-475	240	-61	264	-84	16	-12	32
c_ll02-1-1	871	0	572	434	443	-475	345	-74	367	-4	-40	43	-23
c_ll02-1-2	863	147	719	581	443	-475	240	-177	264	-141	-43	43	-23
c_sh01-1-1	1258	0	671	369	330	-475	440	303	667	119	113	-35	70
c_sh01-1-2	1249	147	818	516	330	-475	331	175	539	-20	109	-35	71
c_sh02-1-1	1202	0	695	693	423	-475	427	-104	404	-61	-299	36	-1
c_sh02-1-2	1193	147	842	840	423	-448	292	-239	269	-198	-302	37	-1
c_sp01-1-1	1661	0	1281	673	330	-475	317	379	671	132	-109	-29	76
c_sp01-1-2	1661	147	1428	820	330	-461	226	289	581	-8	-113	-28	75
c_sp02-1-1	1661	0	1299	643	330	-475	317	423	715	142	-76	-29	76
c_sp02-1-2	1661	147	1446	790	330	-461	225	333	625	3	-80	-29	76
c_wp01-1-1	2312	0	1389	693	151	-475	620	774	967	148	-91	-24	99
c_wp01-1-2	2312	147	1536	840	151	-475	468	630	823	9	-95	-24	99
c_wp02-1-1	2312	0	1389	693	151	-475	648	801	993	163	-79	-24	99
c_wp02-1-2	2312	147	1536	840	151	-475	495	656	849	24	-83	-24	99
c_wp03-1-1	2337	0	1048	351	151	-475	588	955	1148	201	254	-23	99
c_wp03-1-2	2328	147	1195	498	151	-475	435	811	1003	62	250	-23	99

Note 1: All values are in MW.
Note 2: CBX (*Cape Breton Export*) and ONI (*Onslow Import*) are Interconnection Reliability defined interfaces.
Note 3: Wind refers to transmission connected wind only.

For NRIS analysis, this FEAS added IR737 and displaced coal-fired generation in the system based on operating orders. Single contingencies were applied at the 230 kV,138 kV and 69 kV voltage levels for the above system conditions with IR737 interconnected to the POI on L6012. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 5.

Table 5: Contingency List

Transmission Line	Transformer / Bus	Circuit Breaker Failure	Double Circuit Tower
L-7008, L-7009, L5545, L5546, L6531, L6006, L6025, L6002, SHUNT (*138 kV*)	99W-T61, T62, T71, T72 B71, B72, B51	99W: 708, 709, 600, 501, 545, 546, 562	L-7008+L-7009 L-7009+L-8002
L6012, L6013, L6054, L6015, L6052, L5017,	43V-T61, T62, B51, C61	43V: 604, 613, 505, 562, 503, 506, 501, 502, 504,	L5016+L6012

Transmission Line	Transformer / Bus	Circuit Breaker Failure	Double Circuit Tower
L5022, L5035, L5019, 50V-Load (*138kV*),		IR737: 601	
L6051, L6011, L5014, L5060, L5015, L5016	17V-T2, T63, T1, C51, B2	17V: 610, 612, 611, 563, 512, 519, 505	
L5025*, L6053, L6004	51V- T61*, B51*, B52, B61	101V:601, 602	
L5531, L5532*, L5026*	13V- B51, 11V-B51*		
L6002, L6009, L6008, L6004, L6003, L5003, L5004	90H- T1	90H: 611, 608, 605, 604, 602, 612, 609, 606, 603, 610, 607, 601, 503, 506, 501 101H: 600; IR671:601	
L6005, L6010, L6011	120H-T71, T72	120H: 710, 711, 712, 713, 714, 715, 716, 720, 621, 622, 623, 624, 626, 627, 628, 629	L6005+L6016 L6011+L6010 L6005+L6016
L6042, L6007, L6014, L5049, L5012, L5041	91H-T62, T11,	91H: 621, 613, 603, 604, 605, 606, 607, 608, 609, 611, 516, 521, 523	
L6020, L6024, L6025, L6048, L5541, L5530, L5539, L5540	50W-T53, B3, B4, B2, IR597	50W: 615, 600, 514, 517	
L6021, L5535, L5027	9W-T2, T63, B52, B53	9W: 500	
	30W-T62, B51		

*Indicates contingency was studied with/without RAS action

With the interconnection of IR737, the study shows up to 150% overload[5] on L6004 between 101V-MacDonald Pond and 90H-Sackville under various contingency conditions. Thermal overloads are also observed on 138 kV line L6012 between IR737 POI and 17V-St. Croix and on 69 kV lines L5016, L5017 between 17V- St. Croix, 20V-Five Point and 43V-Cannan Rd. In addition, both transformers at 17V- St. Croix show overloads under contingency conditions.

L5535 overload has been identified as pre-existing issues but the interconnection of IR737 indicated 10% overload increase on L5535, which could trigger the existing AAS to cross trip Gulliver's Cove wind farm.

The study shows increased overloads on L6003, L6010 and L6009 in Metro area, mainly due to the low generation dispatch conditions in Tuft's Cove.

[5] Overloads in this report are calculated from emergency ratings, which are already 110% of normal limits.

1-2% thermal overload increase has been identified for L-7009, L6006, L6531 and L6025 post IR737, however these issues are mainly due to the high Western Valley export.

Low voltage in Milton and Tusket area was observed under the contingency of 50W-B3 and 50W-B4, which could be mitigated by the existing Milton/Tusket load rejection AAS by tripping 9W-515 (*L5027*).

Table 6 shows the highest thermal overloads found, but other conditions were found which also violated thermal loading criteria, but to a lesser degree.

It's observed that that IR737 IC station transformer *(160 MVA)* is overloaded up to 113% when the IR737 generation is operating at 147 MW output, while absorbing the maximum reactive power from its WECS.

Table 6: Contingencies Resulting in Highest Overload

Line/ Transformer	Line Segment	Highest Overload (based off Emergency Ratings)	Case	Contingency	IR737 to address
L5016	17V-St. Croix/20V-Five Pt	123%	sh02	17V-611, 17V-612 and L6012 (*IR737 and 17V*)	Yes
L5017	43V-Cannan Rd/20V-Five Pt	147%	sh02, ll02	17V-611, 17V-612 and L6012 (*IR737 and 17V*)	Yes
L6004	101V MacDonald Pd/90H-Sackville	150%	sh02, ll02	CKT L5016/L6012, 17V-611, 17V-612 and L6012 (*IR737 and 17V*)	Yes
L6012	IR737/ 17V-St. Croix	139%	sh02, ll02	90H-604, 90H-605, L6004, IR671-601	Yes
17V-T2	17V-St. Croix	100%	sh02, ll02	17V-611	No
17V-T63	17V-St. Croix	107%	sh02, ll02	17V-612	Yes
L5535	9W-Tusket/15V-Sissiboo	123% (*pre-existing, 10% increase due to IR737*)	sp01, sp02, ll02	50W-501, 514, 517, B2 and L5541	No
L6003	91H-Tuft's Cove/ 90H-Sackville	118% (pre-existing, 10% increase due to IR737)	sp01, sp02, sh02, wp01, wp02	90H-611, 610 and 609, 101H-600, L6009	No
L6010	120H-Brushy Hill/ 90H-Sackville	104% (*pre-existing, 4% increase by IR737*)	wp01, wp02	120H-622, DKT L6005/6016	No

Line/ Transformer	Line Segment	Highest Overload (based off Emergency Ratings)	Case	Contingency	IR737 to address
L6009	101H-Cobequid Rd/ 90H-Sackville	115% (*pre-existing, 5% increase by IR737*)	wp01, wp02	91H-523, 91H-603, 91H-606, 91H-609, 91H-611, 91H-T11, 103H-600, L6033 and 1H-603	No
L6006	99W-Bridgewater/50W-Milton	100% (*1% increase by IR737*)	sh02	L6025 from 99W to IR739	No
L6531	99W-Bridgewater/50W-Milton	128% (*pre-existing, 2% increase by IR737*)	sh02	L6025 from 99W to IR739, 99W-501, L6006, 99W-T61	No
L6025	99W-Bridgewater/IR739	110% (*pre-existing, 1% increase by IR737*)	sh02	99W-562	No
L-7009	120H-Brushy Hill/ 99W-Bridgewater	134% (*pre-existing, 2% increase by IR737*)	sh02	99W-T71, 99W-T61, L-7008, 99W-708, 99W-B71, 99W-562, 99W-501, 120H-715, 716	No

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR737 must be capable of delivering reactive power for a net power factor of at least +/- 0.95 of rated capacity to the high side of the plant interconnection transformer(*s*). Reactive power can be provided by the asynchronous generator or by continually acting auxiliary devices such as STATCOM, DSTATCOM or synchronous condenser, supplied by the Interconnection Customer.

The information provided by IC[6] indicates that the Enercon E-138 EP3 E3 WECS have a rated power factor of 0.9 lagging and leading *(+/- 1.95 MVar per WECS*) at the machine terminal voltage of 0.95-1.15 p.u. The provided Q-P diagram (*Figure* 3) shows a similar Enercon E138 EP3 E3 WECS reactive power capability.

The Enercon E-138 EP3 E3 FTS option enables the WECS to feed in its maximum reactive power according to the PQ chart in Figure 3 at any time, irrespective of the current wind speed, as shown in Figure 4. It indicates that it will meet the NSPI Transmission System Interconnection Requirements (*Section 7.6.2*) for rated reactive power being available through the full range of real power output of the Generating Facility, from zero to full power.

6 Enercon Technical data sheet 'Grid performance E-138 EP3 E3 / 4260 kW / FTS'

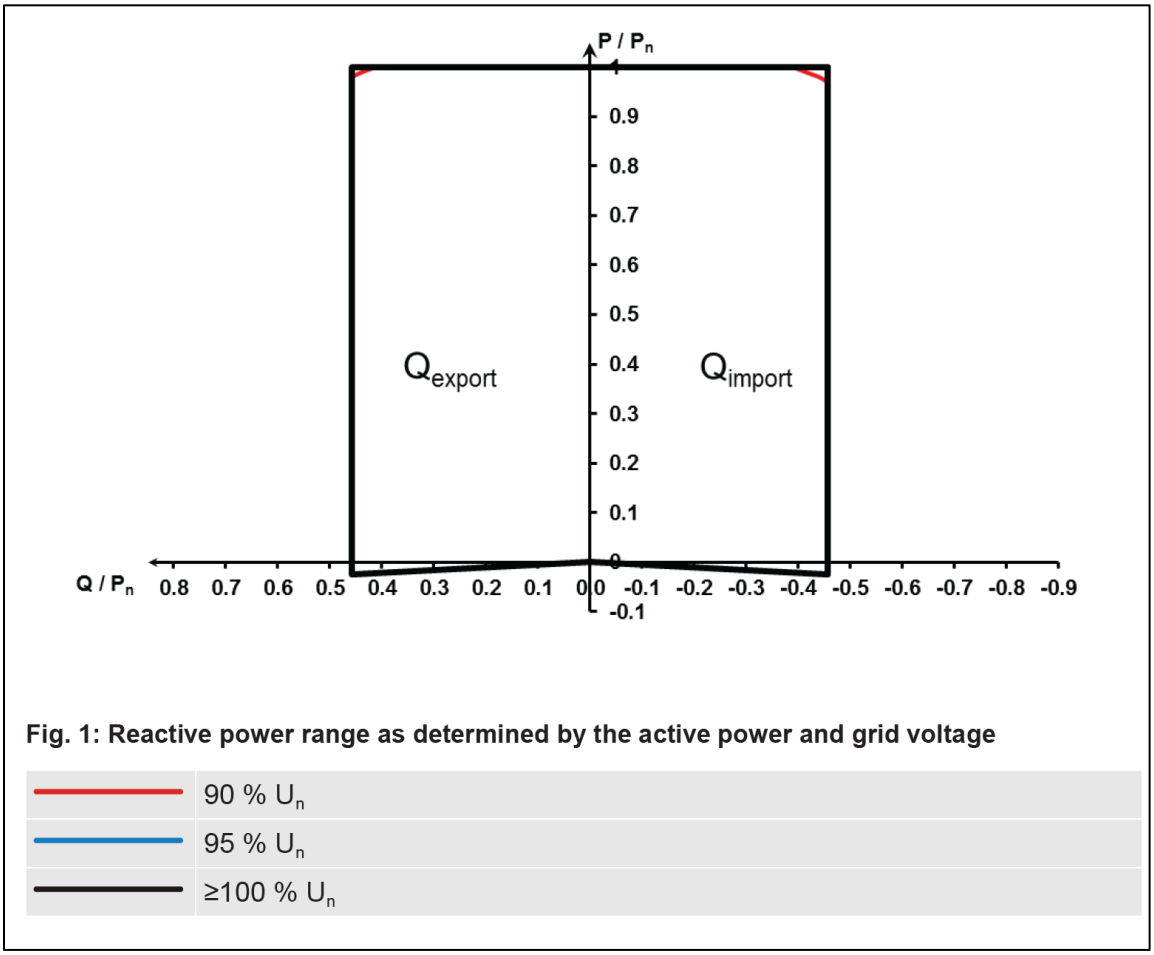

Figure 3 Model Enercon E-138 EP3 E3 PQ Curve and Reactive Capability

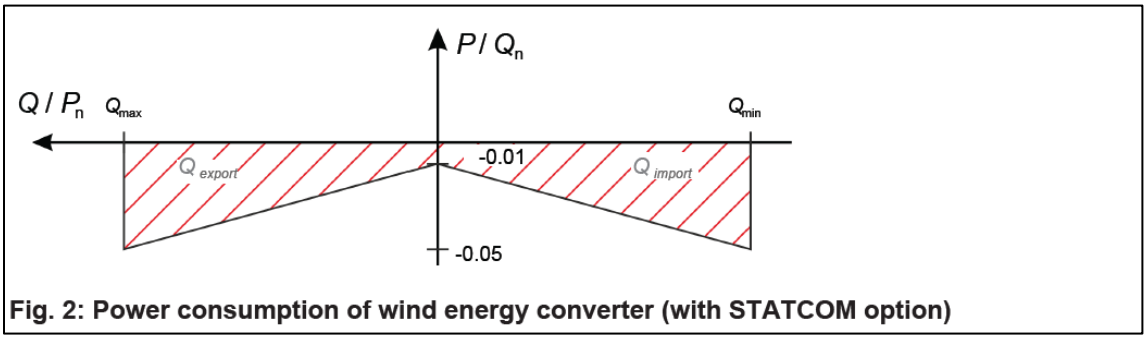

Figure 4 Model Enercon E-138 EP3 E3 FTS PQ Curve and Reactive Capability with STATCOM Option

Analysis shown in Figure 5: Power Factor Analysis indicates that IR737 may not be able to meet the full-load reactive power requirement. The model shows that with 35 WECS units (*Enercon E-138 EP3 E3*) operating at a total 147 MW and 68.3 MVAr, the delivered power to the high side of the ICIF transformers is 143.7 MW and 30.2 MVAr, or a power factor of 0.979 with WECS

terminal voltage at 1.03 p.u. Additional reactive power device might be required and supplied by the Interconnection Customer to meet the NSPI power factor requirements.

This configuration would be able to meet the leading power factor requirement of -0.95 at the high side of ICIF transformer The model shows that with 35 units of WECS operating at a total of 147 MW and -68.3 Mar, the delivered power to the high side of the ICIF transformers is 142.8 MW and -116.4 MVAr, or a power factor of -0.776 with WECS terminal voltage at 0.95 p.u.

It's observed that that IR737 IC station transformer *(160MVA)* is overloaded up to 113% when the IR737 generation is operating at 147 MW output, while absorbing the maximum reactive power from its WECS.

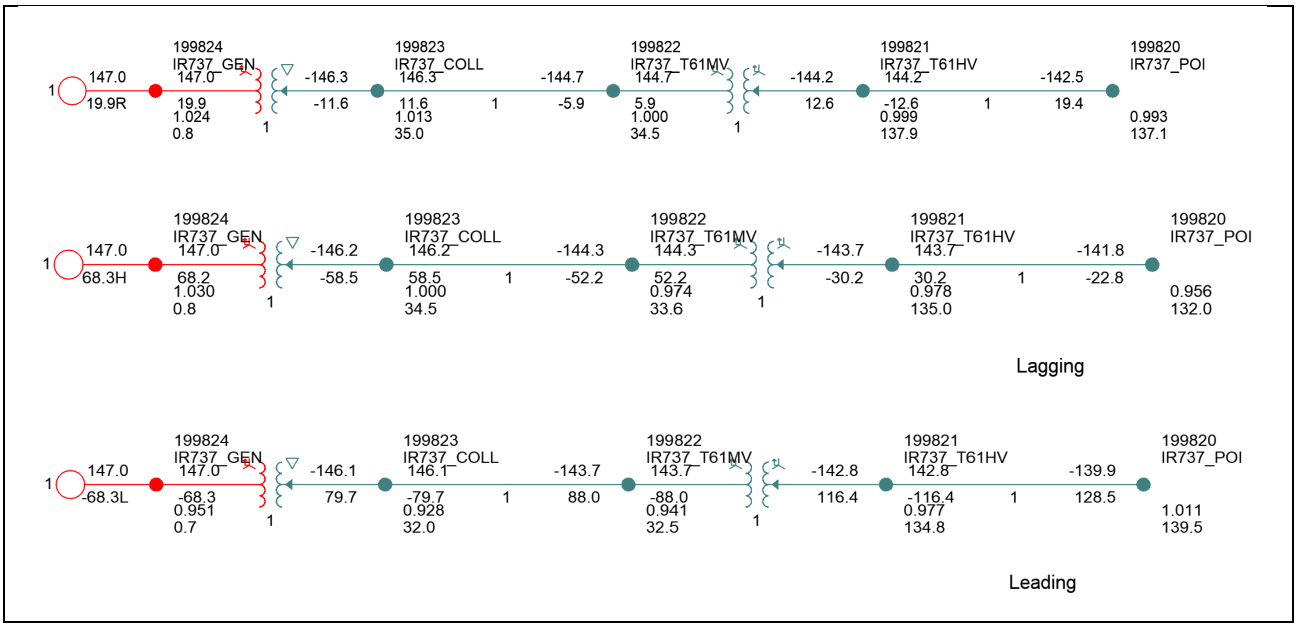

Figure 5: Power Factor Analysis

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

A centralized controller will be required which continuously adjusts individual generator reactive power output within the plant capability limits and regulates the voltage at the 34.5 kV bus voltage. The voltage controls must be responsive to voltage deviations at the terminals of the Interconnection Facility substation; be equipped with a voltage set-point control; and can slowly adjust the set-point over several (*5-10*) minutes to maintain reactive power within the individual generator capabilities. The details of the specific control features, control strategy and settings will be reviewed and addressed in the SIS, as will the dynamic performance of the generator and its excitation. Line drop compensation, voltage droop, control of separate switched capacitor banks must be provided.

The NSPI System Operator must have manual and remote control of the voltage set-point and the reactive set-point of this facility to coordinate reactive power dispatch requirements.

This facility must also have low voltage ride-through capability as per Appendix G of the Standard Generator Interconnection and Operating Agreement (*GIA*). The SIS will state specific options, controls and additional facilities that are required to achieve this.

Settings for the ICIF on-load tap-changer must be coordinated with plant voltage controller for long-term reactive power and voltage management at the POI.

9 System Security / Bulk Power Analysis

IR737's interconnection with L6012 is proposed with a three-breaker 138kV ring bus via a 15 km spur line from the Interconnection Customer substation. L6012 is not presently BPS. The BPS designation of IR737 will be further determined by the System Impact Studies (*SIS*).

As IR737 has dispersed generation with an aggregate more than 75 MVA, and will be categorized Bulk Electric System under NERC criteria. The generators and elements in Interconnection Customer substation (*including collector bus and substation step-up transformer*), are also categorized as BES, subject to the applicable NERC Reliability Criteria.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR737 to the NSPI transmission system at a POI on L6012:

Required Network Upgrades under NRIS:

1. Install a new 138kV substation complete with 3 breaker ring bus at the L6012 POI with control and protection. A Remote Terminal Unit (*RTU*) to interface with NSPI's SCADA, with telemetry and controls as required by NSPI.
2. Modification of NSPI protection systems at 17V-St Croix and 43V-Cannan Rd.
3. Reconductor L6004 (90H / 110) and upgrade 90H breakers, associated switches and equipment, and 90H-L6004 metering.
4. Reconductor L6012 (17V / IR737 POI) and upgrade 17V breakers, associated switches and equipment, and 17V-L6012 metering.
5. Reconductor L5016 (17V / 20V).
6. Reconductor L5017 (20V / 43V) and upgrade L5017 metering at 20V and 43V.
7. Replacement of transformer 17V-T63.

Required Transmission Provider's Interconnection Facilities *(TPIF)*:

1. Construct a total of 15 km transmission spur line between the L6012 POI and the Interconnection Customer's Interconnection Facility. This line would be built to 138kV standards.
2. Add control and communications between the solar plant and NSPI SCADA system (*to be specified*).

Required Interconnection Customer's Interconnection Facilities *(ICIF)*:

1. NS Power notes that NERC standard PRC-029-1 is currently in development. As proposed, this standard will impose performance requirements for voltage and frequency ride through behaviour on inverter-based generating resources. It is anticipated that this standard will be applicable to the project currently under study. The Interconnection Customer is advised to consider the requirements of PRC-029-1 in their project design to ensure that their project can conform to these requirements. Conformance will be validated at the System Impact Study stage.
2. Meet all requirements detailed in the TSIR, including the following:
   - 2.1. Facilities to provide 0.95 leading and lagging power factor when delivering rated output at the HV terminals of the IC Substation Step Up Transformer when the voltage at that point is operating between 95 and 105 % of nominal. This study shows that Enercon E-138 EP3 E3wind turbines would not meet the 0.95 lagging power factor requirement but will meet the requirement that rated reactive power be delivered from zero to full rated real power with the FTS option.
   - 2.2. 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.
   - 2.3. 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.
   - 2.4. Low voltage ride-through capability per Section 7.4.1 of the Nova Scotia Power Transmission System Interconnection Requirements (*TSIR*).
   - 2.5. 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.
   - 2.6. 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.
   - 2.7. With reference to TSIR section 7.6.7: Inertia Response - WECS, IR737 shall provide an inertia response equivalent to a Synchronous Generator with an inertia factor (*H*) of at least 3.0 MW·s/MVA for a period of at least 10 seconds.
   - 2.8. Automatic Generation Control to assist with tie-line regulation.
   - 2.9. Operation at ambient temperature of -30°C.
   - 2.10. Note that Section 7.4.15 of NSPI's TSIR states "System short circuit level may decline over time with changes to transmission configuration and generation mix. The Generating Facility shall be able to accommodate these changes".

11 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 147 MW wind energy at the L6012 POI for NRIS are included in Table 7.

Table 7: Cost Estimate for NRIS @ L6012 POI

Item	Network Upgrades	Estimate
I	Three breaker ring bus 138 kV substation complete with P&C at NSPI POI substation and connection to L6012, including P&C modifications at 17V-St. Croix and 43V-Canaan Rd.	$7,000,000
II	Replace existing 17V-T63 33.6/44.8/56 MVA transformer with a 39/52/65 MVA transformer	$3,500,000
III	Reconductor L6004 (90H to 110W) from 556.5 Drake to 1113 Beaumont, 47.4 km	$38,394,000
IV	Upgrade 90H-604 and 90H-605, associated switches and equipment, and 90H-L6004 metering	$2,950,000
V	Reconductor L6012 (17V to IR737 POI) from 556.5 Drake to 1113 Beaumont, 10.3 km	$8,343,000
VI	Upgrade 17V-611 17V-612, associated switches and equipment, and 17V-L6012 relaying and metering	$2,950,000
VII	Reconductor L5016 (17V to 20V) from 336.4 Linette to 556.5 Dove, 18 km	$9,000,000
VIII	Reconductor L5017 (20V to 43V) from 336.4 Linette to 556.5 Dove, 18 km	$9,000,000
IX	Upgrade L5017 metering at 20V and 43V	$100,000
	Sub-total for Network Upgrades	$81,240,000

Item	TPIF Upgrades	Estimate
I	15 km 138kV spur line from L6012 POI to IR737's substation, with IC responsible for providing Right-Of-Way	$15,000,000
II	Protection and control equipment & modifications	$100,000
III	Telecommunications (teleprotection & SCADA)	$150,000
IV	NSPI SCADA RTU housed at IR737	$60,000
	Sub-total for TPIF Upgrades	$15,310,000

Total Upgrades	Estimate
Network Upgrades + TPIF Upgrades	$96,550,000
Contingency (*25%*)	$24,140,000
Total (*Incl. 25% contingency and Excl. HST*)	$120,690,000

The preliminary non-binding cost estimate for interconnecting 147 MW at the POI on L6012 under NRIS is $120,690,000 including a 25% contingency. In this estimate, $81,240,000 (*plus 25% contingency*) of the amount represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP.

The preliminary cost estimate does not include any reactive power devices that are potentially required to meet the NSPI power factor requirements. It also does not include TBD costs to address any stability issues identified at the SIS stage based on dynamic analysis and EMT analysis.

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

12 Loss Factor

Loss factor is calculated by running the winter peak load flow case with and without the new facility in service while keeping 91H-Tufts Cove as the Nova Scotia Area Interchange bus. This methodology reflects the load centre in and around Metro.

The loss factor for IR737 is calculated as -0.4% at IR737's POI (*L6012, 138kV bus*), net of any losses on the IC facilities up to the POI. This means system losses on peak are marginally decreased when IR737 is operating at 147 MW. The MW measured at POI is 142.5 MW, the displaced generation MW at Tuff's Cove is 143.1MW. Therefore, the loss factor is calculated as -0.6/142.5 = -0.4%.

Table 8: Loss factor analysis

Component	At IR737 POI
IR737 at 147 MW	142.5 MW
Tufts Cove with IR737 on	328.5 MW
Tufts Cove with IR737 off	471.6 MW
IR737 loss factor	-0.4%

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS for IR737.

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, transient stability, ride through capability, 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 response, frequency response, control interactions with other IBR facilities, 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 notice on OASIS provides additional clarification on the SIS model requirements:

> *To be eligible for inclusion in the Interconnection System Impact Study stage, and thereby advance the Interconnection Request's initial Queue Position, the Interconnection Customer must meet the progression milestone requirements of Section 7.2 of the GIP at least ten (10) Business Days prior to the Interconnection System Impact Study commencement date. For clarity, item 7.2 (i) – provision of a detailed stability model for the generator(s) shall mean:*
>
> - *Provision of PSSE and PSCAD models in compliance with documents NSPI-TPR-015-2: PSSE and PSCAD Model Requirements, and*
> - *Provision of test data demonstrating model testing in compliance with NERC, NPCC and NSPI criteria. NSPI-TPR-014-1: Model Quality Testing lists the minimum requirements that will be performed by NSPI. Additional testing may be performed to assess compliance with all applicable criteria. Any test not meeting the minimum NSPI requirements will be documented in the MQT report to the IC.*
>
> *NSPI-TPR-015-2: PSSE and PSCAD Model Requirements and NSPI-TPR-014-1: Model Quality Testing will undergo revision as the grid evolves and performance criteria changes. The most up to date version will be provided as they become available.*

The following outline provides the minimum scope that must be complete to assess the impacts. It is recognized the actual scope may deviate, to achieve the primary objectives.

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

- Facilities that the customer must install to meet the requirements of the GIP and the *Transmission System Interconnection Requirements*.
- 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.
- Guidelines and restrictions applicable to first contingency operation *(curtailments etc.)*.
- Under-frequency load shedding impacts.

The SIS will assess system contingencies such that the system performance will meet the following criteria:

- Table 1 "Planning Design Criteria" of NPCC Directory 1.
- Table 1 "Steady State & Stability Performance Planning Events" of NERC TPL-001-5.1.
- NSPI System Design Criteria, report number NSPI-TPR-003-6.

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

14 Conclusion

The conclusion is covered in the Executive Summary.

Nova Scotia Power
Transmission System Operations
2024-06-14