Interconnection Feasibility Study Report

GIP-IR714-FEAS-R2

Generator Interconnection Request 714

115.5 MW Wind Generation Facility

Hants County, NS

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

Executive Summary

The Interconnection Customer *(IC)* submitted an Interconnection Request, both Network Resource Interconnection Service *(NRIS)* and Energy Resource Interconnection Service *(ERIS)*, for the proposed "Melvin Lake" 115.5 MW wind generation facility interconnected to the NSPI Transmission System with a 2025/12/30 Commercial Operation Date. The Point of Interconnection *(POI)* requested by the customer is the 138kV line L6011, approximately 16.5 km from the 17V-St. Croix substation and 13.5 km from the 120H-Brushy Hill 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 as the IR686 SIS was not complete when IR714 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 IR714 will displace coal-fired generation in eastern Nova Scotia for both NRIS and ERIS.

IR714 will connect to L6011 with a 138kV three-breaker ring bus via a 0.66 km spur line from the Interconnection Customer substation. L6011 is presently categorized as Northeast Power Coordinating Council *(NPCC)* Bulk Power System *(BPS)*. IR714's BPS designation will be determined in the subsequent System Impact Studies *(SIS)*.

IR714 will be subject to the applicable North American Electric Reliability Corporation *(NERC)* Reliability Criteria as its aggregate rated output is greater than 75 MVA. The new substation will be categorized NERC Bulk Electric System *(BES)* along with other elements *(generator step-up transformers, collector bus, and substation step-up transformer)* within its facility.

The assessment of the L6011 POI indicated several pre-existing thermal loading violations *(on Metro transmission lines L-6003, L-6009, and L-6010)*, but none that must be addressed for IR714. The IC should be aware the IC substation transformer's 100% rating *(115 MVA)* will be exceeded when the IR714 generation is operating at its maximum capped 115.5 MW output, while absorbing

or delivering reactive power from its WECS *(Wind Energy Conversion Systems)*. No violations of voltage criteria that were attributed to IR714 were found.

The IC indicated that IR714 will utilize the Nordex N163/5.X type 3 WECS. Based on the provided facility's equipment specifications *(transformers, collector circuits)*, IR714 requires additional equipment to meet the net power factor requirement of +0.95 at the high voltage side of Interconnection Facility. It is noted that the base Nordex N163/5.X wind turbine models require Nordex's "STATCOM function" to produce inductive and capacitive reactive power at below wind cut-in speeds.

IR714 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 34.5kV bus falls to 312.6 MVA with L6011 open at 120H-Brushy Hill, resulting in a short-circuit ratio *(SCR)* of 2.7, which is below the minimum SCR recommended by the generator vendor, Nordex.

The IC should consult Nordex to determine what modifications are required for low SCR conditions. The impact of the low SCR will be further examined when detailed data for the project is made available for the SIS.

IR714 meets NS Power's required short term and long-term voltage flicker requirements based off the supplied data. It is assumed that the project design meets NSPI requirements for low-voltage ride-through and voltage control. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

The preliminary value for the unit loss factor is calculated as 1.16% at the L6011 POI, 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 IR714 as either NRIS or ERIS, the preliminary non-binding cost estimate for interconnecting 115.5 MW to the L6011 POI including the cost of 3 breaker ring bus substation, protection upgrades at 120H-Brushy Hill, and 17V-St. Croix plus a total of 0.66 km spur lines from the POI to the Interconnection Customer's Interconnection Facility is $9,963,000. In this estimate, $7,000,000 *(plus 25% contingency)* of the amount represents Network Upgrade costs which are funded by the Interconnection Customer but are eligible for refund under the terms of the GIP. The remainder of the costs are fully funded by the Interconnection Customer.

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 an Interconnection Request for both Network Resource Interconnection Service *(NRIS)* and Energy Resource Interconnection Service *(ERIS)* for the proposed "Melvin Lake" 115.5 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2025-12-30. The Point of Interconnection *(POI)* requested by the customer is the 138kV line L6011, approximately 16.5 km from 17V-St. Croix substation and 13.5 km from the 120H-Brushy Hill substation.

The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2023-11-16, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 714 in the NSPI Interconnection Request Queue and will be referred to as IR714 throughout this report.

Figure 1 shows the proposed geographic location of IR714 in relation to the NSPI transmission system.

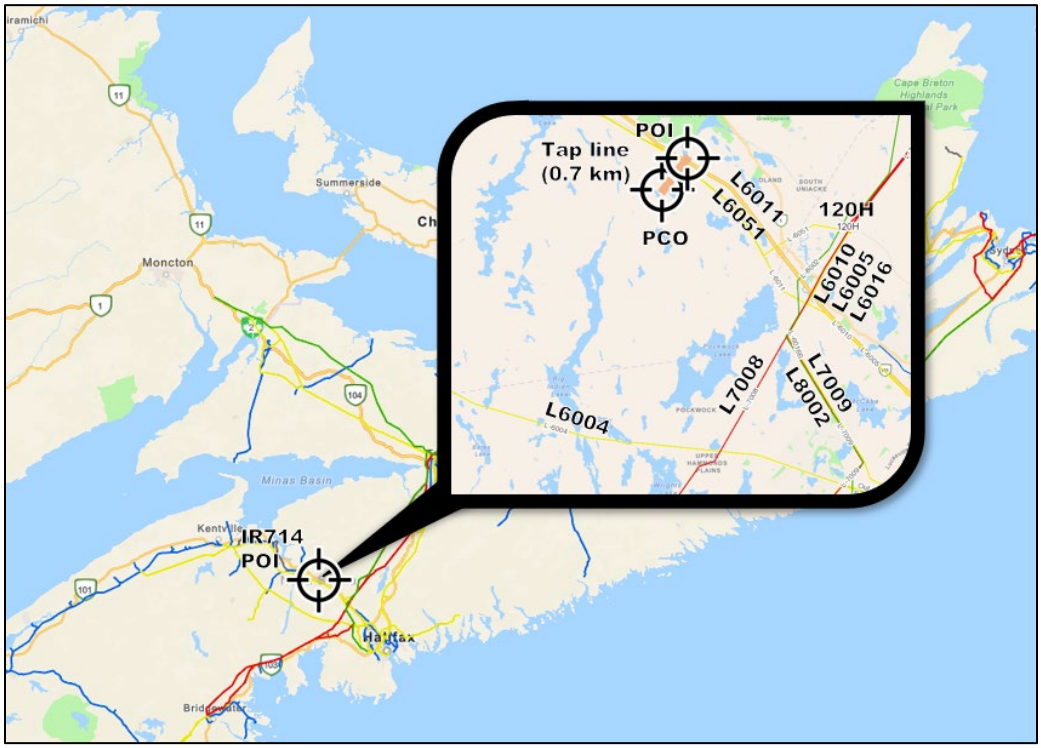

Figure 1 IR714 site location

Figure 2 is a simplified one-line diagram of the transmission system configuration in NS around IR714 POI.

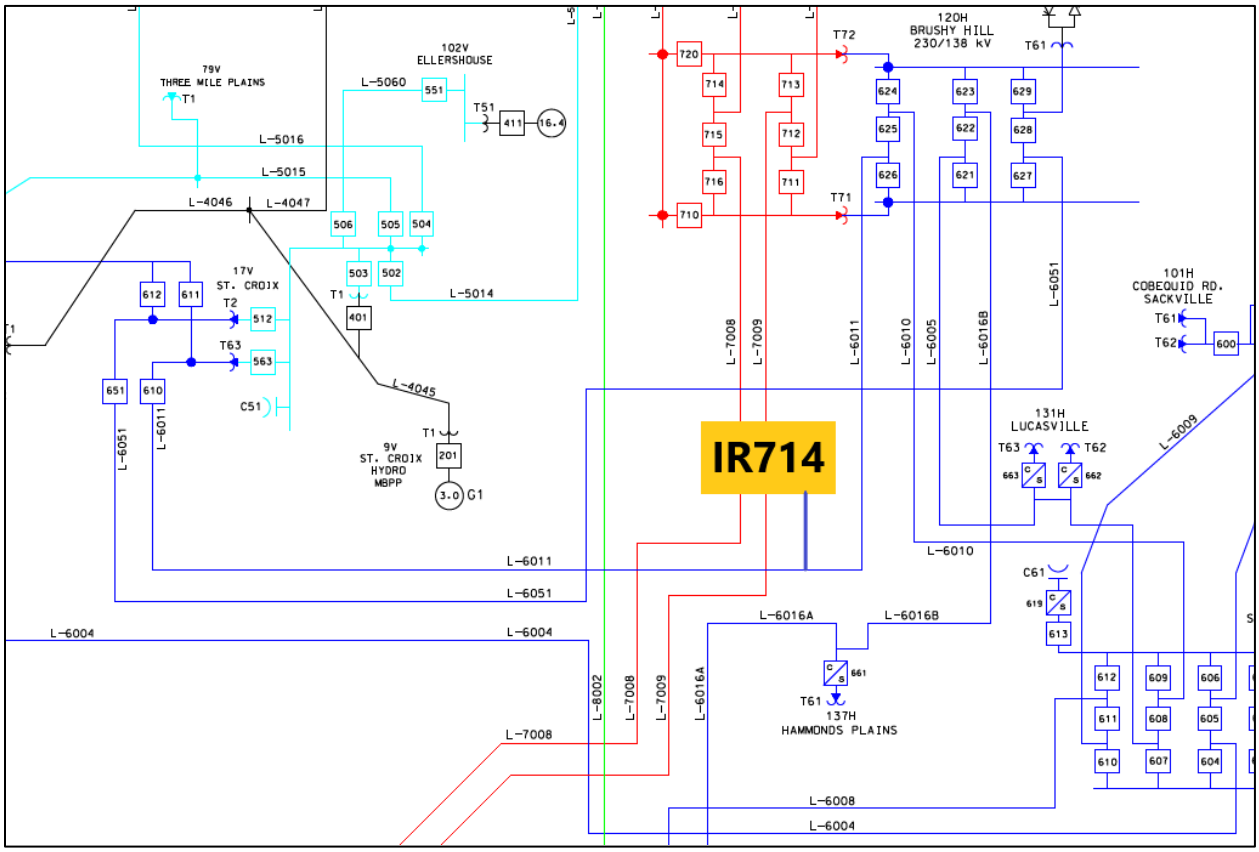

Figure 2 Point of Interconnection ***(not to scale)***

2 Scope

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

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

- Preliminary identification of any circuit breaker short circuit capability limits exceeded because of the interconnection, and any network upgrades necessary to address the short circuit issues associated with the IR. Expected minimum short circuit capability will also be identified for the purposes of Short Circuit Ratio analysis.
- Preliminary identification of any thermal overload or voltage limit violations resulting from the interconnection and identification of the necessary network upgrades to allow full output of the proposed facility. Thermal limits are applied to the seasonal *(summer/winter)* emergency ratings of transmission elements. Voltage violations occur when the post-contingency transmission bus voltage is outside the range of +/-10% of nominal voltage.
- Preliminary analysis of the ability of the proposed Interconnection Facility to meet the reactive power, power quality and cold-weather capability requirements of the NSPI *Transmission System Interconnection Requirements*[1].
- Preliminary description and high-level non-binding estimated cost and time to construct the facilities required to interconnect the generating facility to the transmission system.
- For comparative purposes, the impact of IR714 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] transmission-system-interconnection-requirements *(nspower.ca)*

1. NRIS and ERIS per section 3.2 of the Generator Interconnection procedures *(GIP)*.
2. Commercial Operation date 2025-12-30.
3. The Interconnection Customer Interconnection Facility *(ICIF)* consists of twenty Nordex 163/5.X 5.9 MW Type 3 DFIG *(Double-Fed Induction Generator)* Wind Energy Converter System *(WECS)* units, with a total capacity of 118 MW, capped at 115.5 MW.
    a. The generator terminals are at 750V.
    b. Connected to six collector circuits operating at a voltage of 34.5kV. Four collector circuits connected to 3 WECS units each *(totalling 12 WECS)* and two collector circuits connected to 4 WECS units each *(totalling 8 WECS)*.
4. The ICIF will require the construction of a 0.66 km 138 kV transmission spur line from the POI and a three-breaker ring bus substation prescribed in Table 8 of the NSPI *Transmission System Interconnection Requirements*. 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.
5. The generation technology used must meet NSPI requirements for reactive power capability of at least 0.95 capacitive to 0.95 inductive at the HV terminals of the IC substation step up transformer. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the designated voltage control point during and following system disturbances as determined in the subsequent System Impact Study. The designated voltage control point will either be the low voltage terminals of the wind farm transformer, or if the high voltage terminals are used, equipped with droop compensation controls. It is assumed that the generating units are not de-rated in their MW capability when delivering the required reactive power to the system.
6. Preliminary data was provided by the IC for the IC substation interconnection facility:
    a. The transformer is rated at 69/92/115 MVA and modeled with a positive-sequence impedance of 11.0% on 69 MVA *(15.94% on 100 MVA)* with an assumed X/R ratio of 25.0.
    b. The IC indicated that these interconnection facility transformers have a wye-delta-wye winding configuration with +/-10% on-load tap changer and 33 steps.
    c. The impedance of each generator step-up transformer *(34 kV/0.75 kV)* was modeled as 9.0% on 6.35 MVA with an assumed X/R ratio of 9.0 and +4x0.5 kV taps with 5 steps.
7. Collector circuit impedance *(R = 0.0132, X = 0.04362, B = 0.004676)* 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 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-001-5 *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 IR714 are shown in Table 1: Local Transmission Element Ratings.

Table 1: Local Transmission Element Ratings

Line	Conductor	Design Temp	Limiting Element	Summer Rating Normal/Emergency	Winter Rating Normal/Emergency
L-6054*	556.5 Dove	75°C	Conductor	174/191 MVA	210/231 MVA
L6011	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA
L-6051	795 Drake	100°C	Conductor	268/295 MVA	287/316 MVA
L-6004*	556.5 Dove	75°C	Conductor	174/191 MVA	210/231 MVA
L-6012	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA

*L-6054 and L-6004 currently use Dove 556.5 kcmil ACSR conductors with a design temperature of 75°C, it's assumed that L-6054 and L-6004 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 IR714 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 10,000 MVA at the 230 kV voltage levels, 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 Nordex N163/5.X 5.9

MW DFIG wind turbines is provided as 3.13 times rated current, or X'd = 0.319 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: Short-circuit levels.

Table 2: Short-circuit levels[2]

Location	Without IR714 (MVA)	With IR714 (MVA)
All transmission facilities in service		
IR714 POI on L6011 *(138kV)*	2,050	2,239
IR714 Interconnection Facility *(138kV)*	2,049	2,232
120H-Brushy Hill *(230kV)*	3,836	3,933
120H-Brushy Hill *(138kV)*	3,755	3,919
17V-St. Croix *(138kV)*	1,961	2,052
17V-St. Croix *(69kV)*	869	883
Minimum Conditions *(TC3, LG1, ML in-service)*		
IR714 Interconnection Facility *(138kV kV)*	1,086	1,296
IR714 34.5 kV	398	671
Minimum Conditions *(TC3, LG1, ML in-service)*, L6011 open at 120H		
IR714 Interconnection Facility *(138kV)*	622	812
IR714 34.5 kV	313	586

The interrupting capability of the 230 kV circuit breakers at 120H-Brushy Hill is at least 10,000 MVA. The interrupting capability of the 138 kV circuit breakers at 17V-St. Croix and 120H-Brushy Hill is at least 5,000 MVA. The interrupting capability of the 69 kV circuit breakers at 17V-St. Croix is at least 1,600 MVA. As such, the breaker interrupting ratings at these substations will not be exceeded with the addition of IR714.

Inverter-Based Resource *(IBR)* installations like IR714 often have a minimum Short Circuit Ratio *(SCR)* for proper operation of converters and control circuits. As per the data received from Nordex, the minimum SCR for Nordex N163 5.X WECS is 3.0 at the generator terminals.

Based on the calculated short circuit levels at the 34.5 kV collector bus, the SCR would be 3.4 at IR714's 34.5 kV substation bus in minimum load conditions with all lines in service and IR714

[2] 3-phase classical fault study, flat voltage profile.

offline. This falls to 3.2 with L6011 open at the 17V end, and 2.6 if L6011 is open at the 120H end.

The system short circuit level could be an issue for the WECS during system normal minimal generation conditions, where some WECS could have an SCR < 3.0 due to facility-associated losses *(like the collector circuits and generator step-up transformers)*. Under these conditions, the SCR at the WECS terminals will be < 3.0 when L6011 is open-ended at 120H.

IR714 does not directly share electrical substation endpoints *(17V-St Croix and 120H-Brushy Hill)* with other IBR sites on L6011. However, there are two other IBR sites within 2 km of 17V-St Croix on two separate lines from IR714; approximately 20 km between IR714 and the other two sites:

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

More detailed EMT analysis is required if IR714 proceeds to the SIS stage, as the standard SCR screening methodology becomes less definitive due to the three sites *(IR714, 102V, and 103V)* in relatively close proximity.

The IC should consult Nordex to determine what modifications are required for low SCR conditions. The impact of the low SCR will be further examined when detailed data for the project 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 Nordex N163 5.9 MW DFIG wind turbines *(flicker coefficient c(ψk, Pbin)* of 1.13 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: Calculated Voltage Flicker below.

Table 3: Calculated Voltage Flicker

System Conditions	Flicker at 138 kV Bus IR714 - 20 Machines
	Pst=Plt Continuous
Maximum Generation	
All Transmission in Service	0.016
Minimum Conditions *(TC3, LG1, ML In-Service)*	
All Transmission in Service	0.030
L6011 open at 120H	0.052
L6011 open at 17V	0.033

IR714 is not expected to cause voltage flicker issues as NS Power's required limits are 0.35 for P_{st} and 0.25 for P_{lt}. However, IR714 is required to resolve voltage flicker issues if it does cause them.

IR714 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 IR714 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-IR714 cases ending with "-1": IR714 off.
- Post-IR714 cases ending with "-2": IR714 dispatched at 115.5 MW under both NRIS and ERIS designation.

The cases and dispatch scenarios considered are shown in Table 4: Base cases for IR714.

Table 4: Base cases for IR714

Case	NS Load	IR714	Transmission 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)*
ll01-1-1	871	0	547	330	-475	345	42	367	54	19	-13	32
ll01-1-2	863	115.5	694	330	-475	240	-61	264	-84	16	-12	32
ll02-1-1	871	0	572	443	-475	345	-74	367	-4	-40	43	-23
ll02-1-2	863	115.5	719	443	-475	240	-177	264	-141	-43	43	-23
sh01-1-1	1,258	0	671	330	-475	440	303	667	119	113	-35	70
sh01-1-2	1,249	115.5	818	330	-475	331	175	539	-20	109	-35	71
sh02-1-1	1,202	0	695	423	-475	427	-104	404	-61	-299	36	-1
sh02-1-2	1,193	115.5	842	423	-448	292	-239	269	-198	-302	37	-1
sp01-1-1	1,661	0	1,281	330	-475	317	379	671	132	-109	-29	76
sp01-1-2	1,661	115.5	1,428	330	-461	226	289	581	-8	-113	-28	75
sp02-1-1	1,661	0	1,299	330	-475	317	423	715	142	-76	-29	76
sp02-1-2	1,661	115.5	1,446	330	-461	225	333	625	3	-80	-29	76
wp01-1-1	2,312	0	1,389	151	-475	620	774	967	148	-91	-24	99
wp01-1-2	2,312	115.5	1,536	151	-475	468	630	823	9	-95	-24	99
wp02-1-1	2,312	0	1,389	151	-475	648	801	993	163	-79	-24	99
wp02-1-2	2,312	115.5	1,536	151	-475	495	656	849	24	-83	-24	99
wp03-1-1	2,337	0	1,048	151	-475	588	955	1,148	201	254	-23	99
wp03-1-2	2,328	115.5	1,195	151	-475	435	811	1,003	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 both NRIS and ERIS analysis, this FEAS added IR714 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 IR714 interconnected to the POI on L6011. Automated analysis searched for violations of emergency thermal ratings and

emergency voltage limits for each contingency. Contingencies studied are listed in Table 5: Contingency List.

Table 5: Contingency List

Transmission Line	Transformer / Bus	Circuit Breaker Failure	Double Circuit Tower
L7008, L7009, 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	L7008+L7009 L7009+L8002
L6012, L6013, L6054, L6015, L6052, L5017, L5021, L5022, L5035, L5019, SHUNT *(138 kV)* 50V-Load *(138 kV)*	43V- T61, T62, B51	43V: 604, 613, 505, 562, 503, 506, 501, 502, 504	L5016+L6012
L6051, L6011, L5014, L5060, L5015, L5016, L4045, L4046, SHUNT *(69kV)*	17V-T2, T63, T1, B2	17V: 651, 610, 612, 611, 563, 512, 519, 505, IR714: 601	
L5025*, L6053, L6004, L5053	51V-T62, T61*, B51*, B52, B61	51V: 601, 602, 603, 500, 521, 562, 101V:601, 602	
L5531, L5532*, L5533 L5026*	13V- B51, 11V-B51*		
L6002, L6009, L6008, L6004, L6003, L5003, L5004	90H- T1, C61, C51	90H: 611, 608, 605, 604, 602, 612, 609, 606, 603, 610, 607, 601, 503, 506, 501 101H: 600; IR671:601	
L6005, L6010, L6011, L7008, L7009, L6051, L6016, L7018, 120H-SVC *(7.8 kV)*	120H- T71, T72	120H: 710, 711, 712, 713, 714, 715, 716, 720, 621, 622, 623, 624, 625, 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, 511, 516, 521, 523,	
L6020, L6024, L6025, L6048, L5541, L5530, L5539, L5540	50W-T53, B3, B4, B2, IR597, IR597_IR675	50W: 615, 600, 514, 517, 501	
L5535, L5027, L6021	9W-T2, T63, B52, B53, IR677	9W: 500	
	30W-T62, B51	30W: 508	

*Indicates contingency was studied with/without RAS action

Table 6: Contingencies resulting in reflects the list of all overloaded equipment after IR714 interconnection. With the interconnection of IR714, the study shows up to 116% overload[3], on L6003 between 91H-Tuft's Cove and 90H-Sackville under various contingency conditions. Thermal overloads are also observed on 138 kV line L6009 between 90H-Sackville and 101H-Cobequid Rd and 138 kV line L6010 between 90H-Sackville and 120H-Brushy Hill under various contingency conditions.

L6003, L6009, and L6010 overloads have been identified as pre-existing issues and mainly due to the low generation dispatch at 91H-Tuft's Cove. The interconnection of IR714 indicated 4%, 3.5% and 6.6% overload increase, respectively. 106.5% overload on L-6010 is identified only post-IR714 connection in wp02 case.

The steady state contingencies evaluated in this study demonstrate IR714 does not require Network Upgrades at POI and beyond to operate at request MW capability under NRIS and ERIS. However, the IR714 substation step-up transformer's 100% rating *(115 MVA)* is exceeded when the IR714 generation is operating at its maximum capped 115.5 MW output, while absorbing or delivering reactive power from its WECS.

Table 6: Contingencies resulting in highest line overload

Line/ Transformer	Line Segment	Highest Overload (based off emergency rating)	Case	Contingency
L-6003	91H-Tuft's Cove / 90H-Sackville	116% *(pre-existing, 4% increase due to IR714)*	wp01, sh02	90H-L6009-2 , 90H-L6009, 90H-611, 90H-610, 101H-600
L-6009	90H-Sackville / 101H-Cobequid Rd	115% *(pre-existing, 3.5% increase due to IR714)*	wp01, wp02	91H-611 , 91H-T11, 91H-609, 91H-603, 91H-523, 90H-L6003, 90H-606, 90H-605, 1H-603, 103H-600, DCT_L-5039][L-6033
L-6010	90H-Sackville / 120H-Brushy Hill	107% *(pre-existing, 6.6% increase due to IR714)*	wp01, wp02	DCT_L-6005][L-6016 , 120H-622

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR714 must be capable of delivering reactive power for a net power factor of at least +/- 0.95 of rated

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

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.

IR714 requires modifications to meet the continuous reactive power requirement as the base Nordex N163 5.9 MW DFIG WECS do not provide reactive power support below wind cut-in speeds. The IC should consult Nordex, as they offer a "STATCOM function" enables reactive power support while operating below WECS cut-in speeds.

The WECS have a 0.9 lagging and leading power factor *(+/- 2.761 MVAr per WECS)* when operating with a 0.96-1.06 p.u machine terminal voltage. This assumes each Nordex WECS is capped at 5.78 MW *(a total capped MW of 115.5 MW for IR714)*.

The provided Q-P diagram (Figure 3) performance for the Nordex N163/5.X 5.9 MW WECS. It indicates that the Nordex N163 5.9 MW DFIG alone will not meet the NSPI Transmission System Interconnection Requirements *(Section 7.6.2)* for rated reactive power being available from zero real power output of the Generating Facility.

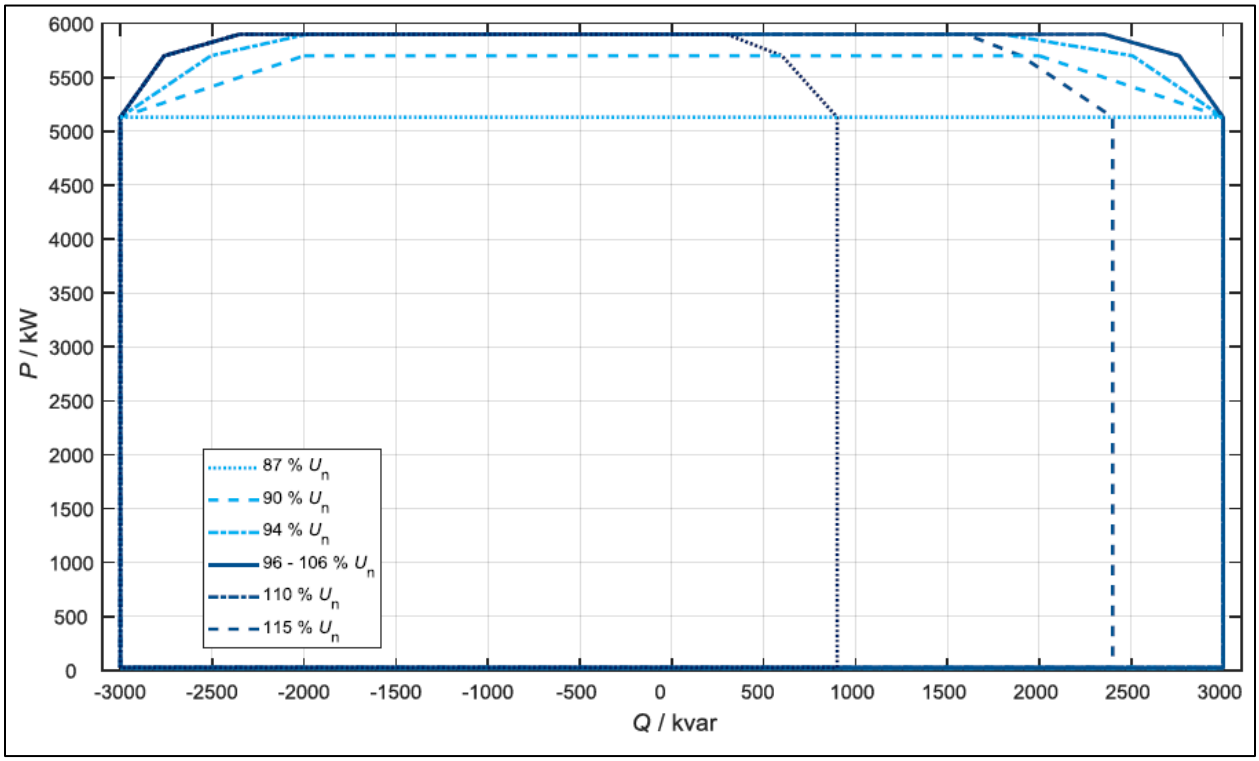

Figure 3: Nordex N163/5.X Mode 0.a *(5900 kW)* Q-P diagram[4]

Analysis shown in Figure 4 demonstrates IR714 will not meet its reactive power requirement. The model shows that with 20 WECS units *(Nordex N163 5.9 MW)* operating at a total 115.5 MW and 55.22 MVAr, the delivered power to the high side of the ICIF transformers is 111.7 MW and 18.1 MVAr, or a power factor of 0.987 with WECS terminal voltage at 1.06 p.u. Additional reactive power equipment is required to be supplied by the Interconnection Customer to meet the power factor 0.95 at the high-voltage side of the interconnection facility.

Due to the high voltage on the medium voltage system (34.5 kV) in these conditions, an onload tap changer is also required on the substation step-up transformer to maintain voltage in the nominal range for the WECS' reactive power support.

This configuration will meet the leading power factor requirement of -0.95 at the high side of ICIF transformer The model shows that with 20 units of WECS operating at a total of 115.5 MW and -55.22 MVAr, the delivered power to the high side of the ICIF transformers is 110.5 MW and -104.2 MVAr, or a power factor of -0.73 with WECS terminal voltage at 0.96 p.u.

[4] Nordex Reactive Power Capability; 2009087EN Rev. 1 / 2021-09-29; Supplied by IC.

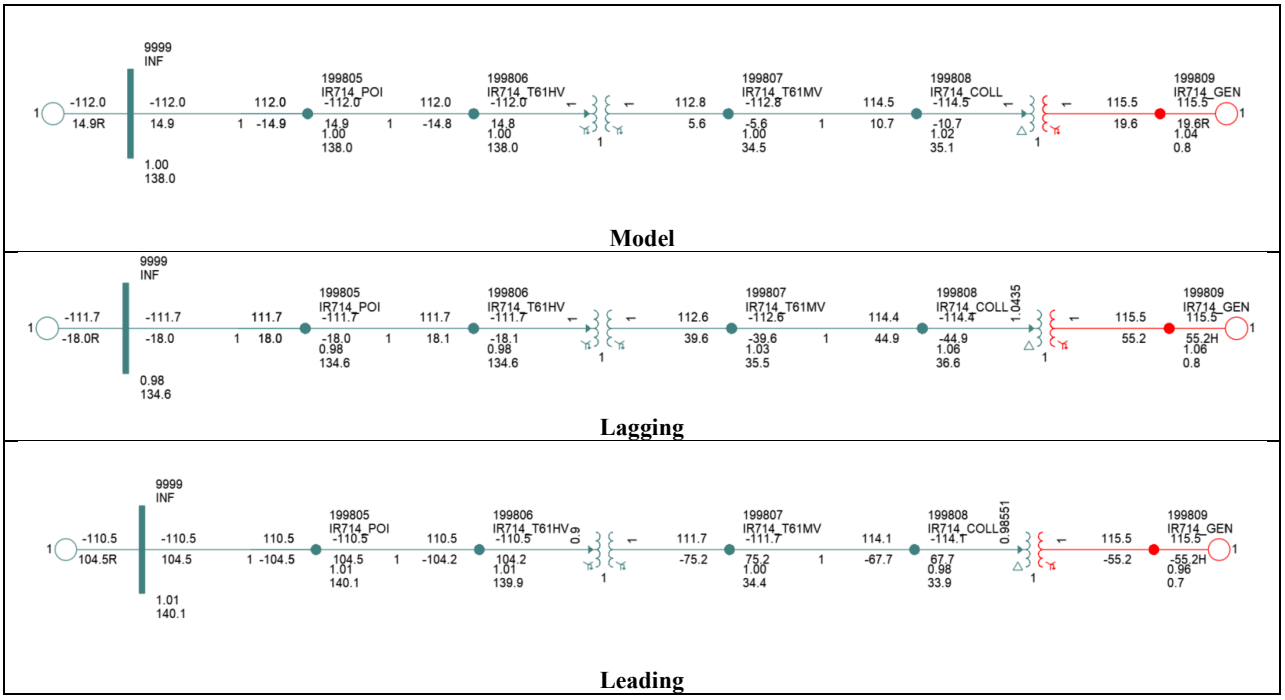

Figure 4 Power Factor Analysis

Please note that based on the preliminary power factor analysis, the IR714 substation transformer's 100% rating is exceeded when IR714 operates under leading and lagging power factor while fully dispatched in both leading and lagging cases. This analysis is based on preliminary transformer data, and assumed collector circuit models. Transformer loading level and IR714's 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

IR714's proposed POI is on L6011 with a 138kV three-breaker ring bus via a 0.66 km spur line from the Interconnection Customer substation. L6011 is presently categorized as NPCC BPS. The BPS designation of IR714 will be further determined in the subsequent System Impact Studies *(SIS)*.

L6011 is presently not NERC BES categorized. However, IR714 will be subject to the applicable NERC Reliability Criteria as its aggregate rated output is greater than 75 MVA. The new substation will be categorized BES under NERC criteria along other elements *(generator step-up transformers, collector bus, and substation step-up transformer)* within its facility.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR714 to the NSPI transmission system at a POI on L6011:

Required Network Upgrades under NRIS/ERIS:

1. Install a new 138kV substation complete with 3 breaker ring bus at the L6011 POI with control and protection. Install a new 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 120H-Brushy Hill.

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

1. Construct a total of 0.66 km transmission spur line between the L6011 POI and the Interconnection Customer's Interconnection Facility. This line would be built to 138kV standards.
2. Add control and communications between the wind 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 96 and 106 % of nominal. This study shows that Nordex N163/5.x DFIG wind turbines would not meet the 0.95 lagging power factor requirement alone and require additional support.

   2.2. Note that the Nordex N163/5.X WECS require the Nordex-supplied "STATCOM function" to provide reactive power support under at below wind cut-in speeds.

   2.3. Centralized controls. These will provide centralized voltage set-point controls and are known as Farm Control Units *(FCU)*, or Plant Controller. 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.

   2.4. 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.

   2.5. Low voltage ride-through capability per Section 7.4.1 of the Nova Scotia Power Transmission System Interconnection Requirements *(TSIR)*.

   2.6. 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.

   2.7. 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.

   2.8. With reference to TSIR section 7.6.7: Inertia Response - WECS, IR714 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.

   2.9. Automatic Generation Control to assist with tie-line regulation.

   2.10. Operation at ambient temperatures as low as -30°C.

   2.11. 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 115.5 MW wind energy at the L6011 POI are included in Table 7: Cost Estimate for NRIS and ERIS at L6011 POI.

Table 7: Cost Estimate for NRIS and ERIS at L6011 POI

Item	Network Upgrades	Estimate
1	Three breaker ring bus 138 kV substation complete with P&C at NSPI POI substation and connection to L6011, including P&C modifications at 17V-St Croix and 120H-Brushy Hill	$7,000,000
	Sub-total for Network Upgrades	$7,000,000
Item	**TPIF Upgrades**	**Estimate**
1	Build 0.66 km 138kV spur line from TPIF to ICIF, with IC responsible for providing Right-Of-Way	$660,000
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	$970,000
	Total Upgrades	**Estimate**
	Network Upgrades + TPIF Upgrades	$7,970,000
	Contingency *(25%)*	$1,993,000
	Total *(incl. 25% contingency and excl. HST)*	$9,963,000

The preliminary non-binding cost estimate for interconnecting 115.5 MW at the POI on L6011 under NRIS is $9,963,000 including a 25% contingency. In this estimate, $7,000,000 *(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 it assumes that RAS additions are approved by NPCC.

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 IR714 is calculated as 1.16% at IR714's POI *(L6011, 138kV bus)*. This means system losses on peak are marginally increased by 1.16% when IR714 is operating at 115.5 MW. The MW measured at POI is 111.9 MW, the displaced MW generation at Tuft's Cove is 110.6 MW. Therefore, the loss factor is calculated as 1.3/111.9 = 1.16%

Table 8: Loss factor analysis

Component	At IR714 POI
IR714 at 115.5 MW	111.9 MW
Tufts Cove with IR714 on	361.0 MW
Tufts Cove with IR714 off	471.6 MW
IR714 loss factor	1.16%

13 Preliminary Scope of Subsequent SIS

The following provides a preliminary scope of work for the subsequent SIS for IR714.

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