Interconnection Feasibility Study Report
GIP-IR724-FEAS-R1

Generator Interconnection Request 724

106.2 MW Wind Generation Facility

Hants County, NS

2024-05-31

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer *(IC)* submitted a Network Resource Interconnection Service *(NRIS)* Interconnection Request for the proposed "Panuke Lake" 106.2 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2027/12/31. The Point of Interconnection (POI) requested by the customer is the 138kV line L6004, approximately 8.5 km from the 101V-MacDonald Pond substation and 38.9 km from the 90H-Sackville substation. Approximately 5.6 km away from IR724 on L6004 and towards 101V is the POI of the IR671-Bear Lake 88.96 MW wind farm.

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 however it was not included in this study as the IR686 SIS was not complete when IR724 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 *(TSR-411)*.

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 IR724 will displace coal-fired generation in eastern Nova Scotia for NRIS.

IR724's proposed POI is on L6004 with a 138kV three-breaker ring bus via a 0.05 km spur line from the Interconnection Customer substation. IR724's BPS designation will be determined in the subsequent System Impact Studies *(SIS)*.

IR724 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.

IR724's assessment indicated five thermal overloads that must be addressed to connect the 106.2 MW as NRIS and five pre-existing conditions that are not IR724's responsibility. The five overloads that must be addressed are:

1. Replacing the existing 43V-T62 33.6/44.8/56 MVA transformer with a 39/52/65 MVA transformer.
2. Reconductoring L6004 (between 90H and IR724 POI), 39.1 km and upgrading associated 90H breakers, switches, and metering.

3. Reconductoring L6012 (between 17V and 43V), 40.25 km and upgrading associated 43V metering.
4. Reconductoring L6054 (between 101V and 43V), 25.2 km and upgrading associated 43V relaying and metering.
5. Uprating L5017 (between 20V and 43V), 18.18 km.

Note that the IR724 substation transformer *(rated 115 MVA)* is load to 110% of nominal when IR724 is operating at maximum active power output while absorbing the maximum reactive power.

The following pre-existing overloads not IR724's responsibility are:

1. L6003 (91H / 90H).
2. L6006 (99W / 50W).
3. L6009 (90H / 101H)
4. L5535A/B (9W / 92W / 15V)

Data provided by the IC indicates IR724 will utilize the Nordex N163/5.x type 3 WECS *(Wind Energy Conversion Systems).* Based on the provided facility's equipment specifications *(transformers, collector circuits),* IR724 will not meet the net power factor requirement of +0.95 at the high voltage side of Interconnection Facility. The IC indicated the WECS will be outfitted with Nordex's STATCOM module to provide MVAr capability at below wind cut-in speeds.

IR724 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 264.0 MVA with L6004 open at 90H-Sackville, resulting in a very low short-circuit ratio *(SCR)* of 2.48, which is below the minimum SCR recommended by the generator vendor, Nordex. Furthermore, there are three other IBR *(Inverter Based Resource)* windfarms in close proximity to IR724's POI, reducing the effective area SCR, and detailed EMT analysis and consultation with Nordex is required if IR724 proceeds to the SIS stage.

The IC should consult Nordex to determine if any support can be provided for IR724’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.

IR724 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 -0.19% at the POI on L6004, 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 IR724 as NRIS, the preliminary non-binding cost estimate for interconnecting its 106.2 MW to the L6004 POI, including the Network Upgrade costs of 43V-T62, L6004, L6012, L6054, and L5017, the three-breaker ring bus 138 kV substation, and associated upgrades is $132,640,000 including a 25% contingency. In this estimate, $106,110,000 *(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.

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1 Introduction

The Interconnection Customer *(IC)* submitted a Network Resource Interconnection Service *(NRIS)* Interconnection Request for a proposed 106.2 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2027/12/31. The Point of Interconnection (POI) requested by the customer is the 138kV line L6004, approximately 8.5 km from the 101V-MacDonald Pond substation and 38.9 km from the 90H-Sackville substation. Approximately 5.6 km away from IR724 on L6004 and towards 101V is the IR671-Bear Lake 88.96 MW wind farm

The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2023/11/02, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 724 in the NSPI Interconnection Request Queue and will be referred to as IR724 throughout this report.

Figure 1 shows the proposed geographic location of IR724 in relation to the NSPI transmission system.

Figure 1 IR724 site location

Figure 2: Point of Interconnection (*not to scale*) is a simplified one-line diagram of the transmission system configuration in NS around IR724 POI.

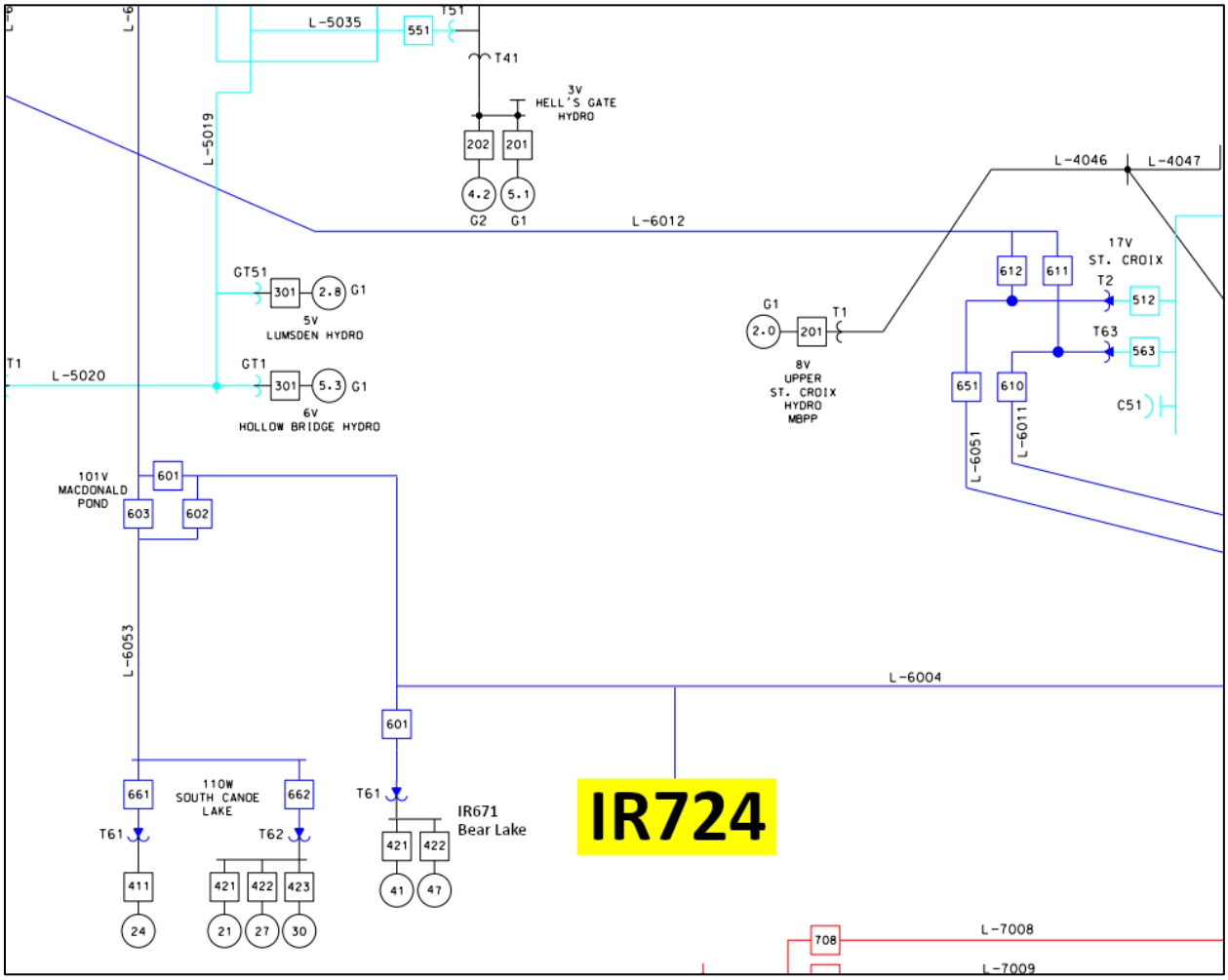

Figure 2: Point of Interconnection (*not to scale*)

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*[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 IR724 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 2027/12/31.
3. The Interconnection Customer Interconnection Facility *(ICIF)* consists of eighteen Nordex 163/5.x 5.9 MW Type 3 *(Doubly-Fed Induction Generator)* Wind Energy Converter System *(WECS)* units, with a total capacity of 106.2 MW.

   3.1. The generator terminals are at 750V.

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

3.2. Connected to three collector circuits operating at a voltage of 34.5kV with six WECS units each *(totalling 18 WECS)*.

4. The ICIF will require the construction of a 0.05 km 138 kV transmission spur line and a three-breaker ring bus substation prescribed in Table 8 of the NSPI *Transmission System Interconnection Requirements*. This configuration is dependent on IR671: Bear Lake's configuration *(presently a direct line tap)*. 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:

   6.1. The transformer is rated at 69/92/115 MVA and modeled with a positive-sequence impedance of 8.0% on 69 MVA *(i.e., 11.59% on 100 MVA)* with an assumed X/R ratio of 25.0.

   6.2. The IC indicated that these interconnection facility transformers have a wye-delta-wye winding configuration assumed with +/-10% tap changer and 33 steps.

   6.3. 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 tap changer with 5 steps.

7. Typical overhead collector circuit conductor was assumed to calculate an equivalent collector circuit since detailed circuit impedance data was not provided. Note that the net real and reactive power output of the plant is 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-001-4 *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 IR724 are shown in Table 1: Local Transmission Element Ratings.

Table 1: Local Transmission Element Ratings

Line	Conductor	Design Temp (°C)	Limiting Element	Summer Rating Normal/ Emergency (MVA)	Winter Rating Normal/ Emergency (MVA)
L6054*	556.5 Dove	75	Conductor	174/191	210/231
L6010	795 Drake	100	Conductor	268/295	287/316
L6011	556.5 Dove	100	Conductor	215/237	242/266
L6051	795 Drake	100	Conductor	268/295	287/316
L6004*	556.5 Dove	75	Conductor	174/191	210/231
L6012	556.5 Dove	100	Conductor	215/237	242/266

*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, except for IR686, as the IR686 SIS was not completed when IR724 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 given 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. V. 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 IR724	With IR724
All transmission facilities in service		
POI on L6004 *(138kV)*	1,378	1,571
Interconnection Facility *(138kV)*	1,375	1,569
101V- MacDonald Pond *(138kV)*	1,358	1,497
90H- Sackville *(138kV)*	3,985	4,089
Minimum Conditions (*TC3, LG1, ML In-Service*)		
IR724 Interconnection Facility *(138kV)*	779	973
IR724 34.5 kV	410	661
Minimum Conditions (*TC3, LG1, ML In-Service*), L6004 open at 90H		
IR724 Interconnection Facility *(138kV)*	379	573
IR724 34.5 kV	264	515
Minimum Conditions (*TC3, LG1, ML In-Service*), L6004 open at 101V		
IR724 Interconnection Facility *(138kV)*	611	805
IR724 34.5 kV	358	609

The interrupting capability of the 138 kV circuit breakers at 101V and 90H is at least 5,000 MVA. As such, the breaker interrupting ratings at these substations will not be exceeded with the addition of IR724.

Inverter-based generation installations often have a minimum Short Circuit Ratio *(SCR)* for proper operation of converters and control circuits. A typical minimum operational SCR 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 3.86 at IR724's 34.5 kV substation bus with all lines in service and IR724 offline. This falls to 2.48 with L6004 opens at 90H-Sackville end, and 3.37 if L6004 opens at 101V-MacDonald Pond end.

[2] Classical fault study, flat voltage profile.

Note, there are three IBR-based windfarms in relatively close proximity to IR724 on the ROW between 90H-Sackville and 43V-Canaan Rd. These sites are listed in Table 3: Windfarms in proximity to IR724.

Table 3: Windfarms in proximity to IR724

Site	Size (MW)	POI distance IR724 (km)	Status
110W-South Canoe	102.00	26.0	In-service
IR673: Benjamins Mill	33.60	12.8	FAC complete
IR671: Bear Lake	88.96	5.6	FAC in progress

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 L6004 is open-ended at 90H. Proximity with the windfarms listed in Table 3: Windfarms in proximity to IR724 will also reduce the effective SCR in the area and detailed EMT analysis and consultation with Nordex will be required if IR724 proceeds to the SIS stage.

The IC should consult Nordex to determine if any support can be provided for IR724'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. 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 1.32 at system angle of 85°).* Two sets of tested data[3] for flicker coefficient factors have been provided by the IC for two types of converters *(Vertiv and Ingeteam)* and the maximum flicker coefficient factor *c(ψk, Pbin)* of 1.32 for Ingeteam converter at system angle of 85° has been selected for the voltage flicker calculations. The voltage flicker Pst and Plt levels are calculated at the Interconnection Facility for various system conditions and are shown in Table 4: Calculated Voltage Flicker.

Table 4: Calculated Voltage Flicker

[3] *2026428EN_0_DD01_WICO_293NVC20-02-EX01_AUS_PQ-IEC_N149-5_X-Vertiv_Siemens_Gensheide.pdf and 9015030_00_DD01_WICO_295NVC20-02-EX01_AUS_PQ-IEC_N149-5.X-Ingeteam_ELIN_Santow.pdf*

System Conditions	Flicker at 138 kV Bus IR724 - 18 Machines
	Pst=Plt Continuous
Maximum Generation	
All Transmission in Service	0.026
Minimum Conditions (*TC3, LG1, ML In-Service*)	
All Transmission in Service	0.046
L6004 open at 101V	0.058
L6004 open at 90H	0.094

IR724 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, IR724 is required to resolve voltage flicker issues if it does cause them.

IR724 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 and winter peak load conditions which are expected to stress the Western-Valley areas. Generation dispatch was also chosen 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 that these wind plants would be near full output when IR724 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-IR724 cases ending with "-1": IR724 off.
- Post-IR724 cases ending with "-2": IR724 dispatched at 106.2 MW under NRIS designation.

The cases and dispatch scenarios considered are shown in Table 5: Base Cases for IR724.

Table 5: Base Cases for IR724

Case	NS Load	IR724	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)*
c_ll01-1-1	871	0	547	330	-475	345	42	367	54	19	-13	32
c_ll01-1-2	863	106.2	694	330	-475	240	-61	264	-84	16	-12	32
c_ll02-1-1	871	0	572	443	-475	345	-74	367	-4	-40	43	-23
c_ll02-1-2	863	106.2	719	443	-475	240	-177	264	-141	-43	43	-23
c_sh01-1-1	1,258	0	671	330	-475	440	303	667	119	113	-35	70
c_sh01-1-2	1,249	106.2	818	330	-475	331	175	539	-20	109	-35	71
c_sh02-1-1	1,202	0	695	423	-475	427	-104	404	-61	-299	36	-1
c_sh02-1-2	1,193	106.2	842	423	-448	292	-239	269	-198	-302	37	-1
c_sp01-1-1	1,661	0	1,281	330	-475	317	379	671	132	-109	-29	76
c_sp01-1-2	1,661	106.2	1,428	330	-461	226	289	581	-8	-113	-28	75
c_sp02-1-1	1,661	0	1,299	330	-475	317	423	715	142	-76	-29	76
c_sp02-1-2	1,661	106.2	1,446	330	-461	225	333	625	3	-80	-29	76
c_wp01-1-1	2,312	0	1,389	151	-475	620	774	967	148	-91	-24	99
c_wp01-1-2	2,312	106.2	1,536	151	-475	468	630	823	9	-95	-24	99
c_wp02-1-1	2,312	0	1,389	151	-475	648	801	993	163	-79	-24	99
c_wp02-1-2	2,312	106.2	1,536	151	-475	495	656	849	24	-83	-24	99

c_wp03-1-1	2,337	0	1,048	151	-475	588	955	1,148	201	254	-23	99
c_wp03-1-2	2,328	106.2	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 NRIS analysis, this FEAS added IR724 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 IR724 interconnected to the POI on L6004. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 6: Contingency List.

Table 6: 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,	
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, IR724-L6004	91H-T62, T11,	91H: 621, 613, 603, 604, 605, 606, 607, 608, 609, 611, 511, 516, 521, 523, 90H: IR724-601	

Transmission Line	Transformer / Bus	Circuit Breaker Failure	Double Circuit Tower
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 7: Contingencies resulting in highest element overload lists of all overloaded transmission facilities in NS Power's system with IR724 interconnected under various contingencies.

Under N-0 *(pre-contingency)* conditions when high generation is present in the Western portion of the system, like during spring run off, the L6004 segment between 90H-Sackville and IR724's POI can be thermally overloaded[4] up to 107%. Further contingencies cause overloads as high as 146%.

Up to 136% overload on L6054 are identified between 43V and IR673-POI under various contingency conditions. Thermal overloads are also identified on 138 kV line L6012 *(116%)* between 17V-St. Croix and 43V-Cannad Rd and 69 kV line L5017 *(119%)* between 20V-Five Point and 43V-Cannan Rd under various contingency conditions. These overloaded lines are solely attributed to IR724 interconnection, and a line uprate is required to resolve these thermal overload issues.

L6003 and L6009 Metro overloads have been identified as pre-existing issues and mainly due to the low generation dispatch at Tuft's Cove. The interconnection of IR724 indicated 10.8% and 4.8% overload increase on these lines, respectively.

L5535 overload has been identified as pre-existing issues but the interconnection of IR724 indicated 7.3% overload increase on L5535, which could trigger the existing AAS to cross trip Gulliver's Cove wind farm.

The transformer 43V-T62 will be overloaded up to 117.2% of 61.6 MVA *(17% increase)* under 43V-613 and 43V-T61 contingency due to IR724 interconnection.

L6006 shows marginal overload *(100.2%)* post IR724, however this is mainly due to the high Western Valley export.

The steady state contingencies evaluated in this study demonstrate IR724 requires L6004, L6054, L6012, L5017 and 43V-T62 upgrades to operate at requested MW capability under NRIS. Please note that the IC substation transformer *(rated at 115 MVA)* is exceeds its 100% nominal rating when the IR724 generation is operating at 106.2 MW output, while absorbing maximum 42.3 MVAr of reactive power.

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

Table 7: Contingencies resulting in highest element overload

Element	Line Segment	Highest Overload (based off emergency rating)	Case	Contingency	IR724 to address?
L6003	91H-Tuft's Cove/90H-Sackville	117.8% of 179.3 MVA (*pre-existing, 10.8% increase due to IR724*)	wp01, wp02, sh02, sp01, sp02,	90H-611, 90H-L6009-2 , 90H-L6009, 90H-610, 101H-600	No
L6004	90H-Sackville/IR724-POI	107% of 215 MVA under system normal 145.9% of 236.5 MVA under contingencies	sh02	System normal condition	Yes
L6006	99W-Bridgewater/50W-Milton	100.2% of 148.5 MVA (*pre- existing, minor increase due to IR724*)	sh02	99W-L6025	No
L6009	90H-Sackville/ 101H-Cobequid Rd	116.2% of 266.2 MVA (*pre-existing, 4.8% increase due to IR724)*	wp01, wp02	91H-611 , 91H-T11, 91H-609, 91H-603, 91H-523, 90H-L6003, 90H-606, 103H-600, 1H-603, 103H_L6033, DCT_L5039][L6033	No
L5535A	9W-Tusket/92W-Carleton	121% of 25.3 MVA (*pre-existing, 7.3% increase due to IR724*)	ll02	50W 50W-B2, 50W L5541, 50W 50W-514, 50W 50W-517, 13V L5026, 50W 50W-501	No
L5535B	92W-Carleton/15V-Sissiboo	123.2% of 25.3 MVA (*pre- existing, 7.3% increase due to IR724*)	ll02	50W 50W-B2, 50W L5541, 50W 50W-514, 50W 50W-517, 50W 50W-502	No
L6012	17V-St Croix/43V-Canaan Rd	116% of 236.5 MVA	sh02	90H-604, 90H-605, 90H_L6004-1	Yes
L5017-1	20V-Five Points/ 0V-Wolftap	104.5% of 45.1 MVA	sh02	90H-604, 90H-605, 90H_L6004-1	Yes
L5017-2	0V-Wolftap/43V-Canaan Rd	119% of 45.1 MVA	sh02	90H-604, 90H-605, 90H_L6004-1, 43V-L6012, 43V-T61	Yes
L6054-1	43V-Canaan Rd/IR673-POI	136% of 236.5 MVA	All cases	90H-604, 90H-605, 90H_L6004-1	Yes
L6054-2	101V-MacDonald Pond/ IR673-POI	122% of 236.5 MVA	All cases	90H-604, 90H-605, 90H_L6004-1	Yes
43V-T62	43V-Canaan Rd:69/ 43V-Canaan Rd:138	117.2% of 61.6 MVA	sp02, wp02, wp03	43V-613, 43V-T61	Yes

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR724 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 WECS have a 0.929 lagging and leading power factor *(+/- 2.35 Mvar per WECS)* when operating with a 0.96-1.06 p.u machine terminal voltage. This assumes each Nordex WECS is operated at 5.9 MW *(a total rated MW of 106.2 MW for IR724)*.

The provided Q-P diagram (Figure 3) shows the performance for the Nordex N163/5.X 5.9 MW WECS. The IC also indicated they would be outfitted with Nordex's "STATCOM function" to provide reactive power while operating below wind cut-in speeds

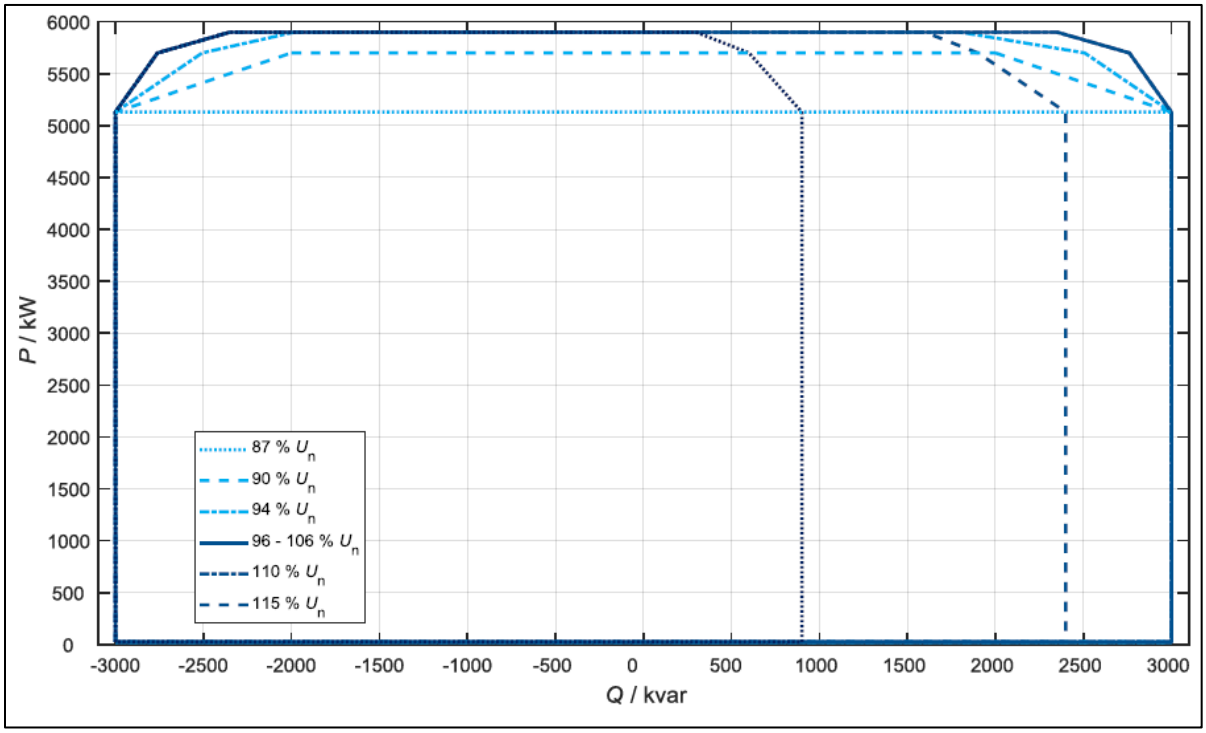

Figure 3 Nordex N163/5.X Mode 0.a (*5900 kW*) Q-P diagram[5]

Analysis shown in Figure 4 illustrates IR724's full-load reactive power performance. The model shows that with 18 WECS units *(Nordex N163 5.9 MW)* operating at a total 106.2 MW and 42.3

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

MVAr, the delivered power to the high side of the ICIF transformers is 103.5 MW and 15.7 MVAr, or a power factor of 0.988 with WECS terminal voltage at 1.06 p.u. Additional reactive power is required by the Interconnection Customer's auxiliary device 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 on-load tap changer may required on the substation step-up transformer to maintain voltage in the optimal range for the WECS' reactive power support.

This configuration is able to meet the leading power factor requirement of -0.95 at the high side of ICIF transformer The model shows that with 18 units of WECS operating at a total of 106.2 MW and -42.3 MVAr, the delivered power to the high side of the ICIF transformers is 102.9 MW and -75.2 MVAr, or a power factor of -0.81 with WECS terminal voltage at 0.96 p.u.

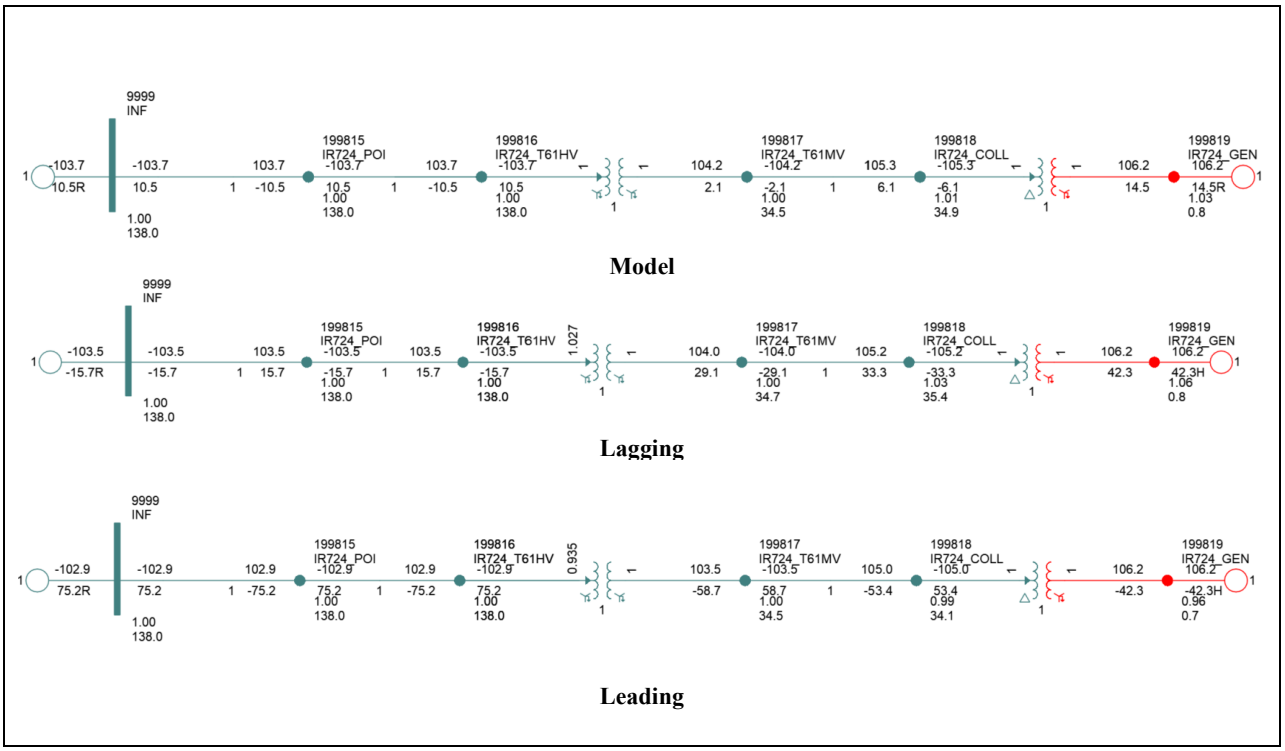

Figure 4 Power Factor Analysis

Additional lagging reactive power support is required when operating below wind cut-in speeds, even when all WECS are equipped with Nordex's "STATCOM function". Figure 5: Nordex's "STATCOM function" capability indicates the maximum reactive power available in these conditions is between -1.9 MVAr and +1.7 MVAr, for a total -34.2 MVAr to 30.6 MVAr plant capability.

Table 1: Maximum possible reactive power during WT standstill in relation to the voltage at the reference point

		Without STATCOM	With STATCOM
Maximum reactive power range (10-min-average)	90 % U_n -Q...+Q / kvar	0	-1700
		0	1700
	100 % U_n -Q...+Q / kvar	0	-1900
		0	1700
	110 % U_n -Q...+Q / kvar	0	-1900
		0	0

Figure 5: Nordex's "STATCOM function" capability

The IC placed a fixed capacitor bank with TBD sizing on the supplied single-line diagram. This capacitor bank may be used to address the lagging reactive power factor deficit provided it is used to bias the combined WECS' reactive power range.

Please note that based on the preliminary power factor analysis, the IR724 substation transformer exceeds its 100% nominal rating when IR724 operates under leading power factor while fully dispatched. Note that in both leading and lagging cases, the transformer will be overloaded. This analysis is based on preliminary transformer data and assumed collector circuit models. Transformer loading level and IR724'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

IR724's proposed POI is on L6004 with a 138kV three-breaker ring bus via a 0.05 km spur line from the Interconnection Customer substation. L6004 is presently not categorized as BPS. The BPS designation of IR724 will be further determined by the subsequent System Impact Studies *(SIS)*.

L6004 is presently not categorized as BES. However, IR724 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.

The combined 195.16 MW of generation (88.96 MW_{IR671}+ 106.2 MW_{IR724}) at this L6004 POI approaches the threshold where its loss can become one of Nova Scotia's largest source loss contingencies. Additional system reserve is required in the conditions that this is a candidate.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR724 to the NSPI transmission system at a POI on L6004:

Required Network Upgrades under NRIS:

1. Install a new 138kV substation complete with 3 breaker ring bus at the L6004 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 101V and 90H substations.
3. Replacement of 43V-T62
4. Uprate the lines L6004, L6012, L6054, and L5017.

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

1. Construct a total of 0.05 km transmission spur line between the L6004 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 alone and require an auxiliary device for reactive power support.
   2.2. Note that the Nordex N163/5.x WECS require the Nordex-supplied "STATCOM function" to provide reactive power support 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*). 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, IR724 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 temperature of -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 106.2 MW wind energy at the L6004 POI are included in Table 8: Cost Estimate for NRIS @ L6004 POI for NRIS.

Table 8: Cost Estimate for NRIS @ L6004 POI

Item	Network Upgrades	Estimate
I	Three breaker ring bus 138 kV substation complete with P&C at NSPI POI substation and connection to L6004, including P&C modifications at 90H and 101V.	$7,000,000
II	Replace existing 43V-T62 33.6/44.8/56 MVA transformer with a 39/52/65 MVA transformer	$3,500,000
III	Reconductor L6004 (90H to IR724 POI) from 556.5 Drake to 1113 Beaumont, 39.1 km	$31,671,000
IV	Upgrade breakers (90H-604 and 90H-605), switches, and metering associated with L6004 at 90H.	$2,950,000
V	Reconductor L6012 (17V to 43V) from 556.5 Dove to 795 Drake, 40.25 km	$32,602,500
VI	Upgrade L6012 metering at 43V	$50,000
VII	Reconductor L6054 (101V to 43V) from 556.5 Dove to 1113 Beaumont, 25.2 km	$20,412,000
VIII	Upgrade switches (43V-604), relaying, and metering associated with L6054 at 43V	$200,000
IX	Uprate L5017 (20V to 43V) 336.4 Linnet from 50°C to 70°C, 18.18 km	$7,362,900
	Sub-total for Network Upgrades	$105,750,000

Item	TPIF Upgrades	Estimate
I	0.05 km 138kV spur line from L6004 POI to IR724's substation, with IC responsible for providing Right-Of-Way	$45,000
II	Protection and control equipment & modifications	$100,000
III	Telecommunications (teleprotection & SCADA)	$150,000
IV	NSPI SCADA RTU housed at IR724	$60,000
	Sub-total for TPIF Upgrades	$355,000

Total Upgrades	Estimate
Network Upgrades + TPIF Upgrades	$106,110,000
Contingency (*25%*)	$26,530,000
Total (*Incl. 10% contingency and Excl. HST*)	$132,640,000

The preliminary non-binding cost estimate for interconnecting 102.6 MW at the POI on L6004

under NRIS is $132,640,000 including a 25% contingency. In this estimate, $105,750,000 *(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 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 IR724 is calculated as -0.19% at IR724's POI (*L6004, 138kV bus*), net of any losses on the IC facilities up to the POI. This means system losses on peak are marginally decreased by 0.19% when IR724 is operating at 106.2 MW. The MW measured at POI is 103.6 MW, the displaced MW generation at Tufts Cove is 103.8 MW. Therefore, the loss factor is calculated as -0.2/103.6 = -0.19%.

Table 9: Loss factor analysis

Component	At IR724 POI
IR724 at 106.2 MW	103.6 MW
Tufts Cove with IR724 on	367.8 MW
Tufts Cove with IR724 off	471.6 MW
IR724 loss factor	-0.19%

13 Preliminary Scope of Subsequent SIS

The following provides a preliminary scope of work for the subsequent SIS for IR724.

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

2024-05-31