Interconnection Feasibility Study Report
GIP-IR723-FEAS-R1

Generator Interconnection Request 723

100.3 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 "Ellershouse 4" 100.3 MW wind generation facility interconnected to the NSPI transmission system, with a 2027/12/31 Commercial Operation Date.

The Point of Interconnection *(POI)* requested by the IC was L6051. However, it has been changed to the 103V-Ellershouse 3 substation 138 kV bus, whose substation is adjacent to IR730's proposed substation location. The 103V substation is connected to L6051 via a 0.075 km spur line whose tap point is 2.5 km from 17V-St. Croix substation and 25 km to the 120H-Brushy Hill substation. Adding IR723 to the 138 kV bus will require changing the 103V's direct line tap associated with IR574 to a three-breaker ring bus.

There are twenty-two transmission and sixteen distribution higher-queued Interconnection Requests in the Advanced Stage Transmission and Distribution Queue included in this study. IR686 is a higher queued transmission-connected generation IR with its SIS in progress, however it was not included in this study as the IR686 SIS was not complete when IR723 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 IR723 will displace coal-fired generation in eastern Nova Scotia for NRIS.

IR723's NPCC BPS categorization will be determined in the subsequent System Impact Study *(SIS)*. The higher queued IR574: Ellershouse 3 project's categorization may change if IR723 proceeds and is BPS categorized. At the time IR574 was studied, it was categorized non-BPS, however both IRs are effectively electrically adjacent and the larger combined injection will have more pronounced system impacts.

IR723 will be categorized as NERC BES due to its aggregated rated output being >75 MVA. By extension, IR574's status will also change to BES as both IR574 and IR723 have an aggregate >75 MVA based on NERC BES point of aggregation criteria *(single point of failure resulting >75 MVA aggregate loss)*.

The assessment of IR723's 100.3 MW indicated the IC substation transformer *(rated at 110 MVA)* is loaded to 110% of nominal when the IR723 generation is operating at 100.3 MW output, while absorbing maximum 39.95 MVAr of reactive power.

17V-T2's loading also approaches its post-contingency limit during peak load conditions. There were also several pre-existing thermal loading violations *(on Metro transmission lines L6003,*

L6009, and L6010, and L5535 between 9W-Tusket and 15V-Sissiboo) that are not required to be addressed for IR714.

Power factor analysis indicates IR723 requires additional reactive power support to meet the +0.95 lagging power factor requirement at the high side of the interconnection transformer's terminals. However, the -0.95 leading power factor requirement is met with the present equipment configuration. The IC may be able to compensate with the TBA capacitor bank specified by the IC, provided the capacitor bank can bias the facility's reactive power output range. Otherwise, other dynamic reactive equipment is required.

There are two other IBR based generation sites in relatively close proximity, further reducing the effective SCR level. Including IR574's influence, which shares the same 138 kV bus as IR737, the SCR at IR737's collector bus is 2.5 under minimum conditions and L6051 open at 17V. Levels lower than this *(Type 3 WECS typically have a recommended operating 3.0 threshold)* would be present at the WECS generator terminals.

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.

IR723 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 0.31% at the 103V 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 IR723 as NRIS, the preliminary non-binding cost estimate for interconnecting 100.3 MW to the 103V-Ellershouse 3 138 kV bus is $9,045,000 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 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 18-24 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.

Contents

1 Introduction

The Interconnection Customer *(IC)* submitted a Network Resource Interconnection Service *(NRIS)* Request for the proposed "Ellershouse 4" 100.3 MW wind generation facility interconnected to the NSPI transmission system, with a Commercial Operation Date of 2027-12-31.

The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2023-11-23, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 723 in the NSPI Interconnection Request Queue and will be referred to as IR723 throughout this report.

The Point of Interconnection *(POI)* requested by the IC was L6051. However, it has been changed to the 103V-Ellershouse 3 substation 138 kV bus, whose substation is adjacent to IR723's proposed substation location. The 103V substation is approximately 2.5 km from the 17V-St. Croix substation and 25 km to the 120H-Brushy Hill substation.

Adding IR723 to the 138 kV bus necessitates changing the 103V's direct line tap associated with IR574 to a three-breaker ring bus as a Network Upgrade.

Figure 1 shows the proposed geographic location of IR723 in relation to the NSPI transmission system.

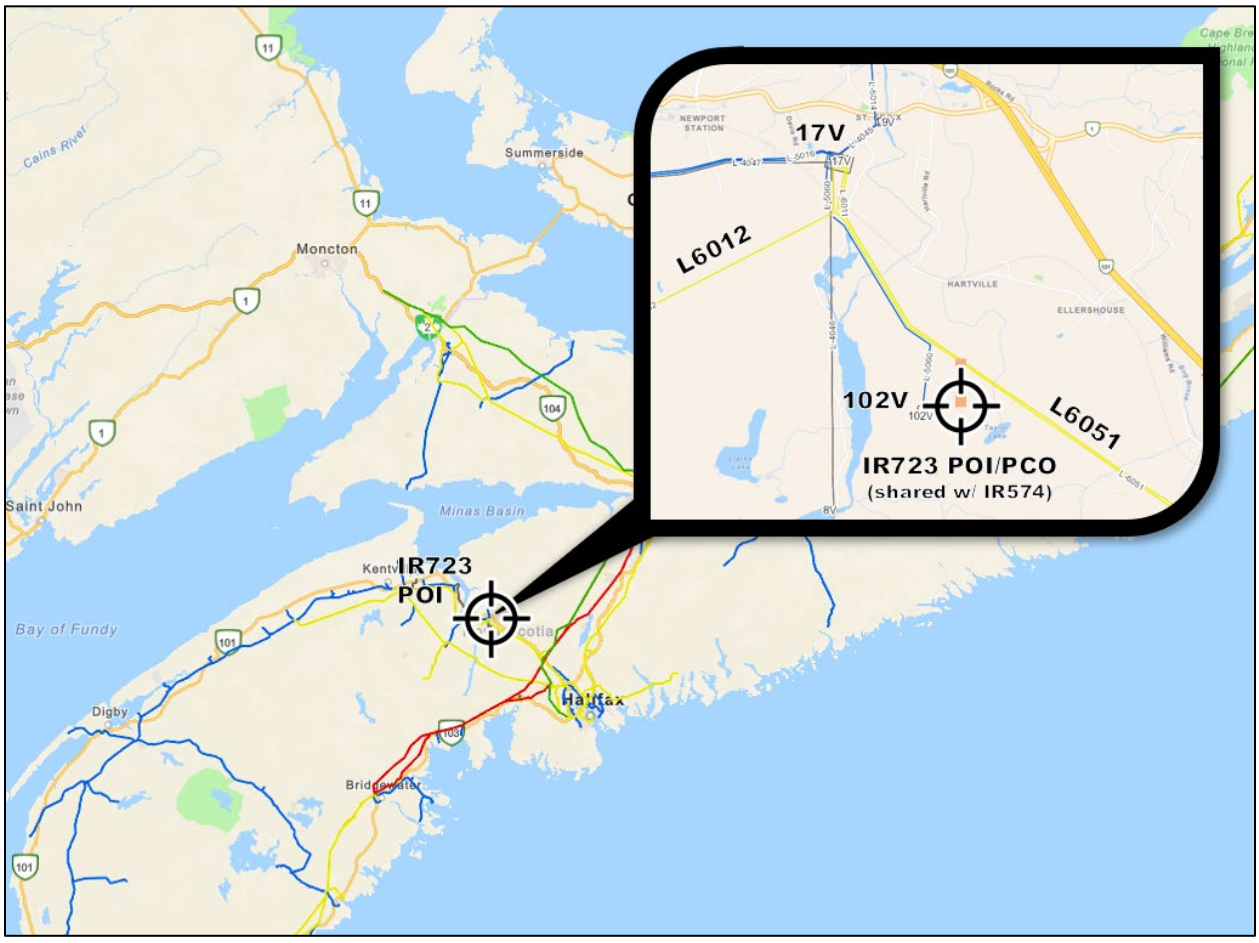

Figure 1 IR723 Site Location

Figure 2:Point of Interconnection *(not to scale)* shows the circuit breaker configuration of transmission lines in the vicinity of the POI.

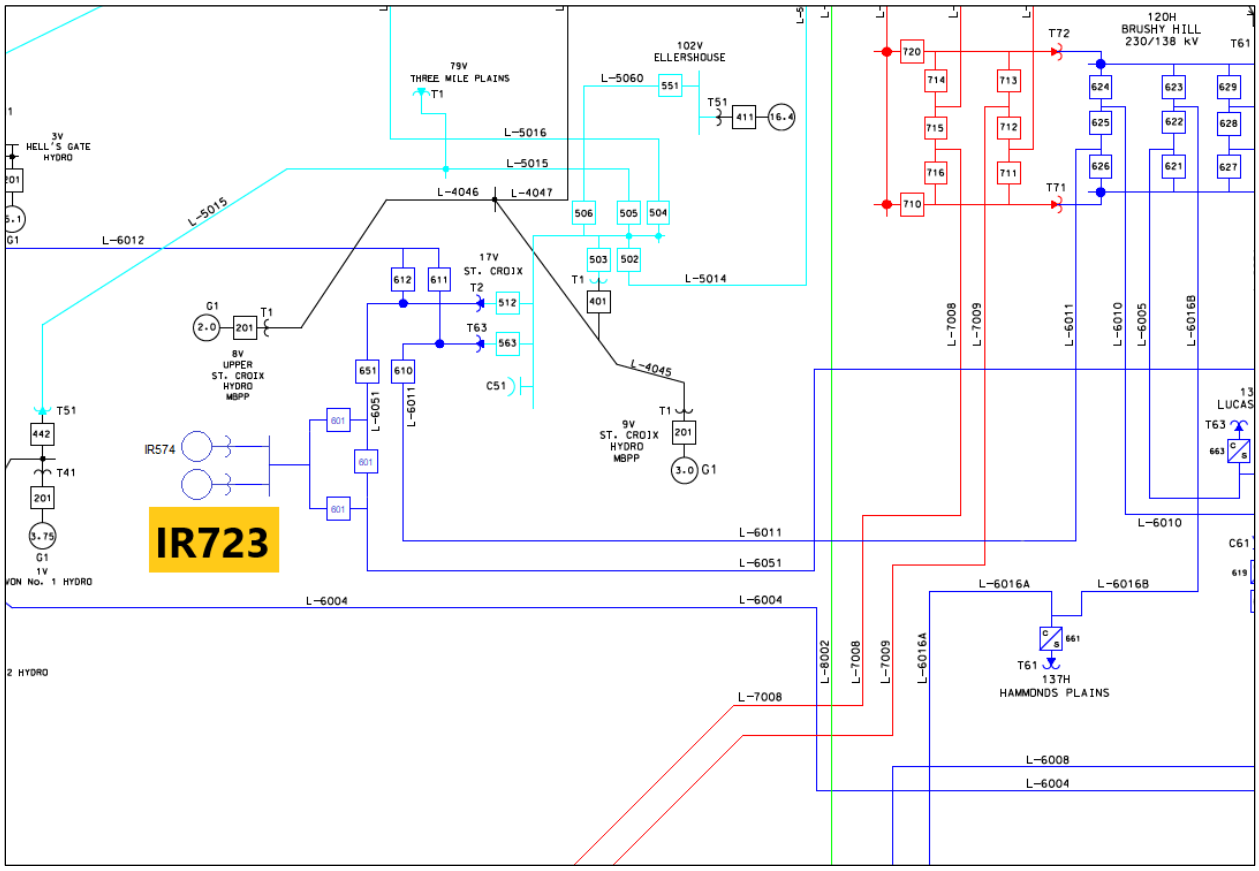

Figure 2:Point of Interconnection *(not to scale)*

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 IR723 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 17 Nordex 163/5.X 5.9 MW Type 3 *(Double-Fed Induction Generator)* Wind Energy Converter System *(WECS)* units with a total capacity of 100.3 MW.
   a. The generator terminals are 750V.
   b. Connected to three collector circuits operating at a voltage of 34.5kV. Two collector circuits connected to 6 WECS units each *(totalling 12 WECS)* and one collector circuit connected to 5 WECS units.
   c. The WECS are equipped with Nordex's "STATCOM function" module.

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

4. The proposed Point of Interconnection *(POI)* is the 103V-Ellershouse 3 substation 138 kV bus shared with IR574: Ellershouse 3. 103V is 0.075 km away from L6051, which is approximately 2 km from the 17V-St Croix substation and 25 km from the 120H-Brushy Hill substation.
5. The direct line tap associated with IR574 on L6051 will change to a 3 breaker ring substation with both IR574 and IR723 connective via the same node.
6. IR723 and IR574's plant controllers are coordinated.
7. The 0.075 km spur line from L6051 to the 138 kV bus is built with 795 ACSR Drake and has the same limits as the L6051 transmission line *(see* Table 1: Local Transmission Element Ratings.
8. 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.
9. Preliminary data was provided by the IC for the IC substation interconnection facility.
    a. The transformer is rated at 66/88/110 MVA and modeled with a positive-sequence impedance of 8.0% on 66 MVA (12.12% 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.
    d. Detailed collector circuit data was not provided, so typical collector circuit impedance R = 0.01 p.u, X = 0.04 p.u, B = 0.004 p.u with a 100 MVA system base was assumed with the understanding that net real and reactive power output of the plant will be impacted by losses through transformers and collector circuits.
10. 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.
11. 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.
12. Planning criteria meeting NERC Standard TPL001-4 *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.

13. Transmission facilities rating in the vicinity of IR723 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
L6054*	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
L6051	795 Drake	100°C	Conductor	268/295 MVA	287/316 MVA
L6051 spur line	795 Drake	100°C	Conductor	268/295 MVA	287/316 MVA
L6004*	556.5 Dove	75°C	Conductor	174/191 MVA	210/231 MVA
L6012	556.5 Dove	100°C	Conductor	215/237 MVA	242/266 MVA

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

4 Projects with Higher Queue Positions

All in-service generation is included in the FEAS, except for Lingan Unit 2, which is assumed to be retired.

As of 2024/01/25, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are committed to the study base cases:

- IR426: GIA executed
- IR516: GIA executed
- IR540: GIA executed
- IR542: GIA executed
- IR517: GIA in progress
- IR574: GIA executed
- IR598: GIA executed
- IR597: GIA executed
- IR647: GIA in progress
- IR664: FAC complete
- IR662: FAC complete
- IR670: FAC complete
- IR671: FAC in progress
- IR669: FAC complete
- IR668: FAC complete
- IR618: FAC complete
- IR673: FAC complete
- IR675: FAC complete
- IR677: SIS in progress

- IR697: SIS in progress
- IR739: SIS in progress
- IR742: SIS in progress

The power system base cases for the feasibility study includes all transmission connected IRs in the GIP queue up to and including IR742 with the exception of IR686, as the IR686 SIS was not completed when IR723 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. 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 IR723	With IR723
All transmission facilities in service		
POI on L6051 *(138kV)*	1,938	2,123
Interconnection Facility *(138kV)*	1,932	2,117
120H-Brushy Hill *(230kV)*	3,836	3,921
120H-Brushy Hill *(138kV)*	3,754	3,896
17V-St. Croix *(138kV)*	1,961	2,129
17V-St. Croix *(69kV)*	869	894
Minimum Conditions *(TC3, LG1, ML in-service)*		

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

IR723 Interconnection Facility *(138kV kV)*	1,036	1,222
IR723 34.5 kV	459	698
Minimum Conditions *(TC3, LG1, ML in-service)*, L6051 open at 17V		
IR723 Interconnection Facility *(138kV)*	772	957
IR723 34.5 kV	399	638
Minimum Conditions *(TC3, LG1, ML in-service)*, L6051 open at 120H		
IR723 Interconnection Facility *(138kV)*	787	972
IR723 34.5 kV	403	642

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 interrupting rating at these substations will not be exceeded by this development on its own.

Inverter-Based Resource *(IBR)* installations like IR723 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 4.6 at IR723's 34.5 kV substation bus in minimum load conditions with all lines in service and IR723 offline. This falls to 4.0 when L6051 is open at the 120H end or the 17V 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)*.

More detailed EMT analysis is required if IR723 proceeds to the SIS stage, as the standard SCR screening methodology becomes less definitive due to the three sites *(IR723, 102V, and 103V)* in relatively close proximity; within 4 km of each other:

- 102V-Ellershouse 1 *(IR461)* & 2 *(IR540)*: 30.55 MW total
- 103V-Ellershouse 3 *(IR574)*: 58.8 MW, which IR723 will share the same 138 kV bus with

The SCR at IR723's 34.5 kV bus, under minimum conditions with L6051 open at 17V, with IR574 considered is calculated to be 2.5 in Equation 1: IR723's SCR with IR574 included.

Equation 1: IR723's SCR with IR574 included

$$SCR_{IR574+IR723} = \frac{399\ MVA}{58.8\ MW_{IR574} + 100.3\ MW_{IR723}} = 2.5$$

The IC should consult Nordex to determine what modifications are required for low SCR conditions and being near IR574's site. 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. Two set of tested data[3] for flicker coefficient factors were 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 3: Calculated voltage flicker below.

Table 3: Calculated voltage flicker

System Conditions	Flicker at 138 kV Bus IR723 - 17 Machines
	Pst=Plt Continuous
Maximum Generation	
All Transmission in Service	0.018
Minimum Conditions *(TC3, LG1, ML In-Service)*	
All Transmission in Service	0.034
L6051 open at 120H	0.044
L6051 open at 17V	0.045

IR723 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, IR723 is required to resolve voltage flicker issues if it does cause them.

The generator is expected to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion *(all frequencies)* to a maximum of 2.5%, with no individual harmonic exceeding 1.5% on 138 kV.

7 Load Flow Analysis

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

For these cases, transmission connected wind generation facilities were dispatched between 19% and 100% of their rated capability. There is high correlation between wind plants in the valley

[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

area, so it is reasonable to expect these wind plants would be near full output when IR723 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-IR723 cases ending with "-1": IR723 off.
- Post-IR723 cases ending with "-2": IR723 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 IR723.

Table 4: Base cases for IR723

Case	NS Load	IR723	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	100.3	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	100.3	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	100.3	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	100.3	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	100.3	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	100.3	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	100.3	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	100.3	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	100.3	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 IR723 and displaced coal-fired generation in the system based on dispatch order. Single contingencies were applied at the 230 kV, 138 kV, and 69 kV voltage levels for the above system conditions with IR723 interconnected. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency. Contingencies studied are listed in Table 5.

Table 5: Contingency list

Transmission Line	Transformer / Bus	Circuit Breaker Failure	Double Circuit Tower
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	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 highest element overload summarizes the list of all overloaded elements identified with IR723's interconnection. However, the single thermal overload that must

be addressed with the present system configuration is the IC substation transformer *(rated at 110 MVA)*. It is overloaded to 110% when the IR723 generation is operating at 100.3 MW output, while absorbing maximum 39.95 MVAr of reactive power.

Note that 17V-T2 loading is right at its 56 MVA maximum rating under the 17V-611 contingency.

Pre-existing conditions that IR723 is not required to address are overloads associated with:

- Metro lines L6003, L6009, and L6010. These are related to low generation dispatch at 91H-Tuft's Cove.
- L5535A/B, the 69 kV transmission line between 9W-Tusket and 15V-Sissiboo.

Table 6: Contingencies resulting in highest element overload

Line/ Transformer	Line Segment	Highest Overload (based off emergency rating)	Case	Contingency
L6003	91H-Tuft's Cove / 90H-Sackville	115.3% *(pre-existing, 4% increase due to IR723)*	wp01, wp02, sh02	90H-L6009-2 , 90H-L6009, 90H-611, 90H-610, 101H-600
L6009	90H-Sackville / 101H-Cobequid Rd	114.6% *(pre-existing, 3.5% increase due to IR723)*	wp01, wp02	91H-611 , 91H-T11, 91H-609, 91H-603, 91H-523, 90H-L6003, 90H-606, 103H-600, DCT_L5039][L6033
L6010	90H-Sackville / 120H-Brushy Hill	105.1% *(pre-existing, 4.8% increase due to IR723)*	wp01, wp02	DCT_L6005][L6016 , 120H-622
L5535A	9W-Tusket to 92W-Carleton	117.4% *(pre-existing, 3.7% increase due to IR723)*	ll02	50W, 50W-B2, 13V L5026, 50W 50W-501, 50W 50W-514, 50W 50W-517, 50W L5541
L5535B	92W-Carleton to 15V-Sissiboo	119.7% *(pre-existing, 3.7% increase due to IR723)*	ll02	50W, 50W-B2, 13V L5026, 50W 50W-501, 50W 50W-514, 50W 50W-517, 50W L5541
17V-T2	17V-St Croix:138 to 17V-St Croix:69	100.4% of 56 MVA	wp03	17V-611
IR723 T61	Shared IR574/IR723 138 kV bus to IR732 34.5 kV bus	110%	n/a	While absorbing max 39.95 MVAr reactive power.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR723 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 study assumes the Nordex N163 5.9 MW WECS are outfitted with Nordex's "STATCOM function" module to provide reactive power support when operating at below wind cut-in speeds.

The information provided by IC indicates the WECS have a power factor of 0.929 lagging and leading *(+/- 2.35 MVAr per WECS)* at the machine terminal voltage of 0.96-1.06 p.u when each Nordex WECS is at maximum 5.9 MW *(totalling 100.3 MW for IR723)*.

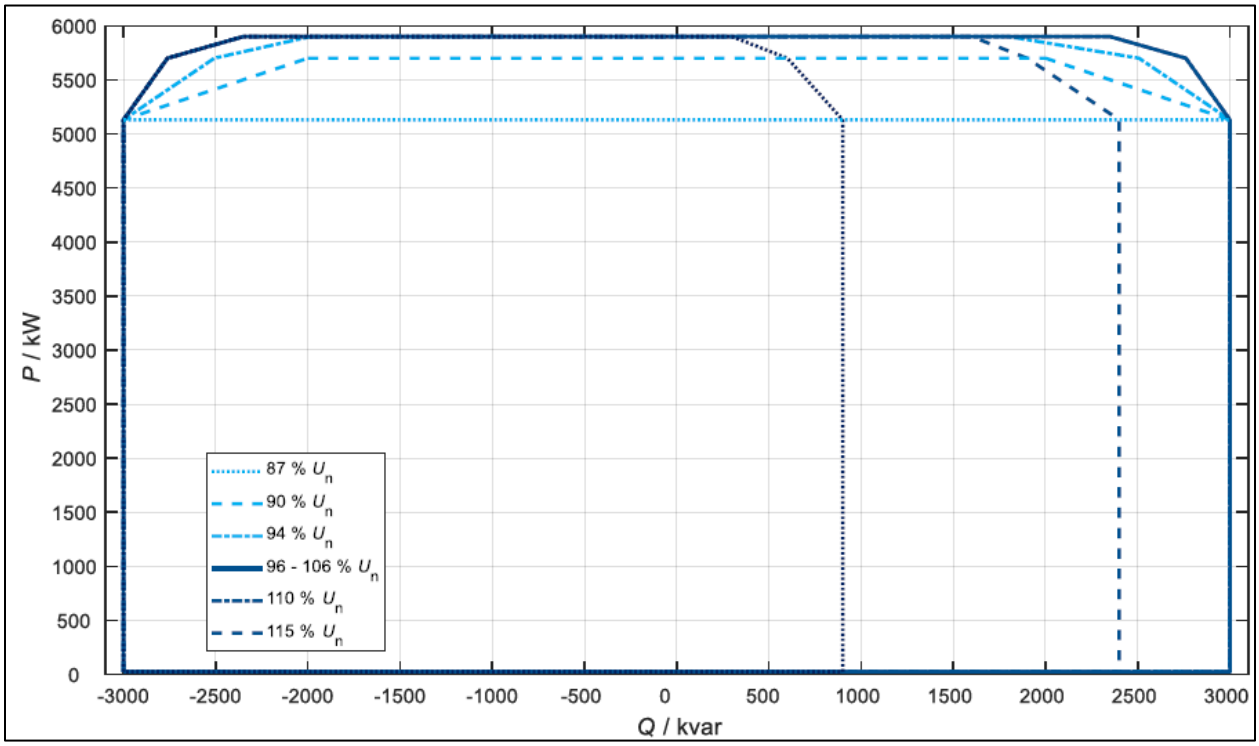

Figure 3: Nordex N163/5.X Mode 0.a *(5900 kW)* Q-P diagram[4]

Analysis shown in Figure 4 Power factor analysis indicates IR723 is not able to meet the +0.95 power factor requirement. The model shows that with 17 WECS operating at a total 100.3 MW and 39.95 MVAr, the delivered power to the high side of the ICIF transformers is 97.9 MW and 16.3 MVAr, or a power factor of 0.986 and WECS terminal voltage at 1.057 p.u. Additional reactive power equipment is required to be supplied by the Interconnection Customer.

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

This configuration would be able to meet the leading power factor requirement of -0.95 at the high side of ICIF transformer The model shows that with 17 units of WECS operating at a total of 100.3 MW and -39.95 MVAr, the delivered power to the high side of the ICIF transformers is 97.2 MW and -70.9 MVAr, or a power factor of -0.808 and WECS terminal voltage at 0.96 p.u.

[4] Nordex Reactive Power Capability; 2009087EN Rev. 2; Supplied by IC for both IR723 and IR724.

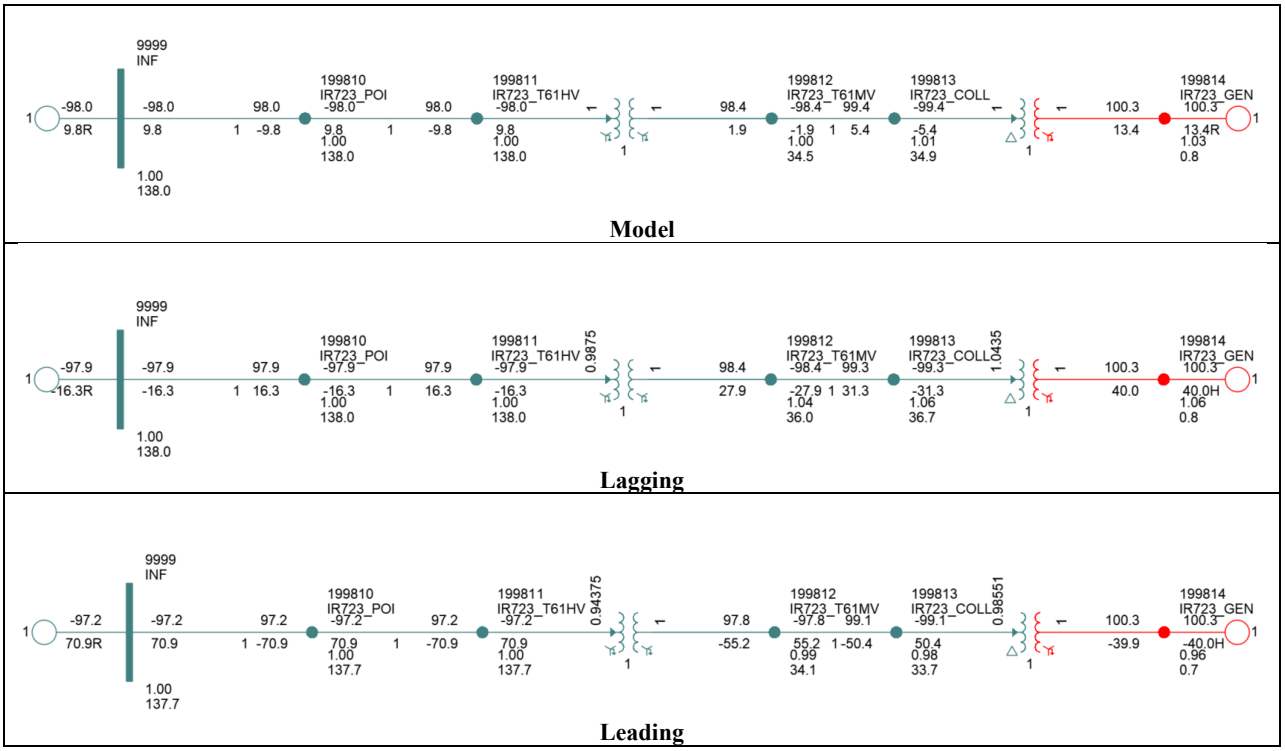

Figure 4 Power factor analysis

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 -32.3 MVAr to 28.9 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	0	-1700
	-Q...+Q / kvar	0	1700
	100 % U_n	0	-1900
	-Q...+Q / kvar	0	1700
	110 % U_n	0	-1900
	-Q...+Q / kvar	0	0

Figure 5: Nordex's "STATCOM function" capability

The IC placed a fixed capacitor bank without sizing data 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 IR723 substation transformer is overloaded when IR723 operates under leading power factor while fully dispatched. Because this analysis is based on preliminary transformer data and assumed collector circuit models, transformer loading level and plant reactive capability will be confirmed in the SIS when detailed design is submitted. The transformer sizing should be evaluated by the IC prior to proceeding with a SIS.

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

IR723's NPCC BPS categorization will be determined in the subsequent System Impact Study (*SIS)*. The higher queued IR574: Ellershouse 3 project's categorization may change if IR723 proceeds and is BPS categorized. At the time IR574 was studied, it was categorized non-BPS, however both IRs are effectively electrically adjacent and the larger combined injection will have more pronounced system impacts.

IR723 will be categorized as NERC BES due to its aggregated rated output being greater than 75 MVA. By extension, IR574 status will also change to BES as IR574 and IR723 have a common point of connection. For both sites, the facilities *(and associated equipment)* from both IRs listed in Table 7: NERC BES applicability are subject to the relevant NERC Reliability Criteria based on NERC BES point of aggregation criteria *(single point of failure resulting > 75 MVA aggregate loss)*.

Table 7: NERC BES applicability

Elements	IR723	IR574

L6051 POI to the 138 kV bus	BES	BES
Substation step-up transformer	BES	non-BES
34.5 kV collector bus	BES	non-BES
WECS generator step-up transformers	BES	BES
Individual WECS	BES	BES

The combined 159.1 MW of generation (58.8 MW_{IR574} + 100.3 MW_{IR723}) at this L6051 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 IR723 to the NSPI transmission system at a POI on L6051:

Required Network Upgrades under NRIS:

1. Upgrading 103V-Ellershouse 3's direct line tap to a three breaker ring bus 138 kV substation complete with P&C, including P&C modifications at 17V and 120H.

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

1. NSPI P&C relaying equipment.
2. NSPI-supplied RTU.
3. Tele-protection and SCADA communications.

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. IR723's plant controller is coordinated with IR574's plant controller.
3. Meet all requirements detailed in the TSIR, including the following:
   - 3.1. 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.
   - 3.2. 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.

3.3. 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.

3.4. 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.

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

3.6. 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.

3.7. 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.

3.8. 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.

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

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

3.11. 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 100.3 MW wind energy at the 103V-Ellershouse 3 138 kV bus are summarized in Table 8: IR723 NRIS cost estimate.

Table 8: IR723 NRIS cost estimate

Item	Network Upgrades	Estimate
1	Upgrading 103V-Ellershouse 3's direct line tap to a three breaker ring bus 138 kV substation complete with P&C, including P&C modifications at 17V and 120H.	$7,000,000
	Sub-total for Network Upgrades	$7,000,000
Item	**TPIF Upgrades**	**Estimate**

1	NSPI P&C relaying equipment	$100,000
2	NSPI supplied RTU	$60,000
3	Tele-protection and SCADA communications	$75,000
	Sub-total for TPIF Upgrades	$235,000

Total Upgrades	Estimate
Network Upgrades + TPIF Upgrades	$7,235,000
Contingency *(25%)*	$1,810,000
Total *(incl. 25% contingency and excl. HST)*	$9,045,000

The preliminary non-binding cost estimate for interconnecting 100.3 MW at 103V-Ellershouse 3 and upgrading the station to a 3-breaker ring bus under NRIS is $9,045,000 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 any costs to address stability issues identified at the SIS stage based on dynamic and EMT 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 18-24 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 IR723 is calculated as 0.31% at IR723's POI *(L6051, 138kV bus)*. This means system losses on peak are marginally increased by 0.31% when IR723 is operating at 100.3 MW. The MW measured at POI is 97.9 MW, the displaced MW generation at Tuff's Cove is 97.6 MW. Therefore, the loss factor is calculated as 0.3/97.9 = 0.31%

Table 9: Loss factor analysis

Component	At IR723 POI
IR723 at 100.3 MW	97.9 MW
Tufts Cove with IR723 on	374.0 MW
Tufts Cove with IR723 off	471.6 MW
IR723 loss factor	0.31%

13 Preliminary Scope of Subsequent SIS

The following provides a preliminary scope of work for the subsequent SIS for IR723.

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 TPL001-5.1.
- 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