Interconnection Feasibility Study Report
GIP-IR721-FEAS-R1

Generator Interconnection Request 721

108.8 MW Wind Generation Facility

Hants County, NS

2024-06-07

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The IC *(Interconnection Customer)* submitted an Interconnection Request for both NRIS *(Network Resource Interconnection Service)* and ERIS (*Energy Resource Interconnection Service)* for the proposed "Red Spruce" 108.8 MW wind generation facility interconnected to the NSPI Transmission System with a 2027/12/31 Commercial Operation Date. The POI *(Point of Interconnection)* requested by the customer is the 230kV line L7018[1], approximately 18 km from 120H-Brushy Hill and 55 km from 67N-Onslow.

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 IR721 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 IR721 will displace coal-fired generation in eastern Nova Scotia for NRIS and ERIS.

IR721 will require a three-breaker 230kV ring bus substation to interconnect to L7018 as that line is classified as NPCC BPS (*Bulk Power System*) per the NSPI TSIR *(Transmission System Interconnection Requirements)*. This new substation will be built to 345 kV design standards and NPCC BPS requirements; IR721's BPS categorization will be determined in its subsequent SIS *(System Impact Study)*.

IR721 will be categorized NERC BES *(Bulk Electric System)* due to having an aggregate dispersed generation greater than 75 MVA. The generators and elements in Interconnection Customer substation (*including generator step-up transformers, collector bus, and substation step-up transformer*), are also categorized as BES and subject to the applicable NERC Reliability Criteria.

The assessment of the L7018 POI did not indicate any thermal loading violations directly attributed to IR721's interconnection. However, thermal overloads on L6515 (*up to 110%*) between 2C-Pt.

[1] Any modifications/additions associated with IR721 and L7018 will follow 345 kV design standard as L7018 was built to 345 kV design standard and may be upgraded in the future. This will be re-evaluated should IR721 advance to the SIS stage.

Hasting and 4C-Lochaber Rd. and L6511 (*up to 106%*) between 50N-Trenton and 93N-Glen Dhu were identified under the loss of L8004 or 101S-813 contingencies. These issues were due to the generation displacement resulting in the reduced transfer flow below the existing RAS *(Remedial Action Schemes)* arming levels. The modifications to the setting of existing RAS should be applied to alleviate these overloads.

No violations of voltage criteria that were attributed to IR721 were found.

The steady state contingencies evaluated in this study demonstrate IR721 does not require Network Upgrades beyond integrating at its POI to operate at the requested MW capability under NRIS and ERIS. Please note that the IR721 IC station transformer's 100% rating (*120MVA*) could be exceeded when the IR721 generation is operating at its maximum 108.8 MW output, while absorbing a combined 56 MVar reactive power from its WECS.

Data provided by the IC indicates that IR721 will be utilizing the Nordex N163 DFIG 6.8 MW WECS *(Wind Energy Conversion Systems)*. Based on the inverters, typical impedances of the transformers and typical collector circuit impedances, IR721 may not meet the net +0.95 power factor requirement at the high voltage side of Interconnection Facility. However, the -0.95 power factor requirement can be met with the present equipment configuration.

The substation step-up transformer will also require an onload tap changer to maintain the medium voltage collector bus voltage within the optimal range for the WECS reactive power support.

The adequacy of reactive power supply will be further investigated in the System Impact Study as specific details of the collector circuits and transformers become available. It is noted that the proposed Nordex N163 DFIG wind turbines models will not meet the requirement to produce full MVAr capability down to zero MW output.

IR721 was not found to adversely impact the short-circuit capabilities of existing circuit breakers. This study shows that the minimum short circuit level at the Interconnection Facility 34.5 kV bus is 489 MVA with all lines in service and IR721 off-line. This falls to 423 MVA with L7018 open at 120H-Brushy Hill, resulting in a short-circuit ratio (*SCR*) of 3.9.

The IC should consult the generator vendor to determine if any modifications for lower SCR conditions are required. The impact of the low SCR will be further examined when detailed data for the project is made available for the SIS. 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.*

It is assumed that the project design meets NSPI requirements for low-voltage ride-through and voltage control. IR721 meets NS Power's required short term and long-term voltage flicker requirements based off the supplied data. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

The preliminary value for the unit loss factor is calculated as +2.26% at the POI on L7018, net of any losses on the IC facilities up to the POI.

To connect IR721 as both NRIS and ERIS, the preliminary non-binding cost estimate for interconnecting 108.8 MW to the L7018 POI is $16,825,000. In this estimate, $13,000,000 (*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. This includes the following:

- A 230 kV 3 breaker ring bus substation built to 345 kV design standards.
- Protection upgrades at 120H-Brushy Hill and 67N-Onslow.
- The 230 kV 75 m spur line, built to 345 kV design standards, from the L7018 POI to the Interconnection Customer's Interconnection Facility

The preliminary cost estimate does not include any reactive power devices that are potentially required to meet the NSPI reactive power and power factor requirements. It also does not include TBD costs to address any stability issues identified at the SIS stage based on dynamic analysis and it assumes that any RAS modifications will be approved by NPCC.

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 IC *(Interconnection Customer)* submitted an Interconnection Request for both NRIS *(Network Resource Interconnection Service)* and ERIS (*Energy Resource Interconnection Service)* for the proposed "Red Spruce" 108.8 MW wind generation facility interconnected to the NSPI Transmission System with a 2027/12/31 Commercial Operation Date.

The IC signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2023/10/13, and this report is the result of that Study Agreement. This project is listed as Interconnection Request 721 in the NSPI Interconnection Request Queue and will be referred to as IR721 throughout this report.

The POI *(Point of Interconnection)* requested by the customer is the 230kV line L7018[2], approximately 18 km from 120H-Brushy Hill and 55 km from 67N-Onslow.

Figure 1 shows the proposed geographic location of IR721 in relation to the NSPI transmission system.

[2] Any modifications/additions associated with IR721 and L7018 will follow 345 kV design standards as L7018 was built to 345 kV design standards and may be upgraded in the future. This will be re-evaluated should IR721 advance to the SIS stage.

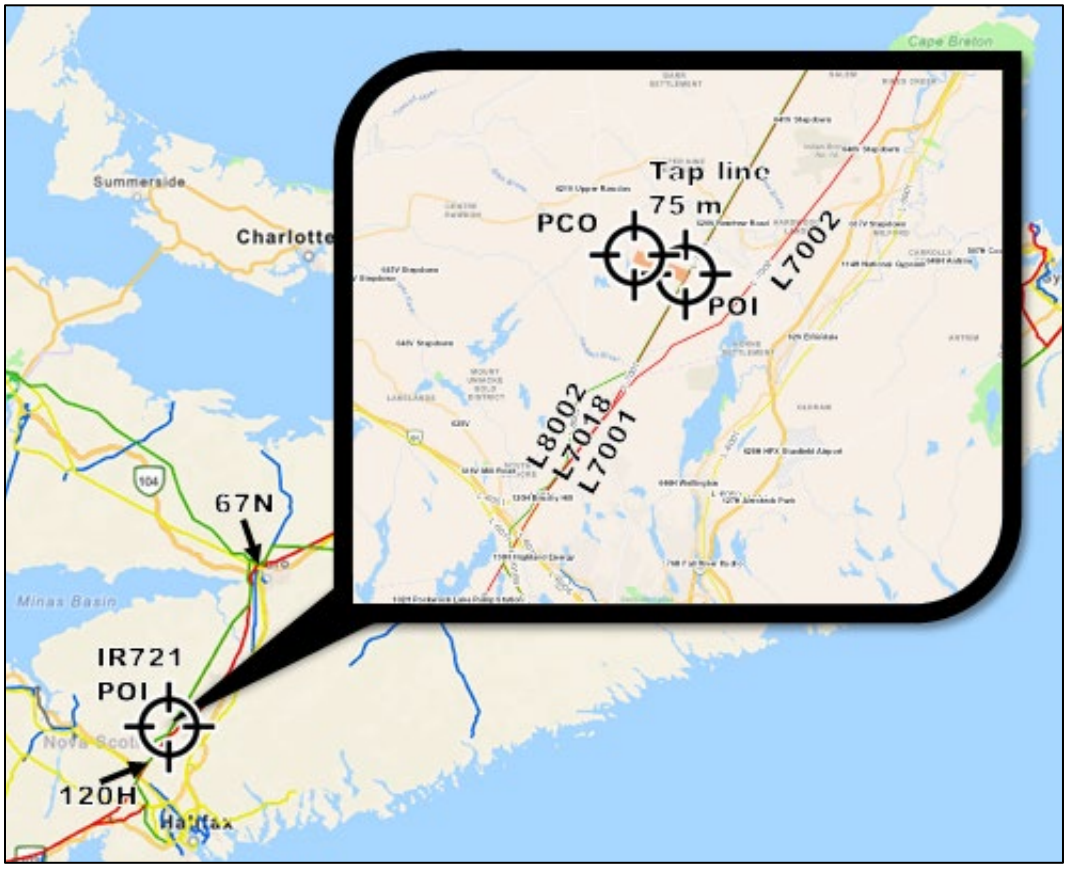


Figure 1 IR721 Site Location

Figure 2 is a simplified one-line diagram of the transmission system configuration in NS with IR721's POI marked.

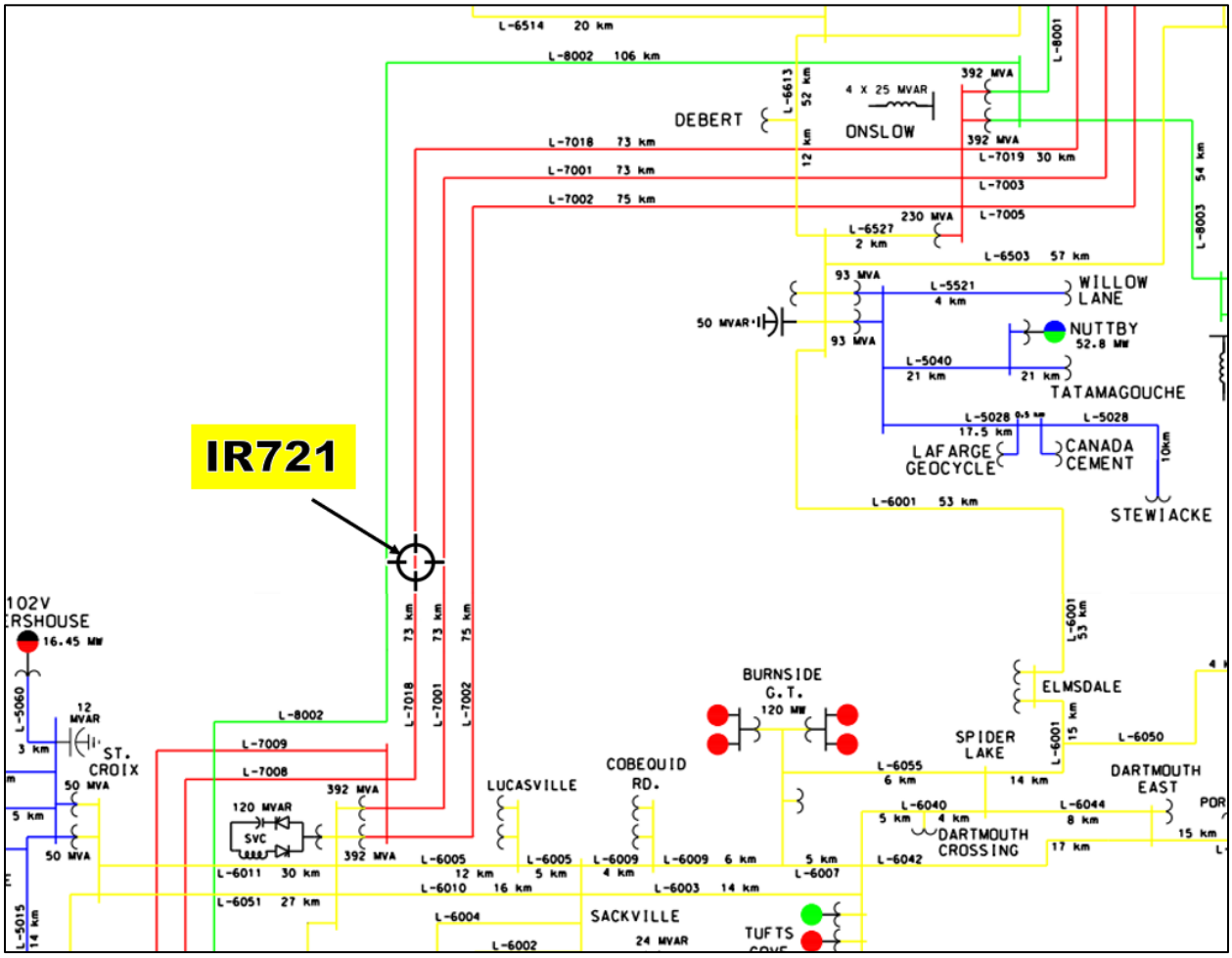


Figure 2 Point of Interconnection (*not to scale*)

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*[3].
- Preliminary description and high-level non-binding estimated cost and time to construct the facilities required to interconnect the generating facility to the transmission system.
- For comparative purposes, the impact of IR721 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 and ERIS per section 3.2 of the GIP *(Generator Interconnection Procedures)*.
2. Commercial Operation date 2027/12/31.
3. The Interconnection Customer Interconnection Facility *(ICIF)* consists of sixteen Nordex 163 6.8 MW Type 3 *(Double-Fed Induction Generator)* Wind Energy Converter System *(WECS)* units, with a total capacity of 108.8 MW.

   3.1. The generator terminals are at 950V.

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

3.2. Connected to three collector circuits operating at a voltage of 34.5kV. Two collector circuits consist of 6 WECS each *(totalling 12 WECS)* and one collector circuit contains 4 WECS.

4. The ICIF will require the construction of an approximate 75 m 230 kV transmission spur line built to 345 kV design standards. The IC will be responsible for providing the Right-of-Way for the lines. Typical data was assumed based on 795 Drake conductor and 60°C as detailed line data was not provided.

5. IR721 will be connected onto L7018 via a three-breaker ring bus in accordance with Table 8 of the NSPI *Transmission System Interconnection Requirements.* The new substation will be constructed to 345 kV design standards.

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

7. Preliminary data was provided by the IC for the IC substation interconnection facility:

   7.1. The transformer was rated at 67/90/120 MVA and modeled with a 9.25% positive-sequence impedance on 100 MVA with an assumed 25 X/R ratio.

   7.2. The IC indicated that these interconnection facility transformers have a wye-delta-wye winding configuration with de-energized tap changers with ±10% taps and 5 equal steps.

   7.3. The impedance of each generator step-up transformer was modeled as 9.0% on 7.8 MVA with an assumed X/R ratio of 9.

   7.4. Collector circuit data was not provided by the IC so typical collector circuit parameters (*Z=0.01 + j0.04 p.u*) were used. The net real and reactive power output of the plant will be impacted by losses through transformers and collector circuits.

8. Generation Interconnection Queue and OATT Transmission Service Queue that have completed a System Impact Study, or that have a System Impact Study in progress will proceed, as listed in Section 4 below.

9. It is required that the wind turbines are equipped with a "cold weather option" suitable for delivering full power under expected Nova Scotia winter environmental conditions.

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 IR721 are shown in Table 1.

Table 1: Local Transmission Element Ratings

Line	Conductor	Design Temp	Limiting Element	Summer Rating Normal/Emergency (MVA)	Winter Rating Normal/Emergency (MVA)
L8002	2x795 Drake	49°C	Conductor/, metering	554	554
L7018	2x795 Drake/AACSR 2156	49°C	Conductor	375/412	589/647
L7002	795 Drake	100°C	Conductor	447/491	506/556
L7001	795 Drake	60°C	Conductor	298/327	383/421
L6054*	556.5 Dove	100°C	Conductor	215/237	242/266
L6051	795 Drake	100°C	Conductor	268/295	287/316
L6013	556.5 Dove	100°C	Conductor	215/237	242/266
L6012	556.5 Dove	100°C	Conductor	215/237	242/266
L6011	556.5 Dove	100°C	Conductor	215/237	242/266
L6004*	556.5 Dove	100°C	Conductor	215/237	242/266
L6001	556.5 Dove	60°C	Conductor	140/154	184/202

* 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.
** L7018 was built to 345 kV design standards.

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 IR721 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 15,000 MVA at 345 kV, 10,000 MVA at 230 kV, 5,000 MVA at 138 kV , and 3,500 MVA at 69 kV voltage levels. The fault current characteristic for this Nordex N163 6.8 MW DFIG wind turbines is given as 3.36 times rated current, or X'd = 0.298 per unit on machine base MVA.

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

Table 2: Short-Circuit Levels[4]

Location	Without IR721	With IR721
All transmission facilities in service		
POI on L7018 (*230kV*)	3,311	3,516
Interconnection Facility (*230kV*)	3,306	3,510
120H-Brushy Hill (*230kV*)	3,836	4,013
67N-Onslow (*345kV*)	4,762	4,837
67N-Onslow (*230kV*)	4,771	4,895
120H-Brushy Hill (*138kV*)	3,755	3,856
1N-Onslow (*138kV*)	2,485	2,504
67N-Onslow (*345kV*)	4,762	4,837
Minimum Conditions *(TC3, LG1, ML In-Service)*		
Interconnection Facility (*230kV*)	1,502	1,706
IR721 34.5 kV	489	773
Minimum Conditions (*TC3, LG1, ML In-Service*)**, L7018 open at 120H**		
Interconnection Facility (*230kV*)	1,018	1,162
IR721 34.5 kV	423	708
Minimum Conditions (*TC3, LG1, ML In-Service*)**, L7018 open at 67N**		
Interconnection Facility (*230kV*)	1,304	1,448
IR721 34.5 kV	466	750

The interrupting capability of the 345 kV circuit breakers at 67N-Onslow is at least 15,000 MVA. The interrupting capability of the 230 kV circuit breakers at 120H-Brushy Hill and 67N-Onslow is at least 10,000 MVA. The interrupting capability of the 138 kV circuit breakers is at least 5,000 MVA at 120H-Brushy Hill and 67N-Onslow. As such, the breaker interrupting ratings at these substations will not be exceeded by this development on its own.

Inverter-based generation installations often have a minimum Short Circuit Ratio (*SCR*) for proper operation of converters and control circuits. Based on the calculated short circuit levels with 108.8 MW installation consisting of 16 Nordex N163 WECS units, the SCR would be 4.5 at the 34.5 kV Interconnection Facility of the IR721 substation with all lines in service and IR721 offline. This falls to 3.9 with L7018 open at 120H end, and 4.3 if L7018 opens at 67N end. SCR is further reduced at the high side of the generator step-up transformers due to the collector circuit impedance. Note 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.*

[4] Classical fault study, flat voltage profile.

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

6 Voltage Flicker and Harmonics

The voltage flicker calculations use IEC Standard 61400-21 based on estimated data provided by Nordex N163 6.8 MW DFIG wind turbines (*flicker coefficient c(ψk, va) of 4.0 at system angle of 85°*). The voltage flicker Pst and Plt levels are calculated at the Interconnection Facility for various system conditions and are shown in Table 3 below.

Table 3: Calculated Voltage Flicker

System Conditions	Flicker at 138 kV Bus IR721 - 16 Machines
	Pst=Plt Continuous
Maximum Generation	
All Transmission in Service	0.038
Minimum Conditions (*TC3, LG1, ML In-Service*)	
All Transmission in Service	0.083
L7018 open at 120H	0.122
L7018 open at 67N	0.095

NS Power's required limits are 0.25 for Pst and 0.35 for Plt. IR721 is able to meet the flicker requirement in minimal generation conditions with L7018 is open at either end.

The generator is expected to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion (*all frequencies*) to a maximum of 1.5%, with no individual harmonic exceeding 1.0% on 230 kV.

7 Load Flow Analysis

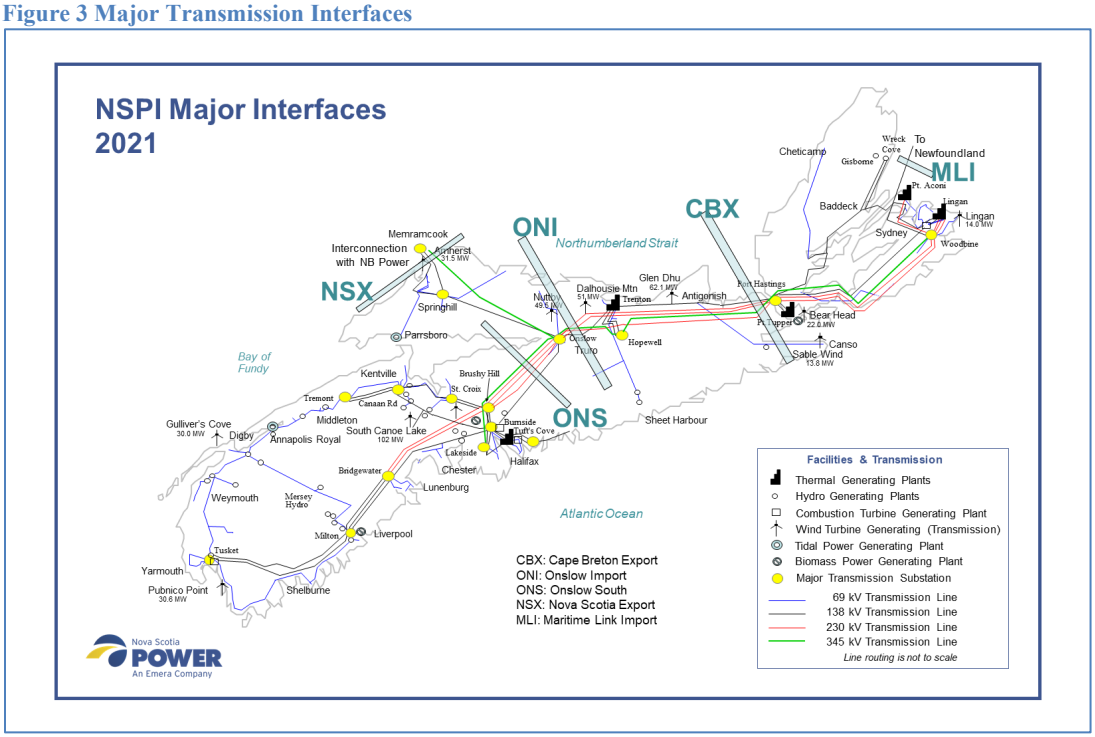
The load flow analysis was completed for generation dispatches under system summer peak and winter peak load conditions which are expected to stress the east-west corridor across the transmission interfaces Cape Breton Export (*CBX*) and Onslow Import (*ONI*). Generation dispatch was also chosen to represent 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.

The major transmission interfaces/corridors relating to the IR721 are shown in Figure 3. NSPI relies on Remedial Action Schemes (*RAS*[5]) approved by NPCC to maintain interface limits. These

[5] Also referred to as Special Protection Scheme (*SPS*),

RAS are armed by system conditions and flow across the respective interfaces and react to pre-determined contingencies to rapidly reduce flow by either tripping generation in Cape Breton or running-back Maritime Link HVDC import.

Figure 3 Major Transmission Interfaces



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 study area, so it is reasonable to expect that these other wind plants would be near full output when IR721 is at rated output. All interface limits were respected for base cases.

Two scenarios were examined for each of the Summer Peak and Winter Peak cases:

- Pre-IR721 cases ending with "-1": IR721 off.
- Post-IR721 cases ending with "-2": IR721 dispatched at 108.8 MW under both NRIS and ERIS designation.

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

Table 4: Base Cases for IR721

Case	NS Load	IR721	Wind generation[3]	NS/NB[4]	ML	CBX[2]	ONS[2]	ONI
-	-	-	-	-	-	*L8004, L7003, L7004, L7005, L6515*	*L8002, L7001, L7002, L7018, L6001*	*L8003, L7003 L7019, L7005, L6503*
c_sp01-1-1	1,390	0	831	331	-475	755	781	1,068
c_sp01-1-2	1,390	108.8	940	331	-475	640	673	960
c_sp02-1-1	1,387	0	698	330	-350	458	-123	333
c_sp02-1-2	1,387	108.8	807	330	-350	354	-225	232
c_sp03-1-1	1,396	0	525	330	-475	739	499	863
c_sp03-1-2	1,396	108.8	634	330	-475	626	392	756
c_wp01-1-1	2,312	0	1,389	150	-170	395	634	826
c_wp01-1-2	2,312	108.8	1,498	150	-170	284	527	719
c_wp02-1-1	2,340	0	835	150	-170	791	946	1,163
c_wp02-1-2	2,340	108.8	943	150	-170	676	837	1,055
c_wp03-1-1	2,340	0	757	74	-170	820	974	1,189
c_wp03-1-2	2,340	108.8	865	74	-170	704	865	1,081
c_wp04-1-1	2,355	0	460	150	-170	814	875	1,092
c_wp04-1-2	2,355	108.8	569	150	-170	699	767	984

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.
Note 4: Positive number indicates export from NS to NB, negative indicates import into NS from NB.

For both NRIS and ERIS analysis, this FEAS added IR721 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 IR721 interconnected to the POI on L7018. Automated analysis searched for violations of emergency thermal ratings and emergency voltage limits for each contingency.

The assessment of the L7018 POI did not indicate any thermal loading violations that would occur due to IR721 interconnection. However, thermal overloads on L6515 (*up to 110%)* between 2C-Pt. Hasting and 4C-Lochaber Rd. and L6511 (*up to 106%*) between 50N-Trenton and 93N-Glen Dhu were identified under loss of L8004 or 101S-813. These issues were due to the generation displacement resulting in the reduced transfer flow below the existing Remedial Action Schemes (*RAS*) arming levels. Modifications to the setting of existing RAS should be applied to alleviate these overloads. No violations of voltage criteria that were attributed to IR721 were found.

The steady state contingencies evaluated in this study demonstrate IR721 does not require Network Upgrades at the POI and beyond to operate at request MW capability under NRIS and ERIS. However, the IR721 IC substation transformer's rating (*120MVA*) could be exceeded (*beyond 110% nominal rating*) when the IR721 generation is operating at its maximum 108.8 MW output, while absorbing 56 MVar reactive power from its WECS.

8 Reactive Power and Voltage Control

In accordance with the *Transmission System Interconnection Requirements* Section 7.6.2, IR721 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, or synchronous condenser, supplied by the Interconnection Customer.

The information provided by IC indicates that the Nordex N163/6.x 6.8 MW DFIG WECS have a power factor of 0.9 lagging and 0.88 leading when each Nordex WECS is at 6.8 MW (*a total MW of 108.8 MW for IR721*) at the machine terminal voltage of 1.0 p.u.

Each WECS can provide +3.75/-3.5 MVar at the machine terminal voltage of 1.02-1.08 p.u (*Figure 5*). The provided Q-P diagram *(Figure 4 Model Nordex 6.8 MW PQ Curve and Reactive Capability)* shows a similar Nordex N163 6.8 MW WECS. It indicates that the Nordex N163 6.8 MW DFIG will not meet the NSPI Transmission System Interconnection Requirements (*Section 7.6.2*) for rated reactive power being available from zero real power output of the Generating Facility. Nordex offers a "STATCOM function" to provide reactive power while operating below WECS cut-in speeds and it might be required for IR721.

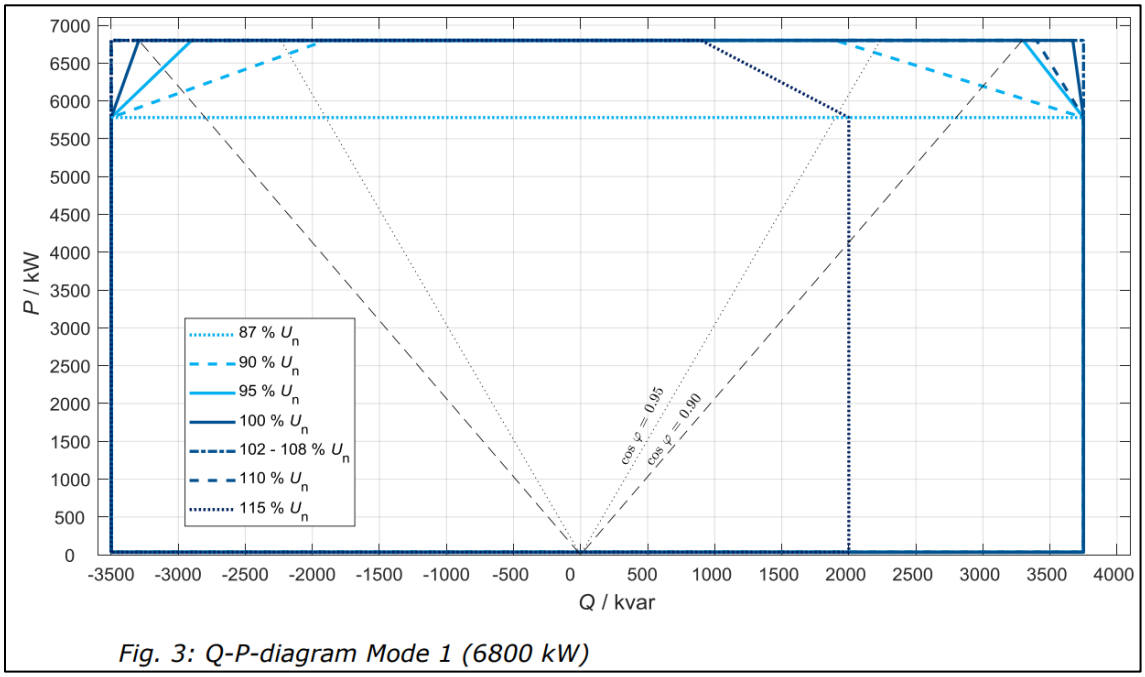


Figure 4 Model Nordex 6.8 MW PQ Curve and Reactive Capability

Active power *P* / kW		25	5780	6800
Maximum reactive power range	87 % U_n	-3500	-3500	-
	-*Q*...+*Q* / kvar	3750	3750	-
	90 % U_n	-3500	-3500	-1900
	-*Q*...+*Q* / kvar	3750	3750	1900
	95 % U_n	-3500	-3500	-2900
	-*Q*...+*Q* / kvar	3750	3750	3300
	100 % U_n	-3500	-3500	-3294
	-*Q*...+*Q* / kvar	3750	3750	3670
	102...108 % U_n	-3500	-3500	-3500
	-*Q*...+*Q* / kvar	3750	3750	3750
	110 % U_n	-3500	-3500	-3500
	-*Q*...+*Q* / kvar	3750	3750	3400
	115 % U_n	-3500	-3500	-3500
	-*Q*...+*Q* / kvar	2000	2000	900

Figure 5 ***Maximum possible reactive power of Mode 1 (6800 kW) in relation to active power and voltage at the reference point***

Analysis shown in Figure 6 indicates that IR721 may not be able to meet the full-load reactive power requirement. The test indicated that, with 16 WECS units (Nordex N163 6.8 MW) operating at a total 108.8 MW and 60.0 MVar with machine terminal voltage of 1.044 p.u (*+3.75 per WECS, as shown in Figure 5*), the delivered power to the high side of the ICIF transformers *(tap set to 110%)* is 105.4 MW and 25.0 MVAr, or a power factor of 0.973. Additional reactive power equipment is required to be supplied by the Interconnection Customer to meet the power factor 0.95 at the high-voltage side of the interconnection facility. An on-load tap changer is also required to maintain the medium voltage collector bus in an optimal range for the WECS.

This configuration would be able to meet the leading power factor requirement of -0.95 at the high side of ICIF transformer When operating at 108.8 MW and -30.4 MVAr with machine terminal voltage of 0.895 p.u (*-1.9 Mvar per WECS, as shown in Figure 5*), the delivered power to the high side of the ICIF transformers is 105.1 MW and -69.8 MVAr, or a power factor of -0.833.

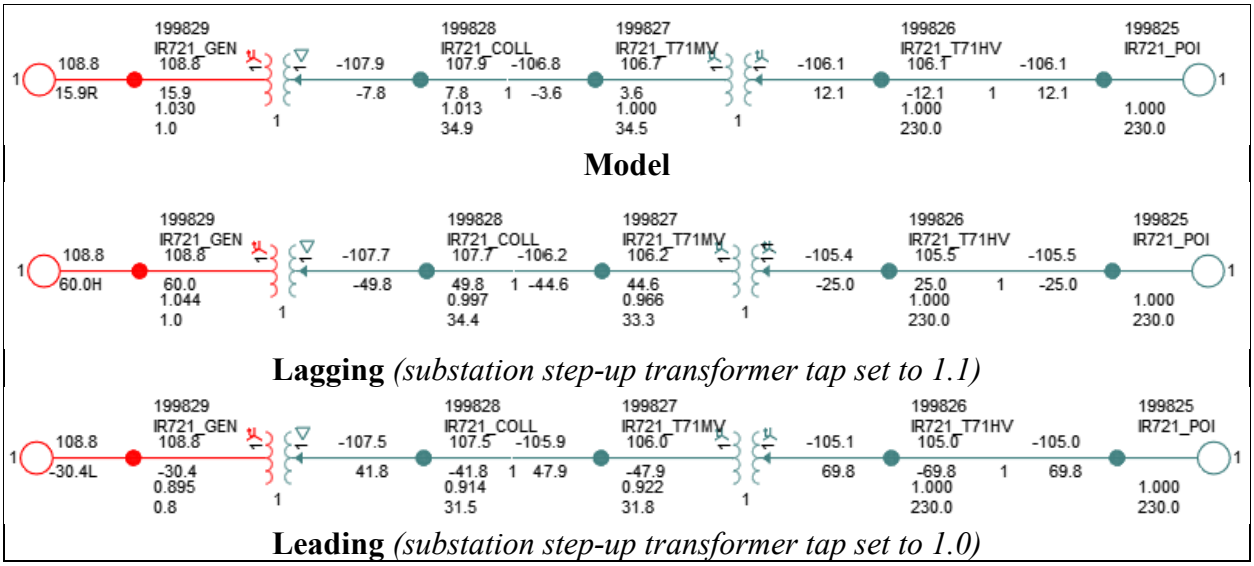


Figure 6 Power Factor Analysis

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

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

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

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

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

9 System Security / Bulk Power Analysis

As L7018 is classified as BPS (*Bulk Power System*), interconnection with that line will require a three-breaker 230kV ring bus as prescribed by the NSPI TSIR. This new substation will be built

to 345 kV design standards and NPCC BPS requirements; IR721's BPS categorization will be determined in its subsequent SIS *(System Impact Study).*

IR721 has dispersed generation with an aggregate greater than 75 MVA and is categorized Bulk Electric System under NERC criteria. The generators and elements in Interconnection Customer substation (*including generator step-up transformers, collector bus, and substation step-up transformer*), are also categorized as BES, subject to the applicable NERC Reliability Criteria.

10 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR721 to the NSPI transmission system at a POI on L7018:

Required Network Upgrades under both NRIS and ERIS:

1. Install a new 230kV substation built to 345 kV design standards complete with 3 breaker ring bus at the L7018 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 120H-Brushy Hill and 67N-Onslow.

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

1. Construct a total of approximately 75m 230 kV transmission spur line between the L7018 POI and the Interconnection Customer's Interconnection Facility. This line would be built to 345 kV standards.
2. Add control and communications between the wind farm plant and NSPI SCADA system (*to be specified*).

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

1. NS Power notes that NERC standard PRC-029-1 is currently in development. As proposed, this standard will impose performance requirements for voltage and frequency ride through behaviour on inverter-based generating resources. It is anticipated that this standard will be applicable to the project currently under study. The Interconnection Customer is advised to consider the requirements of PRC-029-1 in their project design to ensure that their project can conform to these requirements. Conformance will be validated at the System Impact Study stage.
2. Meet all requirements detailed in the TSIR, including the following:
   - 2.1. Facilities to provide 0.95 leading and lagging power factor when delivering rated output at the HV terminals of the IC Substation Step Up Transformer when the voltage at that point is operating between 95 and 105 % of nominal. This study shows that Nordex N163/6.x WECS would not meet the 0.95 lagging power factor requirement alone and require additional reactive power support.
   - 2.2. Note that the Nordex N163/6.x WECS require the Nordex-supplied "STATCOM function" to provide reactive power support under at below wind cut-in speeds.

2.3. Centralized controls. These will provide centralized voltage set-point controls and are known as Farm Control Units (*FCU*). 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, IR721 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 108.8 MW wind energy at the L7018 POI are included in Table 5.

Table 5: Cost Estimates for NRIS and ERIS @ L7018 POI

Item	Network Upgrades	Estimate
1	Three breaker ring bus 230 kV substation, built to 345 kV design standards, complete with P&C at NSPI POI substation and connection to L7018, including P&C modifications at 120H-Brushy Hill and 67N-Onslow.	$13,000,000
	Sub-total for Network Upgrades	$13,000,000

Item	TPIF Upgrades	Estimate
1	Build 75 m 230 kV spur line from TPIF to ICIF, built to 345 kV design standards, with IC responsible for providing Right-Of-Way	$150,000
2	NSPI P&C relaying equipment	$100,000
3	NSPI supplied RTU	$60,000
4	Tele-protection and SCADA communications	$150,000
	Sub-total for TPIF Upgrades	$460,000

Total Upgrades	Estimate
Network Upgrades + TPIF Upgrades	$13,460,000
Contingency (*25%*)	$3,365,000
Total (*Incl. 25% contingency and Excl. HST*)	$16,825,000

The preliminary non-binding cost estimate for interconnecting 108.8 MW at the POI on L7018 under both NRIS and ERIS is $16,825,000 including a 25% contingency. In this estimate, $13,000,000 (*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 reactive power and power factor requirements. It also does not include TBD costs to address any stability issues identified at the SIS stage based on dynamic analysis, and it assumes that any RAS modifications will be approved by NPCC.

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

12 Loss Factor

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

The loss factor for IR721 is calculated as 2.26% at IR721's POI (*L7018, 230kV bus*), net of any losses on the IC facilities up to the POI. This means system losses on peak are marginally increased

by 2.26% when IR721 is operating at 108.8 MW. The MW measured at POI is 106.1 MW, the displaced MW generation at Tuff's Cove is 103.7 MW. Therefore, the loss factor is calculated as 2.4/106.1 = 2.26%.

Table 6: Loss factor analysis

Component	At IR721 POI
IR721 at 108.8 MW	106.1 MW
Tufts Cove with IR721 on	367.9 MW
Tufts Cove with IR721 off	471.6 MW
IR721 loss factor	2.26%

13 Preliminary Scope of Subsequent SIS

The following provides a preliminary scope of work for the subsequent SIS for IR721.

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
2024-06-07