Interconnection Feasibility Study Report
GIP-IR720-FEAS-R0

Generator Interconnection Request 720
68 MW Wind Facility
Queens County, NS

2024-05-31

Control Centre Operations
Nova Scotia Power Inc.

Executive summary

This Feasibility Study report (FEAS) presents the results of a Feasibility Study Agreement for the connection of a 68 MW wind generation facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS).

This project is designated as Interconnection Request #720 in the NSPI Interconnection Request Queue and will be referred to as IR720 throughout this report. The proposed Commercial Operation Date is December 31, 2027.

The Interconnection Customer (IC) identified a 138 kV bus at 50W-Milton as the Point Of Interconnection (POI). This wind generation facility will be interconnected to the POI via an approximately 2.5 km long 138 kV transmission line from the Point of Change of Ownership (PCO) to the three-breaker ring bus associated with IR-739. A fourth breaker will be added to the ring bus to accommodate IR-720.

There are two relevant long-term firm Transmission Service Reservations (TSR) in the System Impact Study (SIS) stage in the Transmission Service Queue, with requested in-service 2027/12/31 dates. These are TSR411 (800 MW from NB to NS) and TSR412 (500 MW from NFLD to NS) and are expected to alter the configuration of the Transmission System in Nova Scotia. As a result, the following notice has been posted to the OASIS site[1]:

> *Effective January 19th, 2021, please be advised that the completion of advanced-stage Interconnection Studies under the Standard Generator Interconnection Procedures (GIP) may be delayed pending the outcome of the Transmission Service Request (TSR) 411 and 412 System Impact Studies, which are expected to identify significant changes to the NSPI transmission system. The expected completion date for these studies is December 31, 2021. Feasibility Studies initiated prior to the completion of these TSR System Impact Studies will be performed based on the current system configuration.*

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.

[1] OASIS Generation Interconnection Procedures; https://www.nspower.ca/oasis/generation-interconnection-procedures

There are no concerns regarding increased short circuit levels. The increase in short circuit level is still within the capability of associated breakers. The minimum short circuit level at the Interconnection Facility's (IF) high side bus is 609 MVA. However, the Short Circuit Ratio (SCR) in minimal generation conditions is approaching the Nordex N163's minimum levels. Refined analysis will be performed in the System Impact Study (SIS) when more detailed transformer specs and collector circuit design is supplied.

Voltage flicker will be examined when data is made available for the SIS, however Type 3 wind turbines, like the Nordex N163 used in this IR, are not expected to introduce significant voltage flicker.

The project design must meet NSPI requirements for voltage ride-through, frequency ride-through, reactive power range, and voltage control. Harmonics must meet the Total Harmonic Distortion requirements in IEEE 519.

Power factor correction for IR720 is required to meet NSPI's ±0.95 net power requirements at the IF 138 kV bus. This is in situations when the wind facility is operating at max output and full reactive power is required.

The 50W-Milton POI for IR720 is not classified as NPCC BPS or NERC BES. Complete NPCC BPS status will be determined in the SIS.

The preliminary loss factor is calculated as 2.65% with IR720 modelled in the winter peak case.

The steady state contingencies evaluated in this study demonstrate IR720 requires Network Upgrades beyond the POI to operate at its full capacity of 68 MW under NRIS. These are detailed in Section 7 of this report.

The present day preliminary non-binding cost estimate for interconnecting IR720 to the 50W-Milton 138 kV bus as NRIS is $215,125,625. This estimate will be further refined in the SIS and Facility (FAC) studies.

The estimated time to construct the Network Upgrades and TPIF for NRIS operation is 24-48 months after the receipt of funds.

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1.0 Introduction

This Feasibility Study report (FEAS) presents the results of a Feasibility Study Agreement for the connection of a 68 MW wind generation facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS).

This project is listed as Interconnection Request #720 in the NSPI Interconnection Request Queue and will be referred to as IR720 throughout this report. The proposed Commercial Operation Date is December 31, 2027.

The Interconnection Customer (IC) identified a 138 kV bus at 50W-Milton as the Point of Interconnection (POI). This wind generation facility will be interconnected via a 2.5 km 138 kV transmission line from the Point of Change of Ownership (PCO) to the three-breaker ring bus associated with IR-739. A fourth breaker will be added to the ring bus to accommodate IR-720. Figure 1 shows the approximate location of the proposed IR720 site.

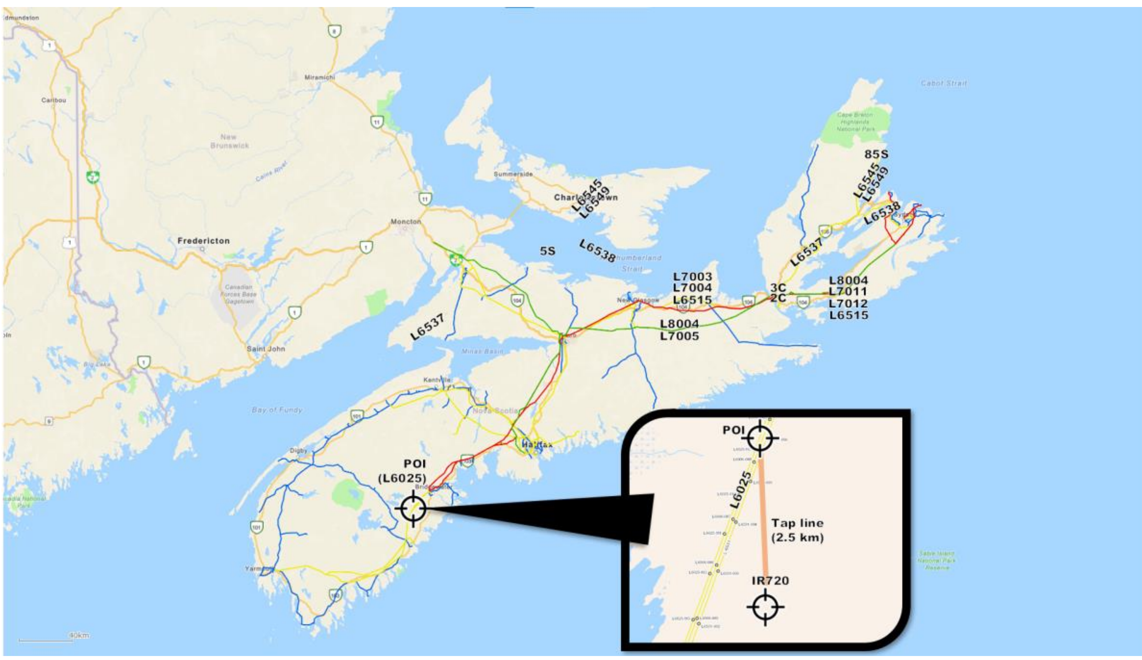

Figure 1: IR720 approximate geographic location

2.0 Scope

This Interconnection Feasibility Study's (FEAS) objective is to provide a preliminary evaluation of system impact and a high-level non-binding cost estimate of interconnecting the new wind generation facility to the NSPI Transmission System, at the designated location, based on single contingency criteria. This assessment will identify potential impacts on transmission element loading, which must remain with their thermal limits. Any potential voltage criteria violations will be identified and addressed. Circuit breakers must be upgraded if the proposed facility increases the short-circuit duty of any circuit breakers beyond their rated capacity.

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

- Identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection and any network upgrades necessary to address the short circuit issues associated with the IR.
- Identification of any thermal overload or voltage limit violations resulting from the interconnection and identify the necessary network upgrades to allow full output of the proposed facility.
- Description and high-level non-binding estimated cost of and time to construct the facilities required to interconnect the generating facility to the transmission system.

This FEAS does not include a complete determination of facility changes/additions required to increase the system transfer capabilities that may be required to the transmission system 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 in order to ascertain the final cost estimate to the interconnect the generating facility.

3.0 Assumptions

This FEAS is based on technical information provided by the IC. The Point of Interconnection (POI) and configuration is studied as follows:

1. Network Resource Interconnection Service (NRIS) per section 3.2 of the Generation Interconnection Procedures (GIP).
2. Commercial Operation date: December 31, 2027
3. The Interconnection Facility consists of 10 Nordex N163-6.8 MW wind energy converters, totalling 68 MW. These are modelled as Type 3 Double Fed Induction generators, evenly split between two collector circuits.
4. The IC identified the POI at one of the 50W-Milton substation's 138 kV buses.
5. The proposed 138 kV transmission line from the POI (50W) to the PCO is 2.5 km of Beaumont conductor to the three-breaker ring bus associated with IR-739. A fourth breaker will be added to the ring bus to accommodate IR-720.
6. Preliminary data was provided by the IC for the substation step-up transformer and generator step-up transformers.

6.1. The substation step-up transformer was modelled as 1x (one) 138 kV (wye) 34.5 kV (wye) transformer with delta tertiary, rated at 45/60/75 MVA, with a positive sequence impedance of 7.5% and assumed 40 X/R ratio.

6.2. The generator step-up transformers were modelled as an equivalent transformer based on 10x (ten) 34.5 kV (delta) – 0.95 kV (grounded wye) 7.8 MVA transformers, with a 9% positive sequence impedance and an assumed 10 X/R ratio.

7. A generic collector circuit layout is assumed since a collector circuit design was not provided. Note the plant's net real and reactive power will be impacted by losses through the transformers and collector circuits.
8. The FEAS analysis is based on the assumption that IRs higher in the Generation Interconnection Queue and OATT Transmission Service Queue that have a completed System Impact Study, or have a System Impact Study in progress, will proceed as listed in Section 4.0: Project queue position.
9. Transmission line ratings used in this study are listed in Appendix A: Transmission line ratings, except that the L-5535A and L-5535B summer ratings will be increased from 23 to 32 MVA by a higher queued IR.

4.0 Project queue position

All in-service generation is included in this FEAS.

As of 2024/05/22, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are included in this study's 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 IR710 was initiated.

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

- TSR 400: System Upgrades in Progress
- TSR 411: Facilities Study in Progress

TSR-411 is included in the queue, which reflects the study of long-term firm Transmission Service Reservation (TSR) from New Brunswick to Nova Scotia. If approved by the NSUARB, the TSR is expected to be in service in 2028 and a system study is currently underway to determine the required updates to the Nova Scotia transmission system. This has not been included in the feasibility study and the following notice is 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 2022 Transmission System configuration plus any material Network Upgrades identified in higher queued projects.

5.0 Short circuit

IR720 will not impact 50W-Milton and neighbouring breaker's interrupting capability based on this study's short circuit analysis. Analysis was performed using PSS/e 34.8.1, classical fault study, flat voltage profile at 1.0 PU voltage, and 3LG faults.

The maximum (design) interrupting capability of the neighbouring 138 kV circuit breakers are at least 5,000 MVA. The Nordex N163 technical bulletin supplied the short circuit characteristics in **Error! Reference source not found.**. The short circuit levels in the area before and after this development are provided in .

The minimum SCR *(Short Circuit Ratio)* specified in the IR documentations for IR720 is 6.1 at the turbine's HV terminals. Minimum fault levels occur when L7008 (50W-Milton/99W-Bridgewater) is out of service. In this scenario, the SCR at the low side of IR720's substation step down transformer is 4.4. This information should be provided to Nordex for design specification as the collector circuit length and generator step-up transformers will further reduce the SCR measured at the wind turbines' HV terminals.

Table 1: Nordex N163 operational characteristics

Characteristic	Value
Minimum required Short Circuit Ratio at turbine HV connection	Greater than 3.0 (study is needed to optimise the turbine for connections with SCRs between 1.5-3.0)

Table 2: Short circuit levels, 3-ph, in MVA

Location	IR720 not in service	IR720 in service	Post % increase
2024, max generation, all facilities in service (MVA)			
IR720_POI	1,374	1,530	11%
IR720_HV	1,371	1,526	11%
IR720-MV	418	628	50%
2024, min generation, all facilities in service (MVA)			
IR720_POI	707	797	13%
IR720_HV	706	796	13%
IR720-MV	325	431	33%
2024, min generation, L7008 OOS (MVA)			
IR720_POI (BUS 199735)	610	700	15%
IR720_HV (BUS 199431)	609	699	15%
IR720-MV (BUS 199432)	302	409	35%

Equation 1: IR720 Post % Increase

$$Post\ \%\ Increase = \left(\frac{(\ IR720_{In\ service} - IR720_{Not\ in\ Service})}{IR720_{Not\ in\ service}}\right) X\ 100\ \%$$

6.0 Voltage flicker & harmonics

Voltage flicker will be examined when data is made available for the SIS. However, Type 3 wind turbines, like the Nordex N163 used in IR720, are not expected to introduce significant voltage flicker.

NS Power's voltage flicker requirements are:

- $P_{st} \leq 0.25$
- $P_{lt} \leq 0.35$

The generator must meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion *(all frequencies)* to no higher than 1.5% with no individual harmonic exceeding 1.5% on 138 kV.

7.0 Thermal limits

The steady state contingencies evaluated in this study demonstrate IR720 does require Network Upgrades beyond the POI to operate at its full capacity of 68 MW under NRIS.

Base cases used in this study are listed in **Error! Reference source not found.**. They were selected to reflect conditions under varying amounts of low/high area load vs historic area generation. This approach was chosen because portions of the Western/Valley transmission system would presently experience overloads if the entire area hydro and wind plants were simultaneously operated at maximum capacity under system light load.

Area transmission line ratings are listed in Appendix A: *Transmission line ratings*.

Table 3: Base case dispatch

Case	System Load (MW)	NS/NB (MW)	ML (MW)	CBX (MW)	ONI (MW)	ONS (MW)
WP_00	2295.2	0	170	738	930	764
WP_01	2487.9	188	170	738	930	574
WP_02	2458.7	141	320	1035	1062	754
WP_03	2672.8	338	320	1035	1062	556
SP_00	1528	149	330	509	616	383
SP_01	1531.7	150	330	509	616	382
SP_02	1676.7	150	475	508	616	382
SP_03	1701.8	300	475	652	754	368
LL_00	720.2	150	170	39.9	68.7	-92.9
LL_01	948.2	371.6	330	199	226.6	-158.4
LL_02	1093.2	371.6	475	199	226.6	-158.4
LL_03	1108	449	330	199	295	-208
SH_00	1195.4	152	330	291.5	369.6	163.7
SH_01	1263.4	218.1	330	291.5	369.7	97.3
SH_02	1483.1	287.3	475	291.6	369.7	27.6

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

Table 4: Contingencies List

Contingencies Studied				
88S_L-7014	67N-705	103H_L-6038	20V-T1	5S_L-6549
88S_L-7021	67N-706	103H-T81	20V-503	3S_L-6539
88S_L-7022	67N-710	103H-T61	20V-504	3S_bus
88S-710	67N-712	103H-T63	20V-401	5S_L-6537
88S-711	67N-713	103H-B61	102V-L5060	2S_L-6516
88S-712	1N_L-6613	103H-B62	102V-T51	5S-606
88S-713	1N_L-6503	103H-881	102V-GT1	5S-607
88S-714	1N_L-6001	103H-600	17V-L6051	2S-513
88S-715	1N-T1	103H-608	17V-L6011	1C-G2

88S-720	1N-T4	103H-681	17V-L5014	48C-G1
88S-721	1N-T65	89S-G1	17V-L4046	50N-G5
88S-722	1N-C61	91H_L-5049	17V-L4045	50N-G6
88S-723_G0	1N-B61	91H_L-5012	17V-SHUNT	50N-L-6511
88S-723_G8	1N-B62	91H_L-5041	17V-T2	91H-G3
88S-T71	1N-600	91H-T62	17V-T63	91H-G4
88S-T72	1N-601	91H-T11	17V-T1	91H-G5
88S-G2	1N-613	91H-511	17V-612	91H-G6
88S-G3	50N-l5500	91H-516	17V-611	104W-G1
88S-G4	50N-l5501	91H-521	17V-563	110W-T62
101S_ML-POLE1	50N-l5502	91H-523	17V-512	104H-600
101S_ML-POLE2	50N-l6503	91H-621	17V-519	50W, 50W-B3_OL
101S_ML-BIPOLE	50N-l6511	91H_L-6042	17V-505	50W, 50W-615_OL
101S-T81	50N-l6507	91H-613	101V-L6004-a	9W, 9W-T2_OL
101S-T82	50N-l6508	91H-604	101V-L6053	50W, 50W-B3
101S_L-7011	50N-GT6	91H_L-6007	101V-601	50W, 50W-615
101S_L-7011_G1	50N-GT5	91H-605	101V-602	9W, 9W-T2
101S_L-7012	50N-T12	91H-606	101V-603	67N-811_G0
101S_L-7012_G2	50N-T8	91H-607	IR379-GT	79N_L-8003_G0
101S_L-7015	50N-LOAD1	91H_L-6014	IR372-GT	67N-811_G5
101S-701	50N-LOAD2	91H-608	IR379-TX	79N_L-8003_G5
101S-702	50N-614	91H-609	IR372-TX	79N_L-8003_G6
101S-703	50N-607	91H-611	110W-661	67N-811_G6
101S-704	50N-604	91N-701	13V L-5531	67N_L-8001_NSX1
101S-705	50N-513	91N-702	13V L-5532	67N-814_NSX1
101S-706	50N-508	91N-703	13V 13V-B51	67N_L-8001_NSX2
101S-711	50N-500	91N-B71	13V L-5533	67N-814_NSX2
101S-712	120H_L-7008	99W-708	51V 51V-B61	67N_L-8001_NSI
101S-713	120H_L-7009	99W-709	51V-601	67N-814_NSI
101S-811	120H_L-6005	99W-T71	51V-T62	67N_L-8001_G0
101S-814	120H_L-6010	99W-T72	51V 51V-B52	67N-814_G0
101S-816	120H_L-6011	99W-L5545-a	51V 51V-T61	DCT_L-7003][L-7004_G3
3C_L-7003	120H Open L-6051	99W-L5546	51V 51V-T61_OL	67N-711_G3
3C_L-7004	120H L-6051	99W-L6531	51V-L5053	3C_L-7005_G3
3C-T71	120H_L-6016	99W-L6006	9W, L-5535	3C-710_G3
3C-T72	120H-T71	99W-L6025	9W 9W-B53	3C-720_G3
3C-711	120H-T72	99W-L6002	9W 9W-B52	DCT_L-7003][L-7004_G0
3C-712	120H-SVC	99W-L7009	9W L-5027	67N-711_G0
3C-713	120H_L-7018	99W-L7008	30W 30W-T62	3C_L-7005_G0

3C-714	120H-710	99W-601	30W 30W-B51	3C-710_G0
3C-715	120H-711	99W-601-IR664	50W L-6020	3C-720_G0
3C-716	120H-712	99W-T62	50W L-6024	79N-T81_G0
2C_L-6515	120H-713	99W-602	50W L-6048	101S_L-8004_G0
2C_L-6516	120H-714	99W-602-IR664	50W 50W-B4	101S-812_G0
2C_L-6517	120H-715	99W-T61	50W L-5541	101S-813_G0
2C_L-6518	120H-716	99W-T61-IR664	50W L-5530	79N-T81_G5
2C_L-6523	120H-720	99W-T62-IR664	50W L-5539	101S_L-8004_G5
2C_L-6537	120H-621	99W-SHUNT	50W 50W-B2	101S-812_G5
2C_B61	120H-622	99W-545	50W IR597	101S-813_G5
2C_B61_SPS	120H-623	99W-501	50W 50W-T53	79N-T81_G6
2C_B62	120H-624	99W-562	50W L-5540	101S_L-8004_G6
2C_L-6537_SPS	120H-625	3W-B53	113H-601	101S-812_G6
2C_B62_SPS	120H-626	3V-L4049	113H-L6043	101S-813_G6
47C_B1	120H-627	3V-L5035	132H-602	DCT_L-7003][L-7004_G3
47C_B2	120H-628	3V-G1	132H-603	67N-711_G3
47C_B3	120H-629	3V-G2	132H-605	3C_L-7005_G3
47C_B4	90H-L6002-1	22V-L5033	132H-606	3C-710_G3
47C_B5	90H-L6009-2	43V-L6012	132H-L6044	3C-720_G3
47C_B6	90H-L-6008	43V-L6013	132H-L6040	DCT_L-7003][L-7004_G0
47C_B7	90H-L6003	43V-L6054	132H-L6055	67N-711_G0
4C_L-6552	90H-L5003-2	43V-L6015	1H-603	3C_L-7005_G0
4C_T63	90H-L5004-1	43V-50VLoad	1H-L-6035	3C-710_G0
4C_T2	90H-T1	43V-L6052	74N-600	3C-720_G0
4C_620	90H-C61	43V-L5017	74N-L6536	79N-T81_G0
4C_621	90H-C51	43V-L5022	74N-L6514	101S-812_G0
4C_622	90H-611	43V-L5021	74N-L5029	101S-813_G0
4C_623	90H-608	43V-T62	74N-L5058	79N-T81_G5
79N_L-6507	90H-605	43V-604	15V-B51	101S_L-8004_G5
79N_L-6508	90H-602	43V-T61	15V-L5050	101S-812_G5
67N_L-8002	90H-612	43V-B61	15V-L5538	101S-813_G5
67N_L-7019	90H-609	43V-B62	92V-B51	79N-T81_G6
67N_L-7001	90H-606	43V-SHUNT	DCT_L-5039][L-6033	101S_L-8004_G6
67N_L-7002	90H-603	43V-B51	DCT_L-7009][L-8002	101S-812_G6
67N-T81	90H-610	43V-505	DCT_L-6011][L-6010	101S-813_G6
67N-T82	90H-607	43V-562	DCT_L-6010][L-6005	51V, L-5025_SPS
67N-T71	90H-604	43V-503	DCT_L-6005][L-6016	13V, L-5026_SPS
67N-812	90H-601	43V-506	DCT_L-7008][L-7009	11V, 11V-B51_SPS
67N-813	90H-503	41V-L4048	DCT_L-6507][L-6508	51V, 51V-B51_SPS

67N-701	90H-506	41V-L4047	DCT_L-7021][L-6534	51V, L-5025
67N-702	90H-501	41V-407	DCT_L-6033][L-6035	13V, L-5026
67N-703	103H_L-6008	79V-L5015	85S_L-6545	11V, 11V-B51
67N-704	103H_L-6033	79V-L5016	5S_L-6538	51V, 51V-B51

Table 5: Results

Item	Description	Solution
1	For the third light load case (LL_03), for contingencies {120H_L-7008 120H-713 120H-715 120H-716 99W-708 99W-T71 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562} Line L-5531 (Quail conductor) is overloaded up to 114% of Rate 2	Increase the light load line rating of Rate 1 from 23 MVA to 30 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 65)
2	For the third summer peak case (SP_03), for contingencies {99W-601 99W-601-IR664 99W-T61 99W-T61-IR664 99W-501 99W-562 9W, L-5535} Line L-5532A (Quail conductor) is overloaded up to 112% of Rate 2	Increase the Summer load line rating of Rate 1 from 23 MVA to 30 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 65)
3	For the third summer peak case (SP_03), for contingencies {99W-601 99W-601-IR664 99W-T61 99W-T61-IR664 99W-501 99W-562 9W, L-5535 9W, 9W-B53 15V-B51} Line L-5532C (Quail conductor) is overloaded up to 116% of Rate 2	Increase the Summer load line rating of Rate 1 from 23 MVA to 30 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 65)
4	For the third summer peak case (SP_03), for contingencies {120H-716 99W-601 99W-601-IR664 99W-T61 99W-T61-IR664 99W-501 99W-562 13V, L-5531 9W, L-5535 9W, 9W-B53 15V-B51} Line L-5532D (Quail conductor) is overloaded up to 119% of Rate 2	Increase the Summer load line rating of Rate 1 from 23 MVA to 30 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 65)
5	For the third summer peak case (SP_03), for contingencies {120H-716 99W-601 99W-601-IR664 99W-T61 99W-T61-IR664 99W-501 99W-562 13V, L-5531 9W, L-5535 9W, 9W-B53 15V-B51} Line L-5532E (Quail conductor) is overloaded up to 119% of Rate 2	Increase the Summer load line rating of Rate 1 from 23 MVA to 30 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 65)
6	For the third summer peak case (SP_03), for contingencies {120H-713 120H-716 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 13V, L-5531 9W, L-5535 9W, 9W-B53 15V-B51} Line L-5532F (Quail conductor) is overloaded up to 121% of Rate 2	Increase the Summer load line rating of Rate 1 from 23 MVA to 32 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 70)
7	For the third summer peak case (SP_03), for contingencies {120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 13V, L-5531 9W, L-5535 9W, 9W-B53 15V-B51 DCT_L-7009][L-8002} Line L-5532G (Quail conductor) is overloaded up to 130% of Rate 2	Increase the Summer load line rating of Rate 1 from 23 MVA to 35 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 80) (full rebuild is required)

8	For the third summer peak case (SP_03) and third light load case (LL_03), for contingencies {120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 9W, 9W-B52 50W, L-6020 50W, 50W-B4 DCT_L-7009][L-8002 9W, 9W-T2 120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 3W-B53 13V, L-5532 50W, L-5541 50W, 50W-B2 DCT_L-7009][L-8002} Line L-5535A (Quail conductor) is overloaded up to 116% of Rate 2	Increase the Summer and Light load line rating of rate 1 from 23 MVA to 40 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 100)(full rebuild is required)
9	For the third summer peak case (SP_03) and third light load case (LL_03), for contingencies {120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 9W, 9W-B52 50W, L-6020 50W, 50W-B4 DCT_L-7009][L-8002 9W, 9W-T2 120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 3W-B53 13V, L-5532 50W, L-5541 50W, 50W-B2 DCT_L-7009][L-8002} Line L-5535B (Quail conductor) is overloaded up to 112% of Rate 2	Increase the Summer and Light load line rating of rate 1 from 23 MVA to 40 MVA (Conductor Type is ACSR 2/0 Quail increase Maximum Operating Temp in Celsius from 50 to 100) (full rebuild is required)
10	For the third light load case (LL_03), for contingencies {99W-L6006 99W-601 99W-601-IR664 99W-T61 99W-T61-IR664 99W-501} Line L-6531 (556.5 Dove conductor) is overloaded up to 123% of Rate 2	Increase the Light load rating of rate 1 from 110 MVA to 155 MVA (Conductor Type is 556.5 Dove increase Maximum Operating Temp in Celsius from 50 to 65)
11	For the third Summer peak case (SP_03) and third light load case (LL_03), for contingencies {120H_L-7008 120H-715 120H-716 99W-708 99W-T71 99W-L7008 99W-601 99W-601-IR664 99W-T61 99W-T61-IR664 99W-501 120H_L-7008 120H-715 120H-716 99W-708 99W-T71 99W-L7008 99W-601 99W-601-IR664 99W-T61 99W-T61-IR664 99W-501} Line L-7009 (795 Drake) is overloaded up to 158% of Rate 2	Increase the Summer and Light load line rating of rate 1 from 223 MVA to 387 MVA (Conductor Type 795 Drake increase Maximum Operating Temp in Celsius from 50 to 80)
12	For the third Summer peak case (SP_03), Winter peak case (WP_03) and third light load case (LL_03) for contingencies {120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 DCT_L-7009][L-8002 120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601	Install ring bus with new transformer. Will require 2 new 138kV breakers, 4 new 230 kV breakers, 1 new 200 MVA transformer (230kV-138kV) and substation work

	99W-601-IR664 99W-T62 99W-602 99W-602-IR664 99W-T61 99W-T61-IR664 99W-T62-IR664 99W-501 99W-562 DCT_L-7009][L-8002 120H_L-7008 120H_L-7009 120H-712 120H-713 120H-715 120H-716 99W-708 99W-709 99W-T71 99W-T72 99W-L7009 99W-L7008 99W-601 99W-601-IR664 99W-T62 99W-602 99W-T61 99W-T61-IR664 99W-501 99W-562 DCT_L-7009][L-8002} Transformers 99W-T71 and 99W-T72 are overloaded up to 159% of Rate 2	
13	For the third winter peak (WP_03) for contingencies {67N_L-8001_NSX1 67N-814_NSX1} Transformer 67N-T71 is overloaded up to 101% of Rate 2	Install one new 230kV breaker, one new 230-138 transformer, one new 138 kV breaker and the work required to do it
14	For the third light load case (LL_03) for contingency {50W, 50W-B4} transformer 9W-T2	This is solved based on IR-677 Report

The following contingencies around the 50W-Milton substation resulted in pre-existing undervoltage conditions in the 69 kV system between 9W-Tusket and 30W-Souriquois, however, the presence of IR720 did not worsen their severity:

- 30W, 30W-B61
- 50W, 50W-B2
- 50W, 50W-B4
- 50W, L6024
- 9W, 9W-B53

8.0 Voltage control

IR720 requires power factor correction to meet NS Power's ±0.95 net power factor requirement at the HV terminals of the ICIF substation. IR720 is also required to produce/absorb reactive power at all production levels from 0 MW up to full rated output.

Using the Nordex N163 reactive power capability, shown in Figure 4*: Nordex N163 6.8 MW* reactive power capability, various levels were calculated and are displayed in Power factor analysis *results*.

Power factor analysis results:

Table 6: 0.95 Power Factor

IR720 MW	IR720 MVAR	Tx HV MW	Tx MVAR	Tx HV MVA	Tx HV Power Factor
68	36.7	66.8	22.1	70.4	0.95

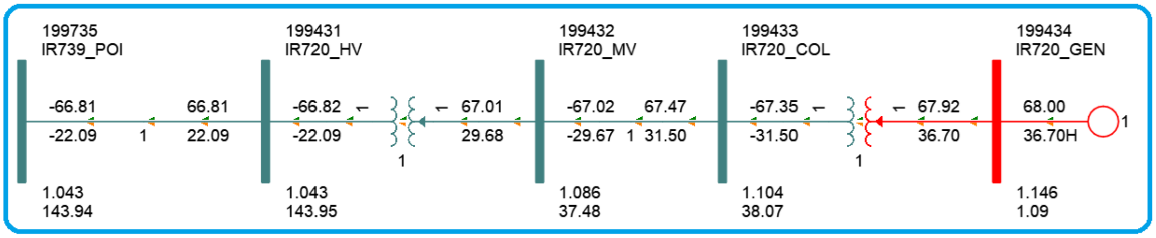

Figure 2: 0.95 Power Factor

Table 7: 0.76 Power Factor

IR720 MW	IR720 MVAR	Tx HV MW	Tx MVAR	Tx HV MVA	Tx HV Power Factor
68	-32.9	66	-56.7	87.0	0.76

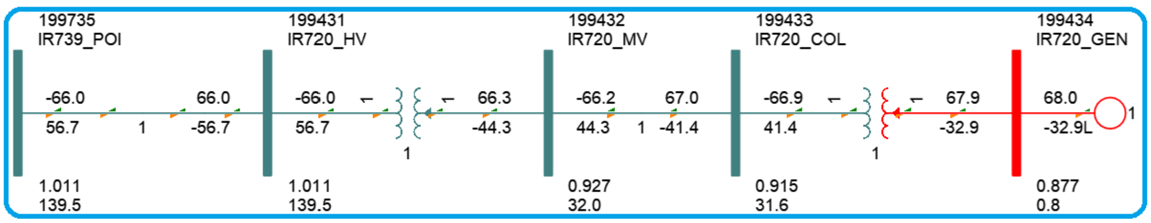

Figure 3: 0.76 Power Factor

IR720 does not meet NS Power's ±0.95 net power factor requirement when the wind farm is operating at 0MW and when operating near its max nameplate capacity. The Nordex technical bulletin's reactive power capability, shown in Figure 4, shows that the reactive power capability is slightly reduced at full output (regions A-B, and C-D), and that it has no reactive capability when the generation is at 0MW.

The net power factor will be re-evaluated when the detailed information on the transformers and collector circuit are available in the SIS stage, to determine if and how much supplemental reactive power support is required.

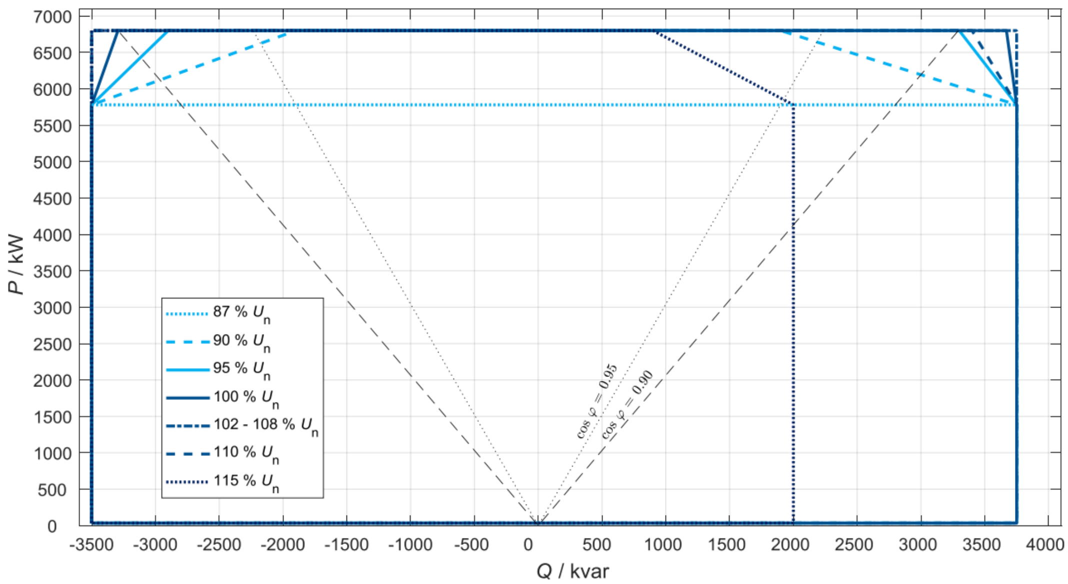

Figure 4: Nordex N163 6.8 MW reactive power capability[2]

A centralized controller will be required, which continuously adjusts the individual generator reactive power output within the plant capability limits and regulates the voltage at the low voltage terminal of the ICIF transformer. The voltage controls must be responsive to voltage deviations, be equipped with a voltage setpoint control, and have facilities that will slowly adjust the setpoint over several (5-10) minutes to maintain reactive power within the individual generators' capabilities. Details of the specific control features, control strategy, and settings will be reviewed and addressed in the SIS.

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

This facility must have voltage ride-through capability as described in the NS Power TSIR *(Transmission System Interconnection Requirements)*. The SIS will examine the plant capabilities and controls in detail to specify options, controls, and additional facilities that are required to achieve low voltage ride through.

In addition, the substation 138kV – 34.5kV step-up transformer must be equipped with an on-load tap changer.

[2] Nordex General Description 4MW platform, document no: 0067-7060 V07, 2021-03-16.

9.0 System security

At the time of this study, the proposed POI at 50W-Milton is neither categorized as NPCC[3] BPS *(Bulk Power System)* or NERC[4] BES *(Bulk Electric System)*.

Further, IR720 is not categorized as NERC BES, since it does not meet any of the four inclusion criteria.

The SIS will complete NPCC BPS analysis[5], which requires additional steady-state and transient state-analysis to determine if there is any of the following:

- System instability that cannot be demonstrably contained within NS.
- Cascading that cannot be demonstrably contained within NS.
- Net loss of source or loss of load greater than NS' thresholds, if applicable.

10.0 Expected facilities required for interconnection

The following facilities are required to interconnect IR720 to the NSPI system via the 138 kV bus at 50W-Milton as NRIS:

1) Network upgrades:

a) A Thermal upgrade for overloaded line L-5531.

b) Thermal upgrade for overloaded lines L-5532A, L-5532C, L-5532D, L-5532E and L-5532F.

c) Full rebuild required for overloaded line L-5532G.

d) Full rebuild required for overloaded lines L-5535A and L-5535B.

e) Thermal upgrade for overloaded line L-6531.

f) Full rebuild required for overloaded line L-7009.

g) Transformers 99W-T71 and 99W-T72 are in a parallel configuration, if one transformer is overloaded, the other is as well due to load distribution, require installation of ring bus with new transformer, 2 new 138kv breakers, 4 new 230kv breakers, 1 new 200 MVA transformer (230kv-138kv) and cost of labour.

h) Transformer overloaded, require one new 230kv breaker, one new 230 138 transformer, one new 138kv breaker and cost of labour.

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[3] Northeastern Power Coordination Council.
[4] North American Electric Reliability Corporation.
[5] Regional Reliability Reference Criteria A-10: *Classification of Bulk Power System Elements*; NPCC.

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

   a) 5.3km 130kV radial transmission line (Beaumont conductor) between 50W Milton and the Interconnection Customers substation.

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

   a) Facilities to provide ±0.95 power factor when delivering rated output (68 MW) at the 138 kV bus when voltage is operating between ±5% of nominal. Rated reactive power shall be available through the full range of real power output, from zero to full power.

   b) Centralized controls for voltage setpoint control for the low side of the ICIF transformer. Fast acting control is required and will include a curtailment scheme, which will limit/reduce total output from the facility, upon receipt of a telemetered signal from NSPI's SCADA system.

   c) NSPI to have supervisory and control of this facility, via the centralized controller. This will permit the NSPI System Operator to raise/lower the voltage setpoint, change the status of reactive power controls, change the real/reactive power remotely.

   d) When curtailed, the facility shall offer over-frequency and under-frequency control with ±0.2 Hz deadband and 4% droop characteristic. The active power controls shall also react to continuous control signals from the NSPI SCADA system's Automatic Generation Control (AGC) system to control tie-line fluctuations as required.

   e) The facility shall support short-duration frequency deviations by providing 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.

   f) Voltage ridethrough capability as described in the NS Power TSIR.

   g) Frequency ridethrough capability in accordance with the NS Power TSIR. The facility shall have the capability of riding through a rate of change of frequency of 4 Hz/s.

   h) Facilities for NSPI to execute high speed generation rejection (transfer trip), if determined in the SIS. The plant may be incorporated in SPS runback or load reject schemes.

   i) Operation at ambient temperatures as low as -30ºC. The IC shall also provide icing models and conduct icing studies for their facility.

   j) 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.

11.0 NSPI Interconnection Facilities and Network Upgrades cost estimate

The high level, non-binding, present day cost estimate, excluding HST, for the IR720's Network Resource Interconnection Service is shown in **Error! Reference source not found.**. This estimate assumes there is adequate space for new equipment and modifications. This does not include any to-be-determined costs to address any stability issues identified at the SIS stage, based on dynamic analysis.

Table 8: NRIS Cost Estimate

Item	TPIF	Estimate
I	2.5 km long radial line	$ 2,500,000
II	One new 138 kV breaker	$ 1,000,000

	Network Upgrades	Estimate
I	Thermal upgrade for overloaded line L-5531	$ 10,035,900
II	Thermal upgrade for overloaded lines L-5532A, L-5532C, L-5532D, L-5532E and L-5532F	$ 33,817,500
III	Full rebuild required for overloaded line L-5532G	$ 6,200,000
IV	Full rebuild required for overloaded lines L-5535A and L-5535B	$ 32,070,000
V	Thermal upgrade for overloaded line L-6531	$ 16,617,150
VI	Thermal upgrade for overloaded line L-7009	$ 63,328,200
VII	Transformer overloaded, require installation of ring bus with new transformer, 2 new 138kv breakers, 4 new 230kv breakers, 1 new 200 MVA transformer (230kv-138kv) and substation work cost	$ 22,000,000
VIII	Transformer overloaded, require one new 230kv breaker, one new 230 138 transformer, one new 138kv breaker and work required cost	$ 8,000,000
	Sub-total	**$ 195,568,750**

Determined costs	
Subtotal	$ 195,568,750
Contingency (10%)	$ 19,556,875
Total of determined cost items	**$ 215,125,625**

The estimated time to construct the Network Upgrades and Transmission Provider's Interconnection Facilities is 36-48 months after receipt of funds.

12.0 Loss factor

With IR720 in service, the loss factor is calculated as 2.65%. The data and calculation is detailed in **Error! Reference source not found.** and Equation 2: *IR720 loss factor calculation*, respectively.

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 NS Area Interchange bus. This methodology reflects the load centre in and around 91H-Tufts Cove. A negative loss factor reflects a reduction in system losses.

Table 9: IR720 Loss Factor Data

Name	Value (MW)
IR720 nameplate	68
TC3 w/ IR720	69.1
Total Losses W/ IR720	78.1
TC3 w/o IR720	135.3
Total Losses W/O IR720	76.3
Total Losses Delta	1.8
2023 loss factor	2.65%

Equation 2: IR720 loss factor calculation

$$Loss\ factor = \frac{(IR720_{nameplate} + TC3_{w/\ IR720}) - TC3_{w/o\ IR720}}{IR720_{nameplate}} = 1.96\%$$

13.0 Preliminary scope of subsequent SIS

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.*

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 TSIR.
- 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.
- NSPI System Design Criteria, report number NSPI-TPR-003-5.

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[6] and NERC[7] criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

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[6] NPCC criteria are set forth in its Reliability Reference Directory #1 *Design and Operation of the Bulk Power System*

[7] NERC transmission criteria are set forth in *NERC Reliability Standard TPL-001-5*

Appendix A: Transmission line ratings

NSPI Transmission Line Ratings Last Updated: 2020-09-01

LINE	STATION	CONDUCTOR Type	Maximum Operating Temp. (Celsius)	SUMMER RATING 25 DEG (MVA)	WINTER RATING 5 DEG (MVA)	BREAKER 100% Name-plate	SWITCH 100% Name-plate	CURRENT TRANSFORMER RELAYING Ratio	RELAYING R.F.	RELAYING MVA	FULL SCALE METERING Ratio	METERING R.F.	METERING MVA	TRIP MVA
L-6006	99W Bridgewater	ACSR 795 Drake	50	135	205	478	478	800	2	382	800	1	231	973
	50W Milton					287	287	800	2	382	800	1	231	973
L-6020	50W Milton	ACSR 336.4 Linnet	50	82	121	287	287	300	2	143	400	1	115	342
	30W Souriqouis							300	2	143	N/A			
L-6024	50W Milton	ACSR 795 Drake	70	203	251	478	287	600	1.3	186	800	1	231	250
	9W Tusket					96	72	400	2	191	600	1	173	97
L-6025	99W Bridgewater	ACSR 1113 Beaumont	70	242	301	287	287	800	1	200	800	1	231	972
	50W Milton					287	287	800	1	200	800	1	231	972
L-6047	50W Milton	ACSR 795 Drake	70	203	251	287	287	800	1.2	229	800	1	231	191
	101W Abitibi-Bowater					287	287	800	1.2	229	800	1	231	
L-6048	50W Milton	ACSR 795 Drake	70	203	251	287	287	800	1.2	230	800	1	231	191
	101W Abitibi-Bowater					287	287	800	1.2	230	800	1	231	
L-5532c	75V S. Milford	ACSR 2/0 Quail	50	23	34		48				NA			
	76V Maitland						72				NA			

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NSPI Transmission Line Ratings Last Updated: 2020-09-01

LINE	STATION	CONDUCTOR Type	Maximum Operating Temp. (Celsius)	SUMMER RATING 25 DEG (MVA)	WINTER RATING 5 DEG (MVA)	BREAKER 100% Name-plate	SWITCH 100% Name-plate	CURRENT TRANSFORMER RELAYING Ratio	RELAYING R.F.	RELAYING MVA	FULL SCALE METERING Ratio	FULL SCALE METERING R.F.	FULL SCALE METERING MVA	TRIP MVA
L-6531	99W Bridgewater	ACSR 556.5 Dove	50	110	165	299	202	800	1.5	287	800	1	231	973
	50W Milton					287	301	800	2	382	800	1	231	943
L-5530a	50W Milton	ACSR 4/0 Penquin	50	31	45	96	72	300	1	36	400	1	58	108
	46W Broad River						72				NA			
L-5530b	46W Broad River	ACSR 4/0 Penquin	50	31	45		72				NA			
	36W Green Harbour						48				NA			
L-5530c	36W Green Harbour	ACSR 4/0 Penquin	50	31	45		48				NA			
	30W Sourquois					96	72	300	2	72	300	2	42	102
L-5532a	13V Gulch Hydro	ACSR 2/0 Quail	50	23	34	143	38	150	2	36	300	1	42	22
	14V Ridge Hydro						72				NA			
L-5532b	14V Ridge Hydro	ACSR 2/0 Quail	50	23	34		72				NA			
	75V S. Milford						48				NA			
L-5532c	75V S. Milford	ACSR 2/0 Quail	50	23	34		48				NA			
	76V Maitland						72				NA			

Appendix A: Transmission line ratings

NSPI Transmission Line Ratings — Last Updated: 2020-09-01

LINE	STATION	CONDUCTOR Type	Maximum Operating Temp. (Celsius)	SUMMER RATING 25 DEG (MVA)	WINTER RATING 5 DEG (MVA)	BREAKER 100% Name-plate	SWITCH 100% Name-plate	CURRENT TRANSFORMER RELAYING Ratio	RELAYING R.F.	RELAYING MVA	FULL SCALE METERING Ratio	FULL SCALE METERING R.F.	FULL SCALE METERING MVA	TRIP MVA
L-5532d	76V Maitland	ACSR 2/0 Quail	50	23	34		72				NA			
	58W Harmony Hills						72				NA			
L-5532e	58W Harmony hills	ACSR 2/0 Quail	50	23	34		72				NA			
	57W Caledonia						48				NA			
L-5532f	57W Caledonia	ACSR 2/0 Quail	50	23	34		48				NA			
	91W Middlefield Dist						48				NA			
L-5532g	91W Middlefield Dist.	ACSR 2/0 Quail	50	23	34		48				NA			
	3W Big Falls					96	72	200	2	48	200	1	28	66
L-5541a	50W Milton	ACSR 4/0 Penguin	50	31	45	96	72	300	1.2	43	400	1	58	43
	4W Lower Great Brook						72				NA			