Interconnection Feasibility Study Report

GIP-IR596-FEAS-REV0

Generator Interconnection Request IR596

50.4 MW Wind Generating Facility

Location Westchester Station, Cumberland County, NS

2021-08-31

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR596) for Network Resource Interconnection Service (NRIS) for a proposed 50.4 MW wind generation facility interconnected to NSPI transmission system, with a Commercial Operation Date of December 1, 2023. The Point of Interconnection (POI) requested by the customer is line L-6613 section between 81N-Debert and 74N-Springhill. The generation will consist of twelve 4.2 MW, Enercon E-138 EP3 generators.

This feasibility assessment is conducted with IR596 generation to be used in NS and not for exporting outside NS. The assessment is completed based on NSPI's Generator Interconnection Procedure (GIP).

Based on the information provided by the IC, this feasibility assessment provides the following findings:

- In general, IR596 rated output does not violate thermal or voltage criteria. However, when it displaces Halifax generation in winter peak, the Metro Dynamic Reactive Reserves can be marginally exceeded and 120H-T71 or 120H-T72 transformer at Brushy Hill substation can marginally exceed their nominal ratings under certain N-1 contingencies. At this time, this assessment considers them marginal and no associated system upgrades are identified.
- IR596 meets NSPI's requirements for voltage flicker and harmonic levels.
- IR596 will require power factor correction or mitigation measure to meet NSPI's power factor requirement when it delivers reactive power to the power system.
- The minimum Short Circuit Ratio (SCR) at 34.5 kV bus is 5.2. This needs to be discussed with Enercon to ensure the wind turbines can operate at this SCR level.
- The estimated loss factor for IR596 is 6% at rated output.
- The high-level cost estimate, in 2021 Canadian dollars, for IR596 connection is $9,146,500 which includes 10% contingency and excludes HST.

IR596 will require to meet NSPI's Generator Interconnection Procedure (GIP) and Transmission System Interconnection Requirements (TSIR).

This assessment is a feasibility study and is further subjected to the subsequent System Impact Study (SIS) and Facility Study which will determine any further system requirements and upgrades for IR596.

Table of Contents

List of Tables

List of Figures

1.0 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR596) for Network Resource Interconnection Service (NRIS) for a proposed 50.4 MW wind generation facility interconnected to NSPI transmission system, with a Commercial Operation Date of December 1, 2023.

The information regarding the proposed generation source is provided in the document titled "GIP-Appendix 2-Interconnection Feasibility Study Agreement", signed by Nova Scotia Power Inc., the Transmission Provider, on June 7, 2021 and by the Interconnection Customer, on April 26, 2021.

The designation of Point of Interconnection (POI) is L-6613 and the alternative POI is L-6513. The Generating Facility (GF) is 50.4 MW wind, comprising of twelve 4.2 MW Enercon E-138 EP3 generators, with 2 collector circuits. The substation transformer is 138 kV (HV) to 34.5 kV (LV) and Tertiary marked as "n/a", 33/44/55 MVA, Taps +/- 5%, Z=6.5%. The location is Westchester Mountain, Cumberland County, NS.

In addition, the Interconnection Request submitted for IR 596 dated March 19, 2021 includes:

- "Interconnection Request Appendix 1 to GIP":
  - Bullet f, which shows "POI-138kV tap switch or 3-breaker ring bus at NSPI 138 kV L-6513 near Westchester Mountain, NS".
  - Bullet 1.a shows generator unit rating of 4.5 MVA, 400 V, and Power Factor of 0.889 Type FT, underground wye generator, 60 Hz, Max 4.2 MW. However, the IC informed NSPI on July 14, 2021 via email that "ENERCON: The E-138 EP3 E2 in configuration FT is a 4.2MW, 4.6MVA WEC with a maximum reactive power contribution of 1850kVAr and hence a minimum power factor of 0.92. Its nominal AC voltage at the output of the inverters is 630V". Hence, the wind turbine model for this feasibility study, which was already underway, was revised to the data provided on July 14, 2021 and the analysis was restarted from the beginning.
  - Bullet 3.a shows step-up transformer maximum rating of 50 MVA, LV 34.5 kV, HV 138 kV, and Fixed Taps +/- 5%, Z1 6.5%, X/R 27.3
  - Bullet 6 shows Enercon, Model E-138, Model Number EP3 (4.2 MW), Version FT.
- "Westchester Wind Project Proposed Single Diagram", dated January 15, 2021:
  - 3-breaker ring bus substation at NSPI Interconnection Facility (IF) substation.
  - Line section from NSPI IF substation to IC facility: 138 kV, 336.4 kcmil ACSR. Linnet. Length TBD.

  - Substation transformer: 33/44/55 MVA, HV 138/79.67kV to LV 34.5/19.9kV Grounded Wye-Grounded Wye, with Tertiary Delta 11 MVA (33%), 4.16kV, Z+=6.5%.
  - 2 collector circuits, 6 wind turbines per collector circuit. The collector circuits are overhead 556.5 kcmil ACSR Dove conductors but the lengths are not indicated.
  - Individual wind turbine transformer 5 MVA, 34.5kV to 630/364V, Z=6%, Delta HV and grounded wye LV. Wind turbine Enercon, E-138, EP3, E2/4.2 MW.
- Map of location
  - The IC substation is about 2.7 km from the POI.

L-6613 is a 138 kV line from 1N-Onslow to 74N-Springhill.

The POI on L-6613 is about 40.8 km from 1N-Onslow substation.

The Point of Change of ownership (POC) will be at the 138 kV side of the IC's 138 kV to 34.5 kV substation, about 2.7 km from the POI on L-6613.

The POI on L-6613 is shown in Figure 1 and Figure 2.

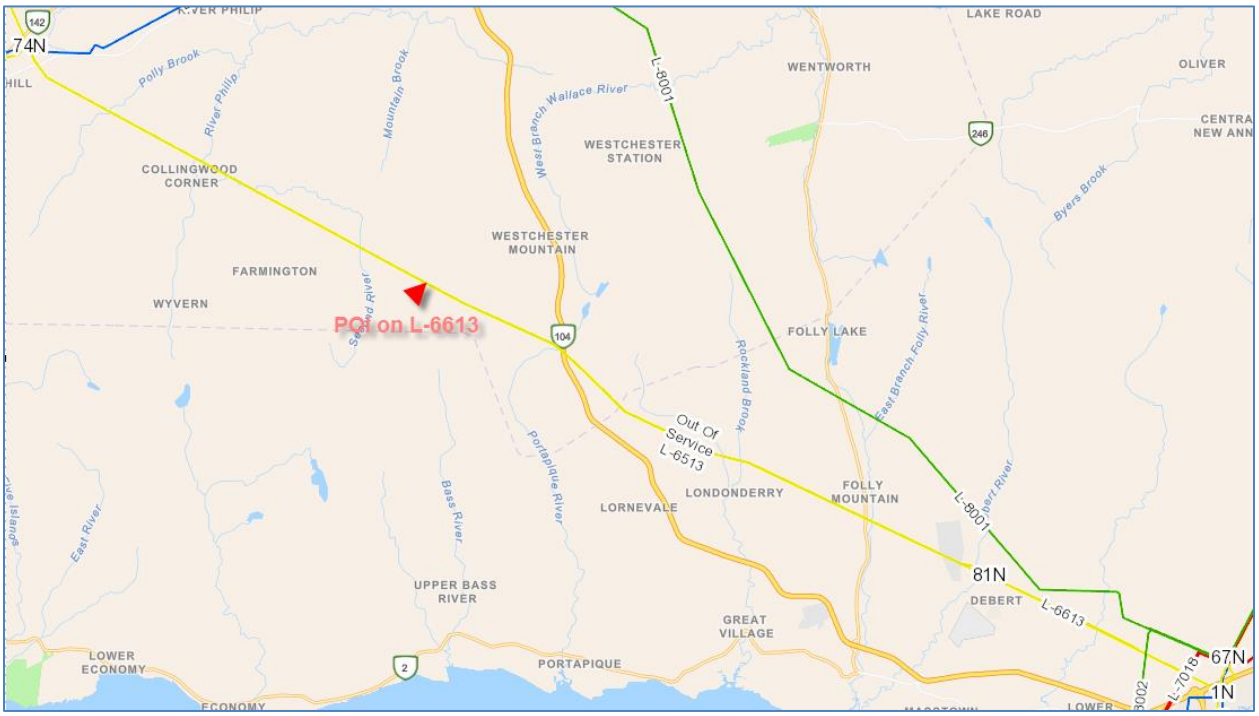

Figure 1: Westchester Mountain

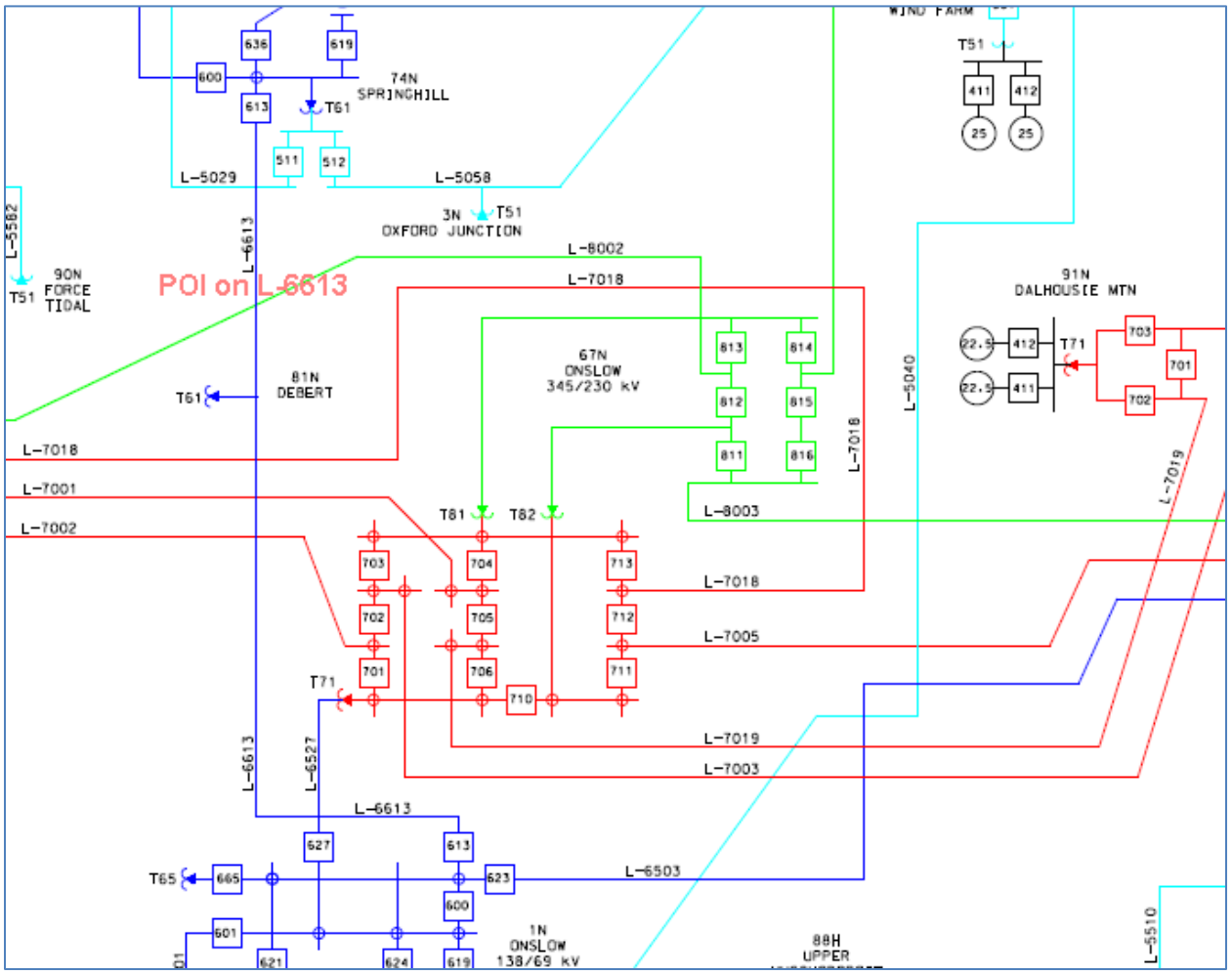

Figure 2 Point of Interconnection (not to scale)

2.0 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 circuit breakers beyond their rated capacity, the circuit breakers must be upgraded.

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 as a result of the interconnection, and any network upgrades necessary to address the short circuit issues associated with the IR.

- 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.

- Preliminary description and high-level non-binding estimated cost to construct the facilities required to interconnect the generating facility to the transmission system.

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 interconnect the generating facility.

Applicable planning criteria 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.

3.0 Assumptions

3.1 System Assumptions

As mentioned in section 4.0 Projects with Higher Queue Positions, TSR411 and TSR412 are not included in this feasibility assessment of IR596.

The power flow cases used for this feasibility assessment contain only transmission connected generating facilities.

The feasibility assessment of IR596 in this report is based on IR596 output being used as network resource in Nova Scotia and not for exporting outside Nova Scotia.

3.2 Project Assumptions

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

1. Network Resource Interconnection Service (NRIS) type per the Generator Interconnection procedures (GIP). The IR596 generation is for used in NS and not for export outside NS.
2. Commercial Operation Date of December 1, 2023
3. The Interconnection Facility is modelled based on the information provided by the IC as per section 1.0 Introduction.
4. The POI on L-6613 will be modelled at 40.8 km from 1N-Onslow substation. The IC has indicated on their system one-line diagram that the Interconnection Facility will be connected to the POI via a new 138 kV spur line built to 138 kV using 336.4 kcmil ACSR Linnet conductors. This feasibility will use the IC's provided conductors at 100 degree C design temperature at a distance of 2.7 km from the POI on L-6613. The IC should be aware that NSPI's practice uses 795 kcmil Drake conductors for 138 kV.
5. The generation technology used must meet NSPI requirements for reactive power capability of at least 0.95 capacitive to 0.95 inductive at the HV terminals of the IC Substation Step Up transformer. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the designated voltage control point during and following system disturbances as determined in the subsequent System Impact Study. The designated voltage control point will either be the low voltage terminals of the wind farm transformer, or if the high voltage terminals are used, equipped with droop compensation controls. It is assumed that the generating units are not de-rated in their MW capability when delivering the required reactive power to the system.
6. The IC's provided one-line indicates the collector circuits being overhead 556.5 kcmil ACSR Dove conductors but the lengths are not indicated, so approximate distances were taken from the site plan to estimate the equivalent impedances of the collector circuits.
7. The FEAS analysis is based on the assumption that IR's higher in the 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, with the exception of TSR411 and TSR412 as discussed earlier in the report.
8. 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.
9. It is the IC's responsibility that the new facility will meet all requirements of NSPI's GIP and NSPI's Transmission System Interconnection Requirements.

4.0 Projects with Higher Queue Positions

All in-service generation is included in the FEAS.

Figure 3 shows the GIP queue, link https://www.nspower.ca/docs/default-source/pdf-to-upload/nspi-combined-interconnection-request-queue.pdf?sfvrsn=d112e57b_9, at the time of this assessment.

Combined T/D Advanced Stage Interconnection Request Queue

Publish Date: *Friday, June 18, 2021*

Nova Scotia POWER An Emera Company

Queue Order*	IR #	Request Date DD-MMM-YY	County	MW Summer	MW Winter	Interconnection Point Requested	Type	Inservice date DD-MMM-YY	Revised Inservice date	Status	Service Type	IC Identity
1 -T	426	27-Jul-12	Richmond	45	45	47C	Biomass	01-Jan-17	01/09/2018	GIA Executed	NRIS	N/A
2 -T	516	05-Dec-14	Cumberland	5	5	37N	Tidal	01-Jul-16	31/05/2020	GIA Executed	NRIS	N/A
3 -T	540	28-Jul-16	Hants	14.1	14.1	17V	Wind	01-Jan-18	31/10/2023	GIA Executed	NRIS	N/A
4 -T	542	26-Sep-16	Cumberland	3.78	3.78	37N	Tidal	01-Jan-19	01/11/2021	GIA Executed	NRIS	N/A
5 -D	557	19-Apr-17	Halifax	5.6	5.6	24H	CHP	01-Sep-18		SIS Complete	N/A	N/A
6 -D	569	26-Jul-19	Digby	0.6	0.6	509V-302	Tidal	01-Mar-21	30/07/2021	GIA Executed	N/A	N/A
7 -D	568	21-May-19	Cumberland	2	2	22N-404	Solar	01-Sep-20	01/09/2021	GIA Executed	N/A	N/A
8 -D	566	16-Jan-19	Digby	0.7	0.7	509V-301	Tidal	31-Jul-19	29/01/2021	GIA Executed	N/A	N/A
9 -T	574	27-Aug-20	Hants	58.8	58.8	L-6051	Wind	30-Jun-23		FAC in Progress	NRIS	N/A

Nova Scotia Power - Interconnection Request Queue: Page 1 of 2

ERIS - Energy Resource Interconnection Service
NRIS - Network Resource Interconnection Service
N/A - Not Applicable
T - Transmission Interconnection Request
D - Distribution Interconnection Request

*** Note: Queue reflects current list of IR's which have established an advanced queue position per GIP/DGIP Section 4.1**

Figure 3: GIP Queue

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
- IR557: SIS complete
- IR569: GIA executed
- IR568: GIA executed
- IR566: GIA executed
- IR574: FAC in Progress

Figure 4 shows the Transmission Service Request (TSR) queue, link https://www.nspower.ca/docs/default-source/test/transmission-service-studies-feb-18-2020.pdf?sfvrsn=5a5228ea_2, at the time of this assessment.

OATT Transmission Service
Queued System Impact Studies
Active June 15, 2021

Project	Date & Time of Service Request	Project Type	Project Location	Requested In-Service Date	Project size (MW)	Status
TSR 400	July 22, 2011	Point to Point	NS-NB	May 2019	330	System Upgrades in Progress
TSR 411	January 19, 2021	Point to Point	NB-NS	Jan 1, 2025	800	SIS In Progress
TSR 412	January 19, 2021	Point to Point	Woodbine-NS	Jan 1, 2025	500	SIS In Progress
TSR 413	April 14, 2021	Network	Antigonish NS	Jan 1, 2022	8.792	Accepted Application

Figure 4: TSR Queue

TSR400 has a firm export from NS to NB of 150 MW in winter and 330 MW in summer. This is a "through NS" export from NL via the Maritime Link (ML) HVDC to the NS and NB border, and NS does not carry the operating reserve for it. The sink entity will be responsible for that reserve. Loss of ML HVDC under this condition, NS will cut the 150 MW or 330 MW "through NS" export.

Regarding TSR411 and TSR412, they are expected to be in service in 2025 and system studies are currently underway to determine the required 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:

> *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.*

5.0 Short-Circuit Duty / Short Circuit Ratio

The maximum (design) expected short-circuit level is 5,000 MVA on 138 kV systems.

Short circuit analysis is based on ASPEN One-Liner v14.4 short circuit case that is maintained and updated by NSPI system protection department for short circuit calculations. The case is imported into PSSE version 33.12.1 and the short circuit analysis is performed in PSSE with higher queued projects and IR596 added to the PSSE models.

The information in the bulletin, D0138322-11/DA, supplied by the IC, is used in the modelling of short circuit.

For three phase short circuit calculations, the maximum steady-state short circuit current $I_{k,max}$ will be used. The aggregate equivalent generator model will have a short circuit

impedance of 0.8603 per unit using the equivalent generator base of 55.2 MVA and 630 Volts.

The short circuit calculations are based on three-phase-fault and flat voltage profile at one per unit voltage.

Minimum generation has only the Maritime Link, Point Aconi, Lingan 1, and Trenton 6 in NS in service under the present system operating requirements. In NB, only the nuclear plant Point Lepreau and the large coal plant Belledune in service.

Table 1 shows maximum short circuit levels at 1N-Onslow, 74N-Springhill, 81N-Debert, IR596 POI and at 34.5 kV terminal.

Maximum generation system normal	1N Onslow	74N Springhill	81N Debert	IR596 POI	IR596 34.5kV MV Term	Unit
IR596 Off	2,325	1,288	1,633	1,219	343	MVA
IR596 On	2,348	1,316	1,660	1,272	403	MVA

Table 1: Maximum generation short circuit level system normal

The interrupting capability of the 138 kV circuit breakers at 1N-Onslow and 74N-Springhill is at least 3,500 MVA, much higher than the maximum short circuit levels at these locations with IR596 being on-line, hence IR596 will not incur any breaker upgrades at these substations.

As for the minimum short circuit level, a variety of N-1 system conditions were simulated for fault conditions under system minimum generation, and it is found that the lowest short circuit level at IR596 is when L-6613 is out of service between IR596 and 81N-Debert.

Table 2 shows minimum short circuit levels at IR596 POI, 34.5 kV bus and 630 V equivalent generator terminal bus.

Minimum generation system normal	IR596 POI	IR596 34.5 kV MV Term	IR596 630V Terminal	Unit
IR596 Off	933	331	254	MVA
IR596 On	986	391	318	MVA

Table 2: Minimum generation short circuit level system normal

Table 3 shows minimum short circuit levels at IR596 POI, 34.5 kV bus and 630 V equivalent generator terminal bus with L-6613 out of service between IR596 POI and Debert.

Minimum generation with L-6613 Out (section from IR596 to Debert)	IR596 POI	IR596 34.5 kV MV Term	IR596 630V Terminal	Unit
IR596 Off	516	262	213	MVA
IR596 On	569	322	277	MVA

Table 3: Minimum generation short circuit level with L-6613 out

Table 3 shows that the lowest system three phase short circuit (with IR596 off-line) at the POI is 516 MVA and at IR596 34.5 kV bus is 262 MVA. Hence, the short circuit ratio (SCR) for IR596 at 34.5 kV level is 262/50.4 = 5.2. The IC should be discuss with Enercon to confirm if IR596 wind turbines can operate at this short circuit ratio at the 34.5 kV bus. In addition, the subsequent system impact study will verify the final SCR.

6.0 Voltage Flicker and Harmonics

The voltage flicker calculations are based on the information in the document, E-138_EP3_E2_4200kW_IEC61400-21-1_estimation_D0750864_1.0.pdf, provided by the IC.

Table 4 shows that IC596 meets NSPI's flicker levels of Pst ≤ 0.25 and Plt ≤ 0.35 at POI.

Pst Calculation	Value
Pst=Plt continuous operations at POI 138 kV	0.0705
Pst switching operations at POI 138 kV	0.0133
Plt switching operations at POI 138 kV	0.0133

Table 4: Calculated voltage flicker levels

NSPI requires IR596 to meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion (all frequencies) to a maximum of 1.5%, with no individual harmonic exceeding 1.5% on 138 kV.

The same document shows that individual harmonic is below 1.5% and THC is 0.79%, which meet NSPI's requirements.

7.0 Thermal Limits

7.1 NS Load Forecast

At the time of this assessment for IR596, the latest NSPI corporate load forecast available was in the "2021 Ten Year System Outlook" report issued by NS Power June 30, 2021. The load forecast for the year 2031 has NS system peak forecast of 2,262 MW with a firm peak of 2,057 MW. The total net system load includes system losses but excludes power plant station service loads. The winter peak load for NS is modeled based on the above load forecast.

7.2 IR596 Model

Based on the information provided by the IC, the following was determined and modelled for IR596:

1. Using NSPI's OneGIS, the POI is determined to be about 40.8 km on L-6513 from 1N-Onslow substation.

2. The spur line from the POI on L-6613 to the IC's 138 kV substation is modelled with Linnet conductors at 138 kV and at 100 degree C using NSPI standard parameters: ambient temperature of 25 degrees in summer and 5 degree in winter, wind 0.61 m/s perpendicular to the conductors. This provides a winter rating of 156 MMVA in summer and 176 MVA in winter at 138 kV.

3. The 138 kV to 34.5 kV transformer is modelled based on 6.5% positive impedance over 33 MVA base rating and X/R of 27.3. The nominal rating is modelled as 55 MVA.

4. The 34.4 kV to 630 V transformer is modelled based on 6% positive impedance over 5 MVA base rating. Since the IC did not provide the X/R ratio, a value of 10 was assumed. The nominal rating is modelled as 60 MVA.

5. The equivalent generator for the 12 wind turbines is modelled based on the information received from the IC, D0750531-3_#_en_#_Data Sheet Grid Performance E-138 EP3 E2_4200 kW_FT.pdf, which shows rated power of 4.6 MVA and 4.2 MW, Qmax 1.85 MVAR and Qmin of -1.85 MVAR, and the nominal AC voltage at the output of the inverters is 630 per wind turbine.

6. The impedances of the collector equivalent circuit are calculated based on the information that the IC provided in the document "Westchester Wind Project Proposed Single Diagram", dated January 15, 2021.

7.3 IR596 Steady State Analysis Result

The load flow analysis was completed for generation dispatches under system light load, summer peak load, and winter peak load conditions. Generation dispatch was also chosen to represent import and export scenarios that take into account expected flows from the existing transmission service reservation associated with the Maritime Link (ML).

At the present, the firm export from Woodbine 345 kV bus in NS to the NS-NB border by the Maritime Link is 150 MW in winter when ML receives 320 MW from Newfoundland (NL) and 330 MW in non-winter when ML receives 475 MW from NL. Under these conditions, NSPI does not carry additional operating reserve for the through export from Woodbine to the NS-NB border. Any customer who buys this flow-through power will carry the additional reserve.

Also, at the present, firm import from NB to NS is zero in winter and in non-winter.

For each system dispatch chosen, a steady state analysis is performed and checked for the system performance with IR596 off-line and with IR596 on-line at full output in order to determine any thermal overload or voltage violation directly caused by IR596.

The initial attempt to dispatch pre-IR596 winter peak case with NB sending 300 MW to PEI in winter peak encountered some local thermal and voltage issues that are unrelated to IR596, hence the final cases were dispatched with NB sending 250 MW to PEI (measured at Memramcook) in winter peak prior to turning on IR596 at full output.

A variety of system dispatch cases were created with the above considerations and were tested in steady state using PSSE software version 33.12.1. The power flows of various interfaces inside and outside NS are displayed in Table 5.

Power System Cases												
Case	NB-NS	NB-PEI	NB-NE	NL-NS	NB-HQ	CBX	ONI	ONS	IR596 Wind	Amh. Wind	Nutt Wind	Total Trans Wind
WP_C24b_R1	-150	250	0	475	-928	933	1009	792	50.4	31	50	540
WP_C24a_R1	-150	250	0	475	-928	986	1058	792	0	31	50	489
WP_C22b_R1	0	250	0	475	-928	835	917	850	50.4	31	50	540
WP_C22a_R1	0	250	0	475	-928	835	916	801	0	31	50	489
WP_C19b_R1	150	150	0	475	-928	1039	1008	1025	50.4	4	7	118
WP_C19a_R1	150	150	0	475	-928	1039	1008	975	0	4	7	68
WP_C16b_R1	0	250	0	475	-928	1123	1086	1020	50.4	31	50	188
WP_C16a_R1	0	250	0	475	-928	1123	1087	971	0	31	50	138
WP_C13b_R1	-320	250	0	475	-928	1124	1159	770	50.4	31	50	188
WP_C13a_R1	-320	250	0	475	-928	1124	1159	720	0	31	50	138
WP_C10b_R1	0	250	0	475	-928	1123	1087	942	50.4	0	0	107
WP_C10a_R1	0	250	0	475	-928	1123	1087	892	0	0	0	57
WP_C07b_R1	0	250	0	475	-928	1123	1087	990	50.4	0	50	157
WP_C07a_R1	0	250	0	475	-928	1123	1087	940	0	0	50	107
WP_C04b_R1	0	250	0	475	-928	1123	1087	972	50.4	31	0	138
WP_C04a_R1	0	250	0	475	-928	1123	1087	923	0	31	0	88
WP_C01b_R1	0	250	0	475	-928	1123	1087	954	50.4	4	7	118
WP_C01a_R1	0	250	0	475	-928	1123	1087	904	0	4	7	68
SP_C25b_R1	-330	235	800	475	-785	748	852	533	50.4	31	50	540
SP_C25a_R1	-330	235	800	475	-785	801	902	533	0	31	50	489
SP_C23b_R1	0	235	800	475	-785	401	518	532	50.4	31	50	540
SP_C23a_R1	0	235	800	475	-785	452	568	532	0	31	50	489
SP_C20b_R1	150	150	800	475	-785	573	585	749	50.4	31	50	188

Power System Cases												
Case	NB-NS	NB-PEI	NB-NE	NL-NS	NB-HQ	CBX	ONI	ONS	IR596 Wind	Amh. Wind	Nutt Wind	Total Trans Wind
SP_C20a_R1	150	150	800	475	-785	625	635	749	0	31	50	138
SP_C17b_R1	0	236	800	475	-785	729	735	749	50.4	31	50	188
SP_C17a_R1	0	236	800	475	-785	781	785	749	0	31	50	138
SP_C14b_R1	-500	236	800	475	-785	953	988	495	50.4	31	50	188
SP_C14a_R1	-500	236	800	475	-785	953	988	445	0	31	50	138
SP_C11b_R1	0	236	800	475	-785	811	813	749	50.4	0	0	107
SP_C11a_R1	0	236	800	475	-785	864	863	749	0	0	0	57
SP_C08b_R1	0	236	800	475	-785	761	766	749	50.4	0	50	157
SP_C08a_R1	0	236	800	475	-785	813	816	749	0	0	50	107
SP_C05b_R1	0	236	800	475	-785	779	783	749	50.4	31	0	138
SP_C05a_R1	0	236	800	475	-785	831	832	749	0	31	0	88
SP_C02b_R1	0	236	800	475	-785	799	802	749	50.4	4	7	118
SP_C02a_R1	0	236	800	475	-785	852	852	749	0	4	7	68
LL_C21b_R1	200	100	1000	-90	-727	61	7	272	50.4	31	50	188
LL_C21a_R1	200	100	1000	-40	-727	111	56	272	0	31	50	138
LL_C18b_R1	0	63	1000	-40	-727	262	206	272	50.4	31	50	188
LL_C18a_R1	0	63	1000	-40	-727	312	255	272	0	31	50	138
LL_C15b_R1	-500	63	1000	475	-727	784	712	273	50.4	31	50	188
LL_C15a_R1	-500	63	1000	475	-727	838	762	273	0	31	50	138
LL_C12b_R1	0	63	1000	-40	-727	341	284	272	50.4	0	0	107
LL_C12a_R1	0	63	1000	-40	-727	392	333	272	0	0	0	57
LL_C09b_R1	0	63	1000	-40	-727	293	236	272	50.4	0	50	157
LL_C09a_R1	0	63	1000	-40	-727	343	286	272	0	0	50	107
LL_C06b_R1	0	63	1000	-40	-727	310	253	272	50.4	31	0	138
LL_C06a_R1	0	63	1000	-40	-727	360	303	272	0	31	0	88
LL_C03b_R1	0	63	1000	-40	-727	329	272	272	50.4	4	7	118
LL_C03a_R1	0	63	1000	-40	-727	380	322	272	0	4	7	68

Table 5: Power system cases

Applicable contingencies in NS and some contingencies in NB around Memramcook substation were simulated in steady state for the above cases. These contingencies are shown in Table 6. Please note that 67N-815 contingency is the same as 67N-814 contingency due to the empty node adjacent to 67N-815 breaker. In NS, system normal uses Rate A and N-1 contingencies use Rate B, whereas in NB, system normal uses Rate A and N-1 contingencies use Rate C. Contingencies marked with * denotes applicable in service SPS may be armed.

Contingencies in NS and NB				
101S_701	120H_710	30N_B61	67N_706	90H_608
101S_702	120H_711	30N_T61	67N_710	90H_609
101S_703	120H_712	3C_711	67N_713	90H_611
101S_704	120H_713	3C_712	67N_811*	90H_612
101S_705	120H_714	3C_713	67N_812	90H_T1
101S_706	120H_715	3C_714	67N_813	91H_511
101S_711	120H_716	3C_715	67N_814	91H_513
101S_712	120H_720	3C_716	67N_T71	91H_516
101S_713	120H_SVC	3C_T71	67N_T81	91H_521
101S_811	120H_T71	3C_T72	67N_T82	91H_523
101S_812*	120H_T72	3C710*	67N711*	91H_603
101S_813*	132H_602	3C720*	67N712*	91H_604
101S_814*	132H_603	3S_T1	70037004*	91H_605
101S_816	132H_605	47C_602	70087009Sep	91H_606
101S_T81	132H_606	47C_603	74N_B61	91H_607
101S_T82	1C_689	47C_674	74N_T61	91H_608
103H_600	1C_B61	47C_T63	79N-T81*	91H_609
103H_608	1C_B62	47C_T64	85S_B61	91H_611
103H_681	1C_G2	47C_T65	85S_G1	91H_613
103H_881	1N_600	47C_T67	88S_710	91H_621
103H_B61	1N_601	49N_600	88S_711	91H_T11
103H_B62	1N_613	4C_T2	88S_712	91H_T62
103H_T81	1N_B51	4C_T63	88S_713	91H_TC3
104H600	1N_B52	50N_500	88S_714	91N_701
108H_600	1N_B61	50N_604	88S_715	IR596_POI
108H_B1	1N_B62	50N_B55	88S_720	L-5003
108H_B3	1N_C61	50N_B57	88S_721	L-5011
113H_600	1N_T1	50N_G6	88S_722	L5012
120H_621	1N_T4	50N_T12	88S_723*	L-5014
120H_622	2CB61WC1	50N_T8	88S_G4	L-5015
120H_623	2CB62WC1	50NB61G6	88S_T71	L-5016
120H_624	2S_513	50NB62G5	88S_T72	L-5017
120H_625	2S_600	67N_701	89S_G1	L-5019
120H_626	2S_B64	67N_702	90H_602	L-5020
120H_627	2S_B65	67N_703	90H_603	L1108
120H_628	2S_T1	67N_704	90H_604	L1142
120H_629	L-5534	L6012	L6523	L1108
L-5021	L-5535	L6013	L6531	L1142
L-5022	L-5536	L6014	L6535	L1143

Contingencies in NS and NB				
L-5023L5053	L-5537	L6015	L6536	L1148-L1151*
L-5024	L-5538	L6016	L6537*	L1157
L-5025	L-5539	L6020	L6538	L1190
L-5026	L-5541	L6021	L6539	L1190-L1215
L-5027	L-5546	L6024	L6551	L1244
L-5028	L-5547L5551	L6025	L6552	L3004
L-5029L5030	L-5548	L6033	L6613_1N	L3006
L-5032L5004	L-5549	L60335039	L6613_74N	L3013
L-5033	L-5550L5582	L60336035	L7001	L3017_3019
L-5035	L-5559L5579	L6035	L7002	Lepreau
L-5036	L-5560	L6038	L7003	ME1-10
L-5037L3031	L-5561L5565	L6040	L7004	ME1-11
L-5039	L-5563	L60406042	L7005*	ME1-12
L-5040	L-5564L5576	L6042	L7008	ME1-13
L5041	L-5571	L6043	L7009	ME1-14
L-5042	L-5573L5575	L6044	L7011	ME1-15
L5049	L-5580	L6047	L7012	ME1-16
L-5054	L6001	L6048	L7014	ME1-6
L-5058	L6002_90H	L6051	L7015	ME1-7
L-5500	L6002_99W	L6052	L7019	ME1-8
L-5501	L6003	L6053	L7021	ME1-9
L-5502	L60036007	L6054	L70216534	ME3-1*
L-5505	L60036009	L6055	L7022	ME3-2*
L-5506	L6004	L6503	L8001*	ME3-3*
L-5507L5508	L6005	L6507	L8002	Mem_T3
L-5511	L60056010	L65076508	L80027009	
L-5512	L60056016	L6508	L8003*	
L-5521	L6006	L6510	L8004*	
L-5524	L6007	L6511	ML_2Poles	
L-5527A	L6008	L6514	ML_Pole1	
L-5527B	L6009	L6515	ML_Pole2	
L-5530	L6010	L6516	PHP	
L-5531	L60106011	L6517	90H_605	
L-5532	L6011	L6518	90H_606	
L-5533L5581	2S_T2	67N_705	90H_607	

Table 6: Contingencies in NS and NB studied

In general, IR596 rated output does not violate thermal or voltage criteria. However, when it displaces Halifax generation at winter peak, the Metro Dynamic Reactive Reserves can be marginally exceeded and 120H-T71 or 120H-T72 transformer at Brushy Hill substation

can marginally exceed their nominal ratings under N-1 contingencies. At this time, this assessment considers them marginal and no associated system upgrades are identified. The subsequent System Impact Study will make the final determination.

8.0 Voltage Limits

The steady state assessment of the power flow cases used in this assessment shows no voltage violations that are directly caused by IR596.

Regarding power factor, NSPI requires IR596 to meet +/-0.95 on the high voltage side of the IC substation transformer.

Figure 5 shows power factor on the high voltage side of the IC substation transformer when IR596 generates maximum reactive power output. Table 7 shows that IR596 does not meet NSPI's required power factor of +0.95 or less, hence IR596 will require power factor correction. This will be further examined in the SIS.

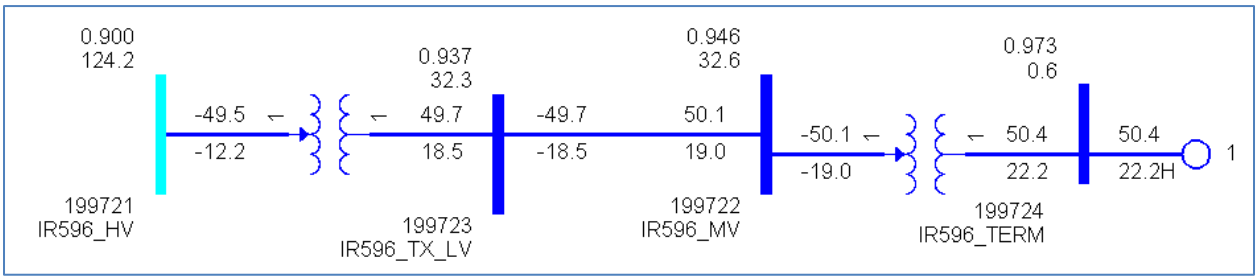

Figure 5 Power Factor with Qmax

Power Factor with Qmax				
IR596 Max MW	IR596 Max MVAR	Tx HV MW	Tx HV MVAR	Tx HV Power Factor
50.4	22.2	49.5	12.2	0.971

Table 7: Power factor with Qmax

Figure 6 shows power factor on the high voltage side of the IC substation transformer when IR596 absorbs maximum reactive power output. Table 8 shows that IR596 meets NSPI's required power factor of -0.95 when it absorbs reactive power from the system.

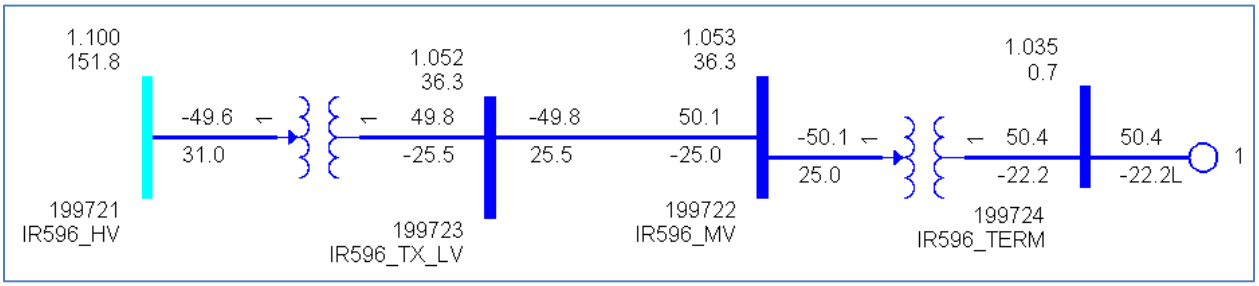

Figure 6 Power Factor with Qmin

Power Factor with Qmin				
IR596 Max MW	IR596 Max MVAR	Tx HV MW	Tx HV MVAR	Tx HV Power Factor
50.4	-22.2	49.6	-31.0	0.848

Table 8: Power factor with Qmin

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 also have the ability to slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual generators capabilities (please refer to NSPI's TSIR). 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 NSPI's TSIR. The SIS will state specific options, controls and additional facilities that are required to achieve this.

9.0 System Security / Bulk Power Analysis

L-6613 is classified as BPS (Bulk Power System) as defined by NPCC and BES (Bulk Electricity System) as defined by NERC. L-6613 is currently on NSPI's 2021 BPS list and BES list, hence IR596 interconnection to L-6613 will be required to meet NPCC and NERC requirements. The SIS will determine the BPS and BES status of IR596.

10.0 Loss Factor

The Loss Factor calculation is based on the peak load case and is used only for comparison purposes. The winter peak load flow case is run with and without the new facility in service, while keeping 91H-Tufts Cove Generator TC3 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. The loss factor for IR596 is shown in Table 9.

Loss Factor	
Description	**MW**
IR596 at POI on L-6613	50.4
TC3 with IR596 at rated output	82.5
TC3 with IR596 Off	129.9
IR596 Loss Factor	+6%

Table 9: Loss factor

11.0 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR596 to L-6613.

a. Required Network Upgrades

- Modification of NSPI protection systems at 1N-Onslow and 74N-Springhill on line L-6613 as IR596 will be connected to this line.
- Install a new 138kV substation complete with 3 breaker ring bus at the POI to L-6613 and control and protection as acceptable to NSPI. A Remote Terminal Unit (RTU) to interface with NSPI's SCADA, with telemetry and controls as required by NSPI.

b. Required Transmission Provider's Interconnection Facilities (TPIF):

- Build a new 138 kV spur line (about 2.7 km) from NSPI Interconnection Facility substation to the IC substation.
- Add P&C, control and communications between the wind farm and NSPI SCADA system (to be specified).

c. Required Interconnection Customer's Interconnection Facilities (ICIF)

- 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.

- 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. Please refer to NSPI's TSIR for additional requirements such as primary frequency responses (curtailed and un-curtailed), full reactive power capability over active power range and voltage/frequency ride through.
- 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.
- Low voltage ride-through capability per Nova Scotia Power Transmission System Interconnection Requirements (TSIR) document.
- 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.
- Facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined in SIS. The plant may be incorporated into SPS run-back schemes.
- Automatic Generation Control to assist with tie-line regulation.
- The facility must meet NSPI's TSIR as published on the NSPI OASIS site at https://www.nspower.ca/oasis/standards-codes.

12.0 Facilities and Network Upgrades Cost Estimate

The cost estimates for Network Upgrades and NSPI Interconnection Facilities (TPIF) for interconnecting IR596 to L-6613 are shown in Table 10.

Please note that this cost estimate is high level, non-binding in 2021 Canadian dollars. This does not include additional costs to be identified by the subsequent SIS and Facility Study.

L-6613 is classified as BPS (Bulk Power System) and BES (Bulk Electricity System) in NSPI's 2021 BPS list and BES list, hence the requirement for a three breaker ring bus substation as per NSPI's "Transmission System Interconnection Requirements", dated February 25, 2021, Version 1.1.

Item	Network Upgrades	Estimate
I	P&C modifications at 1N-Onslow and 74N-Springhill for L-6613	$400,000
II	The breaker ring bus 138 kV substation complete with P&C at NSPI IF substation and connection to L-6613	$6,250,000
	Sub-total for Network Upgrades	$6,650,000
Item	**TPIF Upgrades**	**Estimate**
I	Construct new 2.7 km of 138 kV spur line extension from NSPI IF substation to IC substation	$1,350,000
II	P&C relaying equipment	$100,000
III	NSPI supplied RTU	$65,000
IV	Tele-protection and SCADA communications	$150,000
	Sub-total for TPIF Upgrades	$1,665,000
Item	**Total Upgrades**	**Estimate**
	Network Upgrades + TPIF Upgrades	$8,315,000
	Contingency (10%)	$831,500
	Total (Incl. 10% contingency and Excl. HST)	$9,146,500

Table 10: Cost estimates

13.0 Preliminary Scope of the SIS

The following provides a preliminary scope of work for the subsequent SIS for IR596. 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, ride through, 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, frequency response, active power, low voltage ride-through, frequency ride-through, and power factor to meet NSPI TSIR requirements. The SIS will be conducted in accordance with the GIP with the assumption that all appropriate higher-queued projects will proceed and the facilities associated with those projects are installed.

The following outline provides the minimum scope that must be complete in order to assess the impacts. It is recognized the actual scope may deviate, to achieve the primary objectives. The SIS will consider but not be limited to the following:

1) Correct models of the entire facility from the POI to the IC substation and IR596 facility including the collector circuits.

2) Facilities that the customer must install to meet the requirements of the GIP and NSPI's latest version of "Transmission System Interconnection Requirements", informally referred to as NSPI's Grid Code.
3) The minimum transmission additions/upgrades that are necessary to permit operation of this Generating Facility, under all dispatch conditions, meeting NPCC and NERC criteria.
4) Guidelines and restrictions applicable to first contingency operation (curtailments etc.).
5) Under-frequency load shedding impacts.
6) Metro Dynamic Reactive Reserves requirement and short time ratings of 120H-T71 and 120H-T72.

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 latest revision as approved by NS-UARB.
- Table 1 "Steady State & Stability Performance Planning Events" of NERC TPL-001-x latest revision as approved by NS-UARB.
- NSPI System Design Criteria, report number NSPI-TPR-003-4 latest revision as approved by NSPI and submitted to NS-UARB.

Additionally, electromagnetic transient study may be required to account for IR596 control system to coordinate with other facilities in the transmission system and to ensure fault ride through.

Any changes to SPS 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 all NERC and NPCC criteria approved by the UARB as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

Nova Scotia Power Inc.
Transmission System Operations
2021-08-31