Interconnection Feasibility Study Report
GIP-IR617-FEAS-R0

Generator Interconnection Request 617
78 MW Wind Generation Facility
Hants County, NS

2022-03-29

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 78 MW Wind Turbine Generation (WTG) facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS).

This project is listed as Interconnection Request #617 in the NSPI Interconnection Request Queue and will be referred to as IR617 throughout this report. The proposed Commercial Operation Date is 2023/12/31.

The Interconnection Customer (IC) identified the 230 kV transmission line L7018 (67N-Onslow to 120H-Brushy Hill), approximately 11.6 km from the 120H substation as the Point of Interconnection (POI). This WTG facility would be interconnected to the POI via a new three breaker ring bus and 150m spur line to the Point of Change of Ownership (PCO).

There is one relevant long-term firm Transmission Service Request (TSR) that has established Queue position and is at the System Impact Study (SIS) stage, with a requested in-service date of 2025/01/01. This request, TSR411, is 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 System Impact Study, which is expected to identify significant changes to the NSPI transmission system. The revised expected completion date for the study is February 28, 2022. Feasibility Studies initiated prior to the completion of the TSR System Impact Study will be performed based on the current system configuration.*

The system upgrades resulting from this TSR study have the potential to influence the results of IR617 as they may include modifications to the proposed POI for this IR.

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

- 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 three phase short circuit level at the Interconnection Facility's (IF) low side bus is 616 MVA with all lines in service, 463 MVA with one line out of service.

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

- Voltage flicker will be examined when data is made available for the SIS.
- The project design must meet the NSPI Transmission System Interconnection Requirements (TSIR)[2].
- Supplementary reactive power support for IR617 is required as it is unable to meet NSPI's ±0.95 net power requirements at the IF 230 kV bus. This is in situations when the wind facility is operating near maximum active power output and full reactive power is required. Supplementary reactive power support will be further investigated in the System Impact Study.
- Since IR617 meets the NERC definition of Bulk Electric System (BES), the high side interconnection with the 230 kV bus would also be considered BES. There is the potential for an exclusion from BES to be granted for the high side (230 kV) bus based on further analysis per the NS BES Exception Procedure. This analysis will be initiated as part of the System Impact Study (SIS) and exclusion from BES will only be granted upon subsequent approval by the Nova Scotia Utility and Review Board (UARB).
- IR617 proposes connecting to the 230 kV line L7018 which is designated NPCC Bulk Power System (BPS). As such, all protection systems associated with the new 230 kV substation supplying the IR617 site must comply with NPCC Directory 4 *System Protection Criteria*.
- The preliminary loss factor is calculated as 3.1% while generating via the L7018 tap POI.
- The power flow analysis identified no contingencies inside Nova Scotia that violate thermal loading criteria or voltage criteria while generating at full output.

The present preliminary non-binding cost estimate for interconnecting IR617 to L7018 as Network Resource is $9,801,000 ($8,200,000 for Network Upgrades, $710,000 for TPIF, 10% contingency adder). This does not include any To Be Determined costs associated with the SIS. This estimate will be further refined in the SIS and Facilities (FAC) studies.

Note that it is the customers responsibility to provide a suitable land, right of way, and access roads for the transmission line tap substation and spur line to the ICIF. The right of way shall be registered in NSPI’s name.

The estimated time to construct the Network Upgrades and TPIF for NRIS operation is 24-36 months after the receipt of funds and cleared right of way from the customer.

[2] NS Power Transmission System Interconnection Requirements; https://www.nspower.ca/oasis/standards-codes

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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 78 MW Wind Turbine Generation (WTG) facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS).

This project is listed as Interconnection Request (IR) #617 in the NSPI Interconnection Request Queue and will be referred to as IR617 throughout this report. The proposed Commercial Operation Date is 2023/12/31.

The Interconnection Customer (IC) identified the 230 kV transmission line L7018 (67N-Onslow to 120H-Brushy Hill), approximately 11.6 km from the 120H substation as the Point of Interconnection (POI). Figure 1 shows the approximate location of the proposed IR617 site.

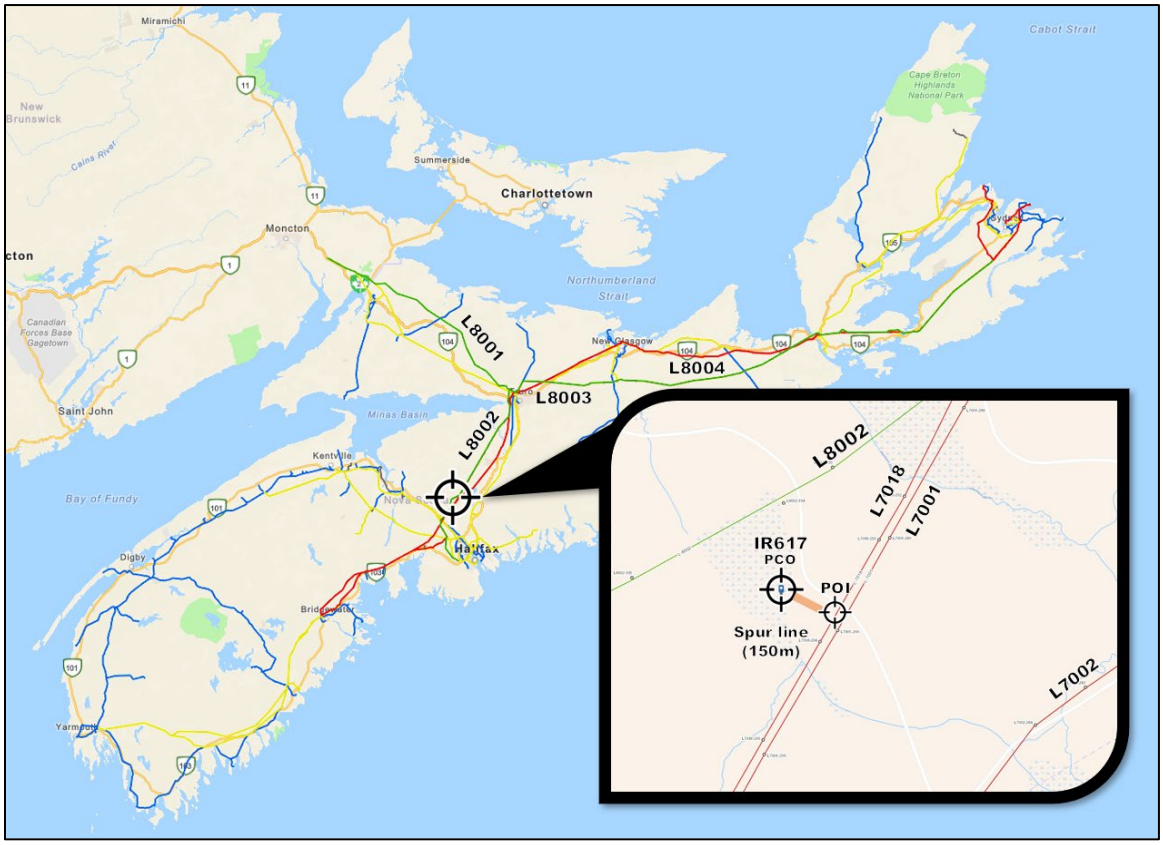


Figure 1: IR617 approximate geographic location

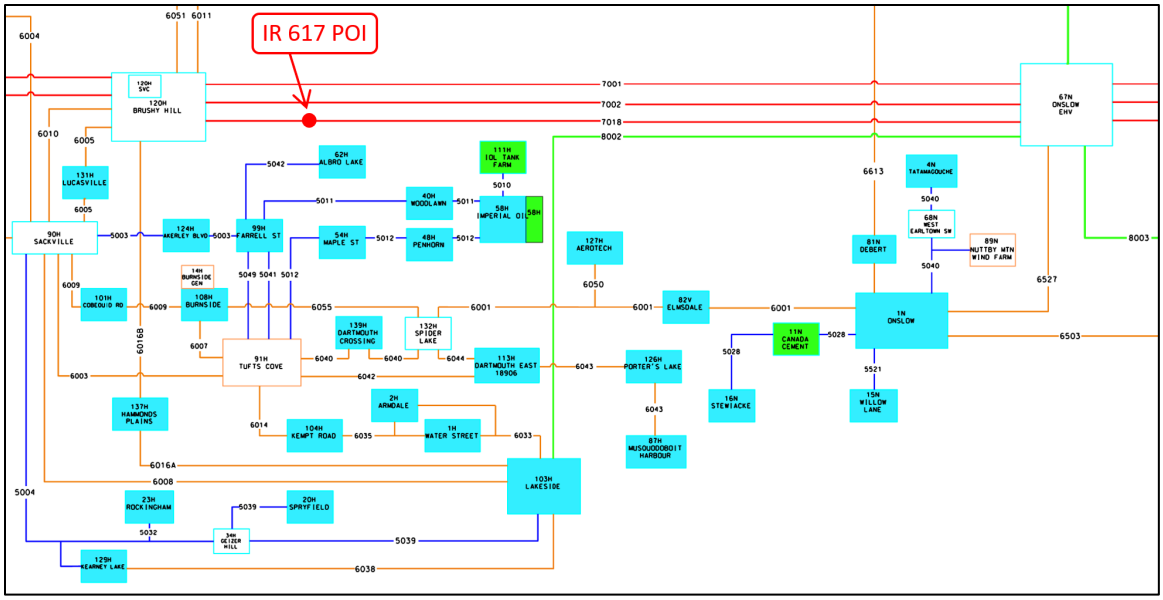


Figure 2: IR617 Point of Interconnection (not to scale)

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 WTG 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 POI and configuration are studied as follows:

1. NRIS will be studied per the IR617 Feasibility Study agreement and section 3.2 of the Generation Interconnection Procedures (GIP).
2. Commercial Operation date: 2023/12/31.
3. The Interconnection Facility consists of 13 x 6 MW Vestas V162 wind turbine generator units (type 4 inverter-based), capped at 78 MW. Each WTG is connected via a 34.5 kV collector circuit to the 54/72/90 MVA substation step-up transformer.
4. The IC identified the 230 kV transmission line L7018 (67N-Onslow to 120H-Brushy Hill), approximately 11.6 km from the 120H substation as the POI. Line L7018 is considered a Bulk Power System facility and will therefore require a three-breaker ring bus in accordance with Table 8 of NSPI's Transmission System Interconnection Requirements.
5. The ICIF is located approximately 150 m from the POI and may require the construction of a 230kV spur line. The spur line was not modelled as part of this study due to the relative proximity to the POI.
6. Preliminary data provided by the IC for the substation step-up transformer and padmount transformers:
    6.1. The substation step-up transformer was modelled as a 230 kV–34.5 kV (with 11 kV tertiary) transformer rated at 54/72/90 MVA, with a positive sequence impedance of 7% and an X/R ratio of 22, as specified for this unit by the IC. Zero sequence impedance of 5.95% at 54 MVA was assumed. It has a winding configuration of Grounded Wye (HV) – Delta (TV) – Grounded Wye (LV).
    6.2. The generator step-up transformers were modelled as an equivalent transformer based on 13 (thirteen) 34.5 kV - 0.72 kV 7.0 MVA transformers, with a 9.9% positive sequence impedance. Zero sequence impedance of 8.42% and X/R ratio of 13 were assumed. The winding configuration is given as Delta (HV) – Grounded Wye (LV).
7. A generic collector circuit impedance is assumed since a detailed collector circuit design was not provided. Note that 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 that have a System Impact Study in progress will proceed, as listed in Section 4.0: Project Queue Position.

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.

10. The transmission line L7018 between 67N-Onslow and 120H-Brushy Hill is 73.4 km long, comprised almost entirely of 795 ACSR Drake rated at 60C. There is one ~860m section of 2156 ACSR conductor used for the Shubenacadie River crossing. L7018 was constructed to 345 kV standards (to allow future conversion) but is currently operated at 230 kV.

11. Ratings of transmission lines in the vicinity of IR617 are:

NSPI Transmission Line Ratings Last Updated: 2021-08-27

LINE	STATION	CONDUCTOR				BREAKER	SWITCH	CURRENT TRANSFORMER						TRIP MVA
								RELAYING			FULL SCALE METERING			
		Type	Maximum Operating Temp. (Celsius)	SUMMER RATING 25 DEG (MVA)	WINTER RATING 5 DEG (MVA)	100% Name-plate	100% Name-plate	Ratio	R.F.	MVA	Ratio	R.F.	MVA	
L-6005	120H Brushy Hill	ACSR 795 Drake	100	268	304	478	478	800	2	382	1200	1	346	1762
	90H Sackvillle					287	287	800	2	382	1200	1	346	1523
L-6010	120H Brushy Hill	ACSR 795 Drake	100	268	304	478	478	800	2	382	1200	1	346	1708
	90H Sackville					287	287	600	2	287	1200	1	346	1880
L-6011	120H Brushy Hill	ACSR 556.5 Dove	100	215	242	478	478	800	2	382	800	1	231	670
	17V St. Croix					287	287	600	2	287	600	1	173	1171
L-6016	120H Brushy Hill	ACSR 1113 Beaumont	70	242	301	478	478	800	2	382	1200	1	346	1323
	103H Lakeside					287	478	800	2	382	800	1	231	1093
L-6051	120H Brushy Hill	ACSR 795 Drake	100	268	304	478	478	800	2	382	800	1	231	865
	17V St. Croix					287	287	800	2	287	800	2	231	456

L-7001	67N Onslow EHV	ACSR 795 Drake	60	298	383	797	797	500	2	398	1000	1	462	533
	120H Brushy Hill					797	797	800	2	637	1200	1	554	1065
L-7002	67N Onslow EHV	ACSR 795 Drake	100	447	506	797	797	800	2	637	1000	1	462	1065
	120H Brushy Hill					797	797	800	2	637	1200	1	577	1065
L-7008	120H Brushy Hill	ACSR 1113 Beaumont	70	404	502	797	797	800	2	478	1200	1	554	1235
	99W Bridgewater EHV					797	797	500	2	398	1000	1	462	1235
L-7009	120H Brushy Hill	ACSR 795 Drake	50	223	340	797	797	800	2	637	1200	1	577	901
	99W Bridgewater EHV					996	797	500	2	398	1200	1	577	751
L-7018	67N Onslow EHV	ACSR 2x795 Drake /AACSR 2156	60	506	675	797	797	800	2	637	800	1.25	462	1441
	120H Brushy Hill					797	797	800	2	637	1000	1	462	1441

Table 1: Transmission line ratings

4.0 Project Queue Position

All in-service generation is included in this FEAS. As of October 15, 2021, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are included in this study's base cases. Figure 3 shows the GIP queue which applies to all Rate Base RFP (Request For Proposal) feasibility studies currently underway.

Combined T/D Advanced Stage Interconnection Request Queue

Publish Date: *Friday, October 15, 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 Complete	NRIS	N/A
10-D	595	11-Mar-21	Halifax	0.1	0.1	1H-454	Battery	11-Jan-21		SIS Complete	N/A	N/A
11-T	598	13-May-21	Cumberland	2.52	2.52	37N	Tidal	01-Dec-22		SIS in Progress	NRIS	N/A
12-D	604	07-Jun-21	Cape Breton	0.45	0.45	11S-303	Solar	15-Jan-22		SIS in Progress	N/A	N/A
13-D	603	31-May-21	Cumberland	0.4	0.4	22N-404	Solar/Battery	16-Feb-22		SIS in Progress	N/A	N/A
14-D	600	27-May-21	Halifax	0.6	0.6	99H-312	Solar/Battery	02-Mar-22		SIS in Progress	N/A	N/A
		Totals:		139.65	139.65							

Figure 3: GIP Queue

The following projects in Figure 4 below are included in the Transmission Service Request (TSR) Queue as of January 22, 2022:

OATT Transmission Service
Queued System Impact Studies
Active January 22, 2022

Item	Project	Date & Time of Service Request	Project Type	Project Location	Requested In-Service Date	Project Size (MW)	Status
1	TSR 400	July 22, 2011	Point-to-point	NS-NB*	May 2019	330	System Upgrades in Progress
2	TSR 411	January 19, 2021	Point-to-point	NS-NB*	January 1, 2025	550	SIS in Progress
3	TSR 412	January 19, 2021	Point-to-point	Woodbine - NS	January 1, 2025	500	Withdrawn

*Indicates project as being located near provincial border.

Figure 4: TSR Queue

Regarding TSR 411, it is 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[3]:

[3] OASIS Generation Interconnection Procedures; 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 System Impact Study, which is expected to identify significant changes to the NSPI transmission system. The revised expected completion date for the study is February 28, 2022. Feasibility Studies initiated prior to the completion of the TSR System Impact Study will be performed based on the current system configuration.

5.0 Short Circuit

IR617 will not impact 120H-Brushy Hill, 67N-Onslow, and neighbouring breaker's interrupting capability based on this study's short circuit analysis. Analysis was performed using PSS/e 34.8, classical fault study, flat voltage profile at 1.0 PU voltage and 3LG faults.

The interrupting capability of the neighbouring 230 kV circuit breakers is at least 10,000 MVA. Short circuit levels with and without IR617 are provided in Tables 2 and 3 below.

Table 2: Maximum Short circuit levels in MVA

Maximum Generation: All Generation On, All Transmission Lines In Service		
Measured Bus	***With IR617 (MVA)***	***Without IR617 (MVA)***
POI on L7018 (230 kV)	3145	3081
120H-Brushy Hill (230 kV)	3583	3527
67N-Onslow (230 kV)	4333	4292
IR617 ICIF (34.5 kV)	685	616

Table 3: Minimum Short circuit levels in MVA

Minimum Generation: PA, ML, LG1, TR6 On, All Transmission Lines In Service		
Measured Bus	***With IR617 (MVA)***	***Without IR617 (MVA)***
POI on L7018 (230 kV)	1888	1825
120H-Brushy Hill (230 kV)	1997	1939
67N-Onslow (230 kV)	2442	2388
IR617 ICIF (34.5 kV)	611	542
Minimum Generation: L7018 Open at 67N		
POI on L7018 (230 kV)	1608	1545
IR617 ICIF (34.5 kV)	583	514
Minimum Generation: L7018 Open at 120H		
POI on L7018 (230 kV)	1220	1157
IR617 ICIF (34.5 kV)	531	463

Further short circuit analysis will be performed in the SIS and will also examine Short Circuit Ratio (SCR) under minimum short circuit level conditions.

6.0 Voltage Flicker & Harmonics

Voltage flicker will be examined when data is made available for the SIS, as the information was not provided at the time of this study. A summary of NS Power's voltage flicker requirements is listed in Table 4: Flicker requirements.

Table 4: Flicker requirements

	P_{st}	P_{lt}
NS Power's requirements	≤ 0.25	≤ 0.35

The WTG facility 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 230 kV.

7.0 Load Flow Analysis

Power flow analysis was performed for generation dispatches under system light load, summer peak load, and winter peak load conditions. Dispatch was selected to represent import and export scenarios with New Brunswick for various flows associated with the existing Maritime Link transmission service reservation. These include exports to NB of up to 330 MW between March 1st and November 30th, and exports of 150MW to NB for the period from December 1st to February 28th. These represent flows under normal system conditions. In the event of a contingency in New Brunswick, NSPI must provide an additional 168 MW of supply. As well, in the event of a contingency in Nova Scotia, New Brunswick is obligated to provide up to 142.5 MW of generation to NS.

IR617 is located to the north of Halifax, connected via L7018, approximately 11.6 km from the 120H-Brushy Hill substation. IR617 is most notably impacted by the Onslow South (ONS) corridor which defines the interface flows into the load centre in Halifax via Truro. The ONS corridor includes line L8002, L7001, L7002, L7018, and L6001.

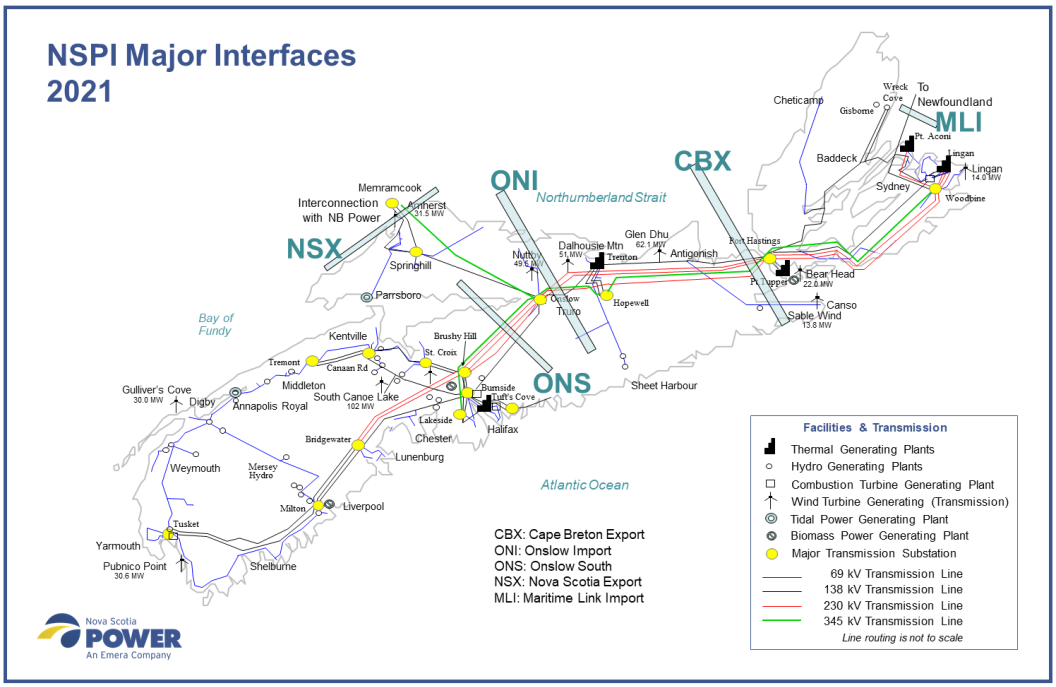


Figure 5: NSPI Major Interfaces

Table 5: Transmission Interface Limits

Interface	MLI[1]	NSX (Export)[2]	NSX (Import)[3]	CBX[4]	ONI	ONS[5]
Summer	475	500	Up to 300	875-1075	1075-1275	600-850
Winter	475	500	Up to 300	950-1150	1275	600-975

[1] *Maritime Link Import from NL limited by simultaneous New Brunswick Import*

[2] *NS Export to NB (NSX) is dependant on Maritime Link runback RAS*

[3] *NS import from NB (NSI) is dependant on conditions in NB and PEI, capped at 28% of NS load.*

[4] *Dependant on generation at Trenton and Point Tupper*

[5] *Dependant on reactive power reserve in Metro*

7.1 Base Cases:

The base cases used in this study are shown in Table 6: Base Case Dispatch. For these cases:

- Transmission connected wind generation facilities were dispatched between 22% and 100% of their rated capability.
- All interface limits were respected for base case scenarios.

Two scenarios were examined for each of the Spring Light Load (SLL), Summer Peak (SUM), and Winter Peak (WIN) cases:

- IR617 off (i.e., SUM_00).
- IR617 generating at full output with NRIS designation (i.e., SUM_00-N).

Table 6: Base Case Dispatch

Case name	NS load	Wind	NS/NB	NS/NL	Cape Breton Export	Onslow Import	Onslow South	Mainland at Hastings	Hastings from
SLL_00-N	854	445	331	-330	245	281	-47	69	219
SLL_00	870	367	332	-330	245	347	18	82	222
SLL_01-N	854	323	0	-165	-45	30	12	-46	95
SLL_01	854	245	0	-165	7	82	64	-13	83
SUM_00-N	1443	568	332	-475	629	686	315	302	339
SUM_00	1443	490	332	-475	708	762	392	346	384
SUM_01-N	1443	408	-99	-330	391	419	456	192	242
SUM_01	1443	330	-98	-330	457	484	520	230	272
SUM_02-N	1452	408	334	-475	828	925	527	432	396
SUM_02	1452	330	335	-475	907	1000	602	476	441
SUM_03-N	1627	378	103	-475	875	955	770	462	435
SUM_03	1635	300	100	-475	955	1029	849	507	481
WIN_00-N	2211	568	150	-320	652	792	535	370	259
WIN_00	2211	490	152	-320	651	867	607	374	263
WIN_01-N	2211	188	0	-320	767	908	741	444	350
WIN_01	2211	110	2	-320	844	981	811	486	394
WIN_02-N	2206	568	332	-320	878	1063	622	489	381
WIN_02	2206	490	335	-320	957	1137	693	533	426
WIN_03-N	2179	188	0	-475	936	1067	901	528	437
WIN_03	2174	110	2	-475	1016	1141	972	572	483

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

7.2 Load Flow Contingencies:

All load flow contingencies must meet the following post contingency requirements:

- All system elements must be within 110% of their thermally limited ratings (assuming system operator action can resolve the overload in < 10 minutes)
- Steady state bus voltage must remain within 90% - 110% of nominal voltage following correction by automatic tap changers.
- Any Pre/Post contingency voltage change at buses must be < 10% prior to tap changer action

The studied contingencies must include breaker failure, which can impact multiple system elements.

7.3 Load Flow Results:

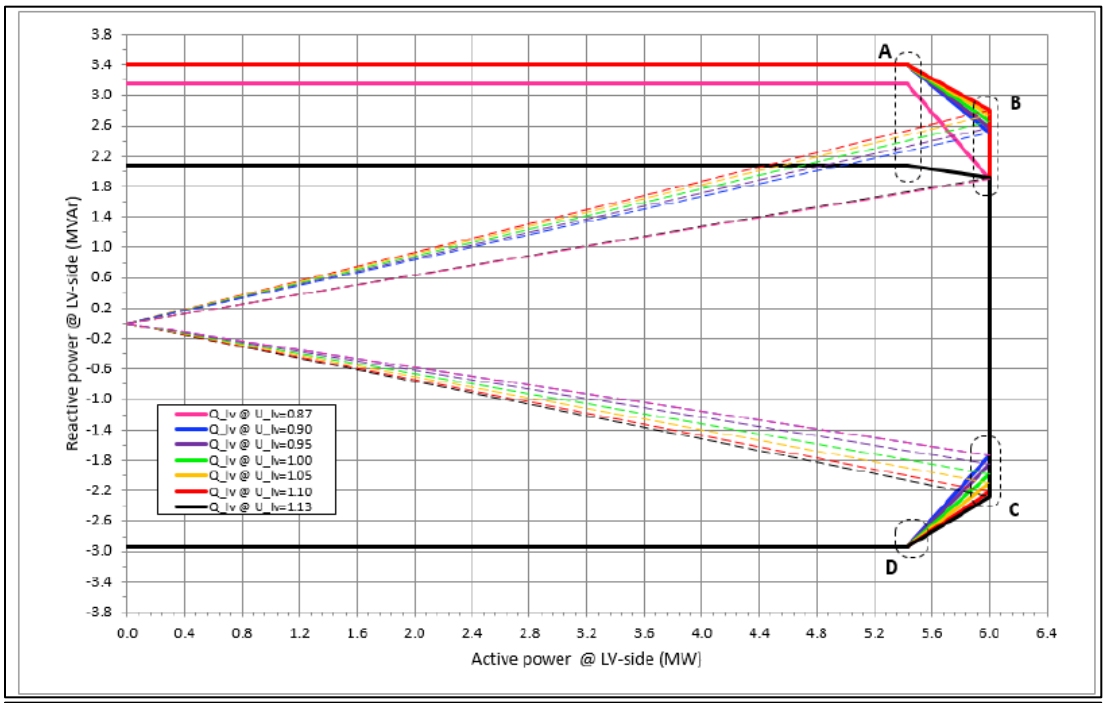
The results for the load flow analysis were acceptable with no criteria violations in any of the dispatch cases considered.

In summary, the steady state contingencies evaluated in this study demonstrate that IR617 does not require Network Upgrades beyond the POI to operate at its full source capacity of 78 MW under NRIS.

8.0 Voltage Control

IR617 requires power factor correction to meet NS Power's ±0.95 net power factor requirement at the HV terminals of the ICIF substation.

Using the Vestas reactive power capability, shown in Figure 6: *Vestas V162 6.0 MW reactive power capability*, various levels were calculated and are displayed in Table 7: *Power factor analysis results*.



	Point:	Coordinates								Power factor	
		A		B		C		D		B (Capacitive)	C (Inductive)
	Coordinate:	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)		
	Reactive power [kVAr] @ LV side @ U_lv = 0.87 p.u. voltage	5.430	3.160	6.000	1.900	6.000	-1.739	5.430	-2.933	0.953	0.960
	Reactive power [kVAr] @ LV side @ U_lv = 0.90 p.u. voltage	5.430	3.400	6.000	2.503	6.000	-1.739	5.430	-2.933	0.923	0.960
	Reactive power [kVAr] @ LV side @ U_lv = 0.95 p.u. voltage	5.430	3.400	6.000	2.584	6.000	-1.856	5.430	-2.933	0.918	0.955
	Reactive power [kVAr] @ LV side @ U_lv = 1.00 p.u. voltage	5.430	3.400	6.000	2.664	6.000	-1.987	5.430	-2.933	0.914	0.949
	Reactive power [kVAr] @ LV side @ U_lv = 1.05 p.u. voltage	5.430	3.400	6.000	2.736	6.000	-2.093	5.430	-2.933	0.910	0.944
	Reactive power [kVAr] @ LV side @ U_lv = 1.10 p.u. voltage	5.430	3.400	6.000	2.807	6.000	-2.213	5.430	-2.933	0.906	0.938
	Reactive power [kVAr] @ LV side @ U_lv = 1.13 p.u. voltage	5.430	2.060	6.000	1.919	6.000	-2.283	5.430	-2.933	0.952	0.935

Figure 3-2: Reactive power capability

Figure 6: Vestas V162 6.0 MW reactive power capability[4]

[4] Vestas Performance Specification V162-6.0 MW, Document no: 0098-0840 V04, 2021/04/14.

The Vestas technical bulletin's reactive power capability, shown above in Figure 6, shows that the reactive power capability is slightly reduced as real power output reaches its max *(regions A-B, and C-D)*. As seen in Table 7, IR617 does not meet NS Power's ±0.95 net power factor requirement when producing VARs while operating at its max real power output.

Breakpoints B and C are applicable only when the site is producing/ absorbing maximum VARs while operating at its max real power output. Because the IR617 site will be restricted to 78 MW output (from a capacity of 111.6 MW), breakpoints A and D are the only relevant operating points. As seen in Table 6 below, IR617 meets NS Power's ±0.95 net power factor requirement at breakpoints A and D on the Vestas reactive capability curve.

Table 7: Power factor analysis results *(@ 1.0 VPU)*

Breakpoints on Vestas reactive capability curve	IR617 rated output (13 x 6.0 MW WTG units)				Measurements at the HV terminals of the ICIF substation				Meets net 0.95 pf requirement?
	MW	MVAR	MVA	pf	MW	MVAR	MVA	pf	
A	70.45	44.20	83.17	0.847	68.7	29.2	74.65	0.920	Yes
B	78.00	34.63	85.34	0.914	76.1	17.7	78.13	0.974	No
C	78.00	-25.83	82.17	0.949	76.1	-44.5	88.16	0.863	Yes
D	70.45	-38.13	80.11	0.879	68.6	-56.3	88.74	0.773	Yes

The net power factor will be re-evaluated when final information on the transformers and collector circuit is provided in the SIS stage.

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 detailed in Figure 7 below and in the NS Power Transmission System Interconnection Requirements *(TSIR)*[5]. 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.

[5] NS Power Transmission System Interconnection Requirements; https://www.nspower.ca/oasis/standards-codes

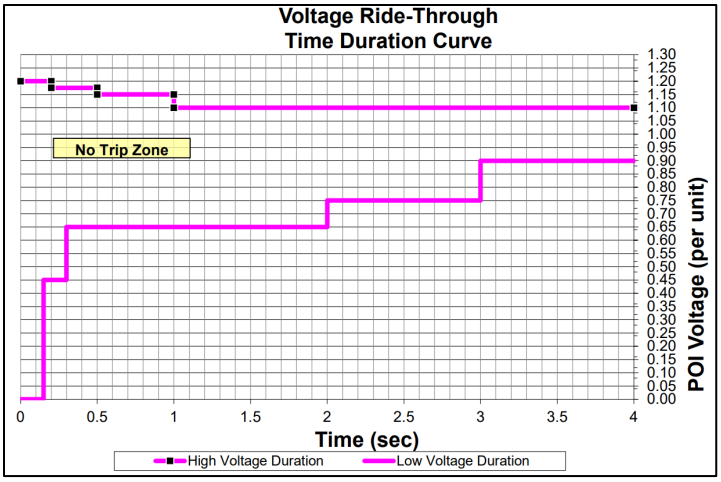


Figure 7: NERC PRC-024-2 Attachment 2

9.0 System Security

Transmission System Elements will be required to meet NPCC[6] Bulk Power System (BPS) and NERC[7] Bulk Electric System (BES) requirements.

Table 8 summarizes the BPS/BES status of system elements in the vicinity of IR617:

Table 8: BPS & BES classification of neighbouring elements

Neighbouring element classification	NPCC BPS	NERC BES
L7018	Yes	Yes
L7001	Yes	Yes
L7002	Yes	Yes
120H 230 kV Bus	Yes	Yes
67N 230 kV Bus	Yes	Yes

NPCC BPS criteria is performance based, and currently the 230 kV line L7018 is designated NPCC BPS. As such, all protection systems associated with the new 230 kV substation supplying the IR617 site must comply with NPCC Directory 4 *System Protection Criteria*.

NERC BES criteria uses a bright line approach for expected facilities required for interconnection. As IR617 has dispersed generation totalling more than 75 MVA, Inclusion I4 of the NERC BES Definition would apply, and each generator would be classified as a BES element. As well, the IR617 230 kV bus and 34.5 kV bus, 230–34.5 kV interconnection transformer, and 230 kV tap line would be classified as BES elements.

[6] Northeastern Power Coordination Council.
[7] North American Electric Reliability Corporation.

There is the potential for an exclusion from BES to be granted for the high side (230 kV) bus based on further analysis per the NS BES Exception Procedure. This analysis will be initiated as part of the System Impact Study (SIS) and exclusion from BES will only be granted upon subsequent approval by the NS Utility and Review Board (UARB).

10.0 Expected Facilities Required for Interconnection

The following facilities are required to interconnect IR617 to the NSPI system via the 230 kV transmission line L7018 (approximately 11.6 km from the 120H-Brushy Hill substation) as NRIS.

1) Network Upgrades:

a) P&C modifications at 120H-Brushy Hill substation and 67N-Onslow substation.

b) Install a new 230kV substation complete with 3 breaker ring bus at the POI at L7018 with control and protection. A Remote Terminal Unit (RTU) to interface with NSPI's SCADA, with telemetry and controls is required by NSPI.

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

a) A 230 kV transmission line (~150 m) built to NSPI standards from POI on L7018 IR617 ICIF substation.

b) Control and communications between the ICIF and the NSPI SCADA and protection system.

2) Interconnection Customer's Interconnection Facilities (ICIF):

a) Facilities to provide ±0.95 power factor when delivering rated output (78 MW) at the 230 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. NSPI will also have remote manual control of the curtailment scheme.

d) When not at full output, the facility shall offer over-frequency and under-frequency control with a deadband of ±0.2 Hz and a droop characteristic of 4%. The active power controls shall also have the capability to react to continuous control signals from the NSPI SCADA system's Automatic Generation Control (AGC) system to control tie-line fluctuations as required.

e) Real-time telemetry will include MW, MVAR, bus voltages, curtailment state, wind speed, and wind direction.

f) Nominal voltage and frequency operation as specified in the NS Power Transmission System Interconnection Requirements *(TSIR)* Section 7.2.

g) Voltage and frequency ride-through capability as detailed in NS Power Transmission System Interconnection Requirements *(TSIR)* Sections 7.4.1 and 7.4.2.

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

i) The facility must use equipment capable of closing a circuit breaker with minimal transient impact on system voltage and frequency *(matching voltage within ±0.05 PU and a phase angle within ±15°)*.

j) Operation at ambient temperatures as low as -30ºC.

11.0 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

The present high level, non-binding, cost estimate, excluding HST, for IR617's Network Resource Interconnection Service is shown in the following table. This estimate assumes there is adequate space for new equipment and modifications. This does not include any costs yet to be determined by the SIS.

Table 9: Cost estimate

Determined Cost Items		Estimate
Transmission Provider Interconnection Facilities (TPIF) Upgrades		
i.	Spur line from POI to IR617 substation (150 m)	$ 400,000
ii.	Protection & control relaying equipment + NSPI RTU	$ 160,000
iii.	Teleprotection & SCADA communications	$ 150,000
	Subtotal:	$ 710,000
Network Upgrades		
iv.	Three breaker ring bus substation (230 kV) complete with P&C at NSPI POI substation and connection to L7018	$ 8,000,000
v.	P&C modifications at 67N-Onslow and 120H-Brushy Hill	$ 200,000
	Subtotal:	$ 8,200,000
Totals		
vi.	Network Upgrades + TPIF Upgrades	$ 8,910,000
vii.	Contingency (10%)	$ 891,000
viii.	Total of Determined Cost Items	$ 9,801,000
To Be Determined Cost Items		
ix.	System additions to address potential stability limits	TBD (SIS)

In this estimate, $8,200,000 (plus 10% contingency) represents Network Upgrade costs which are funded by the Interconnection Customer, but which are eligible for refund under the terms of the GIP. This does not include TBD costs to address any issues identified at the SIS stage.

The estimated time to construct the Network Upgrades and Transmission Provider's Interconnection Facilities is 24-36 months after receipt of funds.

Note that the proposed POI substation location requires more detailed design work that is not in scope for this FEAS. Below are a few highlighted issues that could significantly impact the estimate for this project:

- The requirement for easements and structure relocations for the new transmission line tap substation
- The requirement for easements and structure relocations for the spur line between the new POI substation and the ICIF.

12.0 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 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.

With IR617 in service at full output, the loss factor is calculated as 3.1%.

Table 10: Loss factor

Parameter	Generation (MW)
IR617	78.0
TC3 w/ IR617	85.6
TC3 w/o IR617	161.2
Delta	2.4
2025 loss factor	3.1%

13.0 Preliminary Scope of Subsequent SIS

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. It will provide a more comprehensive assessment, based on NSPI, NPCC, and NERC criteria, of the technical issues and requirements to interconnect the proposed facility as requested.

The assessment will consider, but not be limited, to the following:

- Contingency analysis for both steady state and system stability.
- Ride-through and operation following a contingency (n-1 operation).
- The minimum transmission and substation additions/upgrades that are necessary to permit operation of this generating facility, under all dispatch conditions, catering to, at a minimum, the first contingencies listed below.

- Options and ancillary equipment that the customer must install to control flicker, voltage and ensure that the required ride-through capability.
- Identify guidelines and restrictions applicable following a first contingency (curtailments, etc.).
- Loss Factor.
- Determination of BPS designation.
- Changes to SPS schemes required for operation of this generating facility
- Under-frequency load shedding.
- Facilities that the customer must install to meet the requirements of the GIP.

Parameters for a generic model must be supplied for transient analysis in PSS/e.

The SIS will determine the facilities required to operate this facility at full capacity, withstand the contingencies as defined by NPCC/NERC and identify any restrictions that must be placed on the system following a first contingency loss. The SIS will be conducted with the assumption that all projects higher queued will proceed and the facilities associated with those projects are installed.

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 NERC[8] and NPCC[9] criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

A thorough assessment will be provided to ensure that the facilities will meet applicable NSPI, NPCC and NERC transmission design criteria.

Additionally, electromagnetic transient (EMT) study may be required to account for IR617 control system to coordinate with other facilities in the transmission system and to ensure fault ride through.

Nova Scotia Power
Transmission System Operations
2022-03-29

[8] NPCC Directory #1: *Design and Operation of the Bulk Power System*
[9] NERC Reliability Standard TPL-001-4: *Transmission Operations*