Interconnection Feasibility Study Report

GIP-IR648-FEAS-R0

Generator Interconnection Request IR648

100 MW Wind Generating Facility

Location Windy Ridge, Cumberland County, NS

2022-04-04

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer (IC) submitted an Interconnection Request (IR648) for Network Resource Interconnection Service (NRIS) for a proposed 100 MW wind generation facility interconnected to NSPI transmission system with Commercial Operation Date of December 31, 2025.

In addition to NRIS, the signed Interconnection Feasibility Study Agreement also includes a study option for an ERIS (Energy Resource Interconnection Service).

The IC indicated that the Point-Of-Interconnection (POI) will be at the 138 kV bus at 30N-Maccan substation.

The IC specified that IR648 generating facility will consist of 39 wind turbines, with each turbine being rated at 2.85 MW and +/- 0.9 power factor.

This feasibility assessment is conducted with IR648 generation to be used in NS and not for exporting outside NS and to displace the planned phased out coal generation in Cape Breton as per NSPI's generation plan. If IR648 were to displace non-coal generation in Halifax, then major system upgrades associated with increasing Onslow South corridor and Metro Dynamic Reactive Reserve could be required and are not accounted for in this feasibility assessment.

Based on the information provided by the IC for the modelling of IR648 generating facility and the connection to NSPI power system, this feasibility assessment provides the following findings:

- In IR648 application, the IC specified that the IC's 138 kV/34.5kV substation will be located at 11 km from 30N-Maccan substation. However, in a later correspondence, the IC provided a map which shows the location of the IC's 138kV/34.5kV substation to be about 8.3 km from 30N-Maccan substation, on 30N-Maccan side of the mainland. The IC also confirms that the 138 kV spur line from the IC's substation to the POI has no water crossing.
- The high level non-binding cost estimate for interconnecting IR648 to NSPI network in 2022 Canadian dollars is $10,868,500 (based on 11km of spur line), or $9,201,500 (based on 8.3 km of spur line). The estimates are for both NRIS or ERIS and include 10% contingency but exclude HST.
- The IC will obtain and provide the Rights of Way (ROW) for the spur line and to cover the cost of installing the spur line, but NSPI will own and operate the spur line.
- IR648 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 estimated loss factor for IR648 is 9.5% at 100 MW output.

- IR648 voltage flicker and harmonic levels will be studied in System Impact Study (SIS) as the information was not provided at the time of this feasibility assessment.
- The 34.5kV collector circuit impedances were not provided so assumed values were used in this feasibility assessment. This will be assessed in SIS.
- This feasibility assessment is completed without accounting for TSR411 which could significantly alter the results of this assessment.

IR648 will be required to meet NSPI's Generator Interconnection Procedure (GIP) and Transmission System Interconnection Requirements (TSIR).

This feasibility assessment will be further subjected to the subsequent SIS and Facility Study which will determine the final system requirements and upgrades for IR648.

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1.0 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR648) for NRIS (Network Resource Interconnection Service) with ERIS (Energy Resource Interconnection Service) as an option for a proposed 100 MW wind generation facility interconnected to the NSPI transmission system at 30N-Maccan 138 kV substation bus via a new 138 kV spur line with an approximate length of 11 km, as detailed in IR648's "GIP - Appendix 2 - Interconnection Feasibility Study Agreement" signed by the IC on November 24, 2021 and by NSPI Transmission Provider on December 3, 2021.

The above-mentioned document also includes the following details:

- 39 wind turbines with each turbine rated 2.85 MW
- 2 collector circuits
- Substation step-up transformer 138 kV (HV)/34.5 kV (LV)/13.8 kV (Tert), 70/90/112 MVA, Taps +/- 2 x 2.5%, Impedance 8.0%
- Location Minudie, Cumberland County, NS

The IC also provided "Interconnection Request Appendix 1 to GIP" signed by the IC on September 29, 2021 and NSPI Transmission Provider on October 15, 2021, which includes the following additional information:

- Commercial Operation Date of December 31, 2025
- Individual wind turbine information
    - GE 2.85 MVA
    - 690 V
    - Power Factor +/- 0.9
    - Maximum 2.64 MW
    - Substation step-up transformer positive impedance 8% on 70 MVA with X/R of 40
- Electrical one-line showing
    - Substation step-up transformer with connection HV grounded wye, LV grounded wye, Tertiary delta with one corner grounded
    - Individual wind turbine step-up transformer rating 3.38MVA.

- GE electrical bulletin for the wind turbine shows a range of 11% to 13% impedance on 3.38 MVA for each individual wind turbine step up transformer. For this feasibility study, the value of 12% will be used.

In later correspondence, the IC provided a map showing the location of the IC's substation to be on 30N-Maccan side of the mainland at approximately 8.3 km from POI. Based on the information provided by the IC and additional information received regarding IC substation location, Figure 1 shows the approximate locations of the wind turbines (WECs), IC substation (ICIF) and POI. Figure 2 shows POI electrically (not to scale).

Figure 1: IR648 POI at 30N-Maccan 138 kV bus

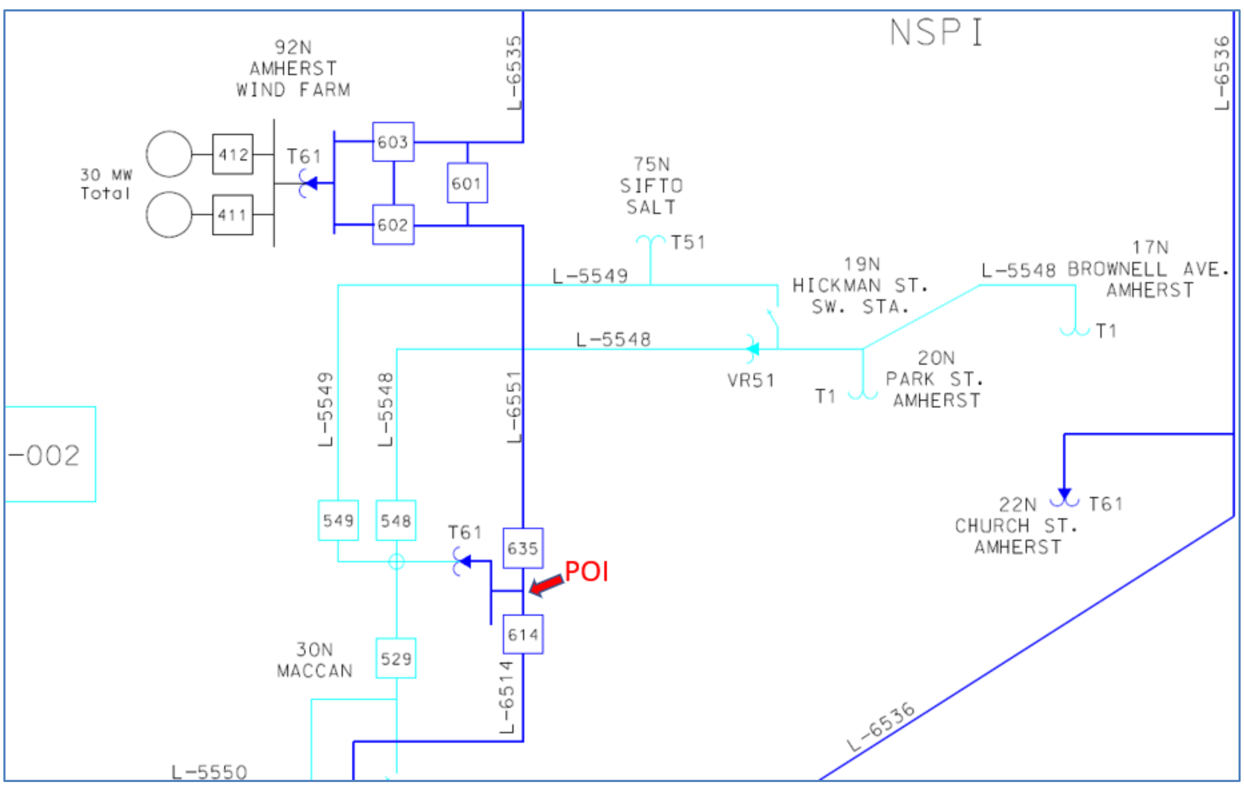

Figure 2 POI electrically (not to scale)

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 system and 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 is not included in this feasibility assessment of IR648.

The power flow cases used for this feasibility assessment contain only transmission connected generating facilities, except for Lingan unit 2 which is assumed to be retired.

Thermal ratings of existing 138 kV transmission lines from 30N-Maccan substation are shown in Table 1.

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

LINE	STATION	CONDUCTOR				BREAKER	SWITCH	CURRENT TRANSFORMER						TRIP MVA
		Type	Maximum Operating Temp. (Celsius)	SUMMER RATING 25 DEG (MVA)	WINTER RATING 5 DEG (MVA)	100% Name-plate	100% Name-plate	RELAYING			FULL SCALE METERING			
								Ratio	R.F.	MVA	Ratio	R.F.	MVA	
L-6514	74N Springhill	ACSR 556.5 Dove	60	140	184	287	287	600	2	287	600	1	173	617
	30N Maccan					287	143	600	2.5	358	600	1	173	820
L-6551	30N Maccan	ACSR 556.5 Dove	100	215	242	299	143	800	1.5	287	800	1	191	543
	92N Amherst Wind Farm					287	287	800	2	382	800	2	441	2000

Table 1: Thermal ratings of existing 138 kV lines from 30N-Maccan substation

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. As requested by the IC, the study will cover two options, one for Network Resource Interconnection Service (NRIS) and one for Energy Resource Interconnection Service (ERIS) as defined in the Generator Interconnection Procedure (GIP). The study will be based on IR648 generation being used in NS and not for exporting outside NS and will displace the planned phased out coal generation in Cape Breton and not generation in Halifax, NS.
2. Commercial Operation Date of December 31, 2025.
3. The Interconnection Facility is modelled based on the information provided by the IC as per section 1.0 Introduction.

4. 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.
5. The information on collector circuits was not provided for estimating the equivalent impedances, so assumed values were used. The subsequent SIS can obtain the details from the IC and update the values at that time.
6. 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 as discussed earlier in the report.
7. 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.
8. 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, except for Lingan Unit 2, which is assumed to be retired.

Figure 3 shows the GIP queue as of October 15, 2021.

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 are higher queued in the Advanced Stage Interconnection Request Queue and are committed to the study:

- 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 Complete.
- IR595: SIS complete.
- IR598: SIS in Progress.
- IR604: SIS in Progress.
- IR603: SIS in Progress.
- IR600: SIS in Progress

Figure 4 shows the Transmission Service Request (TSR) queue on December 20, 2021 to be used in lieu of October 15, 2021.

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

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. In the case of loss of ML HVDC under this condition, NS will cut the 150 MW or 330 MW "through NS" export.

Regarding TSR411, 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 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 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 Analysis

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 IR648 added to the PSSE models.

IR648 short circuit capability used for this assessment is based on the wind turbine technical bulletin provided by the IC as per section “1.0 Introduction”.

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 2 shows maximum and minimum short circuit levels at 1N-Onslow and IR648 POI.

Maximum System Normal Three Phase Short Circuit in MVA			
Case	**30N-Maccan 138kV**	**IR648 34.5kV**	**IR648 690V**
IR648 Off	1,146	333	258
IR648 On	1,322	618	640

Table 2: Maximum generation short circuit level system normal

The interrupting capability of the 138 kV circuit breakers at 138 kV substations is at least 3,500 MVA, much higher than the maximum short circuit levels at these locations with IR648 being on-line, hence IR648 will not incur any breaker upgrades at these substations.

As for the minimum short circuit level, Table 3 shows minimum short circuit levels at IR648 POI, 34.5 kV bus and 690 V equivalent generator terminal bus.

Minimum System Normal Three Phase Short Circuit in MVA			
Case	**30N-Maccan 138kV**	**IR648 34.5kV**	**IR648 690V**
IR648 Off	887	322	255
IR648 On	1,062	607	638

Table 3: Minimum generation short circuit level system normal

In order to find the lowest minimum short circuit levels that can be encountered under minimum generation with one transmission element out of service, three cases were considered. Table 4 shows minimum short circuit levels with L-6613 out of service, Table 5 shows minimum short circuit levels with L-6551 out of service, and Table 6 shows minimum short circuit levels with L-6514 out of service.

Minimum Three Phase Short Circuit in MVA with L6613 Outage			
Case (L6613 1N-74N Out)	**30N-Maccan 138kV**	**IR648 34.5kV**	**IR648 690V**
IR648 Off	706	299	241
IR648 On	881	584	624

Table 4: Minimum generation short circuit level with L-6613 out

Minimum Three Phase Short Circuit in MVA with L6551 Outage			
Case (L6551 30N-92N Out)	30N-Maccan 138kV	IR648 34.5kV	IR648 690V
IR648 Off	620	277	226
IR648 On	796	562	608

Table 5: Minimum generation short circuit level with L-6551 out

Minimum Three Phase Short Circuit in MVA with L6514 Outage			
Case (L-6514 74N-30N Out)	30N-Maccan 138kV	IR648 34.5kV	IR648 690V
IR648 Off	563	269	221
IR648 On	739	554	603

Table 6: Minimum generation short circuit level with L-6514 out

Comparison of the last three tables shows that the lowest minimum short circuit level at the 34.5 kV bus at IR648 is 269 MVA, which equates to a SCR of 2.69 which is above the required 2.5 value as per the technical bulletin for this type of wind turbines, hence IR648 should be able to operate under this system condition. In any case, this will need to be verified and confirmed by the subsequent SIS.

6.0 Voltage Flicker and Harmonics

The voltage flicker can't be determined at the 138 kV bus at 30N-Maccan substation due to lack of information at the time of this assessment. The subsequent SIS can obtain the required information and make the determination.

7.0 Thermal Limits

7.1 NS Load Forecast

At the time of this assessment for IR648, 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 IR648 Model

Based on the information provided by the IC, the following was modelled for IR648:

1. The POI is modelled at the 138 kV bus at 30N-Maccan substation.

2. The 138 kV spur line from POI to IC's 138 kV to 34.5 kV substation is modelled with 11 km of 138 kV Dove overhead line with no water crossing.

3. The 138 kV to 34.5 kV transformer is modelled based on 8.0 % positive impedance on 70 MVA base rating and X/R of 40 with a nominal rating of 112 MVA.

4. The equivalent 34.5kV to 690V transformer for the wind farm is modelled based on the individual wind turbine step up transformer having 12 % positive impedance on 3.38 MVA.

5. The equivalent generator for the 39 wind turbines is modelled based on the information provided by the IC for each wind turbine rated 2.85 MW with power factor of +/- 0.9 and terminal voltage of 690 volts.

6. The information on collector circuits was not provided, so assumed values were used. The subsequent SIS can obtain the details from the IC and complete the correct modelling of the collector circuits at that time.

7.3 IR648 Steady State Analysis Result

This feasibility assessment is completed based on IR648 output being used in NS, not for exporting outside NS, and displacing the planned phased out coal generation in Cape Breton as per NSPI's present plan and guidelines for these feasibility assessments. The guidelines include all wind farms in NS to be dispatched at full outputs in two seasons, winter peak and summer peak.

The present NB to NS firm import is zero. The base cases are dispatched with NB to NS at 142.5 MW to allow ten minute reserve delivery from NB to NS.

The present NS to NB firm export is 150 MW in winter season and 330 MW in non-winter season. The base cases are dispatched with NS to NB at 320 MW in winter peak and 500 MW in summer peak to allow for the ten minute reserve delivery from NS to NB.

In order to maintain ONS or CBX power flow within the existing established operating limits, ten minute operating reserve from NS to NB may need to come from Burnside units. In addition, these units can be dispatched as synchronous condensers as needed to meet the Metro Dynamic Reactive Reserve requirements.

For each system dispatch chosen, a steady state analysis is performed and checked for the system performance with IR648 off-line and with IR648 on-line at full output in order to determine any thermal overload or voltage violation directly caused by IR648.

A number of system dispatch cases were created based on the above conditions using PSSE software version 33.12.1. The power flows of various interfaces inside and outside NS are displayed in Table 7.

Case Name	NB to NS	NB to PEI	NB to NE	NL to NS	NB to HQ	NB to MPS	CBX	ONI	ONS	TC	TR	PT2	LG	PA	BS	VJ	TUS	WC	IR648 Wind	Trans Wind
C01a_WP_R1.sav	142	150	0	475	-928	75	869	948	980	78	165	80	266	185	0	0	23	192	0	489
C01b_WP_R1.sav	142	150	0	475	-928	75	768	853	980	78	165	80	162	185	0	0	23	192	100	589
C02a_WP_R1.sav	-320	250	0	475	-928	75	1237	1273	839	104	150	165	494	189	100	0	33	192	0	489
C02b_WP_R1.sav	-320	250	0	475	-928	75	1131	1177	841	102	150	165	384	189	100	0	33	192	100	589
C03a_SP_R1.sav	142	150	800	475	-785	66	424	424	532	0	0	0	315	0	0	0	0	0	0	489
C03b_SP_R1.sav	142	150	800	475	-785	66	327	329	532	0	0	0	215	0	0	0	0	0	100	589
C04a_SP_R1.sav	-500	236	800	475	-785	66	839	971	430	0	157	0	368	190	100	0	0	140	0	489
C04b_SP_R1.sav	-500	235	800	475	-785	66	736	873	430	0	157	0	264	186	100	0	0	140	100	589

Table 7: 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 8. For load flow, 67N-815 contingency is the same as L-8001 contingency and 67N-816 contingency is the same as L-8003 contingency due to the empty node between 67N-815 breaker and 67N-816 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 Studied				
101S_701	120H_710	30N_B61	67N_706	90H_611
101S_702	120H_711	30N_T61	67N_710	90H_612
101S_703	120H_712	3C_711	67N_713	90H_T1
101S_704	120H_713	3C_712	67N_811*	91H_511
101S_705	120H_714	3C_713	67N_812	91H_513
101S_706	120H_715	3C_714	67N_813	91H_516
101S_711	120H_716	3C_715	67N_814	91H_521
101S_712	120H_690	3C_716	67N_T71	91H_523
101S_713	120H_SVC	3C_T71	67N_T81	91H_603
101S_811	120H_T71	3C_T72	67N_T82	91H_604
101S_812*	120H_T72	3C710*	67N711*	91H_605
101S_813*	132H_602	3C690*	67N712*	91H_606
101S_814*	132H_603	3S_T1	70037004*	91H_607

Contingencies Studied				
101S_816	132H_605	47C_602	70087009Sep	91H_608
101S_T81	132H_606	47C_603	74N_B61	91H_609
101S_T82	1C_689	47C_674	74N_T61	91H_611
103H_600	1C_B61	47C_T63	79N-T81*	91H_613
103H_608	1C_B62	47C_T64	85S_B61	91H_621
103H_681	1C_G2	47C_T65	85S_G1	91H_T11
103H_881	1N_600	47C_T67	88S_710	91H_T62
103H_B61	1N_601	49N_600	88S_711	91H_TC3
103H_B62	1N_613	4C_T2	88S_712	91N_701
103H_T81	1N_B51	4C_T63	88S_713	IR648
104H600	1N_B52	50N_500	88S_714	L-5003
108H_600	1N_B61	50N_604	88S_715	L-5011
108H_B1	1N_B62	50N_B55	88S_690	L5012
108H_B3	1N_C61	50N_B57	88S_721	L-5014
113H_600	1N_T1	50N_G6	88S_722	L-5015
120H_621	1N_T4	50N_T12	88S_723*	L-5016
120H_622	2CB61WC1	50N_T8	88S_G4	L-5017
120H_623	2CB62WC1	50NB61G6	88S_T71	L-5019
120H_624	2S_513	50NB62G5	88S_T72	L-5020
120H_625	2S_600	67N_701	89S_G1	L1108
120H_626	2S_B64	67N_702	90H_602	L1142
120H_627	2S_B65	67N_703	90H_603	L1108
120H_628	2S_T1	67N_704	90H_604	L1142
120H_629	L-5534	L6012	L6523	L1143
L-5021	L-5535	L6013	L6613	L1148-L1151*
L-5022	L-5536	L6014	L6535	L1157
L-5023L5053	L-5537	L6015	L6536	L1190
L-5024	L-5538	L6016	L6537*	L1190-L1215
L-5025	L-5539	L6020	L6538	L1244
L-5026	L-5541	L6021	L6539	L3004
L-5027	L-5546	L6024	L6551	L3006
L-5028	L-5547L5551	L6025	L6552	L3013
L-5029L5030	L-5548	L6033	L7001	L3017_3019
L-5032L5004	L-5549	L60335039	L7002	Lepreau
L-5033	L-5550L5582	L60336035	L7003	ME1-10
L-5035	L-5559L5579	L6035	L7004	ME1-11
L-5036	L-5560	L6038	L7005*	ME1-12
L-5037L3031	L-5561L5565	L6040	L7008	ME1-13

Contingencies Studied				
L-5039	L-5563	L60406042	L7009	ME1-14
L-5040	L-5564L5576	L6042	L7011	ME1-15
L5041	L-5571	L6043	L7012	ME1-16
L-5042	L-5573L5575	L6044	L7014	ME1-6
L5049	L-5580	L6047	L7015	ME1-7
L-5054	L6001	L6048	L7019	ME1-8
L-5058	L6002_90H	L6051	L7021	ME1-9
L-5500	L6002_99W	L6052	L70216534	ME3-1*
L-5501	L6003	L6053	L7022	ME3-2*
L-5502	L60036007	L6054	L8001*	ME3-3*
L-5505	L60036009	L6055	L8002	Mem_T3
L-5506	L6004	L6503	L80027009	
L-5507L5508	L6005	L6507	L8003*	
L-5511	L60056010	L65076508	L8004*	
L-5512	L60056016	L6508	ML_2Poles	
L-5521	L6006	L6510	ML_Pole1	
L-5524	L6007	L6511	ML_Pole2	
L-5527A	L6008	L6514	PHP	
L-5527B	L6009	L6515	90H_605	
L-5530	L6010	L6516	90H_606	
L-5531	L60106011	L6517	90H_607	
L-5532	L6011	L6518	90H_608	
L-5533L5581	2S_T2	67N_705	90H_609	

Table 8: Contingencies in NS and NB studied

Of the cases and contingencies studied, there are two cases and two contingencies that merit discussion.

For case C01b_WP, with IR648 operating at 100 MW, a breaker failure contingency at Memramcook substation that takes out the 345 kV L-8001 between NS and NB would cause L1151, a 138 kV line between Moncton and Salisbury in NB, to exceed Rate C. For case C03b_SP, with IR648 operating at 100 MW, L-8001 contingency would cause L-6514, a 138 kV line between 30N-Maccan substation and 74N-Springhill substation, to exceed Rate B. Since the Import Power Monitor Special Protection Scheme is assumed armed for flows from NB to NS over 100 MW, this existing SPS resolves the issue and IR648 does not affect the existing arming level.

In summary, the steady state analysis shows that IR648 can operate as NRIS and ERIS without violating thermal load criteria.

8.0 Voltage Limits

The load flow results show that, when IR648 rated output is used in NS and displaces the planned phased out coal generation in Cape Breton as per NSPI's plan, IR648 operating at full output does not violate voltage criteria.

Regarding power factor, NSPI requires IR648 to meet |+/-0.95| or less 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 IR648 generates maximum reactive power output. Table 9 shows that IR648 does not meet NSPI's required power factor of |+0.95| or less, hence IR648 will require power factor correction. This will be further examined in the SIS as the collector circuit impedances were not provided for this feasibility assessment and assumed values were used.

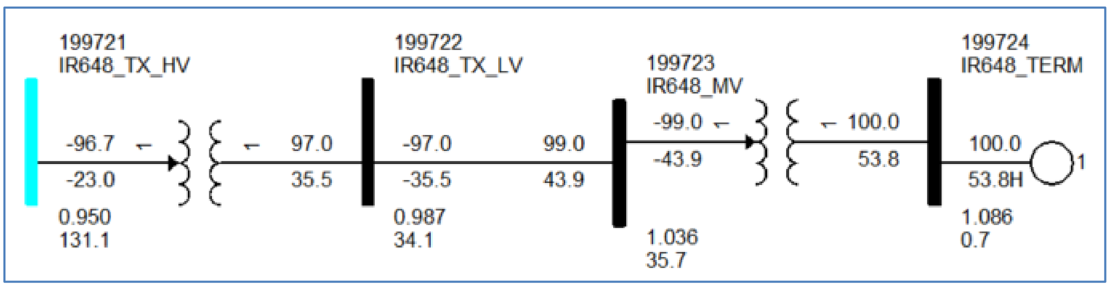

Figure 5 Power Factor with Qmax

IR648 MW	IR648 MVAR	Tx HV MW	Tx HV MVAR	Tx HV Power Factor
100.0	53.8	96.4	23.0	0.973

Table 9: Power factor with Qmax

Figure 6 shows power factor on the high voltage side of the IC substation transformer when IR648 absorbs maximum reactive power output. Table 10 shows that IR648 meets NSPI's required power factor of |-0.95| or less when it absorbs reactive power from the system. This will be further examined in the SIS as the collector circuit impedances were not provided for this feasibility assessment and assumed values were used.

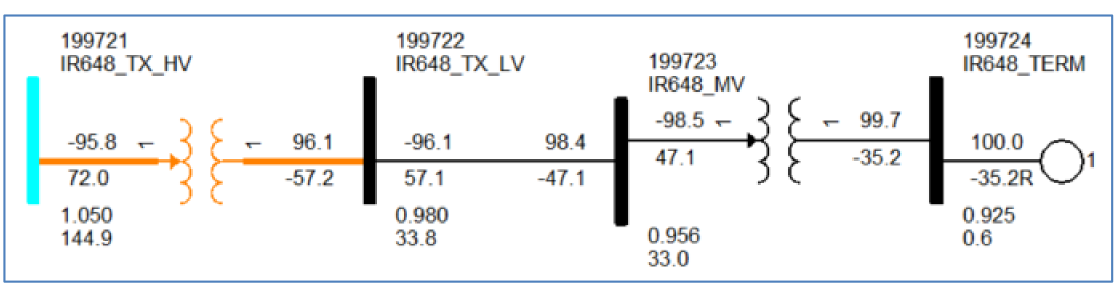

Figure 6 Power Factor with Qmin

IR648 MW	IR648 MVAR	Tx HV MW	Tx HV MVAR	Tx HV Power Factor
100.0	-35.2	95.8	-72.0	0.799

Table 10: 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

30N-Maccan 138 kV substation is not on NSPI's BPS (Bulk Power System) list or BES (Bulk Electricity System) list. Addition of IR648 will require re-assessment of 30N-Maccan substation, the spur 138 kV line, and the IC substation for BPS and BES status. This re-assessment is not within the scope of this feasibility, but it will be in the subsequent SIS when and if the IC pursues the next phase of this project.

For information, NERC bright line criteria categorise all system elements above 100 kV or any generating facility above 75 MW to be BES. In that sense, IR648 generating facility being above 75 MW and IC substation and spur line being above 100 kV will initially be BES. However, in NS, the IC can ask NSPI to conduct a separate system study that is required to prepare and submit a BES exclusion application to Nova Scotia Utility and Review Board, who has the authority to approve or reject the application.

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 IR648 is shown in Table 11:

Loss Factor	
Description	**MW**
IR648 On	100
TC3 with IR648 On	69.5
TC3 with IR648 Off	160
Loss Factor	+9.5%

Table 11: Loss factor

11.0 Expected Facilities Required for Interconnection

The following facility changes will be required to connect IR648 to 138 kV bus at 30N-Maccan substation for NRIS or ERIS.

a. Required Network Upgrades

- Substation expansion and bus modification including P&C at 30N-Maccan 138 kV substation for the new POI at the 138 kV bus.
- The 138 kV line terminal of L-6551 at 30N-Maccan will need to be relocated to make space for the new connection of IR648 138 kV spur line.

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

- Installation of 11 km or 8.3 km of 138 kV spur line from NSPI Interconnection Facility substation at the POI at 138 kV bus in 30N-Maccan substation to the IC substation. The IC is responsible for obtaining and providing ROW.
- Installation of a new 138 kV circuit breaker, associated switches, and P&C at 30N-Maccan substation for the termination of the new spur 138 kV from IC substation.
- Add P&C, control and communications, and tele-protection between IR648 facility 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 Transmission Provide Interconnection Facilities (TPIF) and Network Upgrades for interconnecting IR648, as NRIS or ERIS, to the 138 kV bus at 30N-Maccan substation is shown in Table 12 based on the 138 kV spur line being 11 km or Table 13 based on the spur line being 8.3 km. The cost estimate is based on POI at 138 kV bus at 30N-Maccan substation. Please note that this cost estimate is high level, non-binding in 2022 Canadian dollars. This does not include additional costs to be identified by the subsequent SIS and Facility Study.

Item	Network Upgrades (Based on 11 km Spur Line)	Estimate
I	30N-Maccan 138 kV substation expansion and bus modification including P&C	$1,200,000
II	L-6551 138 kV terminal relocation at 30N-Maccan substation	$1,000,000
	Sub-total for Network Upgrades	$2,200,000
Item	**TPIF Upgrades**	**Estimate**
I	Install a new up to 11 km of wood H-frame 138 kV spur line to connect to IR648 to 30N-Maccan substation	$5,500,000
II	Install a new 138 kV circuit breaker, associated switches, and P&C at 30N-Maccan substation for the new 138 kV spur line to IC substation	$1,700,000
III	P&C relaying equipment at IC substation	$100,000
IV	NSPI supplied RTU at IC substation	$65,000
V	Tele-protection and SCADA communication at IC substation	$150,000
	Sub-total for TPIF Upgrades	$7,515,000
Item	**Total Upgrades**	**Estimate**
I	Network Upgrades + TPIF Upgrades	$9,715,000
II	Contingency (10%)	$971,500
	Total (Excl. HST)	$10,686,500

Table 12: Cost estimates based on 11 km of spur line

Item	Network Upgrades (Based on 8.3 km Spur Line)	Estimate
I	30N-Maccan 138 kV substation expansion and bus modification including P&C	$1,200,000
II	L-6551 138 kV terminal relocation at 30N-Maccan substation	$1,000,000
	Sub-total for Network Upgrades	$2,200,000
Item	**TPIF Upgrades**	**Estimate**
I	Install a new up to 8.3 km of wood H-frame 138 kV spur line to connect to IR648 to 30N-Maccan substation	$4,150,000
II	Install a new 138 kV circuit breaker, associated switches, and P&C at 30N-Maccan substation for the new 138 kV spur line to IC substation	$1,700,000
III	P&C relaying equipment at IC substation	$100,000
IV	NSPI supplied RTU at IC substation	$65,000
V	Tele-protection and SCADA communication at IC substation	$150,000
	Sub-total for TPIF Upgrades	$6,165,000
Item	**Total Upgrades**	**Estimate**
I	Network Upgrades + TPIF Upgrades	$8,365,000
II	Contingency (10%)	$836,500
	Total (Excl. HST)	$9,201,500

Table 13: Cost estimates based on 8.3 km of spur line

13.0 Preliminary Scope of the SIS

The following provides a preliminary scope of work for the subsequent SIS for IR648. 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 IR648 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, thermal and voltage assessment for increasing Onslow South if IR648 is required to displace generation at Tufts Cove instead of the planned phased out coal generation in Cape Breton as per NSPI's present generation plan.

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 IR648 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
2022-04-04