System Impact Study Part 1 Report

Report GIP-IR668-SIS-Part1-R1

Generator Interconnection Request #668

94.4 MW Wind Generating Facility

Weavers Mountain, NS

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Nova Scotia Power Inc.

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June 14, 2023

Executive Summary

The System Impact Study (SIS) was conducted for a proposed 94.4 MW wind turbine generating facility, IR668 for Network Resource Interconnection Service (NRIS). The facility will be connected to the Nova Scotia Power Inc (NSPI) transmission system at a 230 kV line, L-7003, at Weavers Mountain in Nova Scotia (NS). The SIS will be conducted in two Parts.

This report is for Part 1. It uses a Power System Simulator software to determine the impacts of IR668 on the NSPI power system with respect to steady state, stability, short circuit, power factor, voltage flicker, bulk power system status, under-frequency operation, low voltage ride through and loss factor. The assessment is based on NSPI's system design criteria, generator interconnection procedure (GIP), transmission system interconnection requirements (TSIR), applicable Northeast Power Coordinating Council (NPCC) planning criteria for Bulk Power System (BPS), and applicable North American Electric Reliability Corporation (NERC) planning criteria for Bulk Electricity System (BES).

Part 2 study will use Electro Magnetic Transient (EMT) software to determine the impact and control interactions of IR668 with the NSPI power system. This Part 2 study will progress in parallel with the next phase of the GIP process (facilities study). The outcomes of the Part 2 study will be captured as an addendum to the SIS Part 1 report and may trigger restudy for facilities study work completed at that time.

The initial Part 1 R0 report was issued to the Interconnection Customer (IC) for review and comments on March 24, 2023 and the presentation to the IC was made on April 6, 2023. Since then, the IC has revised the main substation transformer impedance as well as opted for the wind turbine STATCOM feature. Subsequently, the analysis for short circuit, short circuit ratio (SCR), power factor, voltage flicker, and electrical losses was reconducted and the initial report was revised to this final R0 report to reflect the changes.

The final R0 report was issued to the IC on June 8, 2023 for review and comment and presentation was made to the IC on June 12, 2023. After that, on June 13, 20223 the IC informed NSPI that the rated MVAR capability for IR668 will be revised to the range of +2.35 MVAR to -1.9 MVAR per wind turbine when IR668 generates rated MW. All 16 wind turbines will be equipped with STATCOM capabilities with each wind turbine providing +1.7 MVAR to -1.9 MVAR range at 0 MW output at unity voltage. This necessitates the reassessment of the power factor and the final R0 report is revised to this R1 report to reflect the changes.

It is very important to note that this study is based on IR668 generation and higher queued IRs displacing Cape Breton coal fired generation, hence Cape Breton Export (CBX) arming level and limit will be reduced accordingly by these IRs. Similarly, CBX and Onslow Import (ONI) levels will be reduced by higher queued IRs depending upon their locations. In addition, this study excludes Transmission Service Request TSR411 as per NSPI's current posting on its GIP site: Generation Interconnection Procedures| Nova Scotia Power (nspower.ca).

IR668 wind facility will be connected to the 230 kV line L-7003 at the Point-Of-Interconnection (POI) at approximately 62 km from 3C-Port Hastings substation and a new 230 kV line extension from the POI to the IC substation will be approximately 122 meters in length.

IR668 generating facility will consist of 16 wind turbines, each rated 5.9 MW at 750 volts for a total of 94.4 MW. Each wind turbine output is stepped from 750 V to 34.5 kV via its individual step up transformers. At 34.5 kV level, there are three collector circuits that will terminate at the IC substation where 34.5 kV is stepped up to 230 kV to connect to NSPI's power system at 230 kV POI.

Due to IR668 location on the congested main transmission corridor between Cape Breton (CB) and Mainland of NS, a higher number of power system cases than typically studied were created and simulated in this SIS. For steady state analysis, 54 cases were created and analyzed, half of them with IR668 off-line and half of them with IR668 on-line (displacing CB generation) to determine the differential impacts for IR668 system upgrades. For stability analysis, 27 cases with IR668 on-line were analyzed to assess system stability. If any system instability is encountered, then the simulation is repeated with IR668 off-line to determine the differential impacts for IR668 system upgrades. An additional stability case with NS importing 300 MW from New Brunswick (NB) was created and simulated to assess the capability of IR668 to remain on-line and stable as NS suddenly is islanded from NB electrically.

Regardless of how many cases are studied for this report, they still represent a limited number of system dispatches as compared to hourly system dispatches of the live power system over future years, hence please note that while this study is for IR668 as NRIS, NSPI's Control Center Operations can curtail IR668 output at anytime as permitted in Section 9.7.2 of NSPI's Standard Generator Interconnection Agreement (GIA).

As per NSPI's GIP, all Interconnection Requests, which are in higher queued positions than IR668 and which are not considered electrically remote from IR668, were modelled, and included in the base cases.

For each 54 steady state cases, a set of 352 contingencies in NS and New Brunswick (NB) were simulated and reviewed. For each of 27 stability cases, a set of 131 contingencies in NS and NB were simulated, reviewed, plotted, and combined into pdf files to be included as appendices.

Based on all the above analysis, below are the findings:

- The short circuit analysis shows that IR668 short circuit contribution does not require any uprating of existing breakers in the transmission system.
- The same analysis shows that the short circuit ratio (SCR) at the 34.5 kV bus can be as low as 3.0 for IR668. For some wind turbine suppliers, SCR less than 4 will require special design, so the IC should discuss with IR668 wind turbine supplier to ensure that the wind turbines. Please note that NSPI's TSIR (version 1.1, dated February 25, 2021), section 7.4.15, requires the following "System short circuit level may decline over time with changes to transmission configuration and generation mix. The Generating Facility shall be able to accommodate these changes. If the Point of Interconnection does not provide

sufficient SCR for acceptable operation of the Generating Facility, the Interconnection Customer must provide facilities such as synchronous condensers or control systems to permit low SCR operation".

- Regarding the power factor requirements:
  - Based on +2.35 MVAR rated reactive capability per wind turbine at rated MW output, the power flow analysis shows that IR668 will need a 26 MVAR capacitor bank at the 34.5 kV bus to meet the power factor requirement of +0.95 on the 230 kV side of the main substation transformer.
  - Based on -1.9 MVAR rated reactive capability per wind turbined at rated MW output, IR668 will need to have the 26 MVAR capacitor bank being switchable and controllable in coordination with the wind farm controller to achieve -0.95 power factor requirement on the 230 kV side of the main substation transformer.
  - Based on all 16 wind turbines equipped with STATCOM capabilities which provide rated +1.7 MVAR and -1.9 MVAR per wind turbine and the switched capacitor bank, IR668 can meet the power factor requirements at 0 MW output.
  - Please note that, depending upon the Part 2 EMT study, requirements for additional resources such as synchronous condenser or other resources may be required for other reasons. If so, these resources may have their own reactive power capability which may help with meeting the power factor requirements.
- The short circuit analysis shows that voltage flicker and harmonics are not expected to be an issue at the POI. If for some reason, in the actual installation, IR668 causes issues with voltage flickers or harmonics, then IR668 will be responsible for mitigating the issues.
- The steady state power flow analysis shows that IR668 addition to the system does not incur any new thermal or voltage violation. The present CBX arming level and limit will need to be reduced accordingly depending upon the output of IR668 and near-by higher queued IRs. The existing Type I RAS (NPCC #119) for CBX will require modification. As IR668 POI will be on L-7003, which has a Limited Impact RAS (NPCC #113), this RAS will also require modification. This RAS also covers the double circuit tower (DCT) lines L-7003 and L-7004 at Canso Causeway and at Trenton. As IR668 POI will be between Canso Causeway and Trenton, this RAS will require a new addition of DCT at Trenton to its logic. Any new RAS or modification of an existing RAS will require submission to and approval of NPCC.
- The stability analysis shows that the power system and IR668 remain stable and well damped for all dynamic contingencies studied hence there is no system upgrades identified for IR668 associated with stability analysis.
- The 230 kV line L-7003, 67N-Onslow and 3C-Port Hastings substation are already Bulk Power System (BPS) and will remain BPS. The dynamic simulations show that the POI substation and the 230 kV line extension from the POI substation to the IC's 230 kV/34.5kV substation, will be BPS and will require the designs to meet NPCC's BPS requirements and NERC's BES requirements. Even though the analysis shows the 230 kV side of the IC substation to be non-BPS, it is so close to the POI BPS substation, only 122 meters apart, the concern of the 230 kV side of the IC substation may become BPS one day was expressed and discussed at the initial report presentation to the IC on March 24, 2023. The discussion recognizes that, since the 122 m 230 kV line extension must be designed for BPS status, to make the 230 kV side of the IC substation to be BPS will involve adding

redundant protection for the 230 kV to 34.5 kV transformer so the extra cost will be minimal. It is recommended to design the 230 kV side of the IC substation to meet NPCC's BPS requirements and NERC's BES requirements.

- The dynamic simulation of NS being suddenly islanded from NB shows that shows that IR668 reduces its output immediately to zero MW then gradually ramps up to rated output and remains stable and well damped post contingency. While this meets the LVRT requirement, it does not provide inertial frequency response as inherently provided by traditional fossil fuel synchronous generators. As more inverter based generators will be added to the NS power system to replace the traditional synchronous generators, the lack of inertial frequency response may increase, and it is expected that the inverter based generators will be required to provide the inertial frequency response or its equivalent in the form of fast frequency response or by synchronous condenser or other means. Please note that NSPI's TSIR, section 7.6.7 requires "WECS Generating Facilities shall support short-duration frequency deviations by providing inertia response equivalent to a Synchronous Generator with an inertia factor (H) of at least 3.0 MW-s/MVA for a period of at least 10 seconds". This issue will be studied in Part 2 EMT study.
- The dynamic simulations show that IR668 meets low voltage ride through (LVRT) capability.
- The power flow analysis shows that the loss factor is +10.7% if IR668 power is measured at its voltage terminal (750 V) or +7.2% if power is measured at IR668 POI (230 kV).

The following facility changes will be required to connect IR668 as NRIS to NSPI transmission system at the POI on L-7003:

- NSPI Transmission Network Upgrades:
    - Installation of a new 230 kV substation complete with a three breaker ring bus at the POI on L-7003. This substation will be designed to meet NPCC's BPS requirements and NERC's BES requirements.
    - Modification of protection system at 67N-Onslow substation and 3C-Port Hastings substation of L-7003 due to the addition of IR668 POI to this line.
    - Modification to a Limited Impact Remedial Action Scheme (RAS), which has a NPCC reference as "Type III SPS#113, 230 PHLO" with NSPI sub-reference as Group 3 for L-7003. This RAS includes a double circuit tower (DCT) line L-7003 and L-7004 at Canso Causeway and at Trenton. As IR668 will be between Canso Causeway and Trenton, a new input will need to be included in this RAS for the Trenton DCT location.
    - Modification to a Type I RAS, which has a NPCC reference as "Type I SPS#119, NS 345 kV SPS", for changes to CBX arming levels and limits due addition of POI BPS substation and the generating facility.
    - Modifications to RASs will require submission to and approval of NPCC.

- New Transmission Provider's Interconnection Facilities (TPIF):
    - Installation of 122 meters of new 230 kV spur line from POI substation to IC substation. This new 230 kV line extension must be designed to meet NPCC BPS requirements and NERC's BES requirements.

  - Installation of NSPI P&C Relaying Equipment.
  - Installation of NSPI supplied RTU.
  - Installation of Tele-protection and SCADA communication.

- New IC Interconnection Facilities (ICIF):
  - As IR668 generating facility will have aggregate rated output greater than 75 MVA, it will require to be designed and operated according to and meeting NERC's BES standards.
  - The 230 kV side of the IC substation will be designed to meet NPCC's BPS and NERC's BES requirements.
  - The 230 kV side of the 230kV/34.5 kV substation is recommended to be designed to meet NPCC BPS requirements and NERC's BES requirements.
  - IR668 must be capable of providing 0.95 leading and lagging power factor at the HV terminals of the IC main substation step up transformer for the full range of IR668 real power output from zero to rated output. The generating facility must be capable of providing rated reactive power at zero MW output. One option for IR668 to meet the power factor requirements is to equip all 16 wind turbines with STATCOM capabilities and install on the 34.5 kV bus a switchable and controllable 26 MVAR capacitor bank working in coordination with the wind farm controller to achieve the power factor requirements.
  - IR668 must provide centralized controls such as a farm control unit (FCU) that can control the 34.5 kV bus voltage to a settable point and will control the reactive output of each wind turbine of IR668 to achieve this common objective. 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 such as section 7.6.6 on "Active Power Control (Fast Frequency Response) and Curtailment" for additional requirements.
  - 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 via NSPI's SCADA (Supervisory Control and Data Acquisition) regarding wind speed, MW and MVAR, bus voltage and curtailment levels.
  - Facilities for NSPI to execute high speed rejection of generation (transfer trip). The plant may be incorporated into RAS 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.
  - Compliance with section 7.6.7 of TSIR, "WECS Generating Facilities shall support short-duration frequency deviations by providing inertia response equivalent to a Synchronous Generator with an inertia factor (H) of at least 3.0 MW-s/MVA for a period of at least 10 seconds.".

- Please note that the assessment of section 7.6.7 of TSIR will be in Part 2 EMT study, which may identify additional resources such as synchronous condenser, Flexible AC Transmission System (FACTS) devices, etc.

The high level non-binding cost estimate in 2023 Canadian dollars for the Network Upgrades is $10.34 million and for the new Transmission Provider's Interconnection Facilities (TPIF) is $0.57 million, for a total of $10.91 million, which includes 10% contingency but excludes HST.

The IC will be responsible for acquiring the ROW (Right-Of-Way) for and access to all the facilities.

This cost excludes any additional costs or changes to be identified by the subsequent Facility Study and Part 2 EMT study as well as any cost associated with ICIF generating facility.

The non-binding estimate for the time to construct NSPI Transmission Network Upgrades is two years after the IC has obtained the necessary easements and ROW. The Facilities Study will confirm the estimated construction time.

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1.0 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR) for Network Resource Interconnection Service (NRIS) to Nova Scotia Power Inc. (NSPI) for a proposed 94.4 MW wind generating facility interconnected to the NSPI transmission system.

This System Impact Study (SIS) is carried out according to the SIS Agreement signed by the IC on August 5, 2022, and NSPI on August 23, 2022. This IR has been designated by the NSPI System Operator as Interconnection Request #668 and will be referred to as IR668 throughout this report.

1.1 Scope

The SIS Agreement states that the Point of Interconnection (POI) of IR668 will be on the 230 kV line L-7003.

The IC provided other documents that indicate:
- POI will be approximately 62 km from 3C-Port Hastings substation.
- A new spur line from the POI to the IC substation will be approximately 122 meters of 230 kV construction using Dove 556ACSR conductors.
- A new three breaker ring bus at POI substation.

The POI is shown on Figure 1. The one line is on Figure 2.

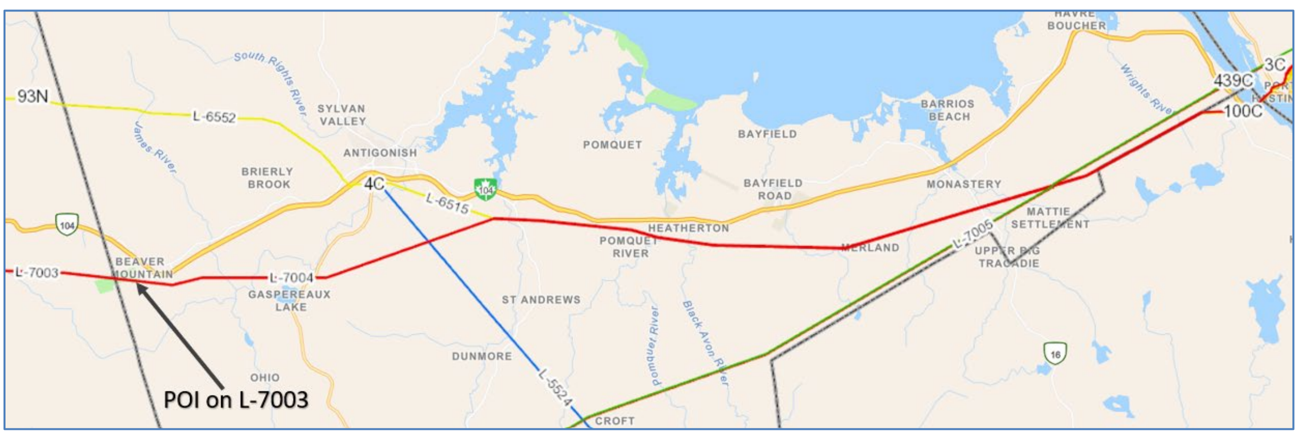

Figure 1: IR668 POI to L-7003

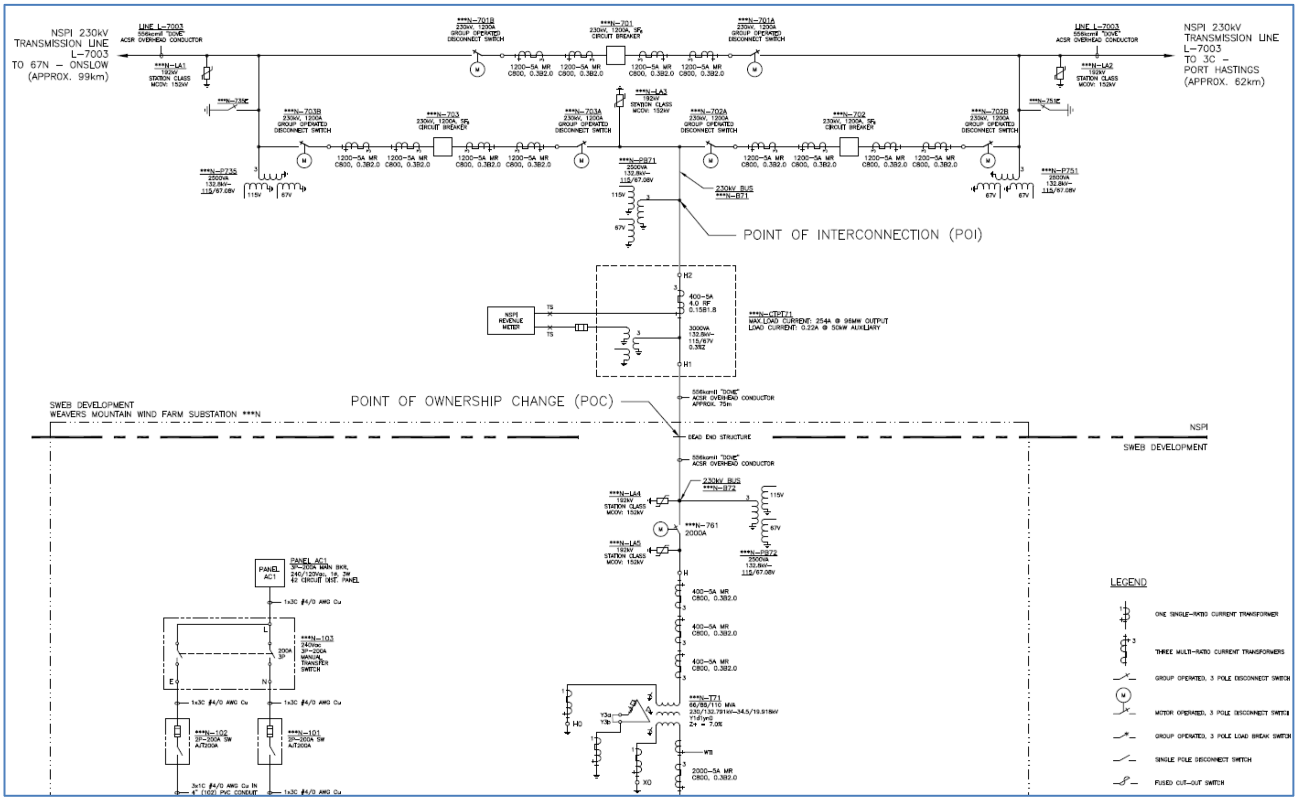

Figure 2: IR668 One-line (provided by IC)

The scope of the SIS Part 1 study is limited to determining the impact of the IR668 generating facility on the NSPI transmission system for the following:

- Short circuit analysis and its impact on circuit breaker ratings.
- Power factor requirement at the high side of the interconnection transformer.
- Voltage flicker and Harmonics.
- Steady state analysis to determine any thermal overload of transmission elements or voltage criteria violation under system normal and contingencies.
- Stability analysis to demonstrate that the interconnected power system is stable and well damped during and post contingencies.
- Bulk Power System (BPS) determination for the substation.
- Low voltage ride through.
- Under frequency operation when NS is suddenly islanded from NB.
- Loss Factor.
- Impact on any existing Special Protection Systems (SPSs) as previously referred to or Remedial Action Scheme as presently known.

This report provides a high-level non-binding cost estimate of requirements for the connection of the generation facility to ensure there will be no adverse effect on the reliability of the NSPI transmission system.

1.2 Assumptions

The study is performed using the following information provided by the IC:

1. Network Resource Interconnection Service (NRIS) with an in-service date of December 1, 2025.
2. The proposed generating facility will be equipped with sixteen Nordex N163 wind turbine generators, each rated at 5.9 MW.
3. Data for individual wind turbine generator step up transformer (750V/34.5 kV) is modeled to have an impedance of 8.5% on 6.35 MVA.
4. The interconnection facility transformer was modelled based on 230 kV grounded wye to 34.5 kV grounded wye and a 12.47 kV delta with a base rating of 66 MVA and a top rating of 110 MVA and +/-5% OLTC. Positive impedance is based on Z=7% of base rating and an X/R ratio of 35 as per the signed Interconnection Request and the SIS agreement. The study was completed, the initial report was issued to the IC for review and comments, and the presentation was made to the IC. After that, the IC has changed the transformer impedance to 10.5% and its X/R to 20. In addition, the IC decided on equipping all 16 wind turbines with the STATCOM capabilities for the purpose of meeting power factor requirement at 0 MW output. Due to these changes, the analysis was reconducted for short circuit, short circuit ratio (SCR), power factor, voltage flicker, and electrical losses in this final report.
5. The POI will be on L-7003 at approximately 62 km from 3C-Port Hastings substation.
6. The collection system is made up of three collector circuits at 34.5 kV. The equivalent circuit impedances are calculated from the provided data.
7. The 230 kV line from the IC main 230 kV substation to the POI will be constructed with Dove ACSR556 conductors with a length of 122 meters.
8. NSPI’s transmission line ratings as last updated and issued on June 13, 2022.

1.3 Project Queue Position

All in-service generation facilities are included in the SIS except for Lingan Unit 2 which is assumed to be retired.

The “Combined T/D Advanced Stage Interconnection Request Queue”, available on NSPI’s OASIS site, captured at the start of this SIS, is shown on Figure 3, 4, and 5.

Combined T/D Advanced Stage Interconnection Request Queue

Publish Date: *Tuesday, November 15, 2022*

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	9/1/2018	GIA Executed	NRIS	NSPI
2 -T	516	05-Dec-14	Cumberland	5	5	37N	Tidal	01-Jul-16	5/31/2020	GIA Executed	NRIS	N/A
3 -T	540	28-Jul-16	Hants	14.1	14.1	17V	Wind	01-Jan-18	10/31/2023	GIA Executed	NRIS	N/A
4 -T	542	26-Sep-16	Cumberland	3.78	3.78	37N	Tidal	01-Jan-19	6/30/2025	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	2/24/2022	GIA Executed	N/A	N/A
7 -D	566	16-Jan-19	Digby	0.7	0.7	509V-301	Tidal	31-Jul-19	4/30/2022	GIA Executed	N/A	N/A
8 -T	574	27-Aug-20	Hants	58.8	58.8	L-6051	Wind	30-Jun-23		GIA Executed	NRIS	N/A
9 -T	598	13-May-21	Cumberland	2.52	2.52	37N	Tidal	01-Dec-22		GIA Executed	NRIS	N/A

Nova Scotia Power - Interconnection Request Queue: Page 1 of 3

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: Advanced Stage IR queue, page 1 of 3

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
10 -D	604	07-Jun-21	Cape Breton	0.45	0.45	11S-303	Solar	15-Jan-22		GIA Executed	N/A	N/A
11 -D	603	31-May-21	Cumberland	0.4	0.4	22N-404	Solar/Battery	16-Feb-22		GIA Executed	N/A	N/A
12 -D	600	27-May-21	Halifax	0.6	0.6	99H-312	Solar/Battery	02-Mar-22		GIA Executed	N/A	N/A
13 -T	597	07-May-21	Queens	36	36	50W	Wind	31-Aug-23		SIS Complete	NRIS	N/A
14 -T	629	20-Sep-21	Cumberland	0.5	0.5	7N	Solar	28-Sep-21		GIA Executed	ERIS	N/A
15 -T	647	06-Oct-21	Cumberland	1.5	1.5	37N	Tidal	31-Dec-23		GIA in Progress	NRIS	N/A
16 -D	653	19-Jan-22	Halifax	0.09	0.09	24H-406	Solar	30-Oct-22		GIA in Progress	N/A	N/A
17 -D	654	16-Feb-22	Halifax	0.125	0.125	127H-413	Solar	20-Sep-22		GIA in Progress	N/A	N/A
18 -T	656	28-Mar-22	Cumberland	4	4	37N	Tidal	31-Dec-22		GIA in Progress	NRIS	N/A
19 -T	672	05-Aug-22	Hants	33.4	33.4	L-5060	Wind	02-Dec-24		SIS in Progress	NRIS	N/A
20 -T	664	26-Jul-22	Lunenburg	50	50	99W	Battery	15-Dec-23		SIS in Progress	NRIS	NSPI
21 -T	662	26-Jul-22	Halifax	50	50	132H	Battery	15-Dec-24		SIS in Progress	NRIS	NSPI

Nova Scotia Power - Interconnection Request Queue: Page 2 of 3

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 4: Advanced Stage IR queue, page 2 of 3

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
22 - T	663	26-Jul-22	Colchester	50	50	1N	Battery	15-Jun-24		SIS in Progress	NRIS	NSPI
23 - T	661	26-Jul-22	Kings	50	50	92V	Battery	15-Mar-24		SIS in Progress	NRIS	NSPI
24 - T	670	05-Aug-22	Colchester	97.98	97.98	L-7005	Wind	28-Feb-26		SIS in Progress	NRIS	NSPI
25 - T	671	05-Aug-22	Halifax	88.96	88.96	L-6004	Wind	28-Feb-26		SIS in Progress	NRIS	NSPI
26 - T	669	04-Aug-22	Cumberland	99	99	L-6613	Wind	31-Dec-25		SIS in Progress	NRIS	N/A
27 - T	668	03-Aug-22	Antigonish	94.4	94.4	L-7003	Wind	01-Dec-25		SIS in Progress	NRIS	N/A
28 - T	618	21-Jul-21	Guysborough	130.2	130.2	L-6515	Wind	01-Jan-25		SIS in Progress	NRIS	N/A
29 - T	673	09-Aug-22	Hants	33.6	33.6	L-6054	Wind	31-Dec-24		SIS in Progress	NRIS	N/A
30 - T	675	10-Aug-22	Queens	112.5	112.5	50W	Wind	01-Dec-24		SIS in Progress	NRIS	N/A
			Totals:	1069.81	1069.8							

Nova Scotia Power - Interconnection Request Queue: Page 3 of 3

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 5: Advanced Stage IR queue, page 3 of 3

According to NSPI's posted Generator Interconnection Procedure (GIP), Transmission Service Requests which are in higher queued positions than IR668 will be modelled and included in IR668 study base cases as the GIP section 4.2 allows for "Transmission Provider may study an Interconnection Request separately to the extent warranted by Good Utility Practice based upon the electrical remoteness of the proposed Generating Facility".

Hence, IRs which are in higher queued positions than IR668 are modelled and included in this SIS, with the exceptions of the following IRs which are considered electrically remote:

- IR540
- IR557
- IR569
- IR566
- IR574
- IR604
- IR603
- IR600
- IR597
- IR629
- IR653
- IR654
- IR672 (was withdrawn prior to IR668 Part 1 SIS R1 Final Report, no impact on IR668)
- IR661 (was withdrawn prior to IR668 Part 1 SIS)
- IR664

- IR662
- IR671

Of the remaining higher queued IRs to be included in this SIS, some are in progress but not yet completed, so the information from the corresponding Feasibility Study will be used to do the modelling. In some cases, to reduce the time to model the details of the local system associated with these higher queued IRs, their generating sources will be modelled directly on the local buses.

As per the GIP, if any of the higher-queued projects included in this SIS are subsequently withdrawn from the Queue, "the Transmission Provider will notify the Interconnection Customer if a SIS re-study is required".

The present Transmission Service Request queue is shown on Figure 6.

Nova Scotia POWER An Emera Company

OATT Transmission Service
Queued System Impact Studies
Active January 31, 2023

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, 2028	550	Facilities Study in Process

* Indicates project as being located near provincial border.

Figure 6: Transmission Service Request Queue

The transmission service request queue was accounted for in this SIS as follows:

- TSR400: included.
- TSR411: excluded as per NSPI's current posting on its GIP site: [Generation Interconnection Procedures| Nova Scotia Power (nspower.ca)]() as shown below:

Nova Scotia POWER An Emera Company | OUTAGE CENTRE | PAY YOUR BILL | START, STOP, MOVE SERVICE | CUSTOMER SERVICE | MYACCOUNT LOGIN

Notices

Please be advised of the following notices.

Due to the ongoing COVID-19 pandemic response there may be delays in processing physical copies of documentation. Please use the contact details above for the Interconnection Engineer to determine suitable submission arrangements.

Due to ongoing development discussions and engineering studies, the Transmission System Network Upgrades identified as part of Transmission Service Request #411 will not be included in the System Impact Study (SIS) Analysis for Generator Interconnection Procedures (GIP) Study Groups #32 and #33. GIP Study Group #32 and #33 analysis will be limited to the 2022 Transmission System configuration plus any material Network Upgrades identified in higher queued projects.

Due to the expected increase in inverter-based generation resources in Nova Scotia and the anticipated decrease in synchronous generation related to the requirement to phase-out of coal fired generation by 2030, GIP System Impact Study analyses are being expanded to include Electromagnetic Transient (EMT) Analysis in addition to Load Flow and Dynamic Analysis. To accommodate this change, Interconnection Customers are required to provide the System Operator with the appropriate PSCAD™ models for their generators in addition to the PSS®E generator models required in the Generator Interconnection Procedures. A separate report will be issued for the Electromagnetic Transient Analysis.

Section 7.6.7 of the Transmission System Interconnection Requirement (TSIR) is currently under review. The review outcome will be posted on OASIS at a later date.

End of Notice

2.0 Technical Model

To facilitate the load flow analysis, the sixteen wind turbines are grouped as one equivalent generator with a terminal voltage of 750V. The voltage is stepped up to 34.5 kV at the collector substation with a single equivalent generator step-up transformer, then to 230 kV via the main substation transformer 34.5 kV to 230 kV, whose high voltage side will be connected to the POI via a spur 230 kV line with an approximate length of 122 meters.

The PSS®E equivalent model for IR668 is shown in Figure 7. The equivalent generator is modelled with rated power of 94.4 MW and +/- 37.6 MVAR, based on the information in the wind turbine technical bulletin.

The equivalent 750 V to 34.5 kV step-up transformer is modelled based on 16 individual wind turbine transformers with each rated at 6.35 MVA and an impedance of 8.5%. The collector equivalent circuit is calculated based on the information provided by the IC.

As for the 34.5 kV to 230 kV IC substation main step up transformer, an impedance of 7% on 66 MVA base rating with a top rating of 110 MVA and an X/R ratio of 35 are modelled in the initial study and report but the impedance was revised to 10.5% on 66 MVA and X/R of 20 at the request of the IC for this final report.

The new 122 meter, 230 kV spur line, from the IC substation to the POI is modeled using NSPI's construction for 230 kV H frame wood pole using Dove, 556 ACSR conductor at 100 degree C.

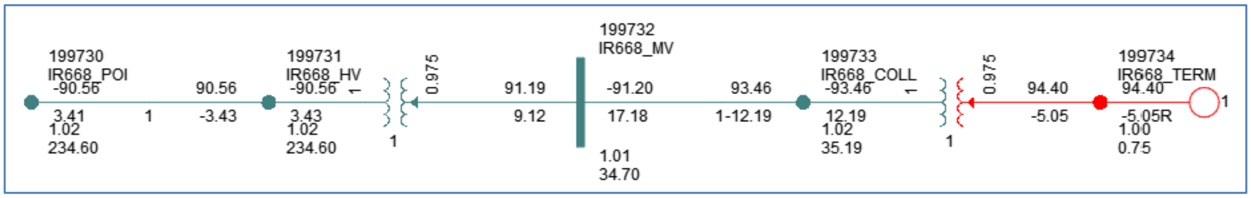

Figure 7: PSS®E model

2.1 System Data

The "*2022 Load Forecast Report",* dated April 29, 2022, produced by NSPI, and submitted to the Nova Scotia Utility and Review Board (NSUARB) was used to allocate the loads in NS. This study uses a Net System Peak Demand of 2,532 MW as shown in Table 1.

Please note that the load forecast includes the power system losses but excludes the station service loads at power generating stations.

Table 1: Study Year Load Forecast

Forecast Year	Season	Net System Peak Demand (MW)	Non-Firm Peak Demand (MW)	Firm Peak Demand (MW)	Demand Response (MW)
2026	Winter Peak	2291	154	2101	-36
2027	Winter Peak	2326	153	2133	-39
2028	Winter Peak	2361	153	2170	-39
2029	Winter Peak	2398	153	2207	-39
2030	Winter Peak	2434	152	2243	-38
2031	Winter Peak	2479	152	2289	-38
2032	Winter Peak	2532	152	2342	-37

As for the summer peak and the light load forecast, their typical values are based on 67% and 35% respectively of the winter peak values.

2.2 Generating Facility

IR668 generating facility will consist of sixteen wind turbine generators with each unit rated at 5.9 MW to provide a total of 94.4 MW. The power flow model of the generating facility is based on the values as described in section 1.2 of this report.

The proposed generating facility will be equipped with a SCADA-based central regulator which controls the individual generator reactive power output to maintain constant voltage at the Interconnection Facility substation.

3.0 Technical Analysis

3.1 Short Circuit

The short circuit capability is modelled based on the information is provided by the wind turbine technical bulletin for IR668.Short circuit analysis was performed using PSSE Version 34. The solution is based on flat voltage profile at 1 per unit voltage**.** The relevant short-circuit levels before and after IR668 are provided in Table 2. Maximum generation includes existing and higher queued generation in NS in service. Minimum generation includes a selected number of generators in NS in service: Tuft Cove 3, Point Aconi, Lingan 4. System normal means all system elements in service.

Table 2: Short-Circuit Levels, Three-phase MVA

Location	**IR668 Off**	**IR668 On**
Maximum Generation System Normal (Magnitude in MVA / Angle in Degree)		
67N-Onslow 230 kV	4395 / -86.06	4483/ -85.94
3C-Port Hastings 230 kV	3590 / -85.20	3700 / -85.07
IR668 POI 230 kV	1831 / -80.96	2023 / -81.13
IR668 34.5 kV	357 / -81.36	701 / -82.54
Minimum Generation System Normal		
67N-Onslow 230 kV	1746 / -87.37	1885 / -86.93
3C-Port Hastings 230 kV	1506 / -86.25	1645 / -85.81
IR668 POI 230 kV	1129 / -83.80	1322 / -83.64
IR668 34.5 kV	334 / -81.66	679 / -82.98
Minimum Generation System Normal Plus L-7003 section IR668-Onslow Out of Service		
67N-Onslow 230 kV	1719 / -87.41	1815 / -87.05
3C-Port Hastings 230 kV	1431 / -86.23	1604 / -85.80
IR668 POI 230 kV	812 / -82.65	1004 / -82.66
IR668 34.5 kV	299 / -81.91	644 / -82.91
Minimum Generation System Normal Plus L-7003 section IR668-Port Hastings Out of Service		
67N-Onslow 230 kV	1718 / -87.41	1881 / -86.94
3C-Port Hastings 230 kV	1433 / -86.24	1494/ -85.88
IR668 POI 230 kV	700 / -81.84	893 / -82.03
IR668 34.5 kV	285 / -81.67	629 / -82.82

The lowest short circuit level, from the above table, is at 34.5 kV bus and is 285 MVA, which equates to a SCR of 3.0 for IR668. For some wind turbine suppliers, SCR less than 4 will require special design, so the IC should discuss with IR668 wind turbine supplier to ensure that the wind turbines can operate at low SCR levels.

Please note that NSPI's TSIR, section 7.4.15, states that "System short circuit level may decline over time with changes to transmission configuration and generation mix. The Generating Facility shall be able to accommodate these changes. If the Point of Interconnection does not provide sufficient SCR for acceptable operation of the Generating Facility, the Interconnection Customer must provide facilities such as synchronous condensers or control systems to permit low SCR operation".

NSPI design criteria for maximum system short circuit capacity (three phase, symmetrical) is 10,000 MVA or 25 kA on 230 kV system voltage. The short circuit table above shows that the maximum short circuit levels are far below 10,000 MVA. As all 230 kV breakers in the area are rated 10,000 MVA for short circuit current interrupting capabilities, IR668 short circuit contribution does not require any uprating of existing breakers in the transmission system.

3.2 Power Factor

NSPI's TSIR (Transmission System Interconnection Requirements, version 1.1, dated February 25, 2021), section 7.6.2 Reactive Power and Voltage Control requires "The Asynchronous Generating Facility shall be capable of delivering reactive power at a net power factor of at least +/- 0.95 of rated capacity to the high side of the plant interconnection transformer" and " Rated reactive power shall be available through the full range of real power output of the Generating Facility, from zero to full power".

In the initial R0 report, the power factor analysis was modelled and studied with the IC 230 kV to 34.5 kV transformer having an impedance of Z=7% on the base rating of 66 MVA and an X/R ratio of 35 as per the signed Interconnection Request and the SIS agreement.

For this final R0 report, the power factor analysis is er-evaluated based on the transformer impedance of 10.5% and the X/R of 20 as per the IC request. In addition, the IC decided on equipping all 16 wind turbines with STATCOM capabilities for the purpose of meeting the power factor requirement at 0 MW output.

Both initial and final R0 reports were based on each wind turbine providing +/- 2.35 MVAR range for a total of +/- 37.6 MVAR range for the wind farm.

Since the IC has changed the rated reactive capability of each wind turbine to +2.35 MVAR and -1.9 MVAR range for a total of +37.6 MVAR and -30.4 MVAR range, the power factor evaluation for the R1 report will be based this new range.

For Qmin evaluation, Figure 8 shows that IR668 can provide a power factor of 0.93 (+90.35 MW and -34.92 MVAR) at the 230 kV voltage side and remains within its regulating MVAR range (-8.55 MVAR is within its range of +37.5 MAVR to -37.6 MVAR). This meets the power factor requirement of 0.95 or less on the 230 kV side when it absorbs MVAR.

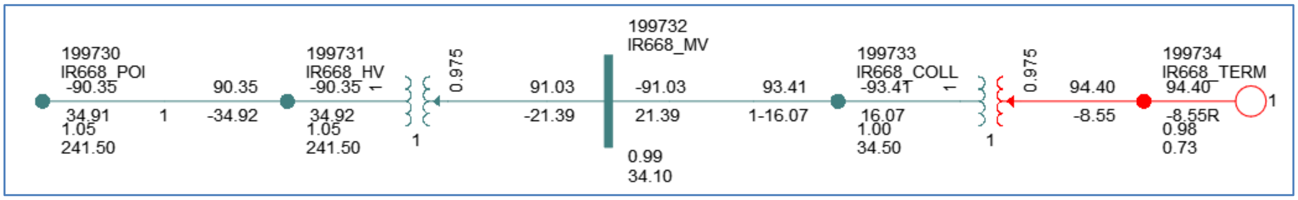

Figure 8: IR668 Power Factor When Absorbing VARs

For Qmax evaluation, Figure 9 shows that even when IR668 provides its Qmax of 37.6 MVAR, the power factor at the 230 kV side of the main substation transformer is 1.0 (+89.67 MW and +6.53 MVAR), which is above 0.95, hence it does not meet the power factor requirement when delivering MVAR.

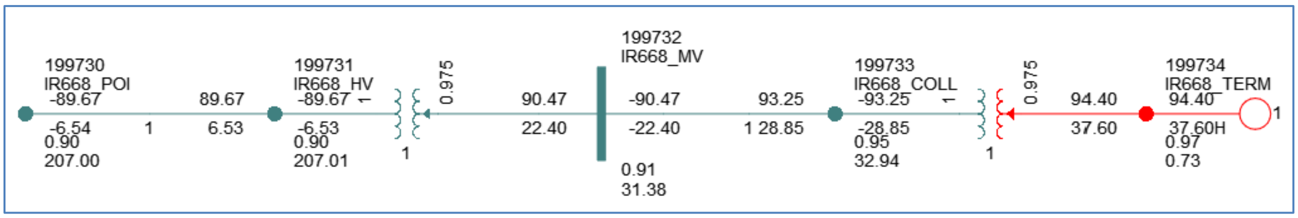

Figure 9: IR668 Power Factor When Delivering VARs

To determine the required MVAR to compensate the power factor to 0.95 at the 230 kV side of the transformer, Figure 10 shows that an addition of 26 MVAR at the 34.5 kV bus will be (+89.86 MW and +29.40 MVAR equate to 0.95 power factor).

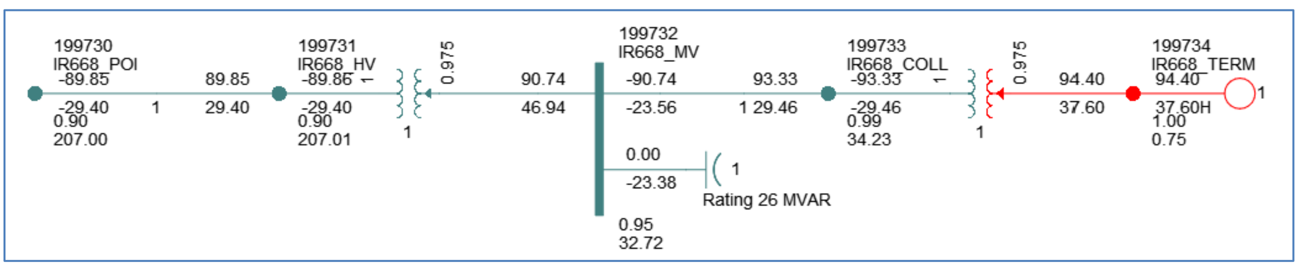

Figure 10: IR668 Plus Additional Capacitor Bank on delivering MVAR.

If the 26 MVAR capacitor bank is in service, Figure 11 shows that IR668 cannot meet the power factor requirement when it absorbs MVAR in the opposite direction. The power factor on the high side of the main substation transformer will be 0.96 (+90.33 MW and -26.65 MVAR) when IR668 absorbs the rated -30.40 MVAR (i.e.-1.9*16). In this case, the capacitor bank needs to be switched out and the power factor requirement will be met as shown in Figure 8.

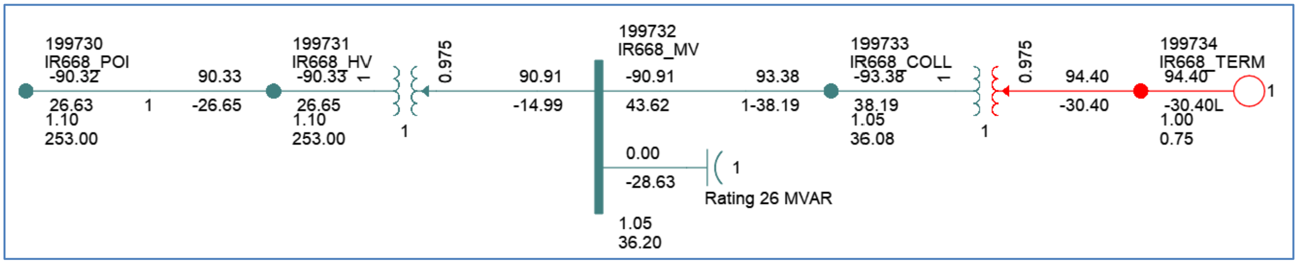

Figure 11: IR668 Plus Additional Capacitor Bank on absorbing MVAR.

The IC confirmed that all 16 wind turbines of IR668 will be equipped with STATCOM capabilities and each turbine can absorb -1.9 MVAR at 0 MW output at unity voltage, hence IR668 meets the rated -1.9 MVAR absorption at 0 MW output.

In conjunction with the switchable 26 MVAR capacitor bank and the STATCOM capabilities, IR668 can meet or exceed the rated MVAR generation at 0 MW. The total delivering MVAR can be 1.7*16 + 26 = 53.2 MVAR which is greater than the rated 37.6 MVAR.

Please note that the pending Part 2 EMT study may identify other resources such as synchronous condenser, flexible AC transmission devices, which can also help with resolving the power factor requirement.

Thus, the power factor requirement will further be assessed by Part 2 EMT study.

3.3 Voltage Flicker & Harmonics

Voltage Flicker contribution is calculated in accordance with the methodology described in CEATI Report No. T044700-5123 “Power Quality Impact Assessment of Distributed Wind Generation”.

The voltage flicker calculation is completed at the POI for the lowest short circuit case. This case has minimum generation and L-7003 section from IR668 to 3C-Port Hastings substation is out of service. If the calculated flicker level meets NSPI’s required levels under this scenario, then voltage flicker should not be an issue in system normal operations.

Under this scenario, based the values provided in the wind turbine technical bulletin, the calculated voltage flicker at the POI 230 kV bus is 0.12 for Pst and Plt for switching operations, which meet NSPI’s requirements of Pst less than 0.25 and Plt less than 0.35, hence voltage flicker is not expected to be an issue for IR668.

As for harmonics, NSPI requires IR668 to meet Harmonics IEEE-519 standard. Since the wind turbine technical bulletin on harmonics states that the harmonics levels are measured at the 750 V wind turbine voltage terminal, the values provided are well below those required in IEEE-519 standard for that voltage level, hence it is expected to meet the harmonic requirements at the 230 kV POI location.

If, for some reason, in the actual installation, IR668 causes issues with voltage flickers or harmonics, then IR668 will be responsible for mitigating the issues.

3.4 Steady State Analysis

3.4.1 Base Cases

There are some transmission lines in the Cape Breton to Mainland corridor that have thermal ratings changed from the values used in 2021 CATR power flow cases to the values in NSPI's latest "Transmission Line Ratings Summary", last updated and issued on June 13, 2022.

Pre IR668, in winter peak cases, 50N-T8 contingency would overload 50N-T12 and vice versa. To resolve it, NSPI is presently designing a new substation to be tapped from L-6507 and L-6508. The case is modified to move the 69 kV load at Trenton bus to the 138 kV bus to reflect this change and to avoid the overload.

For the steady state analysis, fifty four power flow cases were created and studied for this main transmission corridor between Cape Breton and Mainland NS. They are comprised of twenty seven pre-IR668 cases and twenty seven post-IR668 cases.

Pre-IR668 summer peak and winter peak cases are dispatched at pre-IR668 CBX and ONI limits and post-IR668 cases have CBX reduced further by IR668 accordingly as IR668 is studied to displace Cape Breton coal fired generation.

For example, assuming IR668 and the prior higher queued IR670 (98 MW), IR669 (99MW), IR663 (50 MW) are not online, the CBX winter operating limit is between 1050 MW and 1250MW. As all these IRs are studied based on displacing Cape Breton generation, the pre-IR668 CBX winter upper limit will be 1250 – (98 + 99 + 50) = 1003 MW. The post-IR668 CBX winter upper limit will be 1003 – 94.4 = 909 MW. The values are approximate and not exact due to system losses.

Similarly, as IR663 and IR669 are on the Onslow side of ONI, they will cause a reduction of ONI limit. For example, assuming IR663 and UR669 are not online, the ONI summer operating limit is 1275 MW, so pre-IR668 ONI summer limit will be 1275 – (50+99) = 1126 MW. The values are approximate and not exact due to system losses. As IR668 has no impact on ONI limit, it will remain at 1126 MW post-IR668.

The results of post-IR668 steady state contingencies are compared to those of pre-IR668 steady state contingencies for thermal and voltage violations. IR668 will only be responsible for system upgrades that are required to resolve thermal or voltage violations as the result of adding IR668 to the power system, and not any existing system issues.

To differentiate base cases with IR668 off and on, all cases with letter a before .sav have IR668 off and all cases with letter b before .sav have IR668 on at rated output.

Case WP1a.sav has maximum CBX and ONI with IR668 off. Case WP1b.sav has IR668 on, which reduces CBX accordingly because IR668 will displace Cape Breton coal power plants. Since IR668 is before ONI, ONI is kept at its existing maximum limit.

Case WP2a.sav and WP2b.sav have Dalhousie wind farm at rated output while Glendhu wind farm off-line (for maintenance for an example).

Case WP3a.sav and WP3b.sav have Glendhu wind farm at rated output while Dalhousie wind farm off-line (for maintenance for an example).

Case WP4a.sav and WP4b.sav have both Glendhu wind farm and Dalhousie wind farm at rated output.

Case WP5a.sav and WP5b.sav have Trenton 5 and Trenton 6 at rated output.

Case WP6a.sav and WP6b.sav have both Trenton 5 and Trenton 6 off-line.

Case WP7a.sav and WP7b.sav have NB delivering 105 MW of ten minute operating reserve to NS.

Case WP8a.sav and WP8b.sav have NS delivering 170 MW of ten minute operating reserve to NB on top of the firm flow of 150 MW from NS to NB in winter, for a total flow from NB to NB of 320 MW.

Case WP9a.sav and WP9b.sav have NS transmission connected wind farms at 100 % of rated output.

The summer peak and light load cases were developed with similar logics as the winter peak cases, except that some summer peak and light load cases, where NS delivers 170 MW of ten minute operating reserve to NB on top of the firm flow of 330 MW from NS to NB, then the total flow from NS to NB is 500 MW. In addition, in the two light load cases LL5a.sav and LL5b.sav, Trenton 5 and Trenton 6 units are not at maximum output due to system light load and ample wind generation. This is reasonable as wind generation is economically more desirable than fossil fuel. LL9a.sav and LL9b.sav have NS transmission connected wind at 75% as sensitivity cases as the load is light and it is not expected to accommodate 100% wind.

Table 3 shows 54 base cases used in the steady state analysis.

Table 3: Steady State Base Cases

Case Name	NB to NS	NB to PEI	NB to NE	NL to NS	NB to HQ	NB to MPS	CBX	ONI	ONS	NS Load	IR668 Wind	NS Tr. Wind
LL1a.sav	-330	61	1000	330	-441	36	101	327	152	659	0	391
LL1b.sav	-330	61	1000	330	-441	36	88	355	179	659	94	485
LL2a.sav	-330	61	1000	330	-441	36	103	328	152	659	0	391
LL2b.sav	-330	61	1000	330	-441	36	88	353	177	659	94	485
LL3a.sav	-330	61	1000	330	-441	36	127	362	186	659	0	401
LL3b.sav	-330	61	1001	330	-441	36	88	363	187	659	94	495
LL4a.sav	-330	61	1000	330	-441	36	85	336	161	659	0	448

Table 3: Steady State Base Cases											
Case Name	NB to NS	NB to PEI	NB to NE	NL to NS	NB to HQ	NB to MPS	CBX	ONI	ONS	NS Load	IR668 Wind	NS Tr. Wind
LL4b.sav	-330	61	1001	330	-441	36	85	337	161	652	94	542
LL5a.sav	-330	61	1001	330	-441	36	87	354	178	667	0	412
LL5b.sav	-330	60	1000	330	-441	36	88	375	200	659	94	506
LL6a.sav	-330	61	1000	330	-441	36	222	328	152	658	0	391
LL6b.sav	-330	61	1000	330	-441	36	131	328	152	652	94	485
LL7a.sav	105	61	1000	177	-441	36	-63	4	223	652	0	285
LL7b.sav	105	60	999	86	-441	36	-154	4	223	652	94	379
LL8a.sav	-500	61	1001	330	-441	36	214	440	90	673	0	391
LL8b.sav	-500	61	1001	330	-441	36	123	440	90	667	94	485
LL9a.sav	-330	61	1000	421	-441	36	192	305	122	652	0	515
LL9b.sav	-330	61	1000	330	-441	36	101	305	122	652	94	609
SP1a.sav	-330	193	801	475	-797	67	742	1064	774	1591	0	377
SP1b.sav	-330	193	801	475	-797	67	650	1064	774	1591	94	471
SP2a.sav	-330	193	801	475	-797	68	743	1055	765	1594	0	341
SP2b.sav	-330	193	802	475	-797	68	652	1056	765	1594	94	436
SP3a.sav	-330	193	801	475	-797	68	743	1055	765	1594	0	352
SP3b.sav	-330	193	801	475	-797	68	651	1055	765	1594	94	446
SP4a.sav	-330	193	801	475	-797	68	741	1054	764	1594	0	401
SP4b.sav	-330	193	801	475	-797	68	650	1054	764	1594	94	496
SP5a.sav	-330	193	801	475	-797	68	741	1087	797	1594	0	377
SP5b.sav	-330	193	801	475	-797	68	650	1087	798	1594	94	471
SP6a.sav	-330	193	801	475	-797	67	743	786	496	1579	0	377
SP6b.sav	-330	193	801	475	-797	67	652	786	496	1571	94	471
SP7a.sav	105	193	801	175	-797	68	286	624	774	1583	0	377
SP7b.sav	105	193	801	175	-797	68	196	625	774	1575	94	471
SP8a.sav	-500	194	806	475	-797	67	742	1059	594	1594	0	377
SP8b.sav	-500	194	805	475	-797	67	650	1058	595	1586	94	471
SP9a.sav	-330	193	801	475	-797	67	561	924	697	1575	0	686
SP9b.sav	-330	193	801	475	-797	67	470	924	697	1567	94	780
WP1a.sav	-150	294	2	475	-912	76	1040	1179	1004	2391	0	460
WP1b.sav	-150	294	2	475	-912	76	948	1180	1004	2391	94	554
WP2a.sav	-150	294	0	475	-912	76	1006	1178	1003	2391	0	464
WP2b.sav	-150	294	0	475	-912	76	914	1178	1003	2391	94	559
WP3a.sav	-150	294	2	475	-912	76	1041	1179	1004	2391	0	475
WP3b.sav	-150	294	2	475	-912	76	949	1180	1004	2391	94	569
WP4a.sav	-150	294	2	475	-912	76	1040	1179	1004	2391	0	524
WP4b.sav	-150	294	2	475	-912	76	948	1179	1004	2391	94	619
WP5a.sav	-150	294	2	475	-912	76	950	1178	1003	2391	0	460
WP5b.sav	-150	294	2	475	-912	76	858	1178	1003	2391	94	554
WP6a.sav	0	294	2	475	-912	76	801	792	768	2360	0	524

Table 3: Steady State Base Cases												
Case Name	NB to NS	NB to PEI	NB to NE	NL to NS	NB to HQ	NB to MPS	CBX	ONI	ONS	NS Load	IR668 Wind	NS Tr. Wind
WP6b.sav	0	294	2	475	-912	76	708	792	768	2360	94	619
WP7a.sav	105	192	0	237	-912	76	420	681	763	2367	0	460
WP7b.sav	105	192	0	237	-912	76	329	681	763	2367	94	554
WP8a.sav	-320	294	7	475	-912	76	916	1155	807	2448	0	460
WP8b.sav	-320	294	6	475	-912	76	823	1154	807	2448	94	554
WP9a.sav	-150	294	2	475	-912	76	810	1026	895	2375	0	686
WP9b.sav	-150	294	3	475	-912	76	719	1026	895	2367	94	781

3.4.2 Steady-State Contingencies

The NS and NB contingencies for each of the forty eight power flow cases are shown in Table 4.

Table 4: Steady State Contingencies						
101S_701	132H_606	50N_T12	91H_513	L5036	L6005_L6016	L6613
101S_702	1C_689	50N_T8	91H_516	L5037_L3031	L6006	L7001
101S_703	1C_B61	50NB57_L5500	91H_521	L5039	L6007	L7002
101S_704	1C_B62	50NB61	91H_523	L5040	L6008	L7003_7004a*
101S_705	1C_G2	50NB62	91H_603	L5041	L6009	L7003_7004b*
101S_706	1H_LOL	67N_701	91H_604	L5042	L6010	L7003a
101S_711	1N_600	67N_702	91H_605	L5049	L6010_L6011	L7003b
101S_712	1N_601	67N_703	91H_606	L5054	L6011	L7004
101S_713	1N_613	67N_704	91H_607	L5058	L6013	L7005Has
101S_811	1N_B51	67N_705	91H_608	L5500	L6014	L7005Ons
101S_812*	1N_B52	67N_706	91H_609	L5501	L6015	L7008
101S_813*	1N_B61	67N_710	91H_611	L5502	L6016	L7009
101S_814	1N_B62	67N_713	91H_613	L5505	L6020	L7011
101S_816	1N_C61	67N_811*	91H_621	L5506	L6021	L7012
101S_T81	1N_T1	67N_812	91H_T11	L5507_L5508	L6025	L7014
101S_T82	1N_T4	67N_813	91H_T62	L5511	L6033	L7015
103H_600	2CB61*	67N_814*	91H_TC3	L5512	L6033_L5039	L7019
103H_608	2CB62*	67N_T71	91N_701	L5521	L6033_L6035	L7021
103H_681	2S_513	67N_T81	IR670	L5524	L6035	L7021_L6534
103H_881	2S_600	67N_T82	L1108	L5530	L6038	L7022
103H_B61	2S_B64	67N711*	L1142	L5532	L6040	L8001
103H_B62	2S_B65	67N712*	L1143	L5533_L5581	L6040_L6042	L8002
103H_T81	2S_T1	74N_B61	L1148_L1151*	L5534	L6042	L8002_L7009
104H600	2S_T2	74NT61	L1157	L5535	L6043	L8003_G6
108H_600	30N_B61	79N-T81	L1190	L5536	L6044	L8004_g6
108H_B1	30NT61	85S_B61	L1190_L1215	L5537	L6047	ML_2Poles
108H_B3	3C_711	85S_G1	L1244	L5538	L6048	ML_Pole1

Table 4: Steady State Contingencies

113H_600	3C_712	88S_710	L3004	L5539	L6051	ML_Pole2
120H_621	3C_713	88S_711	L3006	L5541	L6052	PHP
120H_622	3C_714	88S_712	L3013	L5546	L6053	L7008_7009
120H_623	3C_715	88S_713	L3017_L3019	L5547_L5551	L6055	ME1-10
120H_624	3C_716	88S_714	L5003	L5548	L6503	ME1-11
120H_625	3C_T71	88S_715	L5011	L5549	L6507	ME1-12
120H_626	3C_T72	88S_720	L5012	L5550_L5582	L6507_L6508	ME1-13
120H_627	3C710*	88S_721	L5014	L5559_L5579	L6508	ME1-14
120H_628	3C720*	88S_722	L5015	L5560	L6510	ME1-15
120H_629	3S_T1	88S_723	L5016	L5561_L5565	L6511	ME1-16
120H_710	47C_602	88S_G4	L5017	L5563	L6514	ME1-6
120H_711	47C_603	88S_T71	L5019	L5564_L5576	L6515	ME1-7
120H_712	47C_674	88S_T72	L5020	L5571	L6516	ME1-8
120H_713	47C_T63	89S_G1	L5021	L5573_L5575	L6517	ME1-9
120H_714	47C_T64	90H_602	L5023_L5053	L5580	L6518	ME3-1*
120H_715	47C_T65	90H_603	L5024	L6001	L6523	ME3-2*
120H_716	47C_T67	90H_605	L5025	L6002_90H	L6531	ME3-3*
120H_720	49N_600	90H_606	L5026	L6002_99W	L6535	Mem_T3
120H_SVC	4C_T2	90H_608	L5027	L6003	L6536	Point Lepreau
120H_T71	4C_T63	90H_609	L5028	L6003_L6007	L6537	
120H_T72	50N_500	90H_611	L5029_L5030	L6003_L6009	L6538	
132H_602	50N_604	90H_612	L5032_L5004	L6004	L6539	
132H_603	50N_B55	90H_T1	L5033	L6005	L6551	
132H_605	50N_G6	91H_511	L5035	L6005_L6010	L6552	

Contingencies with "*" denote applicable Remedial Action Scheme (RAS) available for service. In NS, prior to the adoption of the terms RAS, these schemes were known as SPS (Special Protection Scheme).

L7003a is the line section between IR668 POI substation and 67N-Onslow substation. L7003b is the line section between IR668 POI substation and IR668 POI substation and 3C-Port Hastings substation.

3.4.3 Steady-State Result

Thermal ratings of transmission equipment in NS and NB are checked against rate A under system normal (all equipment in service). Post contingency system conditions are checked against rate B in NS while in NB, if rate B is exceeded, then it is checked against rate C, and if it passes Rate C, then it is acceptable in NB.

In NS and NB, system voltage criteria are 0.95 to 1.05 per unit under system normal and 0.9 to 1.1 per unit under contingencies.

The steady state power flow analysis showed that IR668 addition to the system does not incur any new thermal or voltage violation. The present CBX arming level and limit will need to be reduced accordingly depending upon the output of IR668, hence the existing Type I RAS (NPCC Type I SPS#119, NS 345 kV SPS) will require modification. In addition, as IR668 POI will be on L-7003, which has a limited impact RAS (NPCC Type III SPS#113, 230 PHLO), this RAS will also require modification, including the double circuit tower L-7003 and L7004 at Canso Causeway. As IR668 will be between Trenton and Port Hastings, this RAS will require the addition of Trenton location to its logic. Any new RAS or modification of an existing RAS will require submission to and approval of NPCC.

For each of 54 power flow cases, 352 steady state contingencies were performed for a total of 19,008 simulations. The results are too large to practically include in this report; hence they are contained in a companion document called "Appendices for Report GIP_IR668_SIS_Part1_R1".

3.5 Stability Analysis

The stability analysis is conducted based on NSPI design criteria and NPCC planning criteria that require the system to be stable and well damped following first contingencies (from system normal) as defined in these criteria.

3.5.1 Stability Base Cases

Of the 54 power system cases used in steady state analysis, only twenty seven cases with IR668 being on-line at rated output are used in the system stability analysis as shown in Table 5. The table also includes a case with NS importing 300 MW from NB for simulation of NS islanding, and another case for simulation to determine BPS buses.

If any contingency simulation with IR668 being on-line causes system instability, then the simulation would be repeated with IR668 off-line to determine if the system instability already exists prior to the installation of IR668.

Table 5: Stability Base Cases

Case Name	NB to NS	NB to PEI	NB to NE	NL to NS	NB to HQ	NB to MPS	CBX	ONI	ONS	NS Load	IR668 Wind	NS Tr. Wind
LL1b.sav	-330	61	1000	330	-441	36	88	355	179	659	94	485
LL2b.sav	-330	61	1000	330	-441	36	88	353	177	659	94	485
LL3b.sav	-330	61	1001	330	-441	36	88	363	187	659	94	495
LL4b.sav	-330	61	1001	330	-441	36	85	337	161	652	94	542
LL5b.sav	-330	60	1000	330	-441	36	88	375	200	659	94	506
LL6b.sav	-330	61	1000	330	-441	36	131	328	152	652	94	485
LL7b.sav	105	60	999	86	-441	36	-154	4	223	652	94	379

Table 5: Stability Base Cases												
Case Name	NB to NS	NB to PEI	NB to NE	NL to NS	NB to HQ	NB to MPS	CBX	ONI	ONS	NS Load	IR668 Wind	NS Tr. Wind
LL8b.sav	-500	61	1001	330	-441	36	123	440	90	667	94	485
LL9b.sav	-330	61	1000	330	-441	36	101	305	122	652	94	609
SP1b.sav	-330	193	801	475	-797	67	650	1064	774	1591	94	471
SP2b.sav	-330	193	802	475	-797	68	652	1056	765	1594	94	436
SP3b.sav	-330	193	801	475	-797	68	651	1055	765	1594	94	446
SP4b.sav	-330	193	801	475	-797	68	650	1054	764	1594	94	496
SP5b.sav	-330	193	801	475	-797	68	650	1087	798	1594	94	471
SP6b.sav	-330	193	801	475	-797	67	652	786	496	1571	94	471
SP7b.sav	105	193	801	175	-797	68	196	625	774	1575	94	471
SP8b.sav	-500	194	805	475	-797	67	650	1058	595	1586	94	471
SP9b.sav	-330	193	801	475	-797	67	470	924	697	1567	94	780
WP1b.sav	-150	294	2	475	-912	76	948	1180	1004	2391	94	554
WP2b.sav	-150	294	0	475	-912	76	914	1178	1003	2391	94	559
WP3b.sav	-150	294	2	475	-912	76	949	1180	1004	2391	94	569
WP4b.sav	-150	294	2	475	-912	76	948	1179	1004	2391	94	619
WP5b.sav	-150	294	2	475	-912	76	858	1178	1003	2391	94	554
WP6b.sav	0	294	2	475	-912	76	708	792	768	2360	94	619
WP7b.sav	105	192	0	237	-912	76	329	681	763	2367	94	554
WP8b.sav	-320	294	6	475	-912	76	823	1154	807	2448	94	554
WP9b.sav	-150	294	3	475	-912	76	719	1026	895	2367	94	781
SP10b.sav	300	193	808	0	-797	68	180	470	811	1583	94	471
WP10b.sav	-150	294	0	475	-912	76	1250	1275	954	2391	0	298

3.5.2 Stability Contingencies

The selected stability contingencies in NS and NB used in this SIS are shown in Table 6.

Table 6: Stability Contingencies				
IR668_POI 3P	103H L6008 3P	3C BBU 3C-713	67N BBU 67N-811 T82*	91N BBU 91N-701
IR668_HV 3P	103H L6016 3P	3C BBU 3C-714	67N BBU 67N-813	91N L7004 3P*
IR669_POI 3P	103H L6033 3P	3C BBU 3C-715*	67N BBU 67N-814*	91N L7019 3P*
IR669_HV 3P	103H L8002 3P	3C BBU 3C-716	67N L7001 3P	DCT 6005_6010
IR670_POI 3P	108H L6055 3P	3C L7003b 3P*	67N L7003a 3P*	DCT 6005_6016
IR670_HV 3P	120H BBU 120H-622	3C L7004 3P	67N L7005 3P*	DCT 6010_6011
101S BBU 101S-701*	120H BBU 120H-710	3C L7005 3P*	67N L7018 3P	DCT 6033_6035
101S BBU 101S-702*	120H BBU 120H-715	3C L7012 3P*	67N L7019 3P	DCT 6507_6508 50N
101S BBU 101S-706	120H L6005 3P	3C T71 3P	67N L8001 3P*	DCT 6507_6508 79N

Table 6: Stability Contingencies

101S BBU 101S-712	120H L6010 3P	410N L3006 3P	67N L8002 3P	DCT 6534_7021
101S BBU 101S-811	120H L6011 3P	410N L8001 3P*	67N L8003 3P*	DCT 7003b_7004 3C*
101S BBU 101S-812*	120H L6016 3P	4C BBU 4C-621 3P	79N BBU 79N-601*	DCT 7003a_7004 50N*
101S BBU 101S-813*	120H L7008 3P	50N B61 3P	79N BBU 79N-803*	DCT 7008_7009
101S L7011 3P*	120H L7018 3P	50N B62 3P	79N BBU 79N-810*	DCT 7009_8002
101S L7012 3P*	1N BBU 1N-601	50N L6503 3P	79N L6507 3P	DCT 7009_8002 A
101S L7014 3P	1N BBU 1N-613	50N L6507 3P	79N L8003 3P*	50N_604 BBU LG
101S L7021 3P	1N BKR 1N-600 1P	67N BBU 67N-701	79N L8004 3P*	2S-513 BBU L-G LOL
101S L7022 3P	1N BUS 1N-B61 3P	67N BBU 67N-702	79N T81 HV*	104H-600 BBU L-G LOL
101S L8004 3P*	1N L6001 3P	67N BBU 67N-703	88S BBU 88S-713	47C-602 BBU L-G LOL
101S MLBIPOLE 1LG	1N L6503 3P	67N BBU 67N-704	88S BBU 88S-720	47C-603 BBU L-G LOL
101S MLBIPOLE 3P	1N L6613 3P	67N BBU 67N-705	88S BBU 88S-721	47C-674 BBU L-G LOL
101S MLPOLE1 3P	2C BUS 2C-B61 3P*	67N BBU 67N-706	88S BBU 88S-722	1N BUS 1N-B62 3P
101S MLPOLE2 3P	2C BUS 2C-B62 3P	67N BBU 67N-710	88S BBU 88S-723*	Flat No Fault
103H BBU 103H-608	2C L6515 3P	67N BBU 67N-711	88S L7014 3P	**Legend Notes:**
103H BBU 103H-681	3C BBU 3C-710*	67N BBU 67N-712	88S L7021 3P	* Applicable RAS
103H BBU 103H-881	3C BBU 3C-711*	67N BBU 67N-713	88S L7022 3P	L7003a:IR668-67N
103H BKR 103H-600	3C BBU 3C-712*	67N BBU 67N-811*	90H L6008 3P	L7003b:IR668-3C

3.5.3 Stability Results

After testing and tuning the dynamic model, using the dynamic parameters for IR668 as shown in Figure 12, IR668 and the power system remain stable and well damped for all contingencies studied, hence there is no stability issue associated with the addition of IR668 to the power system. There are some other generator models in the power system that require some changes, but they are unrelated to IR668. In some light load cases with high level of wind generation online, existing gas turbines at generating plants at Burnside or V.J. need to be online in synchronous condenser modes for the system to be stable under some contingencies.

For each 27 stability cases with IR668 dispatched at rated output, 131 dynamic simulations were performed for a total of 3,537 simulations. The resultant dynamic plots are too large to practically include in this report; hence they are contained in a companion document called "Appendices for Report GIP_IR668_SIS_Part1_R1".

The dynamic plots show that IR668 and the power system remain stable and well damped for all contingencies studied, hence there is no stability issue associated with the addition of IR668 to the power system, and hence no system upgrades are attributed to IR668 due to system instability.

```
199734 'USRBUS' 'PLNTBU1' 504 0 7 28 7 15
199733  199734  199733  '1'  1  1  1
0.1  8.5  2.50  0.15  10  0.87  0  0  0.0  1  -1  0  0  0.39830508474576
-0.39830508474576   3.5  0.5  0.001  -0.00833  0.00833  999  -999  2  -2
0.01  20  20  94.4  /
199734 'USRMDL' '1' 'REAX3BU1' 107 0 1 7 2 4
199733  0.01  1  1  0.398305084745763  -0.398305084745763  1.20  -1  /
19973401 'VTGTPAT'  199734  199734 '1'  1.251  1.5    100.0   0.0  /
19973402 'VTGTPAT'  199734  199734 '1'  1.175  1.25   200.0    0.0  /
19973403 'VTGTPAT'  199734  199734 '1'  1.1    1.174  300.0  0.0  /
19973404 'VTGTPAT'  199734  199734 '1'  0.91   1.1    300.0  0.0  /
19973405 'VTGTPAT'  199734  199734 '1'  0.451  0.9    200.0   0.0  /
19973406 'VTGTPAT'  199734  199734 '1'  0.0    0.45   100.0    0.0  /
19973407 'FRQTPAT'  199734  199734 '1'  62.0   65.0   200.0  0.0/
19973408 'FRQTPAT'  199734  199734 '1'  50.0   56.0   200.0  0.0/
199734 'REGCA1' '1'
0
0.01  0.58  0.9  0.4  1.1  1.1  -0.9  -0.1  -1.2  0.01  0.53  999  -999  1  /
199734 'REECA1' '1'
0  0  0  0  0  0
0.87  1.15  0.02  0.0  0.0  3.5  1  -0.8  0  0  0  0  0.05  0.398305084745763
-0.398305084745763  1.1  0.9  1.1  0.01  2  0.115  0  0.001  2  -2  1.2  0
1.16  0.02  0.099  0  0.10  1  0.8  1.00  0.92  0.38  0.001  0.001  0.5
0.50  0.89  1.00  0.90  1.20  /
199734 'WTDTA1' '1'
7.357  0  0.9338  1.75  1.9  /
199734  'WTPTA1' '1'
0.5  89  0  0  0  0.18  90  0  8  -8  /
199734  'WTARA1' '1'
0.01  0  /
199734 'WTTQA1' '1'
1
8  1.3  0.02  5  1  0  0  0.60  1.3  0.62  0.6  0.97  1  1  94.4  /
```

Figure 12: IR668 Dynamic Parameters

3.6 Bulk Power System (BPS) Analysis

NSPI is a member of NPCC and adheres to NPCC's requirements, including the requirements for BPS. The methodology for determining if a substation is BPS is defined in NPCC's criteria document A-10 titled "Classification of Bulk Power System Elements", Version 3, dated May 6, 2020.

The existing L-7003, 67N-Onslow and 3C-Port Hastings are already Bulk Power System (BPS) and will remain BPS, hence L7003 must be designed to meet BPS at the POI substation.

The dynamic simulation plot for applying A-10 test to the POI bus, using base case WP10b.sav, shown in Figure 13, shows the system being unstable, hence the POI substation will be BPS.

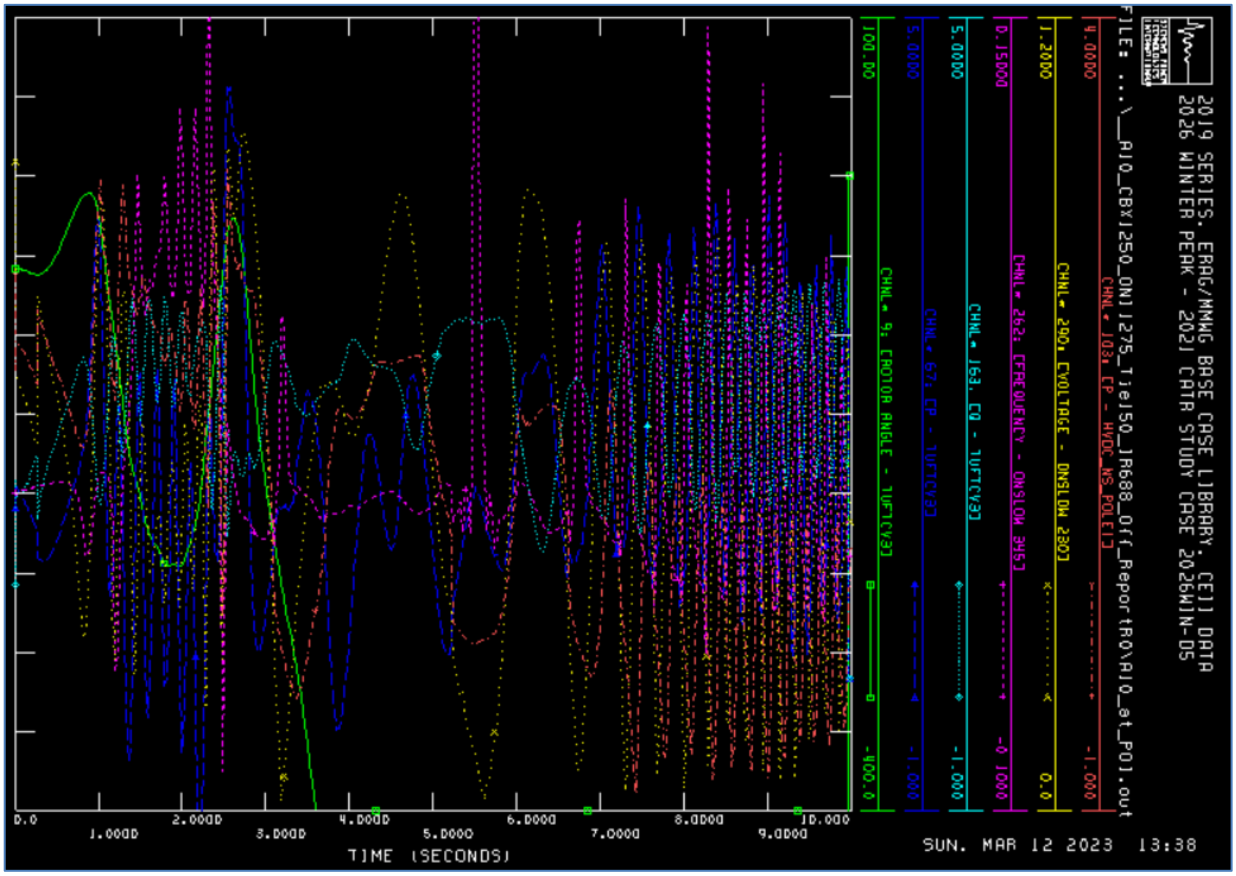

Figure 13: A-10 simulation shows POI 230 kV bus BPS.

Once a bus is identified as BPS, the A10 criteria require the adjacent buses to be tested for BPS. The dynamic simulation was repeated for the IC's 230kV/34.5kV substation on the 230 kV bus.

The dynamic simulation plot for applying A-10 test to the 230 kV bus at the IC's 230 kV to 34.5 kV substation, shown in Figure 14, shows the system being stable and well damped, hence the 230 kV side of the IC substation will be non-BPS. However, as the 230 kV line extension from POI sub to the IC sub is part of POI's 230 kV bus BPS, hence this line extension will be BPS.

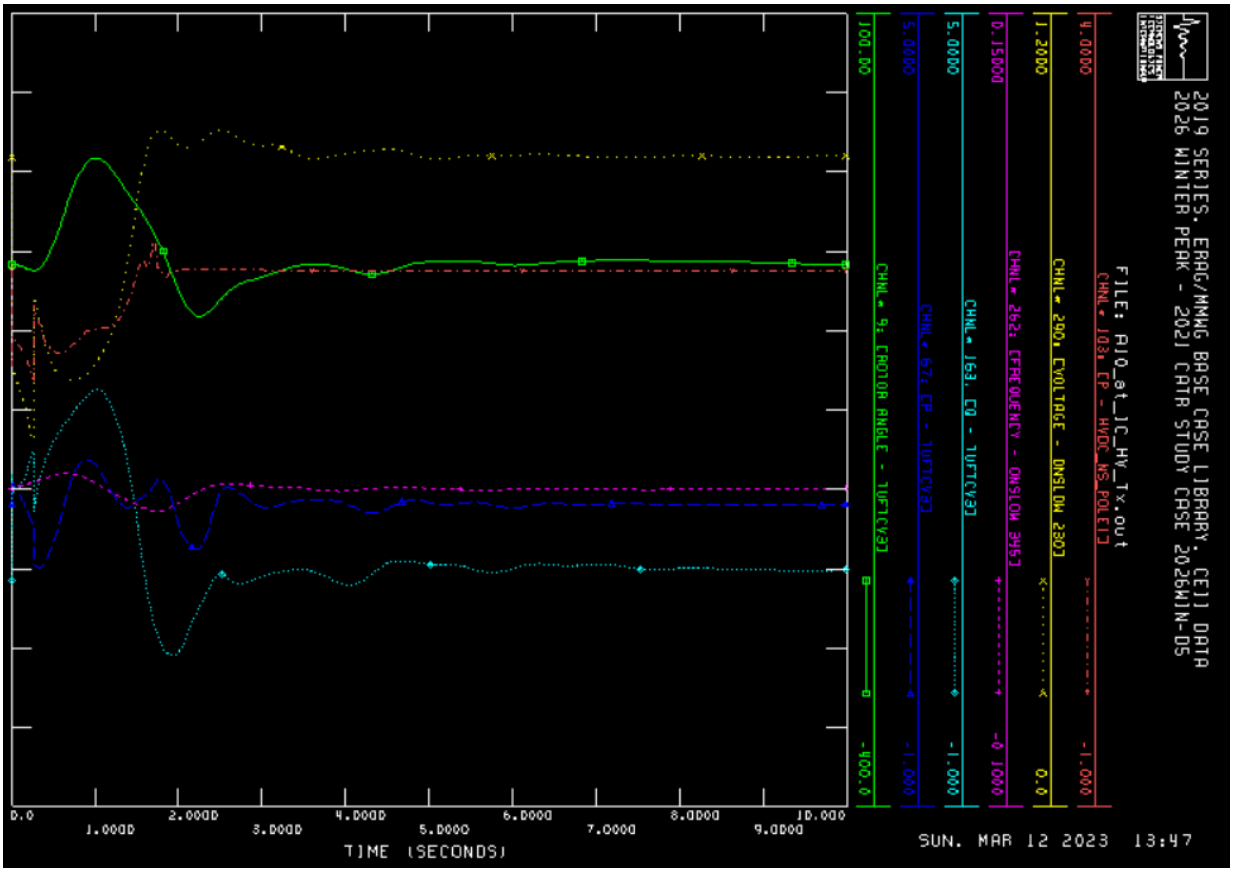

Figure 14: A-10 stability simulation result shows 230 kV bus at IC sub non-BPS.

The dynamic simulation plot for applying A-10 test to the 34.5 kV bus at the IC's 230 kV to 34.5 kV substation, shown in Figure 15, shows the system being stable and well damped, hence the 34.5 kV side of the IC substation will be non-BPS.

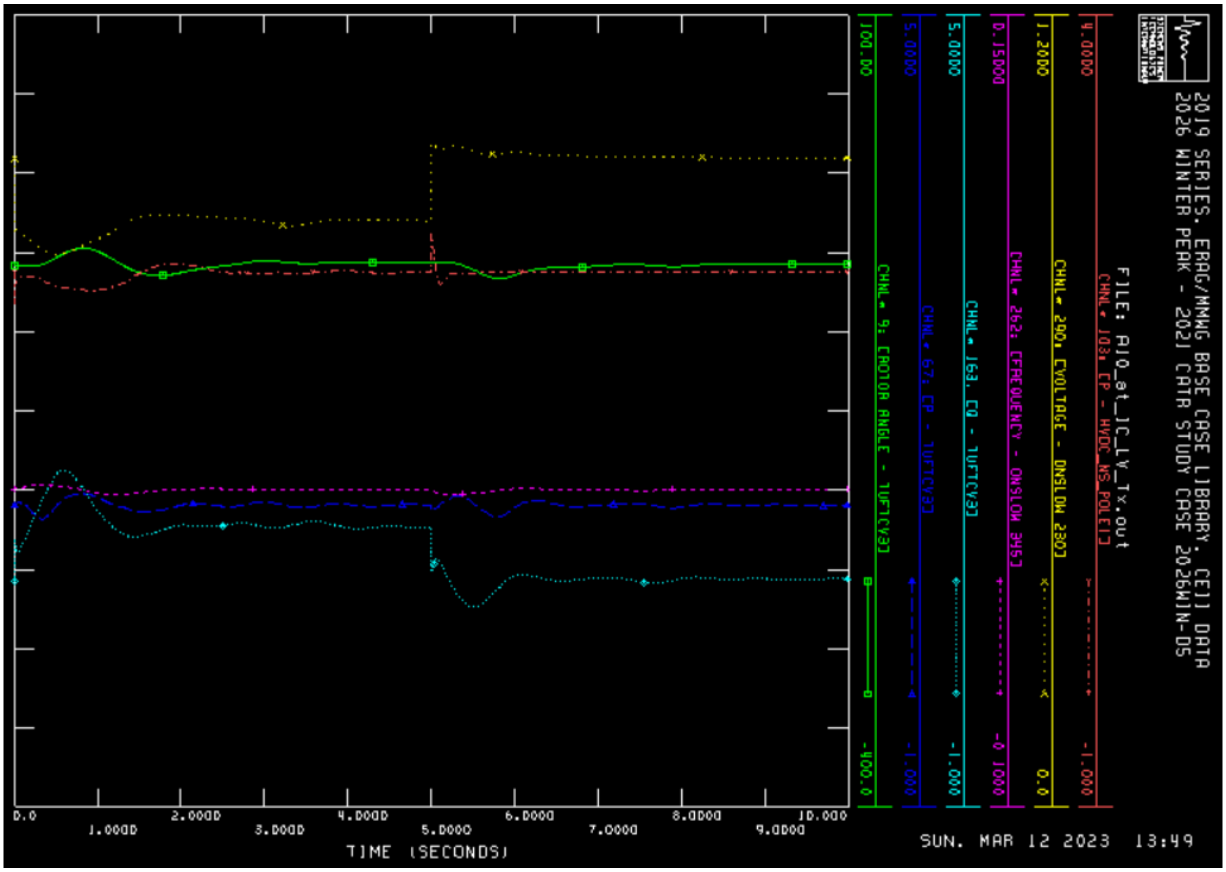

Figure 15: A-10 stability simulation result shows 34.5 kV bus non-BPS.

The above analysis shows that the POI 230 kV substation and the spur 230 kV line from the POI substation to the IC's 230kV/34.5kV substation will be BPS and must be designed to meet NPCC's BPS requirements and NERC's BES requirements.

Even though the analysis shows the 230 kV side of the IC substation to be non-BPS, it is so close to the POI BPS substation, only 122 meters apart, the concern of the 230 kV side of the IC substation may become BPS one day was expressed and discussed at the initial report presentation to the IC on March 24, 2023. The discussion recognizes that, since the 122 m 230 kV line extension must be designed for BPS status, to make the 230 kV side of the IC substation to be BPS will involve adding redundant protection for the 230 kV to 34.5 kV transformer so the extra cost will be minimal. It is recommended that the design for the 230 kV side of the IC substation meets NPCC's BPS requirements and NERC's BES requirements.

3.7 Under Frequency Operation

Nova Scotia is connected to the rest of the Eastern Interconnection power network by a 345 kV line L-8001 and two 138 kV lines L-6535 and L-6536 to New Brunswick. Under certain import conditions, if L-8001 trips or NB trips L-3025 or L-3006, an 'Import Power Monitor' RAS will cross-trip L-6613 at 67N-Onslow to avoid its thermal overload or uncontrolled separation. The Nova Scotia system is then islanded and relies on under frequency load shedding (UFLS) schemes to shed load across Nova Scotia to make up the generation deficiency and restore balance. During and post NS islanding, IR668 is required to remain online and not to trip.

The present NERC standard PRC-006-NPCC-2, “Automatic Underfrequency Load Shedding”, requires the under frequency trip settings of IR668 wind turbine generators must be set below the black trace for Eastern Interconnection in Figure 2 of the standard, which shown on Figure 16.

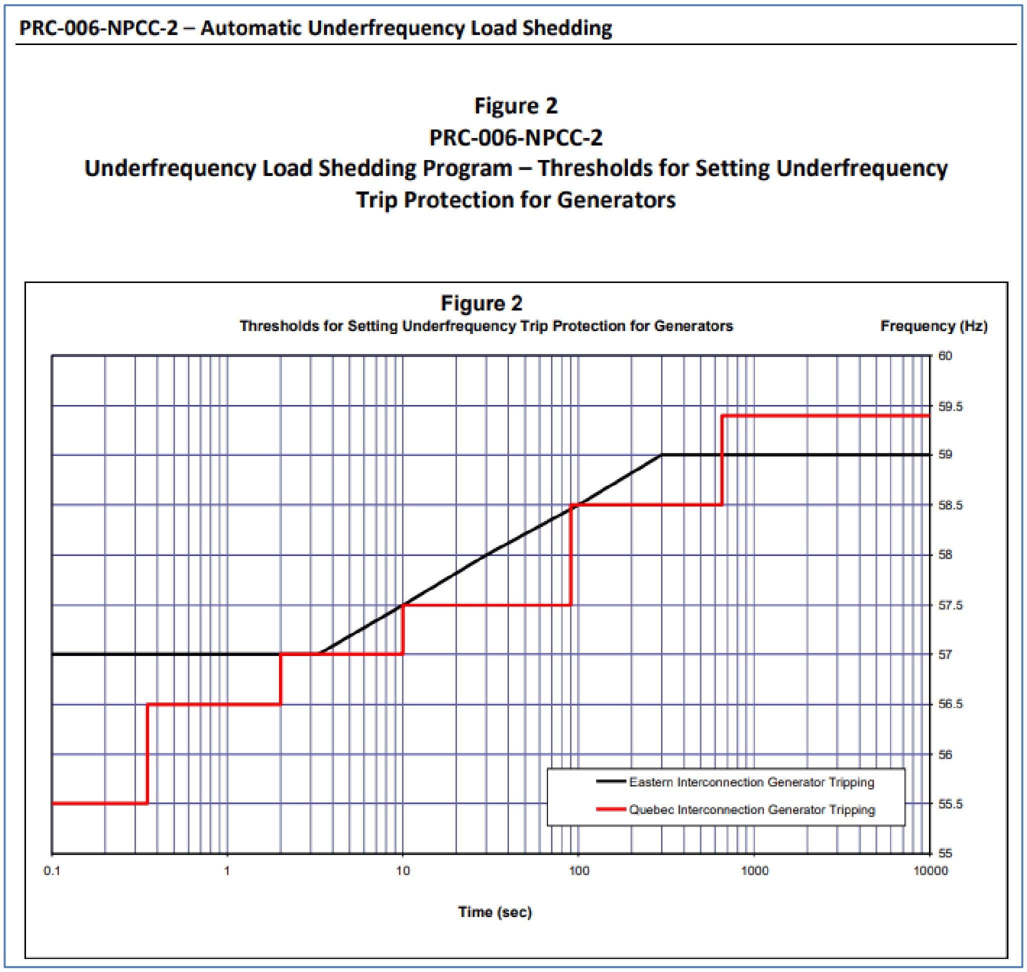

Figure 16: PRC-006-NPCC-2 UFLS Setting Requirement for IR668

The dynamic simulation for IR668 under frequency performance was based on a summer peak case, SP10b.sav, with Nova Scotia importing 300 MW from New Brunswick. A three phase fault is simulated on L-8001, which would cause L-8001 to send a transfer trip to L-6613 at 1N-Onslow terminal. This event causes both L-8001 and L-6513 to trip and island Nova Scotia.

The simulation shows that NSPI under-frequency load shedding (UFLS) scheme activates, shedding 313.8 MW of NS load to stabilize system frequency. The simulation also shows that IR668 reduces its output immediately to zero MW then gradually ramps up to rated output as per its LVRT designed action and IR668 remains stable and well damped post contingency as shown on Figure 17. While this meets the LVRT requirement, it does not provide inertial frequency response, inherently provided by traditional synchronous generators. As more inverter based generators will be added to NS power system to r1eplace the fossil fuel synchronous generators, the lack of inertial frequency response may increase, and it is expected that the inverter based generators will be required to provide the inertial frequency response in the form of fast frequency response or by other means such as synchronous condenser, FACTS etc. This issue will be studied in Part 2 EMT study.

Figure 18 shows NS system frequency stabilizes after being islanded from NB.

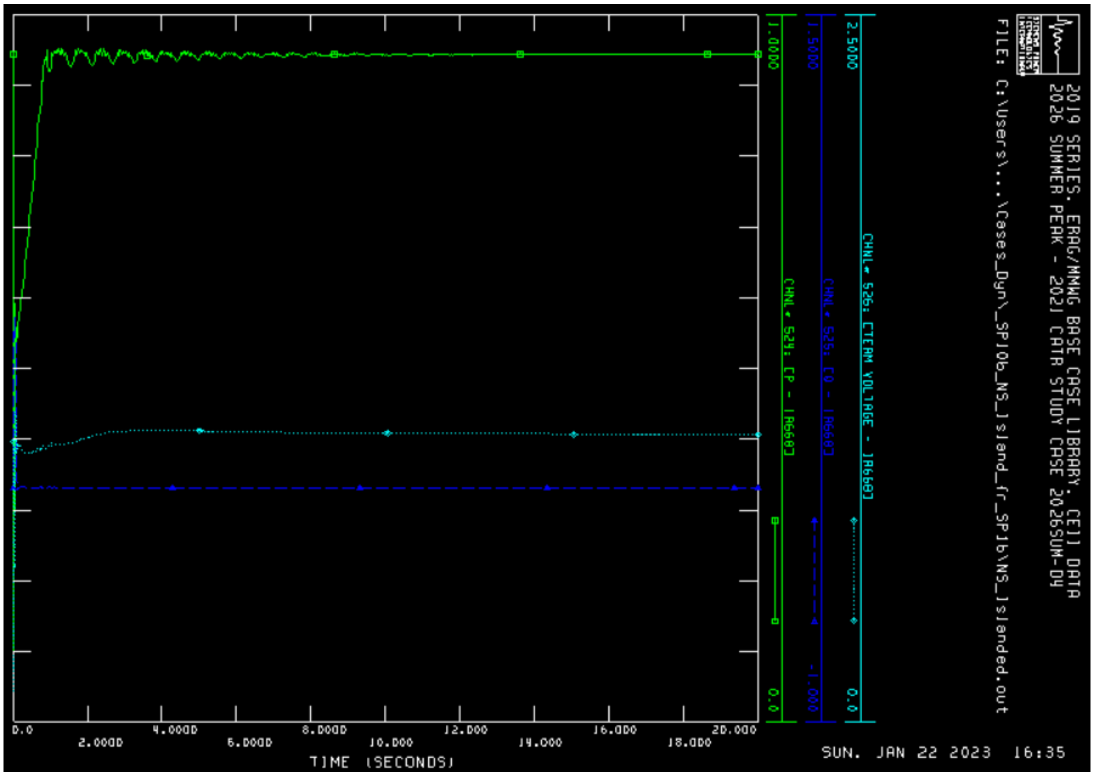

Figure 17: IR668 remains stable and on-line during NS islanding.

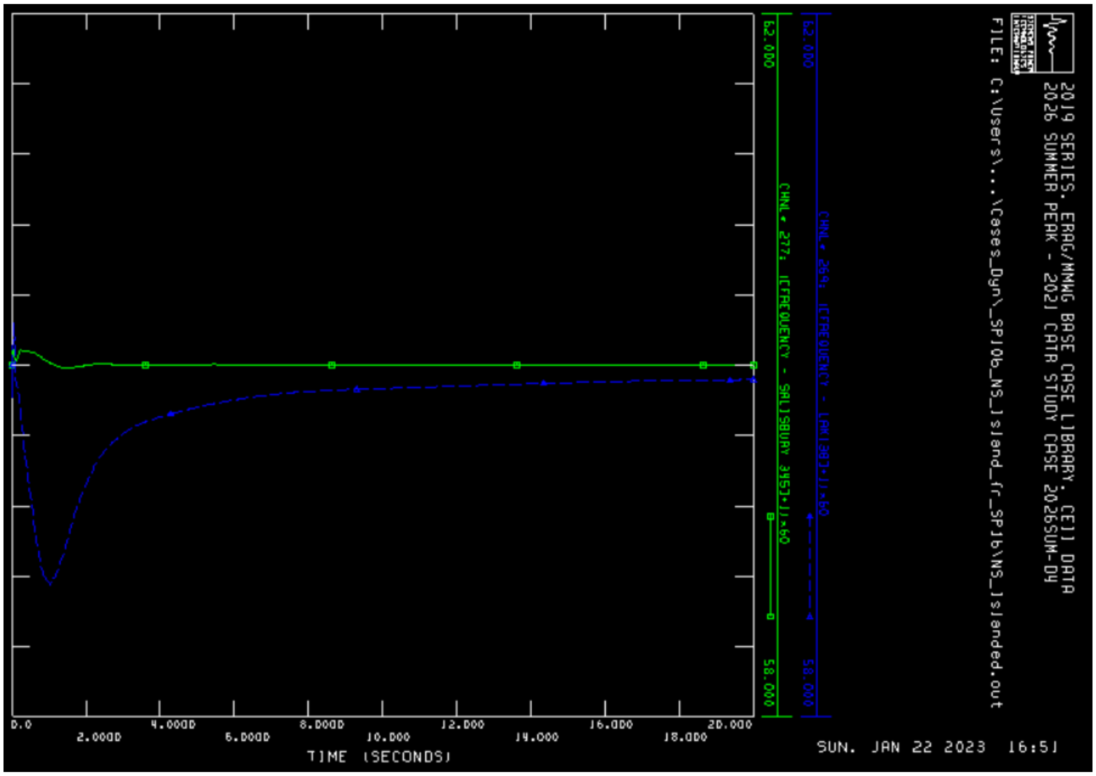

Figure 18: NS system frequency stabilizes after NS being islanded.

3.8 Low Voltage Ride Through

It is a requirement that IR668 must be able to ride through faults in the power system without tripping itself off.

IR668 low voltage ride through (LVRT) capability was modelled and simulated with a three phase fault at the POI for 9 cycles and the dynamic plot, as shown on Figure 19, shows that IR668 is able to ride through the fault and remains on-line at rated output and stable post contingency, thus it meets the LVRT requirement.

While this meets the LVRT requirement, it does not provide inertial frequency response as discussed in the previous section.

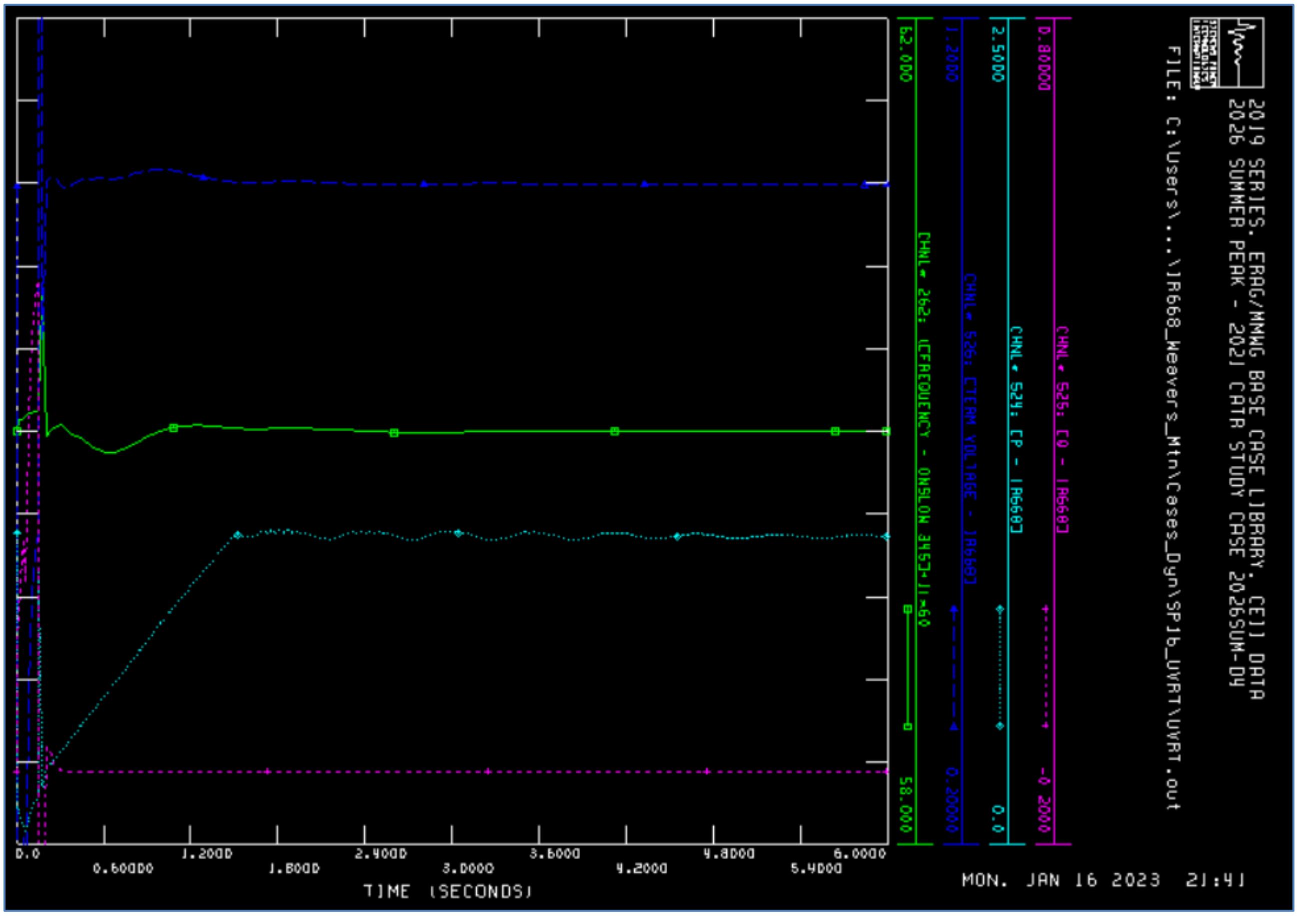

Figure 19: IR668 meets LVRT requirement.

3.9 Loss Factor

The loss factor calculation is based on a winter peak case without IR668 in service and with IR668 at rated output, while keeping 91H-Tufts Cove Generator TC3 as the NS area interchange generator and the power import from NB to NS at zero. This methodology reflects the load centre in Metro Halifax.

The loss factor for IR668 is shown in Table 7 and 8. Table 7 shows the loss factor if the power is measured from IR668 voltage terminal at 750 V (which includes IR668 generating facility losses), whereas for Table 8, power is measured at the POI at 230 kV (which excludes IR668 generating facility losses).

Table 7: Loss Factor Measured at IR668 Terminal (750 V)

Description	MW
IR668 On	94.4
TC3 with IR668 On	65.5
TC3 with IR668 Off	149.4
Loss Factor *measured at IR668 voltage terminal*	**+11.1%**

Table 8: Loss Factor Measured at POI (230 kV)	
Description	**MW**
IR668On	94.4
Power measured at POI	90.4
TC3 with IR668 On	65.5
TC3 with IR668 Off	149.4
Loss Factor *measured at POI*	**+7.2%**

4.0 Expected Facilities Required

The following facility changes will be required to connect IR668 as NRIS to NSPI transmission system at the POI on L-7003:

- NSPI Transmission Network Upgrades
    - Installation of a new 230 kV substation complete with a three breaker ring bus at the POI on L-7003. This substation must be designed to NPCC's BPS requirements and NERC's BES requirements.
    - Modification of protection system at 67N-Onslow substation and 3C-Port Hastings substation of L-7003 due to the addition of IR668 POI to this line.
    - Modification to a Limited Impact Remedial Action Scheme (RAS), which has a NPCC reference as "Type III SPS#113, 230 PHLO" that involves L-7003 and DCT L-7003_L-7004. Because this DCT has 2 locations, one at Canso Causeway and one at Trenton and IR668 POI will be between the two locations of L-7003. The existing RAS covers the Canso Causeway location, but not the Trenton location, so the Trenton location will need to be added to this RAS. NPCC, at one time, used the term SPS for Special Protection Scheme, but now uses the term RAS to be consistent with NERC terms.
    - Modification to a Type I RAS, which has a NPCC reference as "Type I SPS#119, NS 345 kV SPS", for changes to CBX arming levels and limits.
    - Modifications to RASs will require submission to and approval of NPCC.

- Transmission Provider's Interconnection Facilities (TPIF) Upgrades
    - Installation of 122 meters of new 230 kV spur line from POI substation to IC substation,
    - Installation of NSPI P&C Relaying Equipment.
    - Installation of NSPI supplied RTU.
    - Installation of Tele-protection and SCADA communication.

- IC Interconnection Facilities (ICIF)

    - As IR668 generating facility will have aggregate rated output greater than 75 MVA, it will require to be designed and operated according to and meeting NERC's BES standards.
    - The 230 kV side of the IC substation will be designed to meet NPCC's BPS and NERC's BES requirements.
    - IR668 must be capable of providing 0.95 leading and lagging power factor at the HV terminals of the IC main substation step up transformer for the full range of IR668 real power output from zero to rated output. The generating facility must be capable of providing rated reactive power at zero MW output. One option for IR668 to meet the power factor requirements is to equip all 16 wind turbines with STATCOM capabilities and install at the 34.5 kV bus a switchable and controllable 26 MVAR capacitor bank working in coordination with the wind farm controller to achieve the power factor requirements.
    - IR668 must provide centralized controls such as a farm control unit (FCU) that can control the 34.5 kV bus voltage to a settable point and will control the reactive output of each wind turbine of IR668 to achieve this common objective. 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 such as section 7.6.6 on "Active Power Control (Fast Frequency Response) and Curtailment" for additional requirements.
    - 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). The plant may be incorporated into RAS 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.
    - Compliance with section 7.6.7 of TSIR, "WECS Generating Facilities shall support short-duration frequency deviations by providing inertia response equivalent to a Synchronous Generator with an inertia factor (H) of at least 3.0 MW-s/MVA for a period of at least 10 seconds.".
    - This item will be assessed in Part 2 EMT study, which may identity additional resources such as synchronous condenser, Flexible AC Transmission System (FACTS) devices etc.

5.0 Cost Estimate

The high level non-binding cost estimate, excluding applicable taxes, in 2023 Canadian dollars, to interconnect IR668 to NSPI transmission system for NRIS, is shown in Table 9.

It excludes all costs of associated facilities required at the IC's substation and generating facility as well as any additional costs to be identified by the subsequent Part 2 EMT study and Facilities Study.

Table 9: High Level Non-Binding Cost Estimate		
Item	**Network Upgrades**	**Estimate ($M CAN)**
1	Three breaker ring bus 230 kV substation, designed to meet NPCC's BPS and NERC's BES requirements, complete with P&C and connection to L-7003	8.00
2	P&C modifications at 67N-Onslow substation and 3C-Port Hastings substation of L-7003	0.50
3	Modification to the existing Limited Impact RAS (NPCC Type III SPS#113, 230 PHLO) that involves L-7003 and DCT L-7003_L-7004 at Canso Causeway location. As this DCT has 2 locations, one at Canso Causeway and one at Trenton and IR668 POI will be between the two locations, therefore this RAS will require the addition of Trenton location to its logic.	0.60
4	Modification to the existing Type I RAS (NPCC Type I SPS#119, NS 345 kV SPS) for changes to CBX arming levels and limits.	0.30
	Contingency (10%)	0.94
	Network Upgrade Sub-total	10.34
Item	**TPIF Upgrades**	
1	Install 122m (0.122 km) of wood pole H-frame Dove 230 kV line from NSPI IF substation to IC substation. This new 230 kV line extension must be designed to meet NPCC BPS requirements and NERC's BES requirements.	0.15
2	P&C relaying equipment	0.15
3	NSPI supplied RTU	0.07
4	Tele-protection and SCADA communications	0.15
	Contingency (10%)	0.05
	TPIF Upgrade Sub-total	0.57
	Total Network Upgrades and TPIF, excluding HST	**10.91**

The IC will be responsible for acquiring the ROW (Right-Of-Way) for and access to all the facilities.

The non-binding estimate for the time to construct NSPI Transmission Network Upgrades is two years after the IC has obtained the necessary easements and ROW. The Facilities Study will confirm the estimated construction time.

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