System Impact Study Report

Report GIP-IR677-SIS-R0

Generator Interconnection Request #677

84 MW Wind Generating Facility

Yarmouth County, NS

May, 2024

Control Centre Operations
Nova Scotia Power Inc.

Executive summary

The System Impact Study (SIS) for IR677 will be conducted in Part 1 and Part 2. Part 1, using Power System Simulator software, will determine the impacts of IR677 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.

Part 1 system impacts will be assessed based on NSPI 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 software to determine IR677's impacts and control interactions when integrated with NSPI power system. 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.

This report presents the results of Part 1 of the System Impact Study (SIS) for IR677 - a proposed 84 MW wind turbine generating facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS). The Point of Interconnection (POI) is identified on L-6024 adjacent to 9W-Tusket substation. The proposed Commercial Operation Date is 2025/12/31.

IR677 consists of twelve (12) Wind Energy Converter System (WECS) units using Nordex N163 with 950V terminal voltage, each rated at 7.0 MW totaling 84.0 MW. The voltage is stepped up to 34.5 kV at the collector substations with an equivalently modelled generator step-up transformer. The system is interconnected to the POI through one 34.5kV/138kV station transformer and an approximately 17km-long 138kV transmission line. Since L-6024 is not classified as a Bulk Power System and given that the spur line is greater than 10% of the length of L-6024, a three-breaker ring bus would be required in accordance with the NSPI Transmission System Interconnection Requirements.

The short circuit analysis shows that the maximum short circuit levels are far below 5,000 MVA for 138 kV and 3,500 MVA for 69 kV with IR677 added into the system at the proposed POI. IR677 short circuit contribution does not require any uprating of existing breakers in the transmission system. The minimum short circuit level at IR677 34.5 kV bus, with L-6024 (between 50W-Milton and IR677's POI) out of service, is 114 MVA, which equates to a SCR of 1.36 (114 MVA / 84 MW). The minimum SCR recommended for Nordex N163 machines by the wind turbine manufacture is 3 or 4, and this low SCR could cause numeric errors in stability transient simulations and result in IR677's machines tripping or oscillation under certain contingencies. To ensure IR677's stable simulation performance, a 60MVA synchronous condenser was added onto the IR677 POI in the stability analysis. The minimum SCR was then improved to 2.56 at the IR677's 34.5 kV bus. All contingencies were found to be stable and well-damped with the addition of synchronous condenser under the dynamic simulation. The IC should consult the wind turbine manufacture to determine the required modifications to ensure that IR677 meets all reliability requirements under very low SCR conditions. Otherwise, the facility may be curtailed to maintain system stability when the synchronous condenser is out of service.

IR677 meets NS Power's leading power factor requirement, but it may not meet lagging power factor requirement therefore supplemental reactive power compensation device will be required to be supplied by the IC. The IC shall consider the use of additional reactive power device(s) or wind turbine models which have a higher reactive power range. Rated reactive power shall be available through the full range of real power output of IR677, from zero to full power, by adding the synchronous condenser, or other supplemental reactive power compensation options such as Nordex “STATCOM function”.

The steady state power flow analysis indicated that under certain operating conditions several transmission lines and transformers could exceed emergency operating limit for contingencies at 50W-Milton, 9W-Tuesket, 99W-Bridgewater and 120H-Brushy Hill due to the IR677 interconnection. Therefore, it requires the following customer funded Network Upgrades at POI and beyond to operate IR677 at the requested MW capability under NRIS:

- To resolve post contingency overloads on transformer 9W-T2 and line L-6021:
  - Replace 9W-T2 with a 60/80/100 MVA, 138kV-69kV transformer.
  - Replace 9W-516A switch with 144 MVA rated switch.
- To resolve post contingency overloads on transformers 99W-T71, 99W-T72 and line L-7009:
  - Design an AAS to cross trip IR677, armed if the flow through 99W-T71 and 99W-T72 is more than 200MVA towards 120H-Brushy Hill.
- To resolve post contingency overloads on L-5535:
  - Design an AAS to cross trip IR677, which also resolves any consequential overload on L-5532 or L-5541 due to L-5535 cross-trip.
- To resolve post contingency overloads on L-6025:
  - Upgrade of L-6025 current transformer and metering.
- To resolve post contingency overloads on L-6531:
  - Upgrade L-6531 conductor temperature rating from 50 °C to 60 °C.
- Install three-terminal protection for line L-6024 with transfer trips and interlocks for IR677’s cross-trip.

These upgrades are funded by the customer but are refunded per the terms of the Generator Interconnection Agreement (GIA). It is noted that the proposed IR677 substation transformer (rated at 90 MVA) could be overloaded up to 115% when the IR677 is operating at the maximum 84 MW output, while absorbing maximum 40.68MVAr reactive power.

The facilities associated with IR677 are not designated as NPCC BPS as IR677 does not affect the BPS status of existing facilities. However, IR677 qualifies as NERC BES as its aggregate rated output is greater than 75 MVA. It shall be designed and operated according to and meeting NERC’s BES standards. There is the potential for an exclusion from BES to be granted for the high side (138kV) bus based on further analysis per the NS BES Exception Procedure.

The dynamic simulation for NS being suddenly islanded from NB showed NS system frequency swing below under frequency thresholds of NS under frequency load shedding (UFLS) and this program shed 295 MW load in NS. IR677 remained on-line and stable helping to stabilize NS frequency during and post contingency.

IR677 low voltage ride through (LVRT) capability was tested to cover expected system operating conditions in winter peak, summer peak and light load. The simulations showed that IR677 remained on-line with temporarily reduced power and ramped back to rated power during contingency and remained stable post contingency.

The loss factor calculation is based on a winter peak case with and without IR677 in service. The calculated loss factor is 0.9% at IR677's generator terminal (950V) and -1.9% at its POI (L-6024, 138kV bus close to 9W). This means system losses on peak are not much impacted when IR677 is operating at 84 MW.

It is concluded that the incorporation of the proposed facility into the NS Power transmission system at the specified location has no negative impacts on the reliability of the NS Power grid, provided the recommendations provided in this report are implemented.

The following facility changes will be required to connect IR677 as NRIS to NSPI transmission system at the POI:

- Transmission Network Upgrades funded by the Interconnection Customer:
    - Construction of a new 138kV substation completed with a three-breaker ring bus at the POI on L-6024.
    - Modification of protection system at 50W-Milton and 9W-Tusket substation of L-6024 due to the addition of IR677.
    - Replacement of 9W-T2 with a 60/80/100 MVA, 138kV-69kV transformer.
    - Replacement of switch 9W-516A for L-6021.
    - Upgrade of current transformer and metering for L-6025.
    - Upgrade of L-6531 conductor from 50 °C to 60 °C.
    - Install a new automatic action scheme to cross trip IR677, armed if the flow through 99W-T71 and 99W-T72 is larger than 200MVA towards 120H.
    - Install a new automatic action scheme to cross trip IR677 for L-5535 overloads.
- Transmission Provider’s Interconnection Facilities (TPIF) Upgrades:
    - A synchronous condenser installed at IR677 POI or in the vicinity area.
    - Build an approximately 17 km 138kV interconnection transmission line from the POI to the IC substation.
    - Installation of NSPI P&C Relaying Equipment.
    - Installation of NSPI supplied RTU.

  - Installation of Tele-protection and SCADA communication.
- IC Interconnection Facility:
  - Facilities for NSPI to execute high speed rejection of generation (transfer trip). The plant will be integrated into the area Automatic Action Scheme (AAS) and RAS run-back schemes at some point in time in the future.
  - The ability to interface with the NS Power SCADA and communications systems to provide control, communication, metering, and other items to be specified in the forthcoming Interconnection Facilities Study.
  - NSPI to have supervisory and control of this facility, via the centralized controller such as a farm control unit. This will permit the NSPI System Operator to raise/lower the voltage setpoint, change the status of reactive power controls, change the real/reactive power remotely. NSPI will also have remote manual control of the load curtailment scheme.
  - The centralized voltage controller to control the 34.5 kV bus voltage to a settable point and will control the reactive output of each inverter unit of IR677 to achieve this common objective. Responsive *(fast-acting)* controls are required. The setpoint for this controller will be delivered via the NS Power SCADA system. The voltage controller must be tuned for robust control across a broad range of SCR.
  - Facilities to meet ±0.95 power factor requirement when delivering rated output (84 MW) at the 138 kV bus. IR677's power factor capability must be re-evaluated to confirm it has the required amount of supplemental reactive support once detailed design information on its transformers and collector circuits are available.
  - Voltage flicker and harmonics characteristics as described in Section 3.3: Voltage flicker.
  - Frequency ride through capability to meet the requirements in Section 2.3.8: Underfrequency operation.
  - When not at full output, the facility shall offer over-frequency and under-frequency control with a deadband of ±0.2 Hz and a droop characteristic of 4%.
  - The ability to control active power in response to control signals from the NS Power System Operator and frequency deviations. This includes automatic curtailment to pre-set limits *(0%, 33%, 66% and no curtailment)*, over/under frequency control, and Automatic Generation Control *(AGC)* system to control tie-line fluctuations as required.
  - Voltage ride through capability to meet the requirements in Section 2.3.9: Voltage ride-through.
  - The facility must use equipment capable of closing a circuit breaker with minimal transient impact on system voltage and frequency *(matching voltage within ±0.05 PU and a phase angle within ±15º).*
  - To minimize the need to curtail non-dispatchable wind generation at light load, all wind farms must have the functionality to be incorporated into the Export Power Monitor SPS.
  - 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.
  - During the study for this SIS, section 7.6.7 of TSIR, that requires wind turbine generators to provide inertia response of 3.0 MW-s/MVA for a period of at least 10

seconds, was temporarily postponed for review by NSPI. It will be addressed in Part 2 of the System Impact Study.

- Nordex wind turbine generators to meet TSIR section 7.6.9 requirements that the wind generating facility shall be capable of operating at ambient temperatures as low as -30 ºC.
- The facility must meet NSPI's TSIR as published on the NSPI OASIS site.

To accommodate IR677, the total high level non-binding estimated cost in 2024 Canadian dollars for the Network Upgrades is $28,155,000 and for the new Transmission Provider's Interconnection Facilities (TPIF) is $14,640,000, for a total of $42,795,000, plus 10% contingency for a total of $47,074,500 excluding HST. The costs of the synchronous condenser, all associated facilities required at the IC's substation and Generating Facility are in addition to this estimate. This cost excludes any additional costs or changes which may be identified by Part 2 of the System Impact Study as well as any cost associated with ICIF generating facility.

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

The preliminary and non-binding estimate for the construction of the customer funded Network Upgrades is 24-30 months, primarily as a result of long lead time items (e.g., 100 MVA transformer) and the scheduling of line outages. Timelines will be confirmed in the Facility Study.

Table of Contents

List of appendices

Appendix A: Generating facility dynamic data
Appendix B: Base case one-line diagrams
Appendix C: Differential line flows
Appendix D: Steady-state analysis results
Appendix E: NPCC-BPS determination results
Appendix F: Underfrequency operation
Appendix G: Low voltage ride through
Appendix H: Stability analysis results

List of tables & figures

1.0 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR) to Nova Scotia Power Inc. (NSPI) for the connection of a proposed 84 MW wind turbine generating facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS). The proposed Commercial Operation Date is 2025/12/31.

The IC signed a System Impact Study (SIS) Agreement for this 84 MW wind turbine generating facility, and this report is the result of that Agreement. This project is listed as Interconnection Request #677 in the NSPI Interconnection Request Queue and will be referred to as IR677 throughout this report.

1.1 Scope

The IC identified that the Point of Interconnection (POI) for IR677 will be on the 138kV line L-6024. The proposed generation will be interconnected to the POI via an approximately 17km 138kV transmission line form the Point of Change of Ownership (PCO).

Figure 1: Proposed interconnection shows the approximate geographic location of the proposed IR677 site. *Figure 2: Proposed interconnection in one-line diagram* illustrates the electrical locations of IR677.

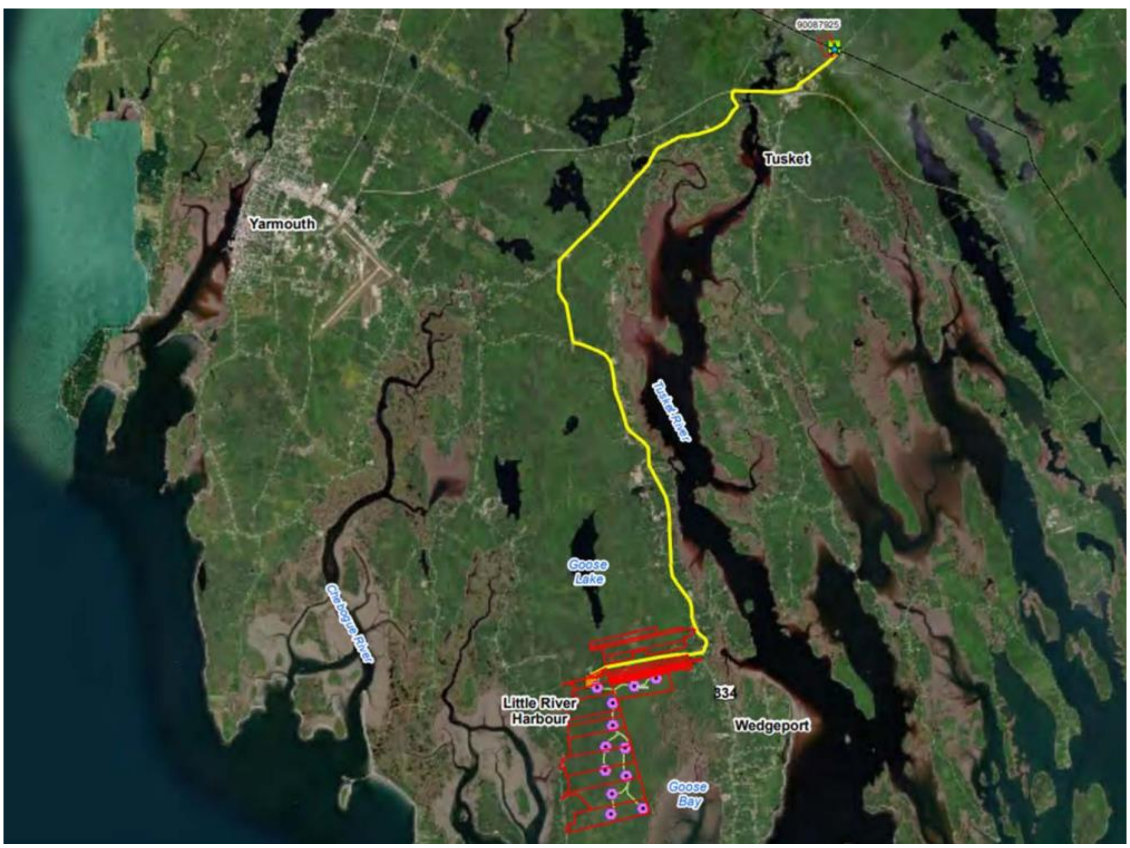


Figure 1: Proposed interconnection

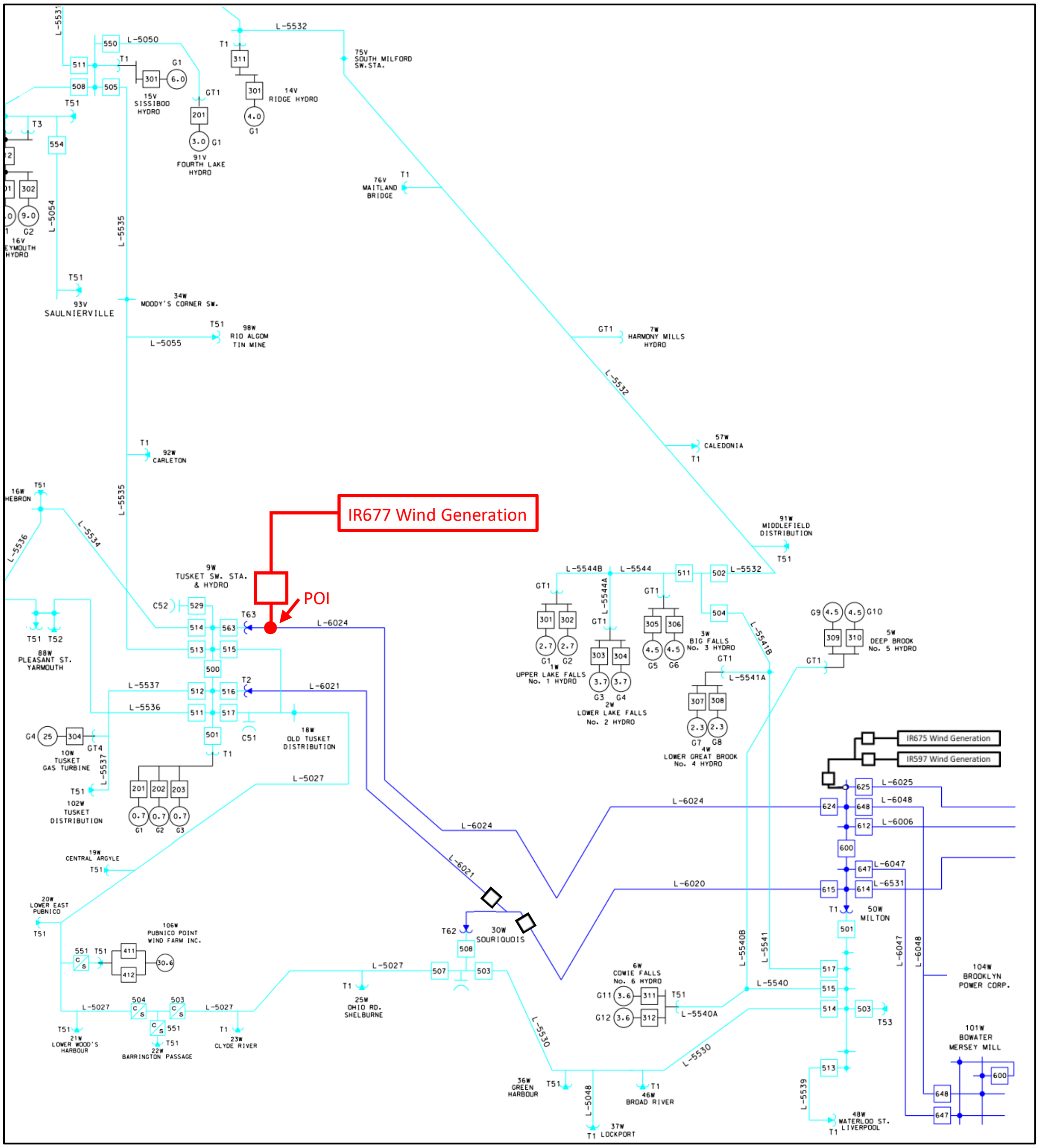


Figure 2: Proposed interconnection in one-line diagram

This report presents the results of the SIS with the objective of assessing the impact of the proposed generation facility on the NS Power Transmission System.

The scope of the SIS is limited to determining the impact of the IR677 generating facility on the NS Power transmission for the following:

- Short circuit analysis and its impact on circuit breaker ratings.
- Power factor requirement at the high side of the ICIF transformer.
- Voltage flicker.

- Steady state analysis to determine any thermal overload of transmission elements or voltage criteria violation.
- Stability analysis to demonstrate that the interconnected power system is stable for various single-fault contingencies.
- NPCC Bulk Power System (BPS) and NERC Bulk Electric System (BES) determination for the substation.
- Underfrequency operation.
- Low voltage ride through.
- Incremental system Loss Factor.
- Impact on any existing Special Protection Systems (SPSs).

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 NS Power Transmission System.

1.2 Assumptions

The study is based on technical information provided by the IC. The POI and configuration are studied with the following assumptions:

1. Network Resource Interconnection Service type with an in-service date of 2025-12-31.
2. The Interconnection Facility consists of twelve (12) x 7.0 MW Nordex N163 wind energy converter units, totalling 84.0 MW. The 12 wind generation units were modeled as one equivalent lumped parameter generator. The equivalent models were developed using the data provided by the Interconnection Customer. The manufacturer's dynamics data is included in *Appendix A: Generating facility dynamic data*

3. of this report.

4. The Nordex N163 wind energy converter units are the 950 V AC, 7000 kVA nameplate variant. A 3.135 PU fault current is used for short circuit analysis.

5. Individual wind turbine generator transformer (950 V/34.5 kV) was modelled to have an impedance of 9.0% on 7.8 MVA with an X/R ratio of 9.09.

6. The collector system is made up of three collector circuits at 34.5 kV. The equivalent circuit impedances are calculated as R = 0.0056, X = 0.0187 and B = 0.0012 p.u. (on system base 100 MVA) according to the preliminary collector system layouts.

7. The interconnection facility transformer was modeled as 138 kV (wye) to 34.5 kV (wye), 54/72/90 MVA, with an impedance of 7.5% (on 54 MVA Base) and an assumed X/R ratio of 40.

8. The Point of Interconnection (POI) is identified on L-6024 adjacent to 9W-Tusket substation. This project utilizes an approximately 17 km interconnection transmission line from the POI to the IR677 IC substation which is assumed to use the ACSR 336.4 Linnet conductor rated at 50ºC with overhead ground wire.

9. NSPI's transmission line ratings are assumed as posted on NSPI's Intranet, including any projected line upgrades for the periods under study.

10. It is assumed that IR677 generation meets IEEE Standard 519 limiting total harmonic distortion (all frequencies) to a maximum of 1.5% with no individual harmonic exceeding 1.5% for 138 kV.

11. Generation in a higher queue position, except for the interconnection requests that are electrically remote from IR677, are modeled in the base cases. The included projects are listed in Section 1.3.

12. The Maritime Link can be used as an SPS target.

13. The rating of transmission facilities in the vicinity of IR677 are shown in *Table 1: Rating of Transmission Lines* and *Table 2: Rating of Transformers*.

Table 1: Rating of Transmission Lines

Line	Conductor	Design Temp	Limiting Element	Summer Rating Normal/Emergency MVA	Winter Rating Normal/Emergency MVA
L-7008	ACSR 1113 Beaumont	70ºC	CT	398.0/437.8	398.0/437.8
L-7009	ACSR 795 Drake	50ºC	Conductor	223.0/245.3	340.0/374.0
L-6006	ACSR 795 Drake	50ºC	Conductor	135.0/148.5	205.0/225.5
L-6025	ACSR 1113 Beaumont	70ºC	CT	200.0/220.0	200.0/220.0
L-6531	ACSR 556.5 Dove	50ºC	Conductor	110.0/121.0	165.0/181.5
L-6020	ACSR 336.4 Linnet	50ºC	Conductor	82.0/90.2	121.0/133.1
L-6021	ACSR 336.4 Linnet	50ºC	Switchgear	72.0/79.2	72.0/79.2
L-6024^	ACSR 795 Drake	70ºC	Switchgear	143	143
L-5541	ACSR 4/0 Penguin	50ºC	Conductor	31.0/34.1	43.0/47.3
L-5535	ACSR 2/0 Quail	50ºC	Conductor	23.0/25.3	34.0/37.4
L-5532	ACSR 2/0 Quail	50ºC	Conductor	23.0/25.3	34.0/37.4

^The existing L-6024 is rated at 72.0/79.2 MVA. It is assumed that L-6024 would be uprated to 143 MVA by the replacement of a breaker and a disconnect switch with units rated for 143 MVA due to a higher queued project.

Table 2: Rating of Transformers

Transformer	Normal Rating / 15 min Emergency	
	Summer MVA	Winter MVA
99W-T71	200/240	200/240
99W-T72	200/240	200/240
9W-T2	56/56	56/61.6
9W-T63*	100	100
30W-T62**	56/56	56/61.6
50W-T1	56/56	56/61.6

*The existing 9W-T63 is rated at 56/61.6 MVA. It's assumed that 9W-T63 would be replaced by a higher rating transformer with emergency overload capability due to a higher queued project.
**The existing 30W-T62 is rated at 25/27.5 MVA. It's assumed that the existing 50/56 MVA 9W-T63 would be moved to replace the existing Souriquois 30W-T2 transformer due to a higher queued project.

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.

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.

As of 2024/04/05, the following projects are higher queued in the Advanced Stage Interconnection Request Queue:

- IR #516: GIA executed, 2023/06/30 in-service date.
- IR #540: GIA executed, 2023/10/31 in-service date.
- IR #542: GIA executed, 2025/06/30 in-service date.
- IR #517: GIA in progress, 2019/10/01 in-service date.
- IR #574: GIA executed, 2025/09/30 in-service date.
- IR #598: GIA executed, 2024/06/30 in-service date.
- IR #597: GIA executed, 2023/08/31 in-service date.
- IR #647: GIA in progress, 2023/12/31 in-service date.
- IR #664: FAC Complete, 2025/11/07 in-service date.
- IR #662: FAC Complete, 2025/11/24 in-service date.
- IR #670: FAC Complete, 2026/02/28 in-service date.
- IR #671: FAC in progress, 2026/02/28 in-service date.
- IR #669: FAC Complete, 2025/12/31 in-service date.
- IR #668: FAC Complete, 2026/04/01 in-service date.
- IR #618: FAC Complete, 2025/09/30 in-service date.
- IR #673: FAC Complete, 2024/12/31 in-service date.
- IR #675: FAC Complete, 2024/12/01 in-service date.

As Section 4.2 of NSPI’s Generator Interconnection Procedure (GIP) allows the “Transmission Provider to study an Interconnection Request separately to the extent warranted by Good Utility Practice based upon the electrical remoteness of the proposed Generating Facility”, the following IRs are not included in this SIS due to their significant electrical remoteness with respect to the IR677:

- IR #662: FAC Complete, 2025/11/24 in-service date.
- IR #670: FAC Complete, 2026/02/28 in-service date.
- IR #669: FAC Complete, 2025/12/31 in-service date.
- IR #668: FAC Complete, 2026/04/01 in-service date.
- IR #618: FAC Complete, 2025/09/30 in-service date.

The remaining of the higher-queued Interconnections will be modelled and included in IR677 study base cases. If any of these included projects are subsequently withdrawn from the Queue, it may be necessary to update this SIS or perform a re-study.

2.0 Technical model

To facilitate the load flow analysis, the proposed twelve (12) wind turbines are grouped as one equivalent generator with a terminal voltage of 950 V. The voltage is stepped up to 34.5 kV at the collector substation with a single equivalent step-up transformer. This equivalent model is then stepped up to 138 kV via the interconnection transformer.

The PSS®E model for load flow is shown in *Figure 3: PSS®E model* below. The equivalent 950 V/34.5 kV generator transformer was modeled to have an impedance of 9.0% on 84.0 MVA. The interconnection transformer was assumed to have 7.5% impedance on 54 MVA rating with an X/R ratio of 40. The SIS results must be updated if the actual nameplate data for these transformers materially differs from these impedance values.

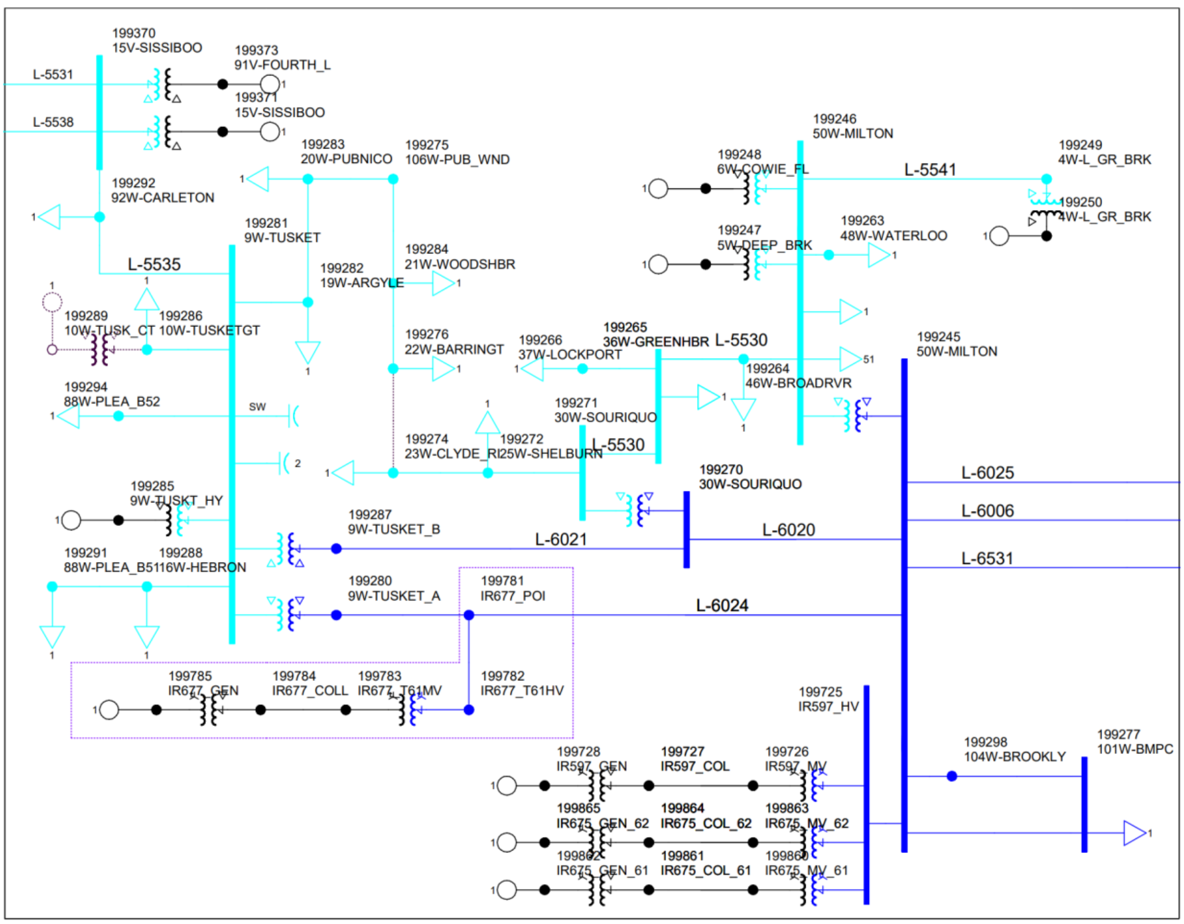


Figure 3: PSS®E model

2.1 System data

The "*2022 Load Forecast Report*", dated April 29, 2022, produced by NSPI, and submitted to Nova Scotia Utility and Review Board *(NSUARB)* was used to allocate the loads in NS. The winter peak load forecast for the near future is shown in *Table 3: Load forecast for study period*, with 2026 used for this study.

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.

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

Table 3: Load forecast for study period

Forecast year	System peak	Interruptible contribution to peak	Firm contribution	Demand response	Growth %
2023	2,185	146	2,035	-4	0.9
2024	2,215	146	2,057	-12	1.4
2025	2,253	152	2,076	-24	1.7
2026	2,291	154	2,101	-36	1.7
2027	2,326	153	2,133	-39	1.5
2028	2,361	153	2,170	-39	1.5
2029	2,398	153	2,207	-39	1.6
2030	2,434	152	2,243	-38	1.5
2031	2,479	152	2,289	-38	1.9
2032	2,532	152	2,342	-37	2.1

2.2 Generating facility

IR677 will be equipped with twelve (12) Nordex N163 wind energy converter units, each rated at 7.0 MW totaling 84.0 MW.

The proposed generator is classified as Type 3 doubly fed induction generator (DFIG). Nordex N163 wind turbine generators are each capable of a reactive power range of +1.80 to -1.70 MVAr within 91% to 110% of 950V nominal (or +3.25 to -3.39 MVAr at 100% of 950V nominal).

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.

2.3 System model & methodology

Testing and analysis were conducted using the following criteria, software, and/or modelling data.

2.3.1 Short circuit

PSS®E 34.8, classical fault study, flat voltage profile at 1 PU voltage, and 3LG fault was used to assess before and after short circuit conditions. The 2026 system configuration with IR677 in service and out of service was studied, with comparison between the two.

2.3.2 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". PSS®E was used to simulate high and low system voltage conditions to determine the machine capability in delivery/absorption of reactive power (VAr).

2.3.3 Voltage flicker

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".

Short-term flicker severity (P_{st}) and long-term flicker severity (P_{lt}) calculations are at the WTG terminals. For multiple wind turbines at a single plant, the estimated flicker contribution is calculated as follows.

Continuous:

$$P_{st} = P_{lt} = \left(\frac{1}{S_k}\right)\sqrt[m]{\sum_{i=1}^{N_{wt}}\left[\left(c_i(\varphi_k, v_a)(S_{n,i})\right)\right]^m}$$

Switching operation:

$$P_{st\Sigma} = \left(\frac{15}{S_k}\right)\sqrt[3.2]{\sum_{i=1}^{N_{wt}}\left[(N_{10,i})\left(k_f(\varphi_k)(S_{n,i})\right)\right]^{3.2}}$$

$$P_{lt\Sigma} = \left(\frac{6.9}{S_k}\right)\sqrt[3.2]{\sum_{i=1}^{N_{wt}}\left[(N_{120,i})\left(k_f(\varphi_k)(S_{n,i})\right)\right]^{3.2}}$$

Where:

S_k = short-circuit apparent power at the high voltage side of the ICIF transformer. As calculations are for the flicker contribution for the addition of IR677 to the existing system, short-circuit values are for the existing system – before the addition of IR677.

m = 2 in accordance with IEC 61400-21 for WTGs.

N_{wt} = number of WTGs at IR677.

$N_{10,i}$ and $N_{120,i}$ = number of switching operations of the individual wind turbine within a 10 and 120 minute period, respectively.

$c_i(\psi_k,v_a)$ = flicker coefficient of the wind turbine for the given network impedance angle, ψ_k, at the PCC, for the given annual average wind speed, v_a, at the hub-height of the wind turbine site. It is to be provided by the wind turbine supplier. NS network impedance angle is typically 80º-85º.

$k_{f,i}(\psi_k)$ = flicker step factor of the individual wind turbine.

$S_{n,i}$ = rated apparent power of the individual wind turbine.

NS Power's requirement is $P_{st} \leq 0.25$ and $P_{lt} \leq 0.35$.

2.3.4 Generation facility model

Modelling data was provided by the IC for PSS®E steady state and stability analysis in this SIS. The 12 wind turbines and collector circuits were grouped as a single equivalent generator with an equivalent impedance line.

2.3.5 Steady state

Analysis was performed in PSS®E using Python scripts to simulate a wide range of single contingencies, with the output reports summarizing bus voltages and branch flows that exceeded established limits.

System modifications and additions up to 2026 were modelled to develop base cases to best test system reliability in accordance with NS Power and NPCC design criteria:

- Light load; high and low Western Valley generation.
- Medium load; high and low Western Valley generation.
- Peak load.

Power flow was run with the contingencies on each of the base cases listed in Section 3.4 Steady state analysis with IR677 in and out of service to determine the impact of the proposed facility on the reliability of the NS Power grid.

2.3.6 Stability

Analysis was performed using PSS®E for the 2026 study year and system configuration. Light load, Fall, Spring, and Winter peak were studied for contingencies that provide the best measure of system reliability. Details on the contingencies studied are provided in Section 3.5 Stability analysis. The system was examined after the addition of IR677 to determine its impact.

Note all plots are performed on 100 MVA system base.

2.3.7 NPCC-BPS/NERC-BES

NS Power is required to meet reliability standards developed by the Northeast Power Coordinating Council (NPCC) and the North American Electric Reliability Corporation (NERC). Both NPCC and NERC have more stringent requirements for system elements that can have impacts beyond the local area. These elements are classified as "Bulk Power System" (BPS), for NPCC, and "Bulk Electric System" (BES), for NERC.

2.3.7.1 NPCC BPS

NPCC's Bulk Power System (BPS) substations are subject to stringent requirements like redundant and physically separated protective relay and tele-protection systems. Determination of BPS status was in accordance with NPCC criteria document A-10: Classification of Bulk Power System Elements, dated March 27, 2020. The A-10 test requires steady state and stability testing.

The steady state test involves opening all elements connected to the bus under test in constant MVA power flow.

The stability test involves simulation of a permanent 3PH fault at the bus under test with all local protection out of service (such as station battery failure), including high speed tele-protection to the remote terminals. The fault is maintained on the bus for 10 seconds to allow remote protection at surrounding substations to trip the lines to the faulted substation with the corresponding back-up protection times. The post-fault simulation is extended to 20 seconds.

A bus will be classified as part of the BPS if any of the following is observed during the steady state and/or stability tests:

- System instability that cannot be demonstrably contained with in the Area.
- Cascading that cannot be demonstrably contained within the Area.
- Net loss of source/load greater than the Area's threshold.

The NPCC A-10 Criteria document does not require rigorous testing of all buses. Section 3.4, item 2 states:

"...

For buses operated at voltage levels between 50 kV and 200 kV, all buses adjacent to a bulk power system bus shall be tested. Testing shall continue into the 50-200 kV system until a non-bulk power system result is obtained, as detailed in Section 3.5. Once a non-bulk power system result is obtained, it is permitted to forgo testing of connected buses unless one of the following considerations shows a need to test these buses:
- Slower remote clearing times.
- Higher short-circuit levels.
..."

2.3.7.2 NERC BES

NERC uses Bulk Electric System (BES) classification criteria based on a "bright-line" approach rather than performance based like the NPCC BPS classification. The NERC Glossary of Terms as well as the methodology described in the NERC Bulk Electric System Definition Reference was used to determine if IR677 should be designated BES or not.

2.3.8 Underfrequency operation

Underfrequency dynamic simulation is performed to demonstrate that NS Power's automatic Underfrequency Load Shedding (UFLS) program sheds enough load to assist stabilizing system frequency, without tripping IR677's generators.

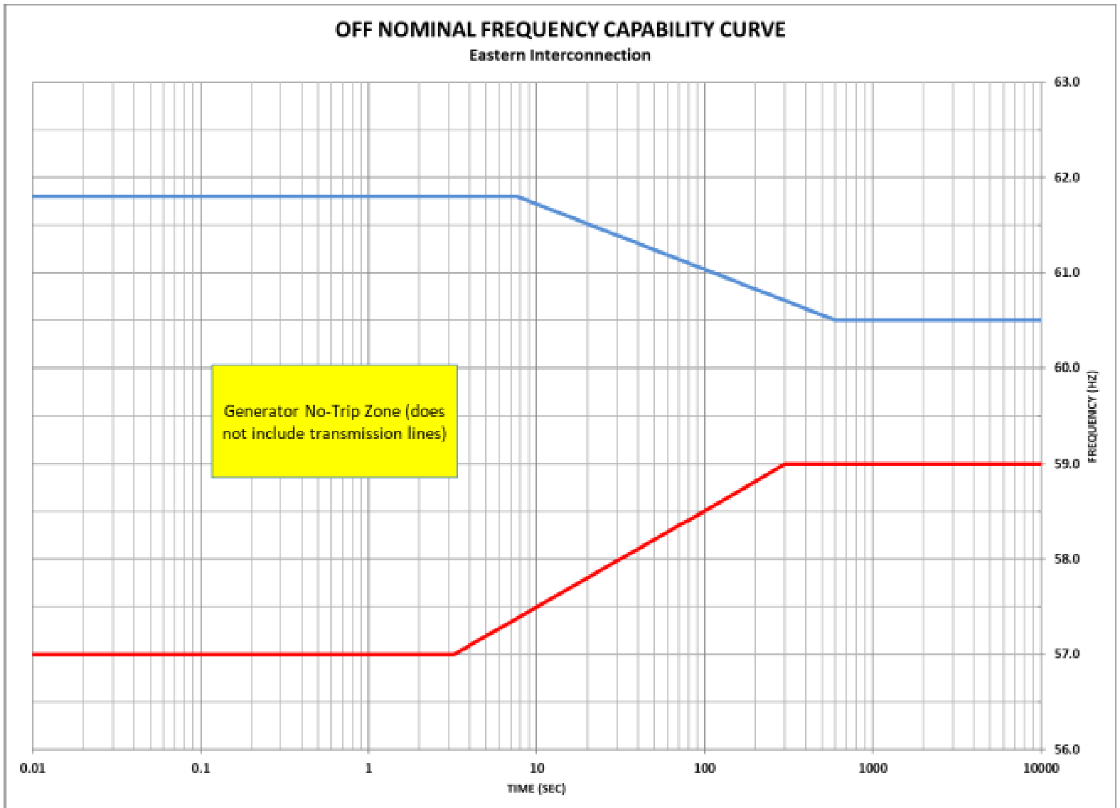
This test is accomplished by triggering a sudden loss of generation by placing a fault on L-8001 under high import conditions.

Nova Scotia is connected to the rest of the North American power grid by the following three AC transmission lines:

- L-8001 (345kV)
- L-6535 (138kV)
- L-6536 (138kV)

Under high import conditions, if L-8001, or, either of L-3025 and L-3006 in NB trips, an "Import Power Monitor" SPS will cross-trip L-6613 at 67N-Onslow to avoid thermal overloads on the 138kV transmission lines. This controlled separation will island Nova Scotia from the rest of the North American power grid. System frequency will be stabilized from the resulting generation deficiency through Under-Frequency Load Shedding (UFLS) schemes to shed load across Nova Scotia. IR677 is required to remain online and not trip under this scenario.

Other contingencies in New Brunswick and New England can also result in under-frequency islanded situation in Nova Scotia.



High Frequency Deviation		Low Frequency Deviation	
Frequency (Hz)	**Time (Sec)**	**Frequency**	**Time**
≥ 61.8	Instantaneous Trip	f ≥ 57.0 Hz	t ≤ 3.3 s
< 61.8 ≥ 60.5	$10^{(90.935 - 1.45713 * f)}$	f ≥ log(t) + 56.5 Hz	3.3s < t ≤ 300 s
< 60.5	Continuous Operation	f ≥ 59.0Hz	t > 300 s

Figure 4: Off-nominal frequency curve (PRC-024-2 and PRC-006-NPCC-2 combined)

In addition to the test, IR677 must be capable of operating reliably for frequency variations in accordance with NERC Standards PRC-024-2 and PRC-006-NPCC-2 as shown in *Figure 4: Off-nominal frequency curve (PRC-024-2 and PRC-006-NPCC-2 combined)*. It should also have the capability of riding through a rate of change of frequency of 4Hz/s.

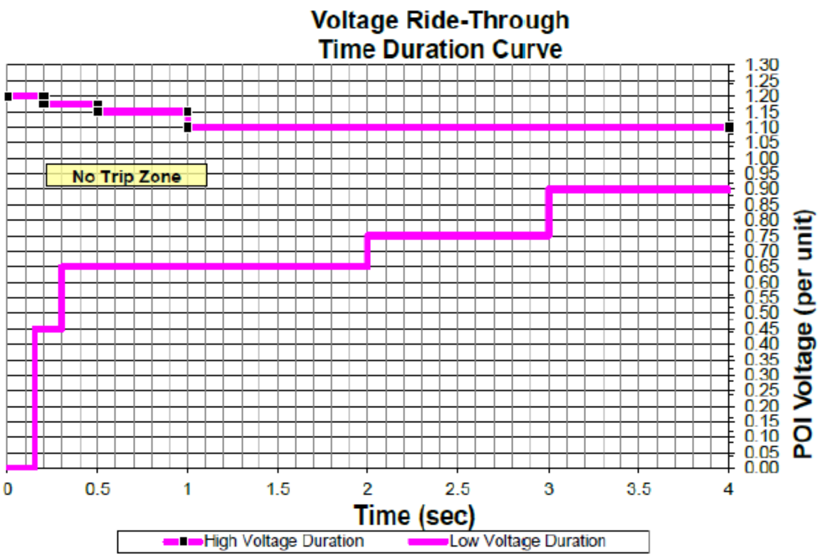
2.3.9 Voltage ride-through

IR677 must remain operational under the following voltage conditions:

- Under normal operating conditions: 0.95 PU to 1.05 PU
- Under stressed (contingency) conditions: 0.90 PU to 1.10 PU
- Under the voltage ride-through requirements in NERC Standard PRC-024-2, see *Figure 5: PRC-024-2 Attachment 2: Voltage ride-through requirements*.

This test is performed by applying a 3-phase fault to the HV and LV buses of the ICIF for 9 cycles. IR677 should not trip for faults on the Transmission System or its collector circuits.

VOLTAGE RIDE-THROUGH REQUIREMENTS



Low Voltage Ride-Through Data Points	
Bus Voltage at Point of Interconnection (pu)	Duration (sec)
< 0.45	0.15
< 0.65	0.30
< 0.75	2.00
< 0.90	3.00
High Voltage Ride-Through Data Points	
Bus Voltage at Point of Interconnection (pu)	**Duration (sec)**
≥1.200	Instantaneous trip permitted
≥1.175	0.2
≥1.150	0.5
≥ 1.100	1.00

Figure 5: PRC-024-2 Attachment 2: Voltage ride-through requirements

2.3.10 Loss factor

Loss factor was calculated by running the power flow using a standardized winter peak base case with and without IR677, while keeping 91H-Tufts Cove generation as the NS area interchange bus. The loss factor for IR677 is the differential MW displaced or increased at 91H-Tufts Cove generation calculated as a percentage of IR677's nameplate MW rating. Although the IR under study and wind generation facilities in the vicinity (existing and committed) are tested at maximum rated output, all other wind generation facilities are dispatched at an average 30% capacity factor.

This methodology reflects the load centre in and around 91H-Tufts Cove and has been accepted and used in the calculation of system losses for the Open Access Transmission Tariff (OATT). It is calculated on the hour of system peak as a means for comparing multiple projects but not used for any other purpose.

Loss factors are provided at the generator terminal bus and the POI (L-6024).

3.0 Technical analysis

The results of the technical analysis are reported in the following sections.

3.1 Short circuit

Short circuit analysis was performed using PSS®E 34.8, classical fault study, flat voltage profile at 1 PU voltage, and 3LG faults. The short circuit levels in the area before and after this development are provided in *Table 4: Short circuit levels, three phase, MVA.*

The machine was modelled as instructed in the IC-supplied model user guide[1] with site-specific data provided by the IC. The transient reactance of 0.319 was used in the short circuit calculation for IR677 generator.

IR677 will not impact the neighbouring breaker's interrupting capability based on this study's short circuit analysis. The interrupting capability of the 138 kV circuit breakers at 30W-Souriquois and 50W-Milton are at least 3,500 MVA. The interrupting capability of the 69 kV circuit breakers at 9W-Tusket, 30W-Souriquois and 50W-Milton are at least 2,000 MVA. The NS Power design criteria for maximum system fault capability (3-phase, symmetrical) is 5,000 MVA at the 138 kV voltage level and 3,500 MVA at the 69 kV voltage level.

Table 4: Short circuit levels, three phase, MVA

Location	**IR677 without synchronous condenser**			**IR677 with synchronous condenser**		
	IR677 OFF	**IR677 ON**	**Post % Increase**	**IR677 OFF**	**IR677 ON**	**Post % Increase**
Maximum generation, all transmission facilities in service						
50W-Milton, 138kV	1461	1533	4.9%	1557	1599	2.7%
50W-Milton, 69kV	644	653	1.5%	657	662	0.8%
30W-Souriquois, 138kV	614	637	3.8%	645	658	2.0%
30W-Souriquois, 69kV	288	292	1.4%	294	296	0.7%
9W-Tusket Hydro & SW STA, 138kV-A	484	631	30.4%	697	844	21.1%
9W-Tusket Hydro & SW STA, 138kV-B	472	496	5.1%	504	518	2.8%
9W-Tusket Hydro & SW STA, 69kV	565	625	10.8%	646	686	6.2%
92W-Carleton, 69kV	349	365	4.6%	371	380	2.5%
15V-Sissiboo Hydro, 69kV	320	321	0.6%	322	323	0.3%
IR677 138kV (POI)	484	631	30.4%	697	844	21.1%
IR677 138kV (GSU_HV)	397	554	39.6%	530	687	29.7%
IR677 34.5kV	256	458	78.6%	306	507	65.9%

[1] *N163_7000_GCV152_CA_PSSE_V8.674_VIC.xls*

Location	IR677 without synchronous condenser			IR677 with synchronous condenser		
	IR677 OFF	IR677 ON	Post % Increase	IR677 OFF	IR677 ON	Post % Increase
Low Generation, all transmission facilities in service						
50W-Milton, 138kV	654	765	16.9%	801	861	7.5%
50W-Milton, 69kV	357	389	9.1%	399	414	3.8%
30W-Souriquois, 138kV	379	434	14.4%	451	479	6.3%
30W-Souriquois, 69kV	223	239	7.2%	243	251	3.0%
9W-Tusket Hydro & SW STA, 138kV-A	300	448	48.9%	513	660	28.7%
9W-Tusket Hydro & SW STA, 138kV-B	294	344	16.8%	359	386	7.6%
9W-Tusket Hydro & SW STA, 69kV	284	356	25.7%	382	429	12.3%
92W-Carleton, 69kV	217	251	15.8%	262	280	6.9%
15V-Sissiboo Hydro, 69kV	165	174	5.7%	177	181	2.2%
IR677 138kV (POI)	300	448	48.9%	513	660	28.7%
IR677 138kV (GSU_HV)	264	422	59.4%	417	574	37.7%
IR677 34.5kV	194	395	104.0%	264	466	76.2%
Minimum Conditions – low Generation, L-6024 (between 50W and IR677 POI) out of service						
50W-Milton, 138kV	654	724	10.7%	738	757	2.6%
50W-Milton, 69kV	356	383	7.3%	388	394	1.7%
9W-Tusket Hydro & SW STA, 138kV-A	144	290	102.3%	356	503	41.3%
9W-Tusket Hydro & SW STA, 138kV-B	252	335	32.9%	355	387	9.0%
9W-Tusket Hydro & SW STA, 69kV	194	309	59.2%	345	408	18.3%
IR677 138kV (POI)	144	290	102.3%	356	503	41.3%
IR677 138kV (GSU_HV)	135	292	116.6%	307	465	51.3%
IR677 34.5kV	114	315	177.1%	215	417	93.5%

The minimum short circuit level for IR677 is expected when L-6024 (between 50W and IR677's POI) is out of service and generation in the Western Valley region is off-line. Under these conditions, the Short Circuit Ratio (SCR), a measure of system strength relative to the size of the wind farm, is calculated to be 1.36 (114 MVA / 84 MW) at the IR677's 34.5 kV bus. The SCR would be further reduced at the high side of the generator step-up transformers due to the collector circuit impedance. The minimum SCR recommended for Nordex N163 machines by the wind turbine manufacture is 3 or 4, and the low SCR of 1.36 could result in IR677's machine tripping or oscillation under certain contingencies in the area. To ensure IR677's stable operational performance, a 60MVA synchronous condenser was added onto the IR677 POI (138kV bus) under the stability analysis. The minimum SCR was then improved to 2.56 at the IR677's 34.5 kV bus with the synchronous condenser in service. The IC must consult the wind turbine manufacture to determine the required modifications to ensure IR677 meets reliability requirements under low SCR conditions detailed in this report. Otherwise, the facility may be curtailed to maintain system stability when the synchronous condenser is out of service.

IR677 will not impact the neighbouring breaker's interrupting capability with the addition of the synchronous condenser in the area.

3.2 Power factor

For IR677 power factor evaluation, at all production levels up to the full rated load, the facility must be capable of operating between 0.95 PU lagging to 0.95 PU leading net power factor at the high side of the ICIF transformer. The power factor will be measured at the high side of the ICIF transformer for this requirement.

Both the 138/34.5 kV substation transformer and the 34.5/0.95 kV generator step-up transformer were assumed to be supplied with de-energized tap changers with ±5% taps and 5 equal steps.

The Nordex N163 wind turbine generators (power factor +0.907/-0.900 at 950 V nominal) can provide +3.25/-3.39 MVAr reactive power when delivering rated power at 7.0 MW. The reactive power capability within normal voltage operation is shown in *Figure 6: Reactive power capability of the Nordex N163 wind turbine under normal voltage operation*. A total of +39.00/-40.68 MVAr reactive power could be provided when delivering capped power at 84.0 MW.

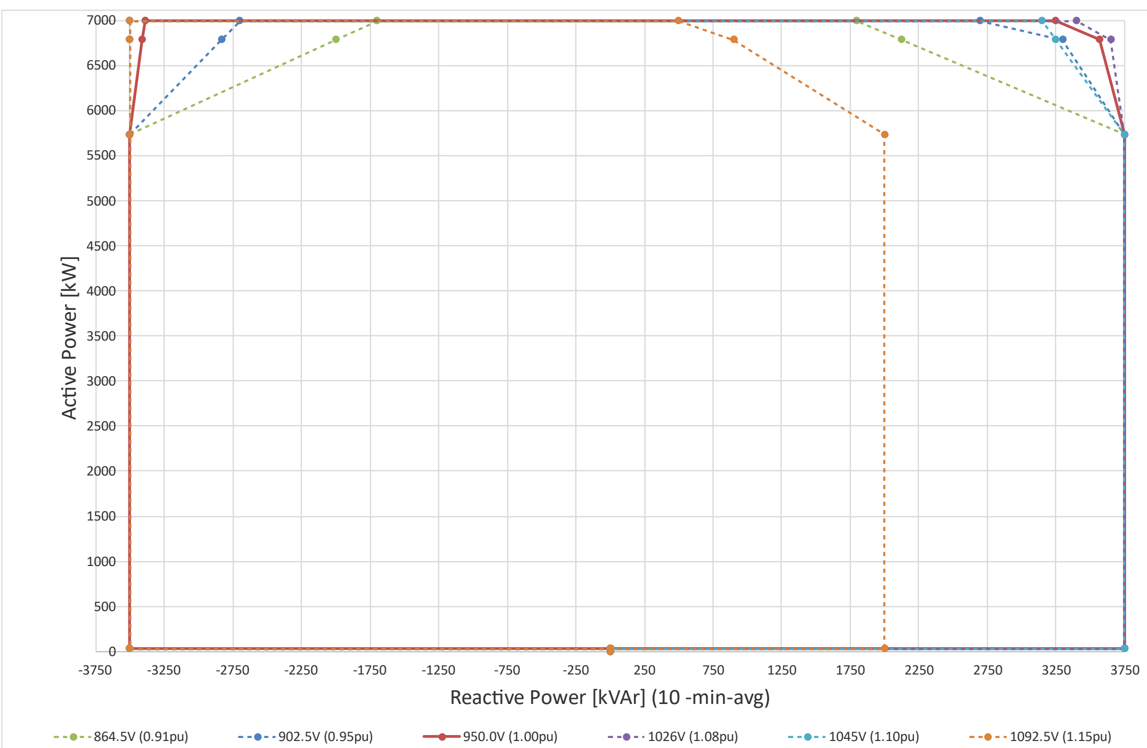


Figure 6: Reactive power capability of the Nordex N163 wind turbine under normal voltage operation[1]

When IR677 generation is at rated 84.00 MW output and producing maximum 39.00 MVAr of reactive power, the real and reactive power delivered to the high side (138 kV) of the ICIF transformers is 82.37 MW and 18.24 MVAr, respectively. This equates to a +0.976 lagging power factor, not meeting the existing +0.95 GIP requirement. Additional reactive power compensation (at least 10 MVAr) will be needed. The IC shall consider the use of additional reactive power device(s) such as the synchronous condenser or wind turbine models which have a higher reactive power range.

When IR677 generation is at rated 84.00 MW output, while absorbing maximum 40.68 MVAr of reactive power, the real and reactive power delivered to the high side (138 kV) of the ICIF transformers is 82.11 MW and 64.95 MVAr, respectively. This corresponds to a -0.784 power factor, meeting the -0.95 GIP requirement.

The calculated reactive power consumption of the IC's components when IR677 is at rated MW output while producing or absorbing reactive power is listed in *Table 5: MVAr consumption at rated MW output*.

Table 5: MVAr consumption at rated MW output

Component	At max MVAr production	At max MVAr absorption
ICIF transformers (138/34.5 kV) *	11.45	13.37
Collector circuit equivalent	1.54	1.80
34.5/0.95 kV generator step-up transformer equivalent (tap setting 1.00)	7.88	9.22

* *Taps setting at 1.05 for max MVAr production and 0.95 for max MVAr absorption*

NSPI’s TSIR section 7.6.2 Reactive Power and Voltage Control requires “Rated reactive power shall be available through the full range of real power output of the Generating Facility, from zero to full power”. However, the IC provided data indicated that the Nordex N163 wind turbine generators does not provide or absorb reactive power during the wind turbine standstill (0 MW). Therefore, the IC shall supply the synchronous condenser or other supplemental reactive power compensation such as Nordex “STATCOM function” option to ensure the rated reactive power will be available through the full range of real power output of IR677, from zero to full power.

3.3 Voltage flicker & Harmonics

Voltage flicker is not calculated in this study as the flicker coefficient data is currently not available. IR677 is required to meet NS Power's short term and long-term voltage flicker requirements based off the measured data.

As for harmonics, NSPI requires IR677 to meet Harmonics IEEE-519 standard limiting Total Harmonic Distortion (all frequencies) to a maximum of 1.5%, with no individual harmonic exceeding 1.5% for 138 kV. The total harmonic distortion (THD) for Nordex N163 is currently not available. If for some reason, in the actual installation, IR677 causes issues with voltage flicker or harmonics, then IR677 will be responsible for mitigating the issues.

3.4 Steady state analysis

3.4.1 Base cases

The bases cases used for power flow analysis are listed in *Table 6: Power flow base cases*. One-line diagrams of each base case are presented in *Appendix B: Base case one-line diagrams*.

For these cases:

- Transmission connected wind generation facilities were dispatched between 19% and 100% of their rated capability.
- All interface limits were respected for base case scenarios.

Two scenarios were examined for each of the Spring Light Load, Summer Peak, and Winter Peak cases:

- Pre-IR677 cases ending with “-1”: IR677 off.
- Post-IR677 cases ending with “-2”: IR677 dispatched at 84 MW under NRIS designation.

Table 6: Power flow base cases

Case	NS Load	IR677	Wind generation	West wind	NSX	MLI	CBX	ONS	ONI	Valley import	Western import	Valley export	West Valley import
c_ll01-1	782	0	575	489	230	-156	74	-199	61	11	-134	-7	33
c_ll01-2	782	84	659	573	231	-156	0	-275	-13	4	-203	-8	34
c_ll02-1	848	0	575	489	230	-156	133	-141	120	15	-39	-7	33
c_ll02-2	848	84	659	573	231	-156	106	-169	93	7	-109	-8	34
c_ll03-1	792	0	761	522	230	0	-90	-241	-31	1	-155	8	18
c_ll03-2	774	84	845	606	232	0	-201	-355	-143	-5	-223	7	19
c_ll04-1	850	0	761	522	230	0	-25	-175	35	5	-60	8	18
c_ll04-2	841	84	845	606	231	0	-82	-235	-23	-2	-129	8	19
c_ll05-1	783	0	761	522	200	0	-201	-324	-144	2	-155	8	18
c_ll05-2	778	84	845	606	202	0	-201	-326	-145	-6	-223	7	19
c_ll06-1	833	0	761	522	105	0	-201	-227	-143	6	-60	8	18
c_ll06-2	828	84	845	606	108	0	-201	-230	-143	-2	-129	8	18
c_sh01-1	1248	0	761	522	350	-475	445	153	532	80	-88	-22	65
c_sh01-2	1238	84	845	606	351	-475	445	85	464	73	-158	-23	67
c_sh02-1	1298	0	761	522	349	-475	445	157	534	85	7	-22	65
c_sh02-2	1298	84	845	606	350	-475	445	153	532	76	-63	-23	66
c_sh03-1	1324	0	605	522	-300	-146	-134	20	-195	29	-130	22	22
c_sh03-2	1319	84	689	606	-299	-146	-134	19	-195	21	-199	21	22
c_sh04-1	1374	0	605	522	-300	-146	-134	20	-195	33	-35	22	22
c_sh04-2	1374	84	689	606	-299	-146	-134	19	-195	25	-105	21	22
c_sp01-1	1382	0	758	519	351	-475	316	61	452	100	-90	-26	74
c_sp01-2	1382	84	842	603	352	-475	317	6	398	92	-160	-27	76
c_sp02-1	1445	0	758	519	350	-475	381	109	500	104	5	-26	74
c_sp02-2	1437	84	842	603	351	-475	317	30	422	96	-66	-27	75
c_sp03-1	1415	0	526	474	350	-475	650	255	703	100	-47	-26	74

Case	NS Load	IR677	Wind generation	West wind	NSX	MLI	CBX	ONS	ONI	Valley import	Western import	Valley export	West Valley import
c_sp03-2	1406	84	610	558	351	-475	567	176	624	92	-119	-27	75
c_sp04-1	1474	0	526	474	350	-475	700	304	752	104	49	-25	74
c_sp04-2	1465	84	610	558	351	-475	616	223	672	96	-24	-26	75
c_sp05-1	1400	0	369	369	0	-475	558	477	592	119	-41	-25	74
c_sp05-2	1400	84	453	453	0	-475	476	396	512	111	-113	-27	75
c_sp06-1	1459	0	369	369	0	-475	609	526	641	123	55	-25	74
c_sp06-2	1450	84	453	453	1	-475	525	444	560	115	-18	-26	74
c_sp07-1	1546	0	648	522	330	-369	229	193	522	17	-177	29	19
c_sp07-2	1546	84	732	606	331	-294	154	118	449	10	-245	27	20
c_wp01-1	2126	0	600	504	151	-320	764	658	958	148	-25	-15	87
c_wp01-2	2117	84	684	588	151	-320	677	575	875	139	-99	-15	88
c_wp02-1	2008	0	600	504	150	-320	550	478	763	129	46	-6	73
c_wp02-2	1999	84	684	588	150	-320	465	396	681	121	-27	-6	73
c_wp03-1	2126	0	483	483	151	-320	753	567	899	156	-11	-26	98
c_wp03-2	2117	84	567	567	150	-320	665	484	816	148	-86	-26	99
c_wp04-1	2008	0	600	504	150	-320	646	571	855	131	71	-6	73
c_wp04-2	1999	84	684	588	150	-320	559	487	772	123	-4	-6	73
c_wp05-1	2349	0	761	522	150	-475	574	741	872	166	-39	-10	89
c_wp05-2	2342	84	845	606	150	-475	599	689	820	158	-111	-12	91

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

- wp01-x, wp02-x, wp03-x, wp04-x represents peak load, with high East-West transfers, where-as wp05-x represents peak load with moderate East-West transfers and high Western Valley Import levels. Generation dispatched is assumed to be typical for peak load, with high load in the Valley area.
- sh03-x represents the NS/NB import limit, presently 23% of net in-province load, to a maximum 300 MW. This case tests the performance of the Underfrequency Load Shedding *(UFLS)* system during contingencies that isolates NS from the interconnected power system *(like the loss of L8001)*.
- sp01-x, sp02-x, sp-07-x, sh01-x, and sh02-x represent off-peak load and high generation in the Western and Valley areas. This represents typical spring hydro run-off conditions. Local hydro generation is managed to ensure transmission limits are maintained.
- ll01-x, ll02-x, ll03-x, ll04-x, ll05-x, ll06-x, sh01-x, sh02-x, sp01-x, sp02-x, sp03-x, sp04-x, sp07-x, wp01-x, wp02-x, wp03-x, wp04-x, and wp05-x represent high enough export levels from NS to NB to require arming of the Export Power Monitor SPS. ll01-x, ll02-x, ll03-x, ll04-x, ll05-x, ll06-x, sp07-x, wp01-x, wp02-x, wp03-x, wp04-x, and wp05-x require low export level arming, while sh01-x, sh02-x, sp01-x, sp02-x, sp03-x, and sp04-x requires high export arming. In either condition, the Maritime Link *(ML)* is targeted to reduce NS generation for conditions resulting from the loss of the 345kV

tie line, L8001, and subsequent action to reduce flow on the 138kV line L6613, between 1N-Onslow and 74N-Springhill.

- ll05-x and ll06-x represents minimum system load under low inertia, with only two equivalent thermal units online and high wind generation.
- sp05-x and sp06-x represent the high import at Valley and Western corridors.

3.4.2 Steady state contingencies

The steady state power flow analysis includes the contingencies listed in *Table 7: Steady state contingencies*.

Table 7: Steady state contingencies

ID	Element	Type	Location	ID	Element	Type	Location
p001	2C-B61	Bus fault	2C-Hastings	p139	88S-713	Breaker fail	88S-Lingan
p002	2C-B62	Bus fault	2C-Hastings	p140	88S-720	Breaker fail	88S-Lingan
p003	3C-712	Breaker fail	3C-Hastings	p141	88S-721	Breaker fail	88S-Lingan
p004	3C-715	Breaker fail	3C-Hastings	p142	88S-722	Breaker fail	88S-Lingan
p005	L6515	Line fault	2C-Hastings	p143	88S-723	Breaker fail	88S-Lingan
p006	L6516	Line fault	2C-Hastings	p144	L7011	Line fault	101S-Woodbine
p007	L6517	Line fault	2C-Hastings	p145	L7014	Line fault	88S-Lingan
p008	L6518	Line fault	2C-Hastings	p146	L7015	Line fault	101S-Woodbine
p009	L6537	Line fault	2C-Hastings	p147	L7021	Line fault	88S-Lingan
p010	L6543	Line fault	2C-Hastings	p148	L7022	Line fault	88S-Lingan
p011	L7004	Line fault	3C-Hastings	p149	L8004	Line fault	101S-Woodbine
p012	103H-B61	Bus fault	103H-Lakeside	p150	L6011 + L6010	Double ckt tower	Sackville
p013	103H-B62	Bus fault	103H-Lakeside	p151	L6507 + L6508	Double ckt tower	Trenton
p014	103H-T63	Transformer fault	103H-Lakeside	p152	L6534 + L7021	Double ckt tower	Lingan / VJ
p015	104H-600	Breaker fail	104H-Kempt Rd	p153	L7003 + L7004	Double ckt tower	Canso Causeway
p016	113H-601	Breaker fail	113H-Dartmouth East	p154	L7008 + L7009	Double ckt tower	Bridgewater
p017	120H-621	Breaker fail	120H-Brushy	p155	L7009 + L8002	Double ckt tower	Sackville
p018	120H-622	Breaker fail	120H-Brushy	p156	101V-601	Breaker fail	101V-MacDonald Pond
p019	120H-623	Breaker fail	120H-Brushy	p157	13V-B51	Bus fault	13V-Gulch
p020	120H-624	Breaker fail	120H-Brushy	p158	15V-B51	Bus fault	15V-Sissiboo
p021	120H-625	Breaker fail	120H-Brushy	p159	17V-B1	Bus fault	17V-St Croix
p022	120H-626	Breaker fail	120H-Brushy	p160	17V-B2	Bus fault	17V-St Croix
p023	120H-627	Breaker fail	120H-Brushy	p161	1V-442	Breaker fail	1V-Avon 1
p024	120H-628	Breaker fail	120H-Brushy	p162	20V-B51	Bus fault	20V-Five Points
p025	120H-629	Breaker fail	120H-Brushy	p163	3V-551	Breaker fail	3V-Hell's Gate
p026	120H-710	Breaker fail	120H-Brushy	p164	43V-B51	Bus fault	43V-Canaan Rd
p027	120H-711	Breaker fail	120H-Brushy	p165	43V-B61	Bus fault	43V-Canaan Rd
p028	120H-712	Breaker fail	120H-Brushy	p166	43V-B62	Bus fault	43V-Canaan Rd
p029	120H-713	Breaker fail	120H-Brushy	p167	43V-T61	Transformer fault	43V-Canaan Rd
p030	120H-714	Breaker fail	120H-Brushy	p168	43V-T62	Transformer fault	43V-Canaan Rd
p031	120H-715	Breaker fail	120H-Brushy	p169	51V-601	Breaker fail	51V-Tremont
p032	120H-716	Breaker fail	120H-Brushy	p170	51V-B51	Bus fault	51V-Tremont
p033	120H-720	Breaker fail	120H-Brushy	p171	51V-T61	Transformer fault	51V-Tremont
p034	132H-602	Breaker fail	132H-Spider Lake	p172	51V-T62	Transformer fault	51V-Tremont
p035	132H-603	Breaker fail	132H-Spider Lake	p173	6V-GT1	Transformer fault	6V-Hollow Bridge
p036	132H-605	Breaker fail	132H-Spider Lake	p174	82V-600	Breaker fail	82V-Elmsdale
p037	132H-606	Breaker fail	132H-Spider Lake	p175	92V-B51	Bus fault	92V-Michelin Waterville

ID	Element	Type	Location	ID	Element	Type	Location
p038	1H-603	Breaker fail	1H-Water St	p176	L4045	Line fault	17V-St Croix
p039	90H-601	Breaker fail	90H-Sackville	p177	L4046	Line fault	17V-St Croix
p040	90H-602	Breaker fail	90H-Sackville	p178	L4047	Line fault	17V-St Croix
p041	90H-603	Breaker fail	90H-Sackville	p179	L4048W	Line fault	39V-Fundy Gypsum
p042	90H-605	Breaker fail	90H-Sackville	p180	L4049	Line fault	3V-Hell's Gate
p043	90H-606	Breaker fail	90H-Sackville	p181	L5014	Line fault	17V-St Croix
p044	90H-608	Breaker fail	90H-Sackville	p182	L5015	Line fault	17V-St Croix
p045	90H-609	Breaker fail	90H-Sackville	p183	L5016	Line fault	17V-St Croix
p046	90H-611	Breaker fail	90H-Sackville	p184	L5021	Line fault	43V-Canaan Rd
p047	90H-612	Breaker fail	90H-Sackville	p185	L5022	Line fault	43V-Canaan Rd
p048	90H-613	Breaker fail	91H-Tufts Cove	p186	L5025	Line fault	11V-Paradise
p049	90H-621	Breaker fail	91H-Tufts Cove	p187	L5026	Line fault	11V-Paradise
p050	91H-603	Breaker fail	91H-Tufts Cove	p188	L5033	Line fault	43V-Canaan Rd
p051	91H-604	Breaker fail	91H-Tufts Cove	p189	L5035	Line fault	3V-Hell's Gate
p052	91H-605	Breaker fail	91H-Tufts Cove	p190	L5050	Line fault	15V-Sissiboo
p053	91H-606	Breaker fail	91H-Tufts Cove	p191	L5053	Line fault	92V-Michelin Waterville
p054	91H-607	Breaker fail	91H-Tufts Cove	p192	L5060	Line fault	17V-St Croix
p055	91H-608	Breaker fail	91H-Tufts Cove	p193	L5531	Line fault	13V-Gulch
p056	91H-609	Breaker fail	91H-Tufts Cove	p194	L5532	Line fault	13V-Gulch
p057	91H-611	Breaker fail	91H-Tufts Cove	p195	L5533	Line fault	13V-Gulch
p058	L6044	Line fault	132H-Spider Lake	p196	L5535	Line fault	15V-Sissiboo
p059	L6002E	Line fault	90H-Sackville	p197	L5538	Line fault	15V-Sissiboo
p060	L6003	Line fault	90H-Sackville	p198	L6001N	Line fault	82V-Elmsdale
p061	L6004	Line fault	90H-Sackville	p199	L6001S	Line fault	82V-Elmsdale
p062	L6005	Line fault	120H-Brushy	p200	L6012	Line fault	43V-Canaan Rd
p063	L6007	Line fault	91H-Tufts Cove	p201	L6013	Line fault	43V-Canaan Rd
p064	L6008	Line fault	103H-Lakeside	p202	L6015	Line fault	43V-Canaan Rd
p065	L6009	Line fault	90H-Sackville	p203	L6051	Line fault	17V-St Croix
p066	L6010	Line fault	120H-Brushy	p206	L6052	Line fault	43V-Canaan Rd
p067	L6011	Line fault	120H-Brushy	p207	L6054	Line fault	43V-Canaan Rd
p068	L6014	Line fault	91H-Tufts Cove	p209	30W-B51	Bus fault	30W-Souriquois
p069	L6016	Line fault	120H-Brushy	p210	30W-B61	Bus fault	30W-Souriquois
p070	L6033	Line fault	103H-Lakeside	p211	3W-B53	Bus fault	3W-Big Falls
p071	L6035	Line fault	1H-Water St	p212	50W-B2	Bus fault	50W-Milton
p072	L6038	Line fault	103H-Lakeside	p213	50W-B3	Bus fault	50W-Milton
p073	L6040	Line fault	91H-Tufts Cove	p214	50W-B4	Bus fault	50W-Milton
p074	L6042	Line fault	91H-Tufts Cove	p215	50W-T53	Transformer fault	50W-Milton
p075	L6043	Line fault	113H-Dartmouth East	p216	99W-B51	Bus fault	99W-Bridgewater
p076	L6044	Line fault	113H-Dartmouth East	p217	99W-B61	Bus fault	99W-Bridgewater
p077	L6051	Line fault	120H-Brushy	p218	99W-B62	Bus fault	99W-Bridgewater
p078	L6055	Line fault	132H-Spider Lake	p219	99W-B71	Bus fault	99W-Bridgewater
p079	L7018	Line fault	120H-Brushy	p220	99W-B72	Bus fault	99W-Bridgewater
p080	90H-T1	Transformer fault	90H-Sackville	p221	99W-T61	Transformer fault	99W-Bridgewater
p081	1N-B61	Bus fault	1N-Onslow	p222	99W-T62	Transformer fault	99W-Bridgewater
p082	1N-B62	Bus fault	1N-Onslow	p223	99W-T71	Transformer fault	99W-Bridgewater
p083	50N-604	Breaker fail	50N-Trenton	p224	99W-T72	Transformer fault	99W-Bridgewater
p084	67N-701	Breaker fail	67N-Onslow	p225	9W-B52	Bus fault	9W-Tusket
p085	67N-702	Breaker fail	67N-Onslow	p226	9W-B53	Bus fault	9W-Tusket
p086	67N-703	Breaker fail	67N-Onslow	p227	L5530	Line fault	50W-Milton
p087	67N-704	Breaker fail	67N-Onslow	p228	L5540	Line fault	50W-Milton

ID	Element	Type	Location	ID	Element	Type	Location
p088	67N-705	Breaker fail	67N-Onslow	p229	L5541	Line fault	3W-Big Falls
p089	67N-706	Breaker fail	67N-Onslow	p230	L5545	Line fault	99W-Bridgewater
p090	67N-710	Breaker fail	67N-Onslow	p231	L5546	Line fault	99W-Bridgewater
p091	67N-711	Breaker fail	67N-Onslow	p232	L6006	Line fault	99W-Bridgewater
p092	67N-712	Breaker fail	67N-Onslow	p233	L6020	Line fault	50W-Milton
p093	67N-713	Breaker fail	67N-Onslow	p234	L6024-1	Line fault	50W-Milton
p094	67N-811	Breaker fail	67N-Onslow	p235	L6025	Line fault	99W-Bridgewater
p095	67N-812	Breaker fail	67N-Onslow	p236	L6048	Line fault	50W-Milton
p096	67N-813	Breaker fail	67N-Onslow	p237	L6531	Line fault	99W-Bridgewater
p097	67N-814	Breaker fail	67N-Onslow	p238	L7008	Line fault	99W-Bridgewater
p098	74N-600	Breaker fail	74N-Springhill	p239	L7009	Line fault	99W-Bridgewater
p099	79N-B61	Bus fault	79N-Hopewell	p240	17V-611	Breaker fail	17V- St. Croix
p100	79N-B81	Bus fault	79N-Hopewell	p241	17V-512	Breaker fail	17V- St. Croix
p101	L5029	Line fault	74N-Springhill	p242	17V-563	Breaker fail	17V- St. Croix
p102	L5058	Line fault	74N-Springhill	p243	17V-T63	Transformer fault	17V- St. Croix
p103	L6001	Line fault	1N-Onslow	p244	1V-B51	Bus fault	1V-Avon 1
p104	L6057	Line fault	50N-Trenton	p245	43V-503	Breaker fail	43V-Canaan Rd
p105	L6503	Line fault	50N-Trenton	p246	43V-562	Breaker fail	43V-Canaan Rd
p106	L6507	Line fault	79N-Hopewell	p247	51V-500	Breaker fail	51V-Tremont
p107	L6508	Line fault	50N-Trenton	p248	51V-521	Breaker fail	51V-Tremont
p108	L6511	Line fault	50N-Trenton	p249	51V-562	Breaker fail	51V-Tremont
p109	L6514	Line fault	74N-Springhill	p250	51V-602	Breaker fail	51V-Tremont
p110	L6527	Line fault	1N-Onslow	p251	51V-603	Breaker fail	51V-Tremont
p111	L6536	Line fault	74N-Springhill	p252	51V-B52	Bus fault	51V-Tremont
p112	L6613	Line fault	74N-Springhill	p253	82V-B61	Bus fault	82V-Elmsdale
p113	L7001	Line fault	67N-Onslow	p254	101V-602	Breaker fail	101V-MacDonald Pond
p114	L7002	Line fault	67N-Onslow	p255	101V-603	Breaker fail	101V-MacDonald Pond
p115	L7003	Line fault	67N-Onslow	p256	50W-501	Breaker fail	50W-Milton
p116	L7005	Line fault	67N-Onslow	p257	50W-514	Breaker fail	50W-Milton
p117	L7019	Line fault	67N-Onslow	p258	50W-517	Breaker fail	50W-Milton
p118	L8001	Line fault	67N-Onslow	p259	50W-600	Breaker fail	50W-Milton
p119	L8002	Line fault	67N-Onslow	p260	50W-615	Breaker fail	50W-Milton
p120	L8003	Line fault	67N-Onslow	p261	99W-501	Breaker fail	99W-Bridgewater
p121	L8003	Line fault	79N-Hopewell	p262	99W-562	Breaker fail	99W-Bridgewater
p122	L8004	Line fault	79N-Hopewell	p263	99W-600	Breaker fail	99W-Bridgewater
p123	101S-701	Breaker fail	101S-Woodbine	p264	99W-601	Breaker fail	99W-Bridgewater
p124	101S-702	Breaker fail	101S-Woodbine	p265	99W-602	Breaker fail	99W-Bridgewater
p125	101S-703	Breaker fail	101S-Woodbine	p266	9W-500	Breaker fail	9W-Tusket
p126	101S-704	Breaker fail	101S-Woodbine	p267	L6024-2	Line fault	9W-Tusket
p127	101S-705	Breaker fail	101S-Woodbine	p268	IR677-Breaker	Breaker fail	IR677
p128	101S-706	Breaker fail	101S-Woodbine	p269	101S_ML-POLE1	Line fault	101S-Woodbine
p129	101S-711	Breaker fail	101S-Woodbine	p270	101S_ML-POLE2	Line fault	101S-Woodbine
p130	101S-712	Breaker fail	101S-Woodbine	p271	101S_ML-BIPOLE	Line fault	101S-Woodbine
p131	101S-713	Breaker fail	101S-Woodbine	p272	89S-G1	Generator loss	89S-Point Aconi
p132	101S-811	Breaker fail	101S-Woodbine	p273	50N-G5	Generator loss	50N-Trenton
p133	101S-812	Breaker fail	101S-Woodbine	p274	50N-G6	Generator loss	50N-Trenton
p134	101S-813	Breaker fail	101S-Woodbine	p275	91H-G3	Generator loss	91H-Tufts Cove
p135	101S-814	Breaker fail	101S-Woodbine	p276	1C-G2	Generator loss	1C-Point Tupper

ID	Element	Type	Location	ID	Element	Type	Location
p136	101S-816	Breaker fail	101S-Woodbine				
p137	88S-710	Breaker fail	88S-Lingan				
p138	88S-712	Breaker fail	88S-Lingan				

3.4.3 Steady state evaluation

The steady state power flow analysis was conducted without IR677 in service and with IR677 in service. The differential line flows are shown in *Appendix C: Differential line flows*. The one-line diagrams display the difference in flow on each transmission line with and without IR677. Notable differences on the lines between 120H-Brushy Hill, 99W-Bridgewater, 50W-Milton, 9W-Tusket, 51V-Tremont, 15V-Sissiboo, 13V-Gulch and 11V-Paradise are expected as these substations are along the corridor towards the system IR677 is placed in. The flow from Western area towards Metro area (Western Import corridor from 99W-Bridgewater to 120H-Brushy Hill) is increased by up to 74.5 MW as IR677 comes online. The flow on Valley Import corridor from Metro area is reduced by up to 8.4 MW.

IR677 also has some impact on constrained transmission system in the Milton and Tusket area. The flow from Milton to Tusket area (on L-6020, L-6024 and L-5530) reduces 76.5 MW as IR677 comes online. The flows on L-5532 and L-5535 from Western to Valley area are increased by up to 0.9MW and 8.4MW, respectively.

Results of the steady state analysis are presented in *Appendix D: Steady-state analysis results*. The power flow analysis identified several electrically remote transmission system contingencies inside Nova Scotia that violate thermal loading criteria.

New thermal issues are identified which are attributed to IR677:

- **9W-T2 Overload Conditions:**
  Contingency p214 (loss of 50W-B4) could overload transformer 9W-T2 up to 123% in ll01-2, ll02-2, ll03-2, ll04-2, ll05-2, ll06-2, sh04-2, and sp07-2 cases even after the Milton/Tusket load rejection AAS activation. This AAS is no longer sufficient to offload 9W-T2 below its overload rating during some summer dispatch scenarios. As a result, transformer 9W-T2 must be replaced with a 60/80/100 MVA unit. However, with the 9W-T2 upgrade, the exiting Milton/Tusket load rejection AAS will need to be modified, and overload on L-6021 (up to 103%) occurs in ll03-2, ll04-2, ll05-2, ll06-2, and sp07-2 cases. To resolve this issue, the 9W-516A switch for L-6021 is to be upgraded.

- **99W-T71 and 99W-T72 Overload Conditions:**
  Contingencies p028 (120H-712 breaker fail), p029 (120H-713 breaker fail), p155 (loss of L-7009 + L-8002), p218 (loss of 99W-B62), p220 (loss of 99W-B72), p222 (loss of 99W-T62), p224 (loss of 99W-T72), p239 (loss of L-7009) and p262 (99W-562 breaker fail) could overload 99W-T71 up to 150% in ll01-2, ll03-2, ll05-2, sh01-2, sh03-2, sp01-2 and sp07-2 cases. Contingencies p031 (120H-715 breaker

fail), p032 (120H-716 breaker fail), p217 (loss of 99W-B61), p219 (loss of 99W-B71), p221 (loss of 99W-T61), p223 (loss of 99W-T71), p238 (loss of L-7008) and p261 (99W-501 breaker fail) could overload 99W-T72 up to 141% in ll01-2, ll03-2, ll05-2, sh03-2, sp01-2 and sp07-2 cases. With the addition of IR677, the existing ratings of 99W transformers are no longer sufficient for the flow exporting from Western area to Metro area. To resolve this issue, an automatic action scheme to cross trip IR677 is proposed and armed if the flow through 99W-T71 and 99W-T72 is larger than 200MVA towards 120H.

- **L-7009 Overload Conditions:**
  Contingencies p031 (120H-715 breaker fail), p032 (120H-716 breaker fail), p217 (loss of 99W-B61), p219 (loss of 99W-B71), p221 (loss of 99W-T61), p223 (loss of 99W-T71), p238 (loss of L-7008) and p261 (99W-501 breaker fail) could overload L-7009 up to 115% in sp07-2 case. This issue could also be resolved by the new automatic action scheme to mitigate 99W-T71 and 99W-T72 overload issue, which is to cross trip IR677 when the flow through 99W-T71 and 99W-T72 is larger than 200MVA towards 120H.

- **L-5535 Overload Conditions:**
  Contingency p156 (101V-601 breaker fail), p195 (loss of L-5533), p211 (loss of 3W-B53), p225 (loss of 9W-B52), p217 (loss of 99W-B61), p218 (loss of 99W-B62), p221 (loss of 99W-T61), p222 (loss of 99W-T62), p234 (loss of L-6024 between IR677 POI and 50W), p261 (99W-501 breaker fail), and p262 (99W-562 breaker fail) could overload L-5535 up to 120% in sh01-2, sh02-2, sp01-2, sp02-2, sp03-2, and sp05-2 cases. To resolve this issue, an automatic action scheme to cross trip IR677 is needed to mitigate L-5535 overload, the cross-trip also resolves any consequential overload on L-5532 or L-5541.

- **L-6025 Overload Conditions:**
  Contingencies p218 (loss of 99W-B62), p222 (loss of 99W-T62) and p262 (99W-562 breaker fail) could overload transmission line L-6025 up to 111% in sp07-2 case. This issue could be resolved by upgrading the current transformer (200MVA) and the metering (231MVA).

- **L-6531 Overload Conditions:**
  Contingencies p217 (loss of 99W-B61), p221 (loss of 99W-T61), p232 (loss of L-6006), p235(loss of L-6025), and p261 (99W-501 breaker fail) could overload transmission line L-6531 up to 107% in sp07-2 case. This issue could be resolved by upgrading the conductor maximum operating temperature of L-6531 from 50 °C to 60 °C.

- **L-5532 Overload Conditions:**
  Contingency p265 (9W-500 breaker fail) could overload L-5532 (between 3W and 91W) up to 102% in sp05-2 cases. No network upgrades are proposed currently for this marginal overload.

Pre-existing thermal issues are identified which are not attributed to IR677 project and are considered as the responsibility of the transmission provider:

- **9W-T63 Overload:**
  Contingency p256 (50W-501) could overload 9W-T63 up to 108% in wp03 cases with the assumption that existing 9W-T63 would have been replaced by a 60/80/100 MVA unit, therefore the replacement transformer should have sufficient emergency overload capability.

- **L-5541 Overload Conditions:**
  Contingencies p170 (loss of 51V-B51), p186 (loss of L-5025), p187 (loss of L-5026), p247 (51V-500 breaker fail), and p248 (51V-521 breaker fail) could overload L-5541 up to 122% in sp07 cases. This is pre-existing issue in sp07 which is not a typical system dispatch and IR677 could contribute to up to 10% of the overload increasing.

- **L-6009 (between 90H and 101H) Overload Conditions:**
  Contingency p056 (91H-609 break fail) could overload L-6009 (between 90H and 101H) up to 102% in wp05-2 case. This is pre-existing issue and can be slightly worsened post IR677 project.

- **L-6003 Overload Conditions:**
  Loss of L-6009 (between 90H and 101H) could overload L-6003 up to 104% in sp07 cases. This pre-existing issue is slightly worsened post IR677 project with 2% increase.

- **43V-T61 Overload Conditions:**
  Contingency p168 (loss of 43V-T62) could overload transformer 43V-T61 up to 115% in wp05 cases. This is pre-existing issue and is not attributed to IR677.

It’s noted that contingencies L-6024 (section between 9W-Tusket and IR677 POI) and IR677-breaker fail (loss of L-6024 and IR677 substation) can still result in the undervoltage issues (below 0.8 p.u.) in Tusket area and along L-5027 after upgrade of 9W-T2. These are pre-existing conditions and not the responsibility of the IC. The existing Milton-Tusket Load Rejection AAS is proposed to be repurposed for a higher queued project, in the area, which is to cross trip L-5027 for undervoltage issues. Low voltage during these contingencies could also be resolved with new capacitor banks at 22W-Barrington and 9W-Tusket, which is the cost responsibility of the Transmission Provider.

It is noted that the IR677 substation transformer (rated at 90 MVA) is overloaded to 115% when IR677 is operating at the maximum 84 MW output, while absorbing maximum 40.68 MVAr of reactive power.

3.5 Stability analysis

System design criteria requires the system to be stable and well damped in all modes of oscillations. Due to the low short circuit levels identified in section 3.1, stability analysis was performed with the addition of a 60MVA synchronous condenser at IR677 POI.

3.5.1 Stability base cases

Selected steady-state cases were studied for contingencies that provide the best measure of system reliability. The parameters of these base cases are listed below in *Table 8: Stability base cases*.

Table 8: Stability base cases

Case	NS Load	IR677	Wind generation	West wind	NSX	ML	CBX	ONS	ONI	Valley import	Western import	Valley export	West Valley import
c_ll01-2	782	84	659	573	231	-156	0	-275	-13	4	-203	-8	34
c_ll02-2	848	84	659	573	231	-156	106	-169	93	7	-109	-8	34
c_ll03-2	774	84	845	606	232	0	-201	-355	-143	-5	-223	7	19
c_ll04-2	841	84	845	606	231	0	-82	-235	-23	-2	-129	8	19
c_ll05-2	778	84	845	606	202	0	-201	-326	-145	-6	-223	7	19
c_ll06-2	828	84	845	606	108	0	-201	-230	-143	-2	-129	8	18
c_sh01-2	1238	84	845	606	351	-475	445	85	464	73	-158	-23	67
c_sh02-2	1298	84	845	606	350	-475	445	153	532	76	-63	-23	66
c_sh03-2	1319	84	689	606	-299	-146	-134	19	-195	21	-199	21	22
c_sh04-2	1374	84	689	606	-299	-146	-134	19	-195	25	-105	21	22
c_sp01-2	1382	84	842	603	352	-475	317	6	398	92	-160	-27	76
c_sp02-2	1437	84	842	603	351	-475	317	30	422	96	-66	-27	75
c_sp03-2	1406	84	610	558	351	-475	567	176	624	92	-119	-27	75
c_sp04-2	1465	84	610	558	351	-475	616	223	672	96	-24	-26	75
c_sp05-2	1400	84	453	453	0	-475	476	396	512	111	-113	-27	75
c_sp06-2	1450	84	453	453	1	-475	525	444	560	115	-18	-26	74
c_wp01-2	2117	84	684	588	151	-320	677	575	875	139	-99	-15	88
c_wp02-2	1999	84	684	588	150	-320	465	396	681	121	-27	-6	73
c_wp03-2	2117	84	567	567	150	-320	665	484	816	148	-86	-26	99
c_wp04-2	1999	84	684	588	150	-320	559	487	772	123	-4	-6	73

3.5.2 Stability contingencies

The contingencies tested for this study are listed in *Table 9: Stability contingency list*.

Table 9: Stability contingency list

90H-605_LG	120H L6051_3PH	67N-813_ LG	17V-B63_3PH	99W-501_LG
90H-606_LG	120H L7008_3PH	67N-814_ LG*	17V L5016_3PH	99W-600_LG*
90H-608_LG	120H L7018_3PH	67N L7001_3PH	43V-503_LG	99W-601_LG
90H-609_LG	132H-602_LG	67N L7003_3PH*	43V-562_LG	99W-602_LG
90H L6003_3PH	132H-603_LG	67N L7005_3PH*	43V-612_ LG	99W-606_LG*

90H L6004_3PH	132H-606_LG	67N L7018_3PH	43V-B61_3PH	99W-625_LG*
90H L6008_3PH	132H-605_LG	67N L7019_3PH*	43V-B62_3PH	99W-631_LG*
90H L6009_3PH	132H L6044_3PH	67N L8001_3PH*	43V L6012_3PH	99W-B61_3PH*
91H L6007_3PH	132H L6055_3PH	67N L8002_3PH	51V-521_LG*	99W-B62_3PH*
91H L6014_3PH	1N-600_LG	67N L8003_3PH*	51V-562_LG	99W L6002_3PH
91H L6040_3PH	1N-601_ LG	74N-600_ LG	51V-B51_3PH*	99W L6006_3PH
103H-600_LG	1N-613_ LG	74N L6514_3PH	51V L5025_3PH*	99W L6025_3PH
103H-608_ LG	1N-B61_3PH	74N L6536_3PH	9W-500_LG	99W L6531_3PH
103H-881_LG	1N-B62_3PH	74N L6613_3PH	9W-B52_3PH	99W L7008_3PH*
103H-681_LG	1N L6001_3PH	410N L3006_3PH	9W-B53_3PH	99W L7009_3PH*
103H L6008_3PH	1N L6503_3PH	410N L8001_3025_3PH*	9W L5535_3PH	DCT L6005_L6010_LLG
103H L6016_3PH	1N L6613_3PH	11V-B51_3PH*	9W L6021_3PH	DCT L6010_L6011_LLG
103H L6033_3PH	67N-701_LG	11V L5025_3PH*	9W L6021_LG	DCT L6005_L6016_LLG
103H L8002_3PH	67N-702_ LG	11V L5026_3PH*	9W L6024-1_3PH	DCT L6033_L6035_LLG
108H L6055_3PH	67N-703_ LG	13V-B51_3PH	9W L6024-2_3PH	DCT L6507_L6508_50N_LLG
113H-600_3PH	67N-704_ LG	13V L5026_3PH	IR677-breaker	DCT L6507_L6508_79N_LLG
120H-622_3PH	67N-705_ LG *	13V L5531_3PH	50W-501_LG*	DCT L6534_L7021_LLG
120H-628_3PH	67N-706_ LG	13V L5532_3PH	50W-514_LG	DCT L7003_L7004_LLG *
120H-710_3PH	67N-710_ LG	15V-B51_3PH	50W-517_LG	DCT L7008_L7009_LLG
120H-715_3PH	67N-711_ LG	15V L5535_3PH	50W-600_LG*	DCT L7009_L8002_LLG
120H L6005_3PH	67N-712_ LG	17V-512_LG	50W-615_LG*	DCT L7009_L8002_A_LLG
120H L6010_3PH	67N-713_ LG	17V-563_LG	50W-B2_3PH	
120H L6011_3PH	67N-811_ LG *	17V-611_LG	50W-B3_3PH	* Indicates RAS/AAS
120H L6016_3PH	67N-811_T82_ LG *	17V-612_LG	50W-B4_3PH	

3.5.3 Stability evaluation

PSS®E plotted output files for each contingency with IR677 in service are presented in *Appendix H: Stability analysis results*. All contingencies were found to be stable and well-damped with the addition of a 60MVA synchronous condenser at IR677 POI.

3.6 NPCC-BPS/NERC-BES

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". To determine if IR677 will be BPS, the latest A-10 document, dated March 27, 2020, is used for the determination.

Both steady state and stability BPS testing was performed using the Spring Light Load, Summer Peak, Winter Peak cases shown in *Table 8: Stability base cases*. The steady state test was conducted by dispatching the new facility at request MW output, then disconnecting it. Post-contingency results reveal no voltage violations or thermal overloads outside the local area.

The stability test was performed by placing a 3-phase fault at the IR677 POI, 138 kV bus for 10 seconds, assuming all local protection out of service. *Appendix E: NPCC-BPS determination results* demonstrates IR677 does not have adverse impact outside the local area, confirming the transmission facilities associated with IR677 are not classified as NPCC BPS.

Note NPCC's A-10 Classification of Bulk Power System Elements requires NS Power to perform a periodic comprehensive re-assessment at least once every five years[2]. It is possible for this site's BPS status to change, depending on future system configuration changes, requiring the IC to adapt to NPCC reliability requirements accordingly[3].

Based on NERC BES criteria, IR677 is considered part of the BES with the aggregated plant nameplate rating greater than 75MVA. It shall be designed and operated according to and meeting NERC’s BES standards. There is the potential for an exclusion from BES to be granted for the high side (138kV) bus based on further analysis per the NS BES Exception Procedure.

3.7 Underfrequency operation

IR677's low frequency ride-through performance was tested by simulating a fault on L-8001 under high import conditions. The case selected for dynamic simulation was based on 2026 Shoulder, with 300 MW import into Nova Scotia from New Brunswick (sh03-2).

IR677 remains stable and online as required. Simulation indicates that NS Power's Stage 3 UFLS activates to stabilize system frequency by shedding 295 MW load. The simulation results are shown in figures *Figure 7: Underfrequency performance (frequency at 120H-Brushy Hill:138kV), Figure 8: Underfrequency performance (frequency at NS_410N, Mass, Cherrywood, Orrington, and 120H-Brushy Hill)* and *Figure 9: Underfrequency performance (IR677 machine output)*. Note values are plotted on 100 MVA system base, so IR677 at 0.84 PU power represents maximum output of the generators rather than 84% output.

[2] Regional Reliability Reference Criteria A-10, *Classification of Bulk Power System Elements*, 2020/03/27, https://www.npcc.org/content/docs/public/program-areas/standards-and-criteria/regional-criteria/criteria/a-10-20200508.pdf

[3] NPCC Reliability Reference Directory # 4, *Bulk Power System Protection Criteria*, 2020/01/30, https://www.npcc.org/content/docs/public/program-areas/standards-and-criteria/regional-criteria/directories/directory-4-tfsp-rev-20200130.pdf.

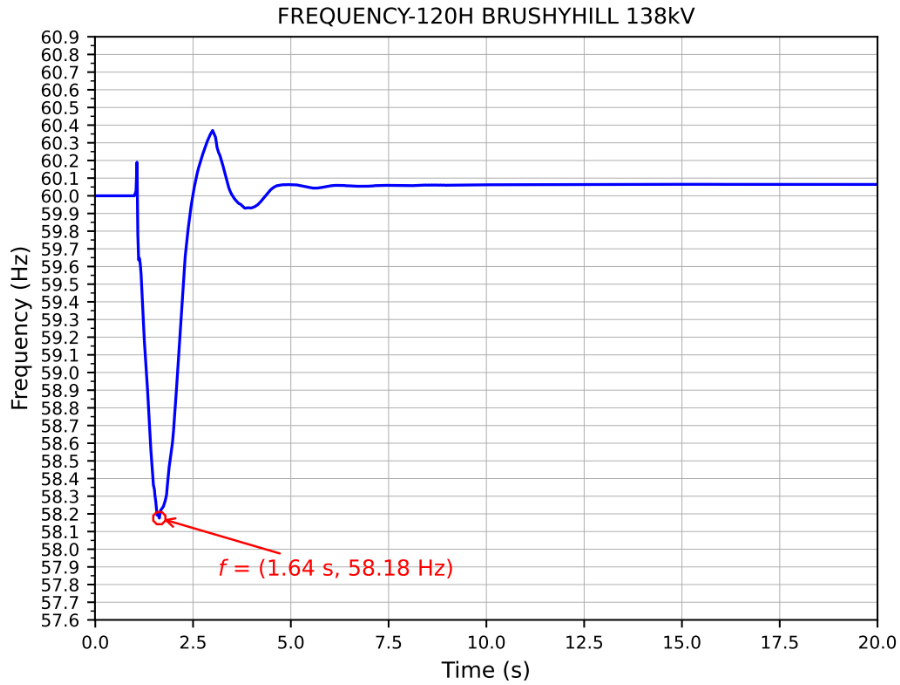


Figure 7: Underfrequency performance (frequency at 120H-Brushy Hill:138kV)

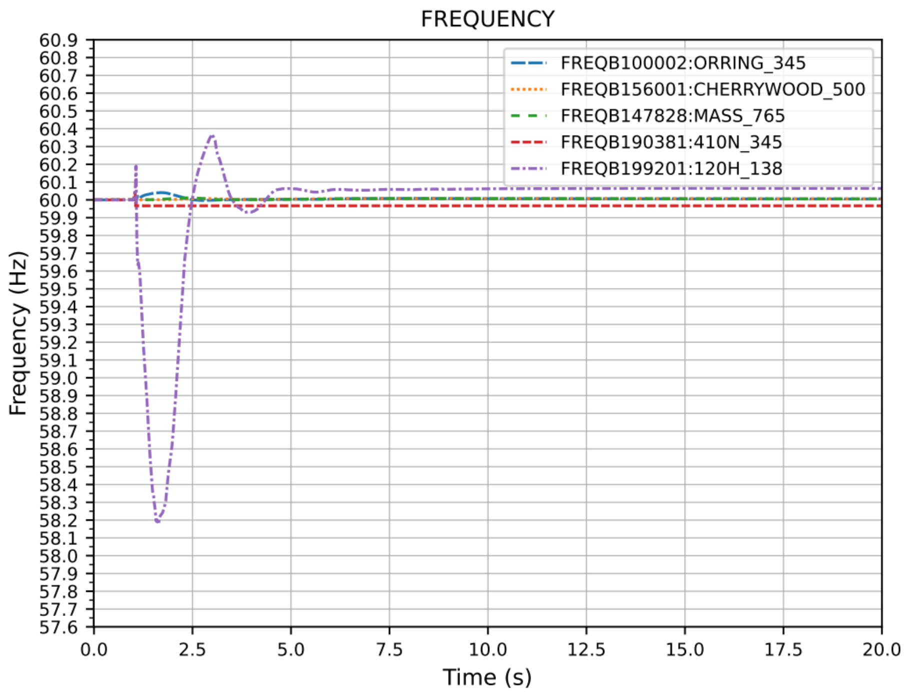


Figure 8: Underfrequency performance (frequency at NS_410N, Mass, Cherrywood, Orrington, and 120H-Brushy Hill)

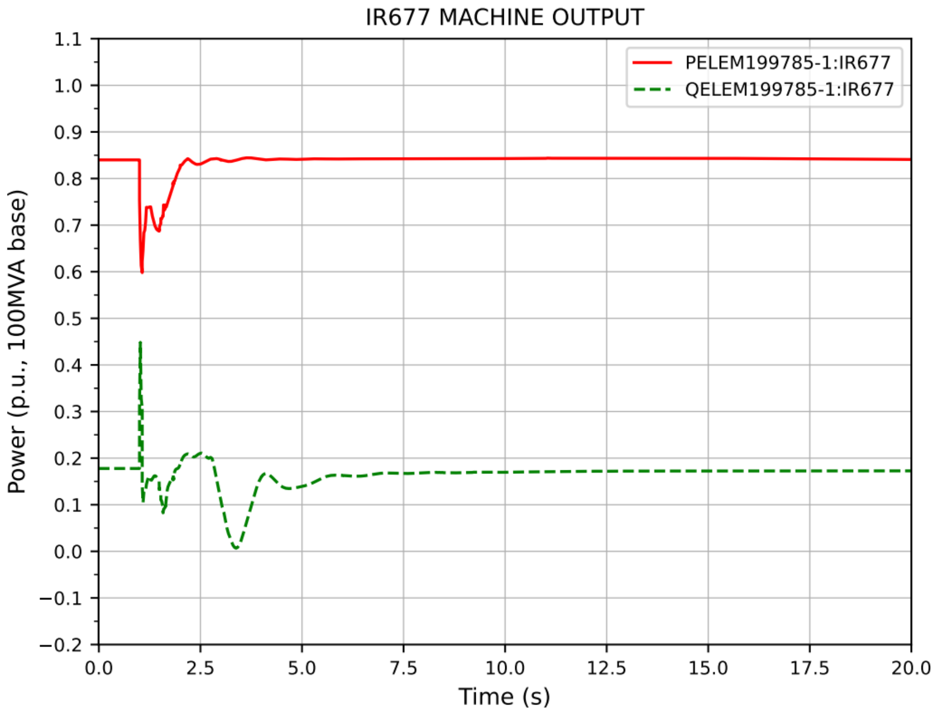


Figure 9: Underfrequency performance (IR677 machine output)

3.8 Voltage ride-through

IR677 low voltage ride through (LVRT) capability was tested under expected system operating conditions in winter peak, summer peak and light load. A 3-phase fault for 9 cycles was applied to 138kV and 34.5kV buses of IR677 ICIF under all stability base cases.

The stability plot in *Figure 10: IR677 LVRT performance (HV fault, 9 cycles)* and *Figure 11: IR677 LVRT performance (MV fault, 9 cycles)* demonstrate IR677 rides through the fault and stays online using wp03 case, as required. Results for all studied cases are shown in *Appendix G: Low voltage ride through*. Note values are plotted on 100 MVA system base, so IR677 at 0.84 PU power represents request capped MW output of the generator rather than 84% output.

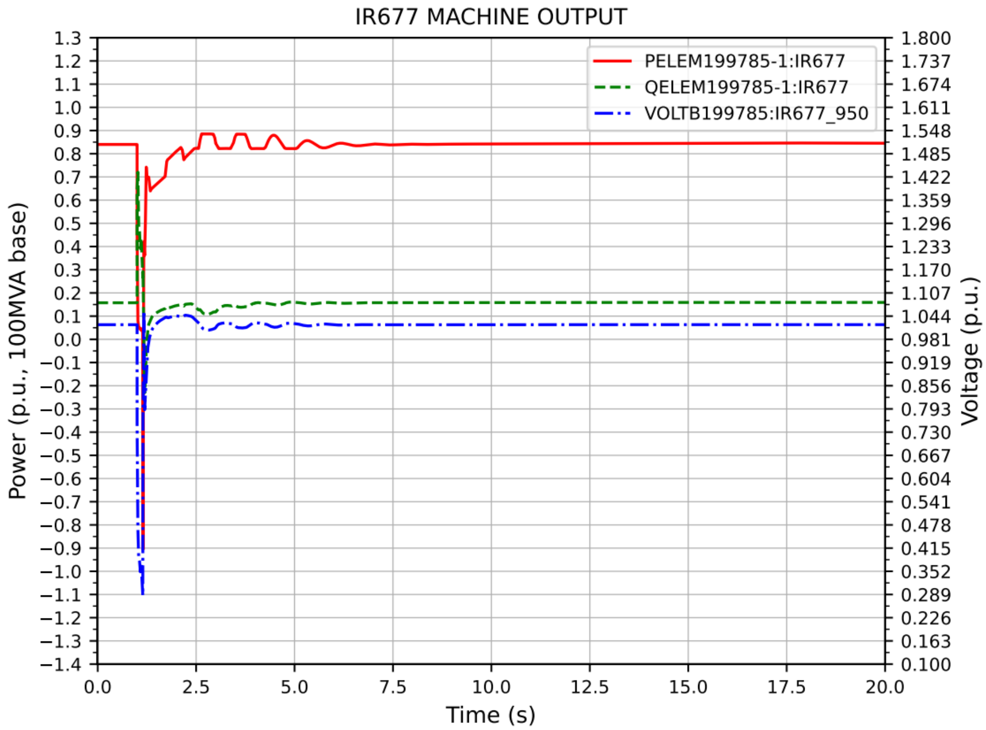


Figure 10: IR677 LVRT performance (HV fault, 9 cycles)

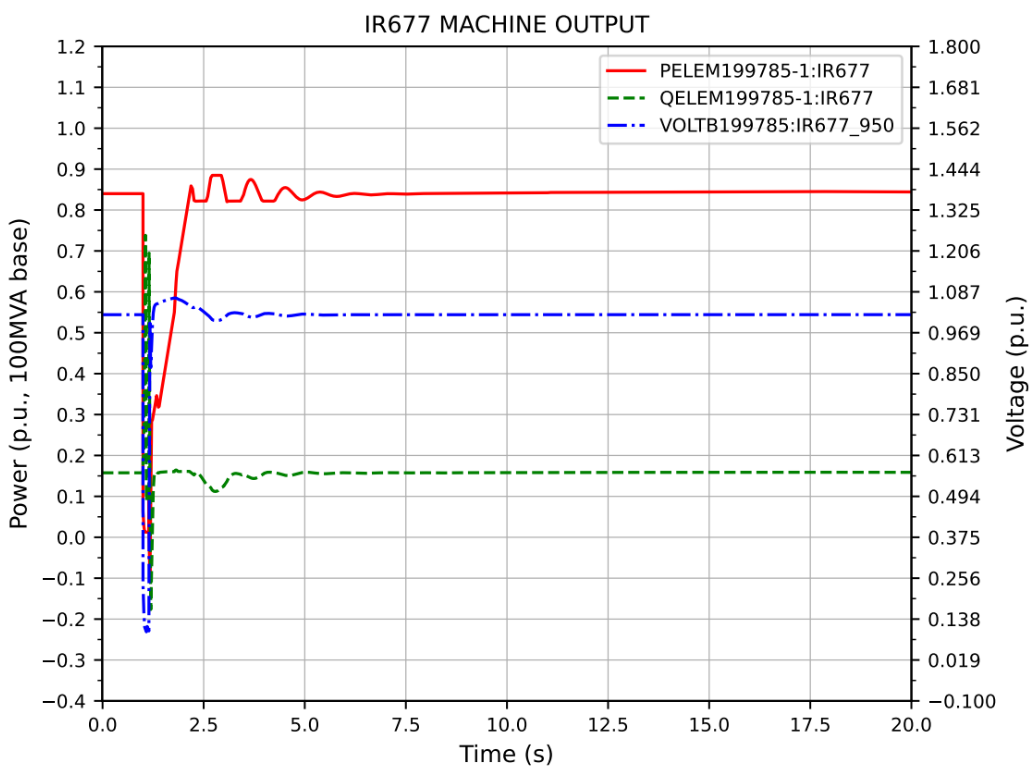


Figure 11: IR677 LVRT performance (MV fault, 9 cycles)

3.9 Loss factor

The loss factor for IR677 is calculated as 0.9% at IR677's generator terminal (950V) and -1.9% at its POI (L-6024, 138kV bus close to 9W). This means system losses on peak are not much impacted when IR677 is operating at 84 MW.

This preliminary loss factor analysis is calculated on the hour of system peak as a means for comparing multiple projects but is not used for any other purpose.

Table 10: 2026 Loss factor

Loss Factor measured at IR677 Generator Terminal (950 V)	
Description	**MW**
IR677 On	84.00
TC2 and TC3 with IR677 On	144.80
TC2 and TC3 with IR677 Off	228.01
Loss Factor Measured at IR677 Voltage Terminal	0.9%

Loss Factor Measured at POI (L-6024, 138kV)	
Description	**MW**
IR677 On	84.00
Power measured at POI with IR677 On	81.67
Power measured at POI with IR677 Off	0.00
TC2 and TC3 with IR677 On	144.80
TC2 and TC3 with IR677 Off	228.01
Loss Factor Measured at POI	-1.9%

4.0 Requirements & cost estimate

The following facility changes will be required to connect IR677 as NRIS to NSPI transmission system at the POI:

- Transmission Network Upgrades funded by the Interconnection Customer:
  - Construction of a new 138kV substation completed with a three-breaker ring bus at the POI on L-6024.
  - Modification of protection system at 50W-Milton and 9W-Tusket substation of L-6024 due to the addition of IR677.
  - Replacement of 9W-T2 with a 60/80/100 MVA, 138kV-69kV transformer.
  - Replacement of switch 9W-516A for L-6021.
  - Upgrade of current transformer and metering for L-6025.
  - Upgrade of L-6531 conductor from 50 °C to 60 °C.
  - Install a new automatic action scheme to cross trip IR677, armed if the flow through 99W-T71 and 99W-T72 is larger than 200MVA towards 120H.
  - Install a new automatic action scheme to cross trip IR677 for L-5535 overloads.

- Transmission Provider's Interconnection Facilities (TPIF) Upgrades:
  - A synchronous condenser installed at IR677 POI or in the vicinity area.
  - Build an approximately 17 km 138kV interconnection transmission line from the POI to the IC substation.
  - Installation of NSPI P&C Relaying Equipment.
  - Installation of NSPI supplied RTU.
  - Installation of Tele-protection and SCADA communication.
- IC Interconnection Facility:
  - Facilities for NSPI to execute high speed rejection of generation (transfer trip). The plant will be integrated into the area Automatic Action Scheme (AAS) and RAS run-back schemes at some point in time in the future.
  - The ability to interface with the NS Power SCADA and communications systems to provide control, communication, metering, and other items to be specified in the forthcoming Interconnection Facilities Study.
  - NSPI to have supervisory and control of this facility, via the centralized controller such as a farm control unit. This will permit the NSPI System Operator to raise/lower the voltage setpoint, change the status of reactive power controls, change the real/reactive power remotely. NSPI will also have remote manual control of the load curtailment scheme.
  - The centralized voltage controller to control the 34.5 kV bus voltage to a settable point and will control the reactive output of each inverter unit of IR677 to achieve this common objective. Responsive *(fast-acting)* controls are required. The setpoint for this controller will be delivered via the NS Power SCADA system. The voltage controller must be tuned for robust control across a broad range of SCR.
  - Facilities to meet ±0.95 power factor requirement when delivering rated output (84 MW) at the 138 kV bus. IR677's power factor capability must be re-evaluated to confirm it has the required amount of supplemental reactive support once detailed design information on its transformers and collector circuits are available.
  - Voltage flicker and harmonics characteristics as described in Section 3.3: Voltage flicker.
  - Frequency ride through capability to meet the requirements in Section 2.3.8: Underfrequency operation.
  - When not at full output, the facility shall offer over-frequency and under-frequency control with a deadband of ±0.2 Hz and a droop characteristic of 4%.
  - The ability to control active power in response to control signals from the NS Power System Operator and frequency deviations. This includes automatic curtailment to pre-set limits *(0%, 33%, 66% and no curtailment)*, over/under frequency control, and Automatic Generation Control *(AGC)* system to control tie-line fluctuations as required.
  - Voltage ride through capability to meet the requirements in Section 2.3.9: Voltage ride-through.
  - The facility must use equipment capable of closing a circuit breaker with minimal transient impact on system voltage and frequency *(matching voltage within ±0.05 PU and a phase angle within ±15º).*

- To minimize the need to curtail non-dispatchable wind generation at light load, all wind farms must have the functionality to be incorporated into the Export Power Monitor SPS.
- 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.
- During the study for this SIS, section 7.6.7 of TSIR, that requires wind turbine generators to provide inertia response of 3.0 MW-s/MVA for a period of at least 10 seconds, was temporarily postponed for review by NSPI. It will be addressed in Part 2 of the System Impact Study.
- Nordex wind turbine generators to meet TSIR section 7.6.9 requirements that the wind generating facility shall be capable of operating at ambient temperatures as low as -30 ºC.
- The facility must meet NSPI's TSIR as published on the NSPI OASIS site.

The cost estimate as shown in *Table 11: System upgrades cost estimate* is high level non-binding in 2024 Canadian dollars. It includes 10% contingency but excludes applicable taxes. This cost estimate includes the additions/modifications to the NS Power system only, and the cost of the synchronous condenser is to be determined. The cost of IC's substation, interconnection facilities and generating facility are not included. It does not include additional costs which may be identified in Part 2 of the System Impact Study and the Facility Study. The Interconnection Facilities Study will provide a more detailed cost estimate.

Table 11: System upgrades cost estimate

	Determined Cost Items	Estimate
Transmission Providers Interconnection Facilities		
1	NSPI P&C relaying equipment	$160,000
2	NSPI supplied RTU	$60,000
3	Tele-protection and SCADA communications	$450,000
4	Construction of 17km spur line from POI to IC substation (Cleared ROW provided by IC)	$13,970,000
5	Installation of a synchronous condenser at IR677 POI / 9W	TBD
Network Upgrades (Interconnection Customer Cost Responsibility) for NRIS		
6	Three breaker ring bus 138kV substation, designed to meet NERC's BES requirements	$7,000,000
7	Replacement of Transformer 9W-T2 with 60/80/100 MVA unit	$4,000,000
8	Replacement of Switch 9W-516A	$50,000
9I	L-6025 current transformer and metering upgrade	$50,000
10	L-6531 conductor upgrades from 50 °C to 60 °C *	$16,605,000
11	L-6021 Switch 9W-516A replacement	$50,000
12	A new automatic action scheme to cross trip IR677 for violations at 99W	$250,000
13	A new automatic action scheme to cross trip IR677 for L-5535 overload	$100,000
14	Protection system modifications at 50W, and 9W	$50,000

Determined costs	
Subtotal	$42,795,000
Contingency (10%)	$4,279,500
Total of determined cost items	$47,074,500

* A line survey to confirm the existing rating of the line is recommended. 50°C is the default rating for NSPI transmission lines. A line survey would identify any portions of L-6531 that might already meet 60°C rating clearance requirements.

5.0 Conclusion & recommendations

5.1 Summary of technical analysis

The System Impact Study (SIS) for IR677 will be conducted in Part 1 and Part 2. Part 1, using Power System Simulator software, will determine the impacts of IR677 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.

Part 1 system impacts will be assessed based on NSPI 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 software to determine IR677's impacts and control interactions when integrated with NSPI power system. It 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.

This report presents the results of Part 1 of the System Impact Study (SIS) for IR677 - a proposed 84 MW wind turbine generating facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS). The Point of Interconnection (POI) is identified on L-6024 adjacent to 9W-Tusket substation. The proposed Commercial Operation Date is 2025/12/31.

IR677 consists of twelve (12) Wind Energy Converter System (WECS) units using Nordex N163 with 950V terminal voltage, each rated at 7.0 MW totaling 84.0 MW. The voltage is stepped up to 34.5 kV at the collector substations with an equivalently modelled generator step-up transformer. The system is interconnected to the POI through one 34.5kV/138kV station transformer and an approximately 17km-long 138kV transmission line.

The short circuit analysis shows that the maximum short circuit levels are far below 5,000 MVA for 138 kV and 3,500 MVA for 69 kV with IR677 added into the system at its POI. IR677 short circuit contribution does not require any uprating of existing breakers in the transmission system. The minimum short circuit level at IR677 34.5 kV bus, with L-6024 (between 50W-Milton and IR677's POI) out of service, is 114 MVA, which equates to a SCR of 1.36 (114 MVA / 84 MW). The minimum SCR recommended for Nordex N163 machines by the wind turbine manufacture is 3 or 4 and this low SCR could cause numeric errors in stability transient simulations and result in IR677's machine tripping or oscillation under certain contingencies. To ensure IR677's stable simulation performance, a 60MVA synchronous condenser was added onto the IR677 POI under the stability analysis. The minimum SCR was then improved to 2.56 at the IR677's 34.5 kV bus. All contingencies were found to be stable and well-damped with the addition of synchronous condenser under the dynamic simulation. The IC should consult the wind turbine manufacture to determine the required modifications to ensure that IR677 meets all reliability requirements under low SCR conditions. Otherwise, the facility may be curtailed to maintain system stability when the synchronous condenser is out of service.

IR677 meets NS Power's leading power factor requirement, but it may not meet lagging power factor requirement therefore supplemental reactive power compensation device will be required to be supplied by the IC. The IC shall consider the use of additional reactive power device(s) or wind turbine models which have a higher reactive power range. Rated reactive power shall be available through the full range of real power output of IR677, from zero to full power, by adding the synchronous condenser, or other supplemental reactive power compensation options such as Nordex “STATCOM function”.

The steady state power flow analysis indicated that under certain operating conditions several transmission lines and transformers could exceed emergency operating limit for contingencies at 50W-Milton, 9W-Tuesket, 99W-Bridgewater and 120H-Brushy Hill due to IR677 interconnection. Therefore, it requires the following customer funded Network Upgrades at POI and beyond to operate IR677 at the requested MW capability under NRIS:

- To resolve post contingency overloads on transformer 9W-T2 and line L-6021:
  - Replace 9W-T2 with a 60/80/100 MVA, 138kV-69kV transformer.
  - Replace 9W-516A switch with 144 MVA rated switch.
- To resolve post contingency overloads on transformers 99W-T71, 99W-T72 and line L-7009:
  - Design an AAS to cross trip IR677, armed if the flow through 99W-T71 and 99W-T72 is more than 200MVA towards 120H-Brushy Hill.
- To resolve post contingency overloads on L-5535:
  - Design an AAS to cross trip IR677, which also resolves any consequential overload on L-5532 or L-5541 due to L-5535 cross-trip.
- To resolve post contingency overloads on L-6025:
  - Upgrade of L-6025 current transformer and metering.
- To resolve post contingency overloads on L-6531:
  - Upgrade L-6531 conductor temperature rating from 50 °C to 60 °C.
- Install three-terminal protection for line L-6024 with transfer trips and interlocks for IR677’s cross-trip.

These upgrades are funded by the customer but are refunded per the terms of the Generator Interconnection Agreement (GIA). It is noted that the IR677 substation transformer (rated at 90 MVA) could be overloaded up to 115% when the IR677 is operating at the maximum 84 MW output, while absorbing maximum 40.68MVAr reactive power.

The facilities associated with IR677 are not designated as NPCC BPS as IR677 does not affect the BPS status of existing facilities. However, IR677 qualifies as NERC BES as its aggregate rated output is greater than 75 MVA. It shall be designed and operated according to and meeting NERC’s BES standards. There is the potential for an exclusion from BES to be granted for the high side (138kV) bus based on further analysis per the NS BES Exception Procedure.

The dynamic simulation for NS being suddenly islanded from NB showed NS system frequency swing below under frequency thresholds of NS under frequency load shedding (UFLS) and this program shed 295 MW load in NS. IR677 remained on-line and stable helping to stabilize NS frequency during and post contingency.

IR677 low voltage ride through (LVRT) capability was tested to cover expected system operating conditions in winter peak, summer peak and light load. The simulations showed that IR677 remained on-line with temporarily reduced power and ramped back to rated power during contingency and remained stable post contingency.

The loss factor calculation is based on a winter peak case with and without IR677 in service. The calculated loss factor is 0.9% at IR677's generator terminal (950V) and -1.9% at its POI (L-6024, 138kV bus close to 9W). This means system losses on peak are not impacted when IR677 is operating at 84 MW.

It is concluded that the incorporation of the proposed facility into the NS Power transmission system at the specified location has no negative impacts on the reliability of the NS Power grid, provided the recommendations provided in this report are implemented.

5.2 Summary of expected facilities

To accommodate IR677, the total high level non-binding estimated cost in 2024 Canadian dollars for the Network Upgrades is $28,155,000 and for the new Transmission Provider’s Interconnection Facilities (TPIF) is $14,640,000, for a total of $42,795,000, plus 10% contingency for a total of $47,074,500 excluding HST. The costs of the synchronous condenser, all associated facilities required at the IC's substation and Generating Facility are in addition to this estimate. This cost excludes any additional costs or changes which may be identified by Part 2 of the System Impact Study as well as any cost associated with ICIF generating facility.

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

The preliminary and non-binding estimate for the construction of the customer funded Network Upgrades is 24-30 months, primarily as a result of long lead time items (e.g. 100 MVA transformer) and the scheduling of line outages. Timelines will be confirmed in the Facility Study.

Appendix A: Generating facility dynamic data

```
/ NXWTG_8674, N163 7000 GCV152 CA-Nova Scotia CA PSSE V8.674

199785 'USRMDL' 1 'NXWTG_8674' 1 1    29 239 33 229

 1 1 1 21 2 2 1 1 1 0 1 1 0 1 1 2 1 1 0 1 1 0 1 1 0 0 1 0 0 0.0081
0.1784 5.2846 0.0083 0.2301 0.4196 3.8248 42.09 0.6871 1.0005 0.0867
0.8560 0.05 5.00 0.30 50.00 100.0 250.0

 0.4231 -0.4231 1.826 0.90 0.5187 -0.130 -0.120 0.150 0.140 0.000
102000 0.300 -1150 2708 8000 32 300 7.00 48.00 60.00 6.00 0.80 15564
1.2 321 0.05 0.00 2.50 0.00

 0.08 15.00 25.00 1.225 11.000 1.042 0.200 1.040 5.000 0.950 0.200
0.950 0.200 1.151 0.500 1.430 0.500 0.010 0.100 0.010 7.000 7.00 0.250

 0.300 1.0000 0.667 0.04 0.20 0.950  1.003  0.0001  1.050  0.04  0.9500
0.9940 1.0000 1.0060 1.0367 1.000 1.000 1.000 1.000 1.000 -1.000 -1.000
-0.130 0.150

 1.000  1.000  1.000  1.000  1.000 1.7400 1.7400 0.0000 0.0000 -1.7000
-1.7000 -1.7000 -1.7000 -1.7000 0.00 0.50 0.92 0.92  1.10  0.00  0.50
0.92  1.00 1.00

 0.000 0.000 0.300 3.200 180.000 180.000 180.000 180.000 220.000
230.000 240.000 0.000 0.000 0.800 0.800 0.870 0.870 0.870 0.870 0.870
0.870 0.025 0.000 0.150 0.150

 60.000 60.000 60.000 60.000 90.000 100.000 110.000 1.300 1.300 1.250
1.250 1.150 1.150 1.150 1.150 1.150 1.150 1.50 0.87 0.88 0.15 0.500
0.500 0.217 2.171 1.000 1.000 1.00 0.20

 2.00 1.00 0.40  0.00 0.00 10.00 0.000 0.000 0.00 0.50 0.233 0.233
0.8462 0.0119 0.0793 0.0071 0.0139 0.0317 0.2500 3.20 0.00 0.90 0.00
0.04 0.07 0.000 0.50 0.100 0.15 0.70 10.00

 2 0.300 0.030 1 1.00 5.00 0.30 0.80 1 1 1 1 -1.0000 1.0000 -1150 1150
0.87 0.88 0.00 10.00 1.11 9.00 0.10 2.00 0.00 1.00 1 10.00 7.00 59.50
59.80 59.00 0.25 200 4.0 2.0 /


/ Nordex WFC V4.181 WPP Wedgeport (CAN)

19978501      'USRMSC'    'NXWFC_4181'     512   0     50    130   19
      978   1     3     199783      199782      1
      12    175   176   2     1     2     2     0     2     1     158
      34    156   188
      189   2     2     2     0     2     1     1     213   0     '1'
      199785      1     0
      0     0     0     0     0     0     0     0     0     0     0
      0     0     0
      0     0     0
```

```
0      0      0      0      1.1    0.257 0.315 8.2171      8.2171
0      0      0      -0.3287     0.3287
20     0      1.3    0.995 0      1.1    0.5    0.9    -0.6081
0.6081      0.5    1.2    0.5    1.5
0.4107      0.7393      -0.5916     0.5916      3.7134
0.1300      0.7000      0.4000      0.0160      1.0500
0.9500      0.9567      0.9967      0.9967
1.0000      1.0033      1.0033      1.0433      1.0500
2.0000      2.0000      1.0000      1.0000      1.0000
1.0000      1.0000      0.0000      0.0000
84.0000     1.0167      1.0083      0.2000      0.0200
0.0200      0.0200      0.0200      0.0100      0.0100
0.0100      0.0100      1.0000      0.0000
0.1000      0.0000      5.0000      0.0000      0.0000
0.1000      0.4500      0.9000      33.00 33.00 4.00  4.00  0.25
0.05
1.0000      -1.0000     1.0000      -1.0000     0.1000
-0.1000     0.5000      1.2000      0.5000      1.2000
0.5000      1.2000      0.9900      -0.9900
0.9900      -0.9900     60000 1.0502      1.0517      0.13  54.60
67.20 0.00  0.00  0.00  0.00  33.60 0.00
0.00  1.100 0.900 1.100 0.900 0.00  0.00  84.00 0.00  0.50  1.20
0.02  -0.3287     20.00
0.95  10.00 0.98  10.00 /
 /
```

Appendix B: Base case one-line diagrams

Appendix C: Differential line flows

Appendix D: Steady-state analysis results

Appendix E: NPCC-BPS determination results

Appendix F: Underfrequency operation

Appendix G: Low voltage ride through

Appendix H: Stability analysis results