System Impact Study Report

GIP-IR664-SIS-R4

Generator Interconnection Request #664

50 MW Battery Energy Storage System Facility

Lunenburg County, NS

June 29, 2023

Control Centre Operations
Nova Scotia Power Inc.

Executive summary

The System Impact Study *(SIS)* for IR664 will be conducted in Part 1 and Part 2. Part 1, using Power System Simulator software, will determine the impacts of IR664 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 2 is in progress and will be issued separately from this document. It will use Electro Magnetic Transient software to determine IR664's impacts and control interactions when integrated with the NSPI power system.

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)*.

This report presents the results of Part 1 of the System Impact Study *(SIS)* for IR664 - a proposed 50 MW Battery Energy Storage System *(BESS)* facility interconnected to the NSPI system as Network Resource Interconnection Service *(NRIS)*. The Point of Interconnection *(POI)* is identified as the 138kV bus at 99W-Bridgewater. The proposed Commercial Operation Date is 2023/12/15.

IR664 consists of twenty SMA Sunny Central Storage 3800 battery storage inverters with 660V terminal voltage, each rated at 3.8 MW, totaling 76.0 MW but capped at 50.0 MW. The voltage is stepped up to 34.5kV through ten pad-mounted transformers. The system is interconnected to the POI through one 34.5kV/138kV station transformer and a 750m-long 138kV transmission line.

IR664 short circuit contribution does not require any uprating of existing breakers in the transmission system. The short circuit analysis shows that the maximum short circuit levels are far below 5,000 MVA for 138 kV with IR664 added into the power system at POI. The minimum short circuit level at IR664 34.5 kV bus, with L7008 out of service, is 355 MVA, which equates to a SCR of 7.1.

IR664 meets and exceeds the leading and lagging power factor requirement based on the preliminary information supplied. The IC confirmed the BESS inverters can provide ±50.0 MVAr reactive power when delivering capped power at ±50.0 MW and have full ±50.0 MVAr reactive power capability at 0 MW real power. This should be re-evaluated once the detailed design information on transformer impedances and collector circuit design are finalized.

IR664 does not require any major Network Upgrades at 99W-Bridgewater and beyond to operate at requested MW capability under NRIS, provided the Western Valley Transmission System is operated within historical limits. No issues were identified in the steady state or stability analysis that are attributed to IR664.

The facilities associated with IR664 are not designated as NPCC BPS as IR664 does not affect the BPS status of existing facilities. IR664 also does not qualify as NERC BES based on project size.

IR664 Under Frequency Ride Through capability was tested under dynamic simulation. The facility remained connected when system frequency deviation caused Under Frequency Load Shedding *(UFLS)* relays to activate. While charging, IR664 also assisted in frequency recovery by momentarily switching to discharging while system frequency was below nominal.

IR664 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 IR664 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 IR664 in service. The calculated loss factor is 0.78% at IR664's generator terminal *(660V)* and 0.02% at its 138kV ICIF bus. This means system losses on peak are marginally increased when IR664 is discharging at 50 MW.

Due to the higher-queued project IR672's withdrawal from the Queue, a re-study on IR664 is performed for the steady state analysis, stability analysis, and NPCC BPS testing with IR672 removed from the study. No issues were identified in the steady state or stability analysis that are attributed to IR664. IR664 does not affect the BPS status of existing facilities.

It is concluded that the incorporation of the proposed facility into the NS Power transmission 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 IR664 as NRIS to NSPI transmission system at the 99W POI:

- Transmission Provider's Interconnection Facilities *(TPIF)* Upgrades:
    - A 138 kV breaker, associated switches, and substation modifications at 99W-Bridgewater.
    - Transmission line exit re-routing at 99W-Bridgwater to accommodate IR664's facility.
    - Protection modifications at 99W-Bridgewater.
    - Modifications to existing 99W-Bridgewater RTU.

- IC Interconnection Facility *(ICIF)*:
    - The facility must meet NSPI's TSIR as published on the NSPI OASIS site. The following requirements are items of note from the TSIR.

- Facilities to meet ±0.95 power factor requirement when delivering rated output *(50 MW)* at the 138 kV bus. Rated reactive power shall be available through the full range of real power output, from zero to full power.
- 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 plant 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 IR664 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.
- 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.
- 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.
- 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%.
- Voltage ride through capability to meet the requirements in Section 2.3.9: Voltage ride-through.
- Operation at ambient temperatures as low as -30ºC.
- 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)*.
- Facilities for NSPI to execute high speed rejection of generation and load *(transfer trip)*. The plant may be incorporated in SPS runback or load reject schemes.

The total high level non-binding estimated cost in 2023 Canadian dollars for the new Transmission Provider’s Interconnection Facilities *(TPIF)* is $2,220,000, which includes 10% contingency but excludes HST. The costs of 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 to be identified by the subsequent Facility 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 right of way shall be registered in NSPI’s name.

The non-binding construction tine estimate of NSPI Transmission Provider Interconnection Facilities is two years, but to be confirmed by the Facility Study.

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1.0 Introduction

The Interconnection Customer *(IC)* submitted an Interconnection Request *(IR)* to Nova Scotia Power Inc. *(NSPI)* for the connection of a 50 MW Battery Energy Storage System *(BESS)* facility interconnected to the NSPI system as Network Resource Interconnection Service *(NRIS)*. The proposed Commercial Operation Date is 2023/12/15.

The IC signed a System Impact Study *(SIS)* Agreement for this 50 MW Battery Energy Storage System *(BESS)* facility, and this report is the result of that Agreement. This project is listed as Interconnection Request #664 in the NSPI Interconnection Request Queue and will be referred to as IR664 throughout this report.

1.1 Scope

The Interconnection Customer *(IC)* identified a 138 kV bus at 99W-Bridgewater as the Point of Interconnection *(POI)*. This BESS facility will be interconnected to the POI via a 750 m long 138 kV transmission line from the Point of Change of Ownership *(PCO)*.

Figure 1: Proposed interconnection shows the approximate geographic location of the proposed IR664 site. *Figure 2: Proposed interconnection in one-line diagram* illustrates the electrical locations of IR664.

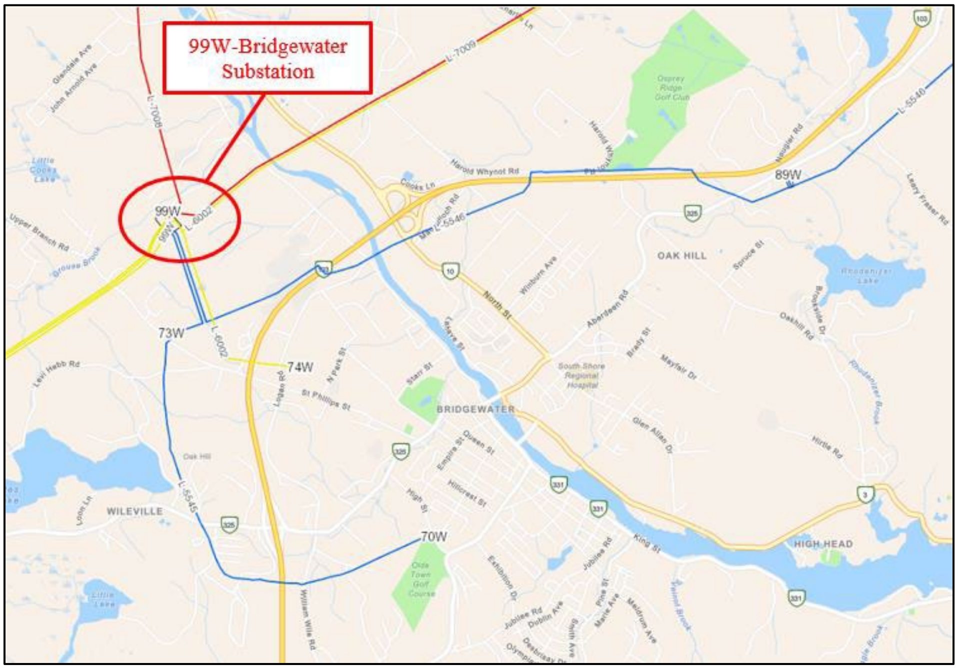


Figure 1: Proposed interconnection

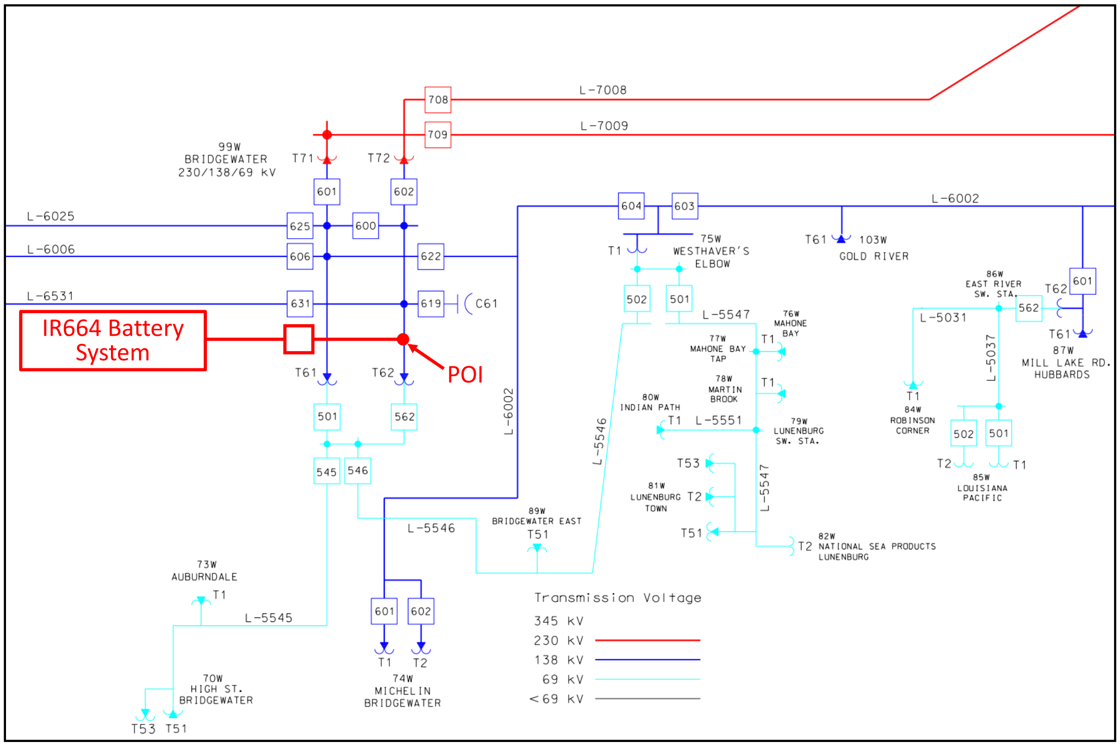


Figure 2: Proposed interconnection in one-iine diagram

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 IR664 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 2023-12-15.
2. The Interconnection Facility consists of 20 x 3.8MVA SMA SCS 3800 inverters, capped at 50 MW total.
    - 2.1. The inverter units are grouped in blocks of 7.6MVA with two SMA SCS 3800 units per block.
    - 2.2. Each block is connected to the collector circuits through one pad-mounted transformer.
    - 2.3. The total 20 battery inverter units and the 10 generator transformers were modeled as an equivalent lumped parameter generator connected to an equivalent transformer.
    - 2.4. This equivalent model was developed using the data provided by the Interconnection Customer. The manufacturer's dynamics data is included in Appendix A of this report.
3. The SMA SCS 3800 inverters battery system units are the 660 VAC, 3800 kVA nameplate variant. A 1.0 PU fault current is used for short circuit analysis.
4. The 10 generator transformers *(660 V/34.5 kV)* were modeled as a single unit with an impedance of 7.5% on 75 MVA base with an assumed X/R ratio of 8.
5. The feeder circuit impedance was assumed to be negligible, due to the short distance from the power transformer.
6. The interconnection facility transformer was modeled as 138 kV *(wye)* to 34.5 kV *(wye)*, 60 MVA, with an impedance of 7.5% *(60 MVA Base)* and an X/R ratio of 40.
7. The IC identified the 138 kV bus B62 at the 99W-Bridgewater substation as the POI. This study will use 1113 ACSR Beaumont rated at 100ºC for the 750m transmission line between 99W and the IC substation.
8. NSPI's transmission line ratings as posted on NSPI's Intranet, including any projected line upgrades for the periods under study.
9. It is assumed that IR664 generation meets IEEE Standard 519 limiting total harmonic distortion *(all frequencies)* to a maximum of 2.5% with no individual harmonic exceeding 1.5% for 138 kV.
10. Generation in a higher queue position, as listed in Section 1.3, is modeled in the base cases.
11. The Maritime Link can be used as an SPS target.

1.3 Project queue position

All in-service generation facilities are included in the SIS.

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.

As of 2023/02/10, the following projects are higher queued in the Advanced Stage Interconnection Request Queue:

- IR426: GIA executed, 2018/09/01 in-service date.
- IR516: GIA executed, 2020/05/31 in-service date.
- IR540: GIA executed, 2023/10/31 in-service date.
- IR542: GIA executed, 2025/06/30 in-service date.
- IR557: SIS Complete, 2018/09/01 in-service date.
- IR517: GIA in progress, 2019/10/01 in-service date.
- IR569: GIA executed, 2022/02/24 in-service date.
- IR566: GIA executed, 2022/04/30 in-service date.
- IR574: GIA executed, 2025/09/30 in-service date.
- IR598: GIA executed, 2024/06/30 in-service date.
- IR604: GIA executed, 2023/03/30 in-service date.
- IR597: FAC in progress, 2023/08/31 in-service date.
- IR647: GIA in progress, 2023/12/31 in-service date.
- IR653: GIA executed, 2022/10/30 in-service date.
- IR654: GIA executed, 2022/09/20 in-service date.
- IR656: GIA in progress, 2022/12/31 in-service date.
- *IR672: SIS in progress, 2024/12/02 in-service date.

*IR672 was withdrawn 2023/04/19 and portions of this report were restudied accordingly.

If any higher-queued projects included in this SIS 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 20 x 3.8MVA SMA SCS 3800 inverters battery system unit is modelled as a single generator with a terminal voltage of 660 V. The voltage is stepped up to 34.5 kV with a single equivalent generator step-up transformer. This equivalent model is then stepped up to 138 kV via interconnection transformer.

The PSS®E model for load flow is shown in *Figure 3: PSS®E model* below. The equivalent 660 V/34.5 kV generator transformer was modeled to have an impedance of 7.5% on 75 MVA. The interconnection transformer was assumed to have 7.5% impedance on the 60 MVA rating with an X/R ratio of 40. The SIS results must be updated when actual nameplate data for transformers becomes available.

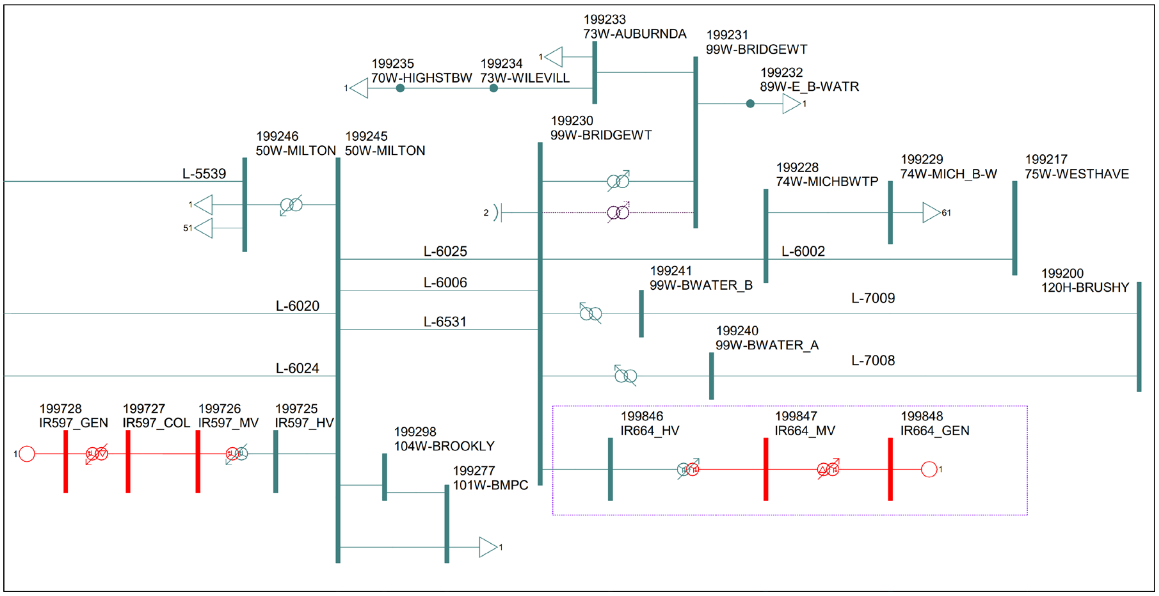


Figure 3: PSS®E model

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 1: 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 1: 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

IR664 will be equipped with twenty SMA SCS 3800 inverters battery system units, each rated at 3.8MW totaling 76 MW. However, the plant output will be capped to the 50 MW request.

The proposed BESS facility is assumed to be equipped with a SCADA-based central regulator which controls the individual generator reactive power output to maintain constant voltage at the ICIF substation. It's indicated by the IC that SMA SCS 3800 inverters battery system units are capable of a reactive power range of ±50 MVAr at ±50 MW real power output levels.

2.3 System model & methodology

Testing and analysis were conducted using the following criteria, software, and 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 IR664 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

Not applicable for battery energy storage system.

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 twenty SMA SCS 3800 inverters battery system units 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; 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 0 As for harmonics, NSPI requires IR664 to meet Harmonics IEEE-519 standard limiting Total Harmonic Distortion *(all frequencies)* to a maximum of 2.5%, with no individual harmonic exceeding 1.5% for 138 kV. The total harmonic distortion *(THD)* for SMA SCS 3800 inverters battery system is currently not available. If for some reason, in the actual installation, IR664 causes issues with voltage flickers or harmonics, then IR664 will be responsible for mitigating the issues.

Steady state analysis; with IR664 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 IR664 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 categorized 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 teleprotection systems. Determination of BPS status was in accordance with NPCC criteria document A-10:

Classification of Bulk Power System Elements, 2020/03/27. 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 teleportation to the remote terminals. The fault is maintained on the bus for 10 second to allow remote protection at surrounding substations to trip the lines to the faulted bus, and 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 IR664 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 IR664's generators.

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

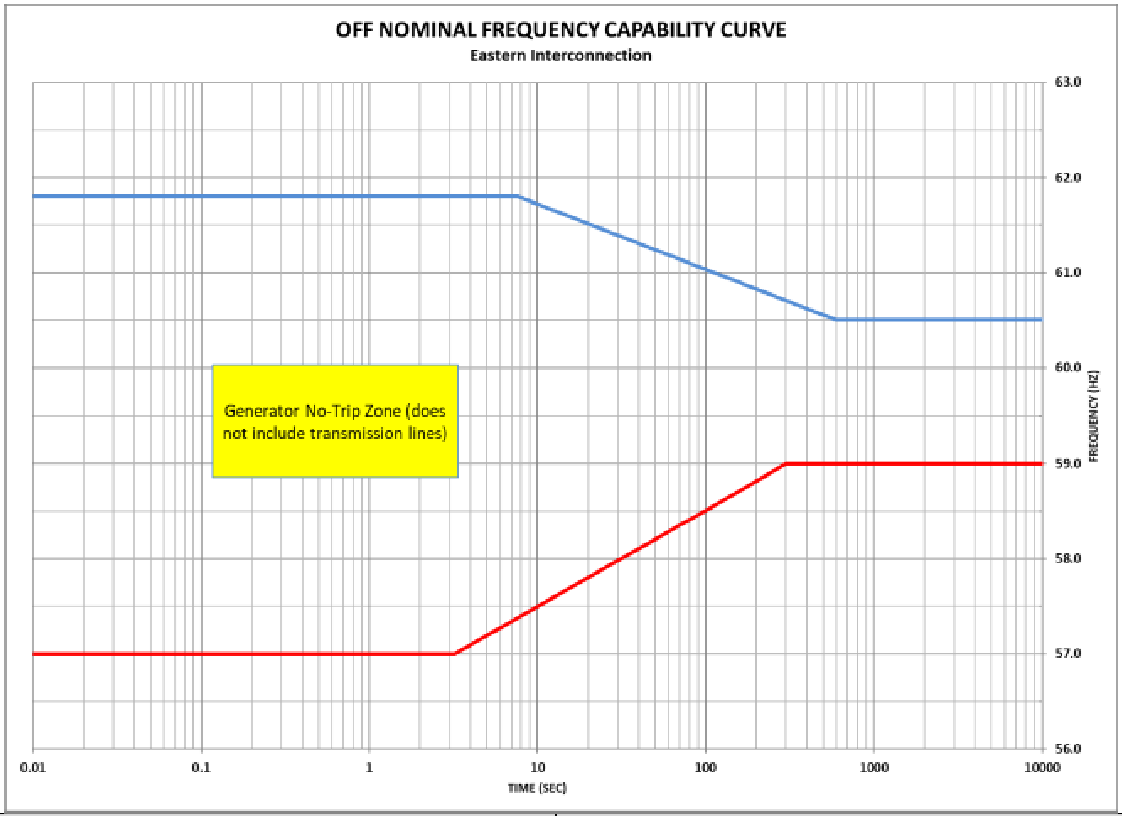
Nova Scotia is connected to the rest of the North American power grid by the following three AC transmission lines:

- 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 1N-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. IR664 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.

In addition to the test, IR664 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 shall have the capability of riding through a rate of change of frequency of 4Hz/s.



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

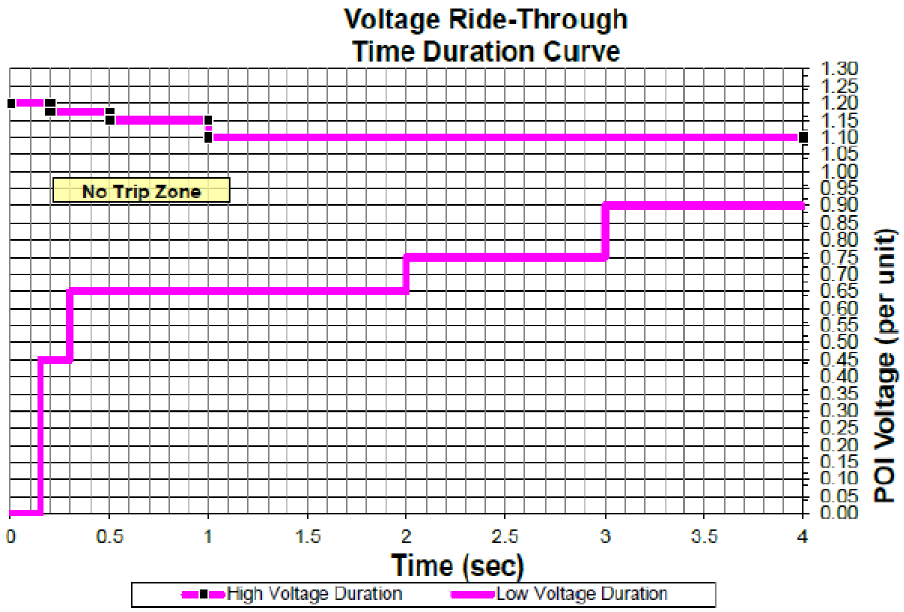
Figure 4: Off-nominal frequency curve *(PRC-024-2 and PRC-006-NPCC-2 combined)*

2.3.9 Voltage ride-through

IR664 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*.

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

This test is performed by applying a 3-phase fault to the HV and MV buses of the ICIF for 9 cycles. IR664 should not trip for faults on the Transmission System or its collector circuits.

2.3.10 Loss factor

Loss factor was calculated by running the power flow using a standardized winter peak base case with and without IR664, while keeping 91H-Tufts Cove generation as the NS area interchange bus. The loss factor for IR664 is the differential MW displaced or increased at 91H-Tufts Cove generation calculated as a percentage of IR664's rated MW rating.

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.

Because of the uncertainty the collector circuit design and transformer equipment specification, loss factors are provided at the generator terminal bus and the high side of the ICIF transformer.

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 1.0 PU voltage, and 3LG faults. The short circuit levels in the area before and after this development are provided in *Table 2: 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 and sub-transient reactance of 1.0 was used in the short circuit calculation for IR664 generator.

IR664 will not impact 99W-Bridgewater and neighbouring breaker's interrupting capability based on this study's short circuit analysis. The interrupting capability of the neighbouring 138 kV circuit breakers is at least 3,500 MVA. The NS Power design criteria for maximum system fault capability *(3-phase, symmetrical)* at the 138 kV voltage levels is 5,000 MVA.

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[1] *SMA_SunnyCentral_ShortCircuitData.pdf*

Table 2: Short circuit levels, three phase, MVA

Location	IR664 off	IR664 on	Post % increase
Maximum generation, all transmission facilities in service			
99W-Bridgewater, 230kV-a	1424	1449	1.7%
99W-Bridgewater, 230kV-b	1643	1671	1.7%
99W-Bridgewater, 138kV *(POI)*	1704	1768	3.8%
IR664 34.5kV	539	610	13.1%
Low Generation, all transmission facilities in service			
99W-Bridgewater, 230kV-a	801	843	5.2%
99W-Bridgewater, 230kV-b	878	924	5.2%
99W-Bridgewater, 138kV *(POI)*	827	892	7.8%
IR664 34.5kV	404	474	17.5%
Minimum Conditions – low Generation, L-7008 out of service			
99W-Bridgewater, 230kV-a	733	782	6.8%
99W-Bridgewater, 230kV-b	472	506	7.1%
99W-Bridgewater, 138kV *(POI)*	644	709	10.0%
IR664 34.5kV	355	425	19.9%

When L7008 is out of service, the SCR[2] is calculated as 7.1 *(355 MVA / 50 MW)* at IR664's 34.5kV bus. Note that the minimum short circuit level on the 34.5kV bus can be greatly impacted by the impedance of the ICIF transformer and collector circuit impedance.

3.2 Power factor

IR664 must be capable of providing between 0.95 lagging to 0.95 leading net power factor at the high side of the ICIF transformer, at all production levels up to the full rate load.

The technical data provided by the IC specified a 138/34.5 kV transformer, with off-load tap changer, and ±5% taps; each tap step is assumed to be a value of 2.5% since the number of steps were not specified. The 34.5/0.66 kV generator step-up transformers were assumed to be supplied with ±5% taps.

The SMA SCS 3800 battery system inverters' PQ curves within normal voltage operation are shown in *Figure 6: Reactive power capability of the SCS 3800 UP at 25 °C under normal voltage operation* and *Figure 7: Reactive power capability of the SCS 3800 UP at 40 °C under normal voltage operation*. However, despite the reactive range indicated in Figure 6 and Figure 7, the IC has confirmed that the inverters battery system units can provide ±50.0 MVAr reactive power when delivering capped power at ±50.0 MW and have full ±50.0 MVAr reactive power capability at 0 MW real power.

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[2] Short Circuit Ratio: a measure of system strength relative to the BESS facility size.

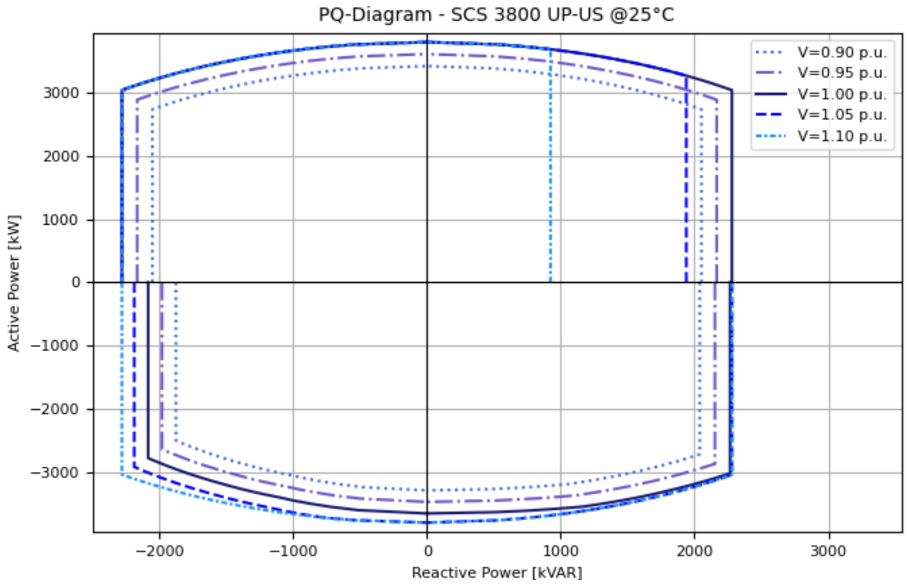

Figure 6: Reactive power capability of the SCS 3800 UP at 25 °C under normal voltage operation[3]

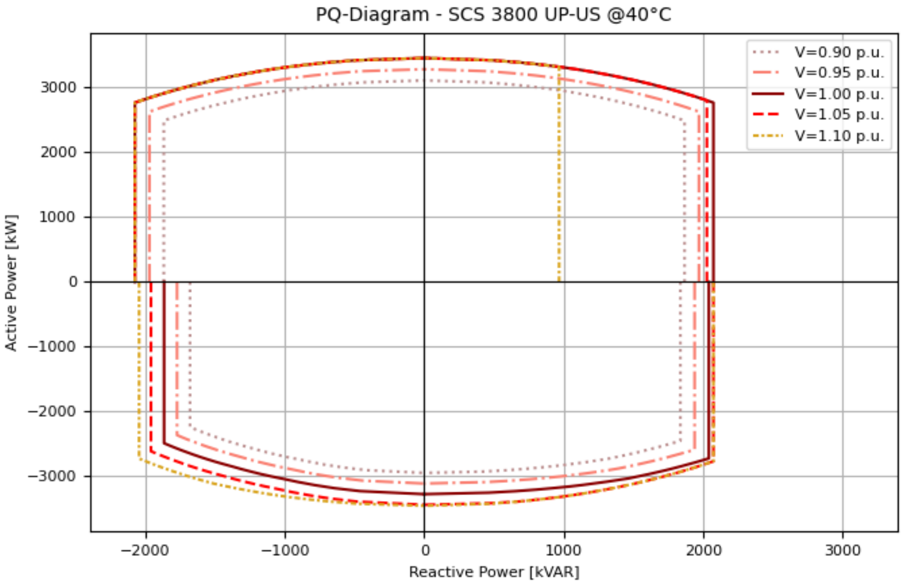

Figure 7: Reactive power capability of the SCS 3800 UP at 40 °C under normal voltage operation[4]

When IR664 generation is at capped 50.0 MW output and producing maximum 50.0 MVAr of reactive power, the real and reactive power delivered to the high side *(138kV)* of the

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[3] *scs3800 25c 0.90vpu.pdf; scs3800 25c 0.95vpu.pdf; SCS3800 25c 1 vpu.pdf; scs3800 25c 1.05vpu.pdf; scs3800 25c 1.10vpu.pd*

[4] *scs3800 40c .90vpu.pdf; scs3800 40c .95vpu.pdf; SCS 3800 40c 1 vpu.pdf; scs3800 40c 1.05vpu.pdf; scs 3800 40c 1.10vpu.pdf*

ICIF transformer is 49.30 MW and 40.11 MVAr, respectively. This equates to a +0.776 power factor, exceeding the existing +0.950 TSIR requirement.

When IR664 generation is at capped 50.0 MW output, while absorbing maximum 50.0 MVAr of reactive power, the real and reactive power delivered to the high side *(138 kV)* of the ICIF transformer is 49.17 MW and 61.82 MVAr, respectively. This corresponds to a -0.622 power factor, exceeding the -0.950 TSIR requirement.

The calculated reactive power consumption the IC's components when IR664 is at max MW output while producing or absorbing reactive power is listed in *Table 3: MVAr consumption at rated MW output*. Overall, IR664 meets both lagging and leading power factor requirement of NS Power. This should be re-evaluated once detailed design information on the transformers and collector circuits *(if any)* are available.

Table 3: MVAr consumption at rated MW output

Component	**At max MVAr production**	**At max MVAr absorption**
138/34.5 kV ICIF transformer*	5.39	6.44
34.5/0.66 kV generator step-up transformer equivalent *(tap setting 1.025)*	4.50	5.37

* Taps setting at 1.000 for max MVAr production and 0.95 for max MVAr absorption

3.3 Voltage flicker & Harmonics

Voltage flicker is not calculated for IR664 as it is not applicable for BESS.

As for harmonics, NSPI requires IR664 to meet Harmonics IEEE-519 standard limiting Total Harmonic Distortion *(all frequencies)* to a maximum of 2.5%, with no individual harmonic exceeding 1.5% for 138 kV. The total harmonic distortion *(THD)* for SMA SCS 3800 inverters battery system is currently not available. If for some reason, in the actual installation, IR664 causes issues with voltage flickers or harmonics, then IR664 will be responsible for mitigating the issues.

3.4 Steady state analysis

Power flow analysis was performed for generation dispatches under system light load, summer peak load, and winter peak load conditions. Dispatch was selected to represent import and export scenarios with New Brunswick for various flows associated with the existing Maritime Link transmission service reservation.

IR664 is located the Western region of Nova Scotia where Primary and Electrically Remote Transmission Systems interface. Electrically Remote is defined as parts of the system having a three-phase fault level less than 1,500MVA. IR664 is not materially impacted by changes to the interface flows on the Primary NSPI transmission system to the North/East of the Halifax load centre.

3.4.1 Base cases

The base cases used for power flow analysis are listed in Table 4: *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.
- Spring Light Load and Summer Peak cases tested charging at the same system load levels as discharging.
- For Winter Peak cases, charging was performed at off-peak hours of peak load dispatch *(91% of peak, based on historical measured load 4 hours after system peak)*.
- All interface limits were respected for base case scenarios.
- Historic flow levels were considered when dispatching Western generation.

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

- IR664 off.
- IR664 discharging at 50 MW under NRIS designation.
- IR664 charging at 50 MW.

For Spring Light Load and Summer Peak, both IR664 charging and discharging are derived from the same IR664 off cases *(i.e., ll01-1 and sp-02-1)*. For Winter cases, IR664 discharging is derived from Winter Peak cases *(i.e., wp02-1)* and IR664 charging is based on off-peak hours of peak load dispatch *(i.e., wp02-3)*.

Table 4: Power flow base cases

Case Name	NS load	IR664	Wind generation	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
ll01-1	798	-	373	230	-330	325	309	15	19	-7	33
ll01-2	798	50	373	230	-330	283	267	13	-29	-7	33
ll01-4	798	-50	373	230	-330	325	309	17	67	-7	33
ll03-1	798	-	559	230	-	109	168	6	-2	8	18
ll03-2	798	50	559	230	-	59	119	4	-50	8	18
ll03-4	798	-50	559	230	-	109	168	8	46	8	18
ll04-1	790	-	559	-	-	-70	-11	5	-2	8	18
ll04-2	790	50	559	-	-	-120	-61	4	-50	8	18
ll04-4	790	-50	559	-	-	-70	-11	8	46	8	18
ll05-1	790	-	559	230	-300	326	301	37	21	-1	40
ll05-2	790	50	559	230	-300	276	251	-12	20	-49	40
ll05-4	790	-50	559	230	-300	326	301	37	24	48	40
sh02-1	1,256	-	559	350	-475	571	730	86	65	-22	65
sh02-2	1,256	50	559	350	-475	519	680	84	17	-22	65
sh02-4	1,256	-50	559	350	-475	571	730	88	113	-22	65

Case Name	NS load	IR664	Wind generation	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
sh03-1	1,337	-	404	-300	-300	183	123	33	24	22	21
sh03-2	1,328	50	404	-300	-300	133	73	31	-24	22	21
sh03-4	1,337	-50	404	-300	-300	183	123	35	72	22	21
sp02-1	1,399	-	556	350	-475	544	695	105	63	-26	74
sp02-2	1,399	50	556	350	-475	492	644	103	15	-26	74
sp02-4	1,399	-50	556	350	-475	572	725	107	112	-26	74
sp03-1	1,433	-	326	350	-475	905	947	104	107	-25	74
sp03-2	1,433	50	324	350	-475	854	898	104	59	-25	74
sp03-4	1,433	-50	324	350	-475	907	949	108	156	-25	74
sp05-1	1,418	-	142	-	-475	846	867	149	114	-25	73
sp05-2	1,418	50	142	-	-475	792	816	147	66	-25	73
sp05-4	1,418	-50	142	-	-475	846	867	151	162	-25	73
wp02-1	2,135	-	398	150	-320	1,032	1,209	155	129	-15	87
wp02-2	2,135	50	398	150	-320	976	1,157	152	81	-15	87
wp02-3	1,967	-	398	150	-320	757	961	131	105	-6	73
wp02-4	1,967	-50	398	150	-320	757	961	133	153	-6	73
wp03-1	2,135	-	282	150	-320	1,019	1,150	163	143	-26	99
wp03-2	2,135	50	282	150	-320	964	1,098	160	95	-26	99
wp03-3	1,967	-	398	150	-320	856	1,055	133	129	-6	73
wp03-4	1,967	-50	398	150	-320	856	1,055	136	178	-6	73
wp04-1	2,140	-	282	150	-320	1,019	1,150	182	165	-26	99
wp04-2	2,140	50	282	150	-320	963	1,098	180	116	-26	99
wp04-3	1,972	-	282	150	-320	879	1,029	156	141	-17	84
wp04-4	1,972	-50	282	150	-320	878	1,029	159	190	-17	84

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.

Note 4: Negative MW in the IR664 column indicates charging.

Note 5: Negative MW in NS/NB and ML columns, represent imports to NS.

- wp02-x, wp03-x and wp04-x represents peak load, with high East-West transfers. 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 27% 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)*.
- sp02-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 generation is managed to ensure transmission limits are maintained.
- ll01-x, ll03-x, sp02-x, and sp03-x represent high enough export levels from NS to NB to require arming of the Export Power Monitor SPS. ll01-x and ll03-x require Group 5 arming, while sp02-x and sp03-x requires Group 6 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.

- ll04-x represents minimum system load under low inertia, with only two equivalent thermal units online and high wind generation.
- sp05-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 5: Steady state contingencies*.

Table 5: Steady state contingencies

ID	Element	Type	Location
p001	2C-B61	Bus fault	2C-Hastings
p002	2C-B62	Bus fault	2C-Hastings
p003	3C-712	Breaker fail	3C-Hastings
p004	3C-715	Breaker fail	3C-Hastings
p005	L6515	Line fault	2C-Hastings
p006	L6516	Line fault	2C-Hastings
p007	L6517	Line fault	2C-Hastings
p008	L6518	Line fault	2C-Hastings
p009	L6537	Line fault	2C-Hastings
p010	L6543	Line fault	2C-Hastings
p011	L7004	Line fault	3C-Hastings
p012	103H-B61	Bus fault	103H-Lakeside
p013	103H-B62	Bus fault	103H-Lakeside
p014	103H-T63	Transformer fault	103H-Lakeside
p015	104H-600	Breaker fail	104H-Kempt Rd
p016	113H-601	Breaker fail	113H-Dartmouth East
p017	120H-621	Breaker fail	120H-Brushy
p018	120H-622	Breaker fail	120H-Brushy
p019	120H-623	Breaker fail	120H-Brushy
p020	120H-624	Breaker fail	120H-Brushy
p021	120H-625	Breaker fail	120H-Brushy
p022	120H-626	Breaker fail	120H-Brushy
p023	120H-627	Breaker fail	120H-Brushy
p024	120H-628	Breaker fail	120H-Brushy
p025	120H-629	Breaker fail	120H-Brushy
p026	120H-710	Breaker fail	120H-Brushy
p027	120H-711	Breaker fail	120H-Brushy
p028	120H-712	Breaker fail	120H-Brushy
p029	120H-713	Breaker fail	120H-Brushy
p030	120H-714	Breaker fail	120H-Brushy
p031	120H-715	Breaker fail	120H-Brushy
p032	120H-716	Breaker fail	120H-Brushy
p033	120H-720	Breaker fail	120H-Brushy
p034	132H-602	Breaker fail	132H-Spider Lake
p035	132H-603	Breaker fail	132H-Spider Lake
p036	132H-605	Breaker fail	132H-Spider Lake
p037	132H-606	Breaker fail	132H-Spider Lake
p038	1H-603	Breaker fail	1H-Water St
p039	90H-601	Breaker fail	90H-Sackville
p040	90H-602	Breaker fail	90H-Sackville
p041	90H-603	Breaker fail	90H-Sackville
p124	101S-702	Breaker fail	101S-Woodbine
p125	101S-703	Breaker fail	101S-Woodbine
p126	101S-704	Breaker fail	101S-Woodbine
p127	101S-705	Breaker fail	101S-Woodbine
p128	101S-706	Breaker fail	101S-Woodbine
p129	101S-711	Breaker fail	101S-Woodbine
p130	101S-712	Breaker fail	101S-Woodbine
p131	101S-713	Breaker fail	101S-Woodbine
p132	101S-811	Breaker fail	101S-Woodbine
p133	101S-812	Breaker fail	101S-Woodbine
p134	101S-813	Breaker fail	101S-Woodbine
p135	101S-814	Breaker fail	101S-Woodbine
p136	101S-816	Breaker fail	101S-Woodbine
p137	88S-710	Breaker fail	88S-Lingan
p138	88S-712	Breaker fail	88S-Lingan
p139	88S-713	Breaker fail	88S-Lingan
p140	88S-720	Breaker fail	88S-Lingan
p141	88S-721	Breaker fail	88S-Lingan
p142	88S-722	Breaker fail	88S-Lingan
p143	88S-723	Breaker fail	88S-Lingan
p144	L7011	Line fault	101S-Woodbine
p145	L7014	Line fault	88S-Lingan
p146	L7015	Line fault	101S-Woodbine
p147	L7021	Line fault	88S-Lingan
p148	L7022	Line fault	88S-Lingan
p149	L8004	Line fault	101S-Woodbine
p150	L6011 + L6010	Double ckt tower	Sackville
p151	L6507 + L6508	Double ckt tower	Trenton
p152	L6534 + L7021	Double ckt tower	Lingan / VJ
p153	L7003 + L7004	Double ckt tower	Canso Causeway
p154	L7008 + L7009	Double ckt tower	Bridgewater
p155	L7009 + L8002	Double ckt tower	Sackville
p156	101V-601	Breaker fail	101V-MacDonald Pond
p157	13V-B51	Bus fault	13V-Gulch
p158	15V-B51	Bus fault	15V-Sissiboo
p159	17V-B1	Bus fault	17V-St Croix
p160	17V-B2	Bus fault	17V-St Croix
p161	1V-442	Breaker fail	1V-Avon 1
p162	20V-B51	Bus fault	20V-Five Points
p163	3V-551	Breaker fail	3V-Hell's Gate
p164	43V-B51	Bus fault	43V-Canaan Rd

ID	Element	Type	Location	ID	Element	Type	Location
p042	90H-605	Breaker fail	90H-Sackville	p165	43V-B61	Bus fault	43V-Canaan Rd
p043	90H-606	Breaker fail	90H-Sackville	p166	43V-B62	Bus fault	43V-Canaan Rd
p044	90H-608	Breaker fail	90H-Sackville	p167	43V-T61	Transformer fault	43V-Canaan Rd
p045	90H-609	Breaker fail	90H-Sackville	p168	43V-T62	Transformer fault	43V-Canaan Rd
p046	90H-611	Breaker fail	90H-Sackville	p169	51V-601	Breaker fail	51V-Tremont
p047	90H-612	Breaker fail	90H-Sackville	p170	51V-B51	Bus fault	51V-Tremont
p048	90H-613	Breaker fail	91H-Tufts Cove	p171	51V-T61	Transformer fault	51V-Tremont
p049	90H-621	Breaker fail	91H-Tufts Cove	p172	51V-T62	Transformer fault	51V-Tremont
p050	91H-603	Breaker fail	91H-Tufts Cove	p173	6V-GT1	Transformer fault	6V-Hollow Bridge
p051	91H-604	Breaker fail	91H-Tufts Cove	p174	82V-600	Breaker fail	82V-Elmsdale
p052	91H-605	Breaker fail	91H-Tufts Cove	p175	92V-B51	Bus fault	92V-Michelin Waterville
p053	91H-606	Breaker fail	91H-Tufts Cove	p176	L4045	Line fault	17V-St Croix
p054	91H-607	Breaker fail	91H-Tufts Cove	p177	L4046	Line fault	17V-St Croix
p055	91H-608	Breaker fail	91H-Tufts Cove	p178	L4047	Line fault	17V-St Croix
p056	91H-609	Breaker fail	91H-Tufts Cove	p179	L4048W	Line fault	39V-Fundy Gypsum
p057	91H-611	Breaker fail	91H-Tufts Cove	p180	L4049	Line fault	3V-Hell's Gate
p058	L0644	Line fault	132H-Spider Lake	p181	L5014	Line fault	17V-St Croix
p059	L6002E	Line fault	90H-Sackville	p182	L5015	Line fault	17V-St Croix
p060	L6003	Line fault	90H-Sackville	p183	L5016	Line fault	17V-St Croix
p061	L6004	Line fault	90H-Sackville	p184	L5021	Line fault	43V-Canaan Rd
p062	L6005	Line fault	120H-Brushy	p185	L5022	Line fault	43V-Canaan Rd
p063	L6007	Line fault	91H-Tufts Cove	p186	L5025	Line fault	11V-Paradise
p064	L6008	Line fault	103H-Lakeside	p187	L5026	Line fault	11V-Paradise
p065	L6009	Line fault	90H-Sackville	p188	L5033	Line fault	43V-Canaan Rd
p066	L6010	Line fault	120H-Brushy	p189	L5035	Line fault	3V-Hell's Gate
p067	L6011	Line fault	120H-Brushy	p190	L5050	Line fault	15V-Sissiboo
p068	L6014	Line fault	91H-Tufts Cove	p191	L5053	Line fault	92V-Michelin Waterville
p069	L6016	Line fault	120H-Brushy	p192	L5060	Line fault	17V-St Croix
p070	L6033	Line fault	103H-Lakeside	p193	L5531	Line fault	13V-Gulch
p071	L6035	Line fault	1H-Water St	p194	L5532	Line fault	13V-Gulch
p072	L6038	Line fault	103H-Lakeside	p195	L5533	Line fault	13V-Gulch
p073	L6040	Line fault	91H-Tufts Cove	p196	L5535	Line fault	15V-Sissiboo
p074	L6042	Line fault	91H-Tufts Cove	p197	L5538	Line fault	15V-Sissiboo
p075	L6043	Line fault	113H-Dartmouth East	p198	L6001N	Line fault	82V-Elmsdale
p076	L6044	Line fault	113H-Dartmouth East	p199	L6001S	Line fault	82V-Elmsdale
p077	L6051	Line fault	120H-Brushy	p200	L6012	Line fault	43V-Canaan Rd
p078	L6055	Line fault	132H-Spider Lake	p201	L6013	Line fault	43V-Canaan Rd
p079	L7018	Line fault	120H-Brushy	p202	L6015	Line fault	43V-Canaan Rd
p080	T1	Transformer fault	90H-Sackville	p203	L6051	Line fault	17V-St Croix
p081	1N-B61	Bus fault	1N-Onslow	p206	L6052	Line fault	43V-Canaan Rd
p082	1N-B62	Bus fault	1N-Onslow	p207	L6054	Line fault	43V-Canaan Rd
p083	50N-604	Breaker fail	50N-Trenton	p209	30W-B51	Bus fault	30W-Souriquois
p084	67N-701	Breaker fail	67N-Onslow	p210	30W-B61	Bus fault	30W-Souriquois
p085	67N-702	Breaker fail	67N-Onslow	p211	3W-B53	Bus fault	3W-Big Falls
p086	67N-703	Breaker fail	67N-Onslow	p212	50W-B2	Bus fault	50W-Milton
p087	67N-704	Breaker fail	67N-Onslow	p213	50W-B3	Bus fault	50W-Milton
p088	67N-705	Breaker fail	67N-Onslow	p214	50W-B4	Bus fault	50W-Milton
p089	67N-706	Breaker fail	67N-Onslow	p215	50W-T53	Transformer fault	50W-Milton
p090	67N-710	Breaker fail	67N-Onslow	p216	99W-B51	Bus fault	99W-Bridgewater
p091	67N-711	Breaker fail	67N-Onslow	p217	99W-B61	Bus fault	99W-Bridgewater

ID	Element	Type	Location	ID	Element	Type	Location
p092	67N-712	Breaker fail	67N-Onslow	p218	99W-B62	Bus fault	99W-Bridgewater
p093	67N-713	Breaker fail	67N-Onslow	p219	99W-B71	Bus fault	99W-Bridgewater
p094	67N-811	Breaker fail	67N-Onslow	p220	99W-B72	Bus fault	99W-Bridgewater
p095	67N-812	Breaker fail	67N-Onslow	p221	99W-T61	Transformer fault	99W-Bridgewater
p096	67N-813	Breaker fail	67N-Onslow	p222	99W-T62	Transformer fault	99W-Bridgewater
p097	67N-814	Breaker fail	67N-Onslow	p223	99W-T71	Transformer fault	99W-Bridgewater
p098	74N-600	Breaker fail	74N-Springhill	p224	99W-T72	Transformer fault	99W-Bridgewater
p099	79N-B61	Bus fault	79N-Hopewell	p225	9W-B52	Bus fault	9W-Tusket
p100	79N-B81	Bus fault	79N-Hopewell	p226	9W-B53	Bus fault	9W-Tusket
p101	L5029	Line fault	74N-Springhill	p227	L5530	Line fault	50W-Milton
p102	L5058	Line fault	74N-Springhill	p228	L5540	Line fault	50W-Milton
p103	L6001	Line fault	1N-Onslow	p229	L5541	Line fault	3W-Big Falls
p104	L6057	Line fault	50N-Trenton	p230	L5545	Line fault	99W-Bridgewater
p105	L6503	Line fault	50N-Trenton	p231	L5546	Line fault	99W-Bridgewater
p106	L6507	Line fault	79N-Hopewell	p232	L6006	Line fault	99W-Bridgewater
p107	L6508	Line fault	50N-Trenton	p233	L6020	Line fault	50W-Milton
p108	L6511	Line fault	50N-Trenton	p234	L6024	Line fault	50W-Milton
p109	L6514	Line fault	74N-Springhill	p235	L6025	Line fault	99W-Bridgewater
p110	L6527	Line fault	1N-Onslow	p236	L6048	Line fault	50W-Milton
p111	L6536	Line fault	74N-Springhill	p237	L6531	Line fault	99W-Bridgewater
p112	L6613	Line fault	74N-Springhill	p238	L7008	Line fault	99W-Bridgewater
p113	L7001	Line fault	67N-Onslow	p239	L7009	Line fault	99W-Bridgewater
p114	L7002	Line fault	67N-Onslow	p240	17V-611	Breaker fail	17V- St. Croix
p115	L7003	Line fault	67N-Onslow	p241	50W-501	Breaker fail	50W-Milton
p116	L7005	Line fault	67N-Onslow	p242	50W-600	Breaker fail	50W-Milton
p117	L7019	Line fault	67N-Onslow	p243	9W-500	Breaker fail	9W-Tusket
p118	L8001	Line fault	67N-Onslow	p244	43V-562	Breaker fail	43V-Canaan Rd
p119	L8002	Line fault	67N-Onslow	p245	43V-503	Breaker fail	43V-Canaan Rd
p120	L8003	Line fault	67N-Onslow	p246	17V-512	Breaker fail	17V-St Croix
p121	L8003	Line fault	79N-Hopewell	p247	17V-563	Breaker fail	17V-St Croix
p122	L8004	Line fault	79N-Hopewell	p248	51V-562	Breaker fail	17V-St Croix
p123	101S-701	Breaker fail	101S-Woodbine	p249	51V-521	Breaker fail	17V-St Croix

3.4.3 Steady state evaluation

The steady state contingencies evaluated in this study demonstrate IR664 does not require Network Upgrades beyond the POI to operate at requested MW.

IR664 has little impact on constrained transmission in the Western region due to its location on the far Eastern end of the Western region. This is also demonstrated with 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 IR664.

Notable flow differences on the Western transmission corridor from Metro including lines between 99W-Bridgewater, 120H-Brushy Hill, 90H-Sackville, and 91H-Tuft’s Cove are expected as these substations are endpoints around the corridor IR664 is placed in. Flows from 99W-Bridgewater to Western Valley change no more than 0.2 MW as IR664 comes online and goes to full load. The circuits likely to limit Western Valley generation *(L5532 and L5535)* change no more than 0.2 MW.

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

- Contingency p179 *(loss of L-4048)* can cause overvoltage at 41V-MBPP substation *(up to 1.18 p.u)* in wp02, wp03 and wp04 cases.
- Contingencies p213 *(loss of 50W-B3)*, p241 *(50W-501)*, and p242 *(50W-600)* can cause overload on 9W-T63 transformer and L-6024, also cause low voltage *(down to 0.84 p.u)* in Tusket area in ll01, sh03, sp03, sp05, wp02, wp03, and wp04 cases, which could trigger the rejection of Tusket area load by the tripping of 9W-515 *(L-5027)*.
- Contingencies p214 *(loss of 50W-B4)* p234 *(loss of L-6024)* , and p242 *(50W-600)* can overload 9W-T2 transformer, also cause low voltage *(down to 0.74 p.u)* in Tusket area and at the 23W-Clyde River; 25W-Shelburne, 30W-Souriquois, 36W-Green Harbor and 37W-Lockport substations in wp02, wp03 and wp04 cases.
- Contingency p233 *(loss of L-6020/6021)* can also cause low voltage *(down to 0.87 p.u)* at the 23W-Clyde River; 25W-Shelburne, 30W-Souriquois, 36W-Green Harbor and 37W-Lockport substations in wp02, wp03 and wp04 cases.
- Contingency p245 *(43V-503)* can cause low voltage *(down to 0.89 p.u)* at the 55V-Waterville and 92V-Michelin Waterville substations in wp03 case.

All these violations are pre-existing and are not the responsibility of IR664.

3.5 Stability analysis

System design criteria requires the system to be stable and well damped in all modes of oscillations.

3.5.1 Benchmark Test Performance

The IC supplied two sets of dynamic models and parameters for the SMA SCS 3800 inverters battery system units: generic models and vendor specific User Defined Models *(UDM)* in PSS®E DYR file format. Both types of dynamic models are shown in *Table 6: Modeling Package for SMA SCS 3800 Inverters Battery System units*. The detailed generic and user defined dynamics data is included in Appendix A of this report.

Table 6: Modeling Package for SMA SCS 3800 Inverters Battery System units

Model Type	PSS®E Model	Description
Generic Models	REGCA1	Renewable Energy Generator/Converter Module
	REECCU1	Renewable Energy Electrical Control Module for battery-energy storage systems *(BESS)*
	REPCA1	Renewable Energy Plant Controller Module
User Defined Models	SMASC_G177	SMA solar and storage inverters model
	SMAPPC_G140	SMA plant control model for solar and battery storage inverters

Benchmarking was conducted to compare the generic and UDM model performance by applying a 3-phase fault at the POI for 9 cycles using the MMWG light load and winter peak cases. PSS®E plotted output curves of P, Q and terminal voltage of the inverters battery system units for both the UDM *(red curves)* and generic models *(green curves)* are presented in Figure 8 and Figure 9.

The UDM dynamic models and parameters in the PSSE DYR file have been used to form a basis of parameters of IR664 for further studies, with the assumption that the parameters provided are more accurate.

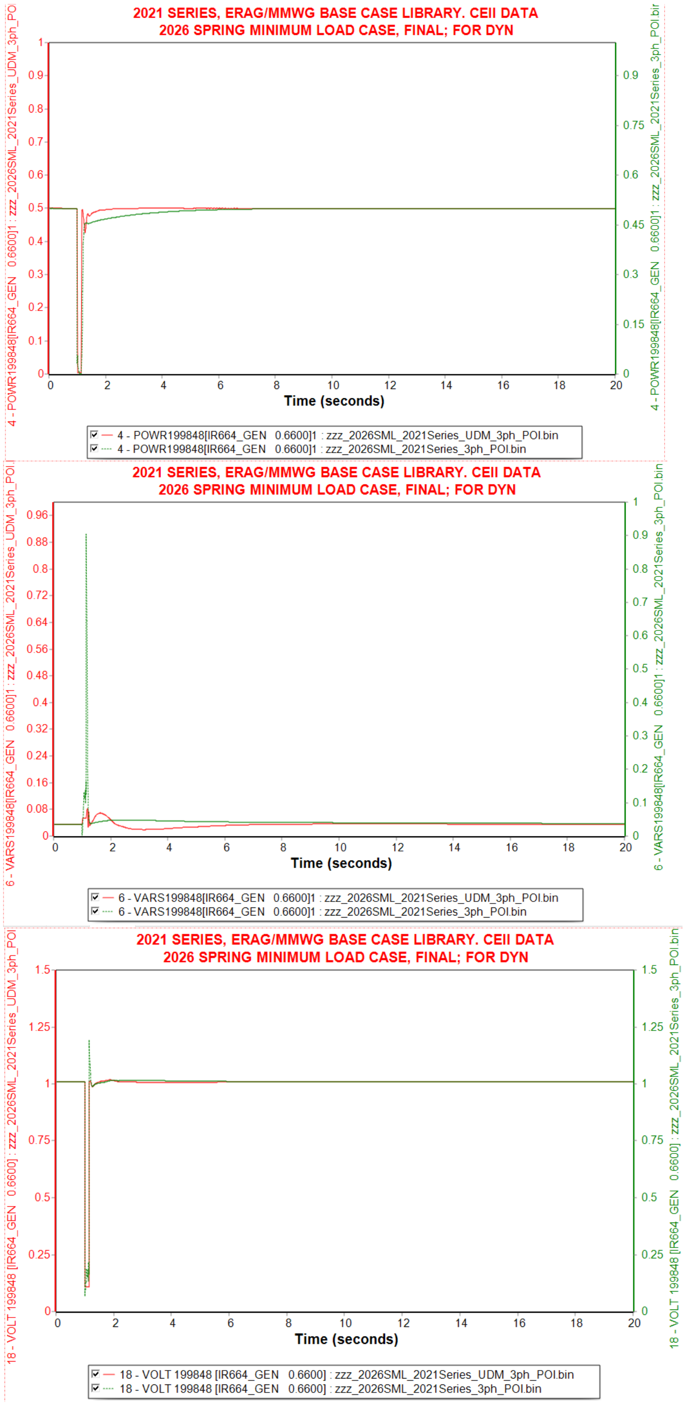

Figure 8: Generic vs. UDM Benchmark Performance _2026SML

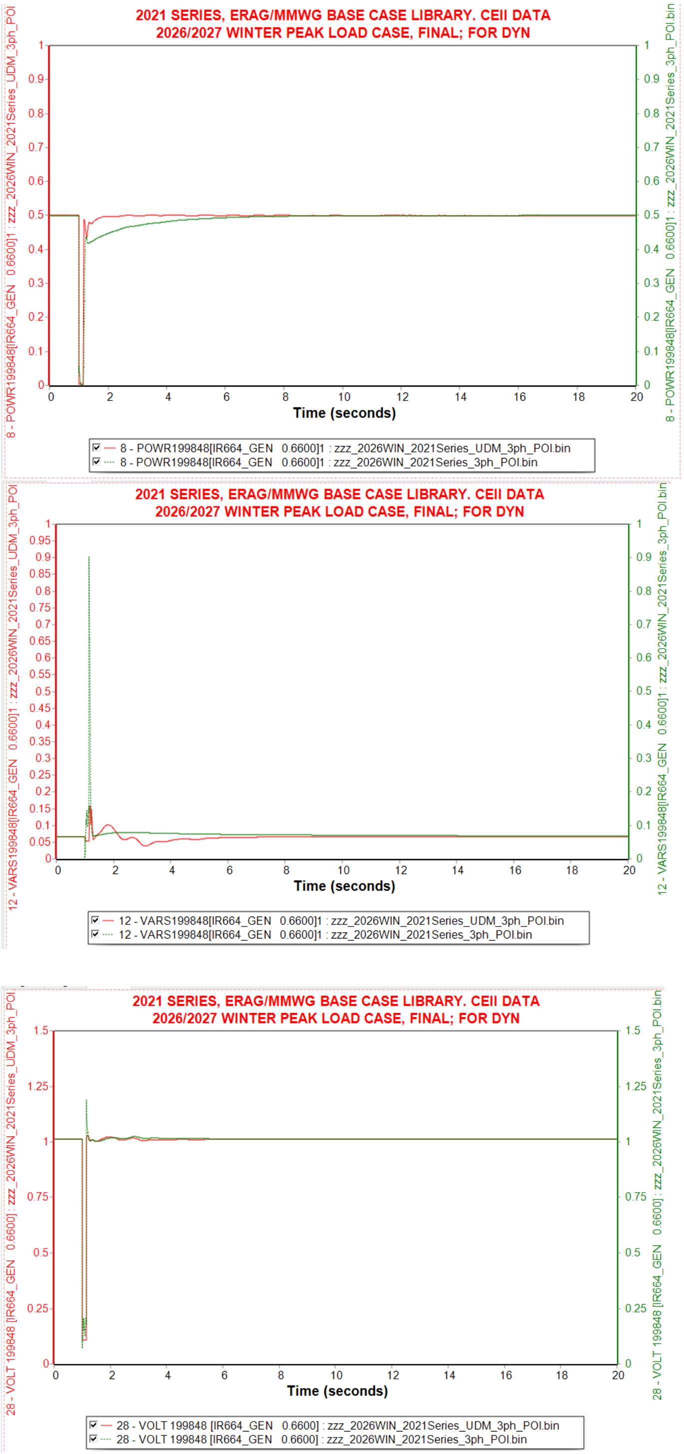

Figure 9: Generic vs. UDM Benchmark Performance _2026WIN

3.5.2 Stability base cases

All steady-state cases were studied for contingencies that provide the best measure of system reliability. The parameters of these base cases are repeated below in *Table 7: Stability base cases* for convenience.

Table 7: Stability base cases

Case Name	NS load	IR 664	Wind generation	West wind	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
ll01-2	798	50	373	254	230	-330	283	267	13	-29	-7	33
ll01-4	798	-50	373	254	230	-330	325	309	17	67	-7	33
ll04-2	790	50	559	287	-	-	-120	-61	4	-50	8	18
ll04-4	790	-50	559	287	-	-	-70	-11	8	46	8	18
ll04-2	790	50	559	271	230	-300	276	251	20	-49	40	-14
ll04-4	790	-50	559	271	230	-300	326	301	24	48	40	-14
sh02-2	1,256	50	559	287	350	-475	519	680	84	17	-22	65
sh02-4	1,256	-50	559	287	350	-475	571	730	88	113	-22	65
sh03-2	1,328	50	404	287	-300	-300	133	73	31	-24	22	21
sh03-4	1,337	-50	404	287	-300	-300	183	123	35	72	22	21
sp02-2	1,399	50	556	284	350	-475	492	644	103	15	-26	74
sp02-4	1,399	-50	556	284	350	-475	572	725	107	112	-26	74
sp05-2	1,418	50	142	134	-	-475	792	816	147	66	-25	73
sp05-4	1,418	-50	142	134	-	-475	846	867	151	162	-25	73
wp02-2	2,135	50	398	269	150	-320	976	1,157	152	81	-15	87
wp02-4	1,967	-50	398	269	150	-320	757	961	133	153	-6	73
wp04-2	2,140	50	282	248	150	-320	963	1,098	180	116	-26	99
wp04-4	1,972	-50	282	248	150	-320	878	1,029	159	190	-17	84

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.
Note 4: Negative MW in the IR664 column indicates charging.
Note 5: Negative MW in NS/NB and ML columns, represent imports to NS.

3.5.3 Stability contingencies

The contingencies tested for this study are listed in *Table 8: Stability contingency list*.

Table 8: Stability contingency list

90H-605_LG	120H L6011_3PH	67N-712_ LG	15V 15V-B51_3PH	50W-B4_3PH
90H-606_LG	120H L6016_3PH	67N-713_ LG	15V L5535_3PH	99W-606_LG*
90H-608_LG	120H L6051_3PH	67N-811_ LG *	17V-512_LG	99W-625_LG*
90H-609_LG	120H L7008_3PH	67N-811_T82_ LG *	17V-563_LG	99W-631_LG*
90H L6003_3PH	120H L7018_3PH	67N-813_ LG	17V-612_LG	99W-B61_3PH*
90H L6004_3PH	132H-602_LG	67N-814_ LG*	17V-B63_3PH	99W-B62_3PH*
90H L6008_3PH	132H-603_LG	67N L7003_3PH*	17V L5016_3PH	99W L6002_3PH
90H L6009_3PH	132H 132H-606_3PH	67N L7001_3PH	43V-503_LG	99W L6006_3PH
91H L6007_3PH	132H 132H-605_3PH	67N L7005_3PH*	43V-562_LG	99W L6025_3PH
91H L6014_3PH	132H L6044_3PH	67N L7018_3PH	43V-B61_3PH	99W L6531_3PH

91H L6040_3PH	132H L6055_3PH	67N L7019_3PH*	43V-612_ LG	99W L7008_3PH*
103H-600_LG	1N-600_LG	67N L8001_3PH*	43V-B62_3PH	99W L7009_3PH*
103H-608_ LG	1N-601_ LG	67N L8002_3PH	43V L6012_3PH	DCT L6005_L6010_LLG
103H-881_LG	1N-613_ LG	67N L8003_3PH*	51V-521_LG	DCT L6010_L6011_ LLG
103H-681_LG	1N-B61_3PH	74N-600_ LG	51V-562_LG	DCT L6005_L6016_ LLG
103H L6008_3PH	1N-B62_3PH	74N L6514_3PH	51V-B51_3PH*	DCT L6033_L6035_ LLG
103H L6016_3PH	1N L6001_3PH	74N L6536_3PH	51V L5025_3PH*	DCT L6507_L6508_50N_LLG
103H L6033_3PH	1N L6503_3PH	74N L6613_3PH	9W-500_LG	DCT L6507_L6508_79N_LLG
103H L8002_3PH	1N L6613_3PH	410N L3006_3PH	9W-B53_3PH	DCT L6534_L7021_ LLG
108H L6055_3PH	67N-701_LG	410N L8001_3025_3PH*	9W L5535_3PH	DCT L7003_L7004_ LLG *
113H-600_3PH	67N-702_ LG	11V 11V-B51_3PH*	9W L6021_3PH	DCT L7008_L7009_ LLG
120H-622_3PH	67N-703_ LG	11V L5025_3PH*	9W L6021_LG	DCT L7009_L8002_ LLG
120H-628_3PH	67N-704_ LG	11V L5026_3PH*	9W L6024_3PH	DCT L7009_L8002_A_ LLG
120H-710_3PH	67N-705_ LG *	13V 13V-B51_3PH	50W-501_LG	* Indicates RAS/AAS
120H-715_3PH	67N-706_ LG	13V L5026_3PH	50W-600_LG*	
120H L6005_3PH	67N-710_ LG	13V L5531_3PH	50W-B2_3PH	
120H L6010_3PH	67N-711_ LG	13V L5532_3PH	50W-B3_3PH	

3.5.4 Stability evaluation

PSS®E plotted output files for each contingency with IR664 in service are presented in Appendices H through W. All contingencies were found to be stable and well-damped.

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". Methodology from latest A-10 document, dated March 27, 2020, is used for the testing.

Both steady state and stability BPS testing was performed using the Spring Light Load, Summer Peak and Winter Peak case shown in Table 7-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 99W 138 kV bus for 10 second, assuming all local protection out of service. *Appendix E: NPCC-BPS determination results* demonstrates IR664 does not have adverse impact outside the local area, confirming the transmission facilities associated with IR664 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[5]. 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[6].

Based on NERC BES criteria, IR664 is not considered part of the BES because:

- The ICIF transformer's secondary terminal is <100kV.
- The gross plant/facility aggregate nameplate rating is <75MVA.
- The POI is not on a Black Start path.

3.7 Underfrequency operation

IR664'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. sh03-2 represents IR664 discharging, and sh03-4 is for IR664 charging. IR664 remains stable and online as required for both discharging and charging scenarios.

When IR664 is discharging at 50MW *(sh03-2)*, simulation indicates that NS Power's Stage 5 UFLS activates to stabilize system frequency by shedding 245 MW load. The simulation results are shown in figures Figure 10, Figure 11, and Figure 12.

IR664 is required to cap the plant’s steady state output to 50 MW as the requested injection amount is 50 MW and the plant’s nameplate capability is 76 MW. However, as Figure 12 indicates, the plant is capable and does inject more than the 50 MW in the post-contingency transient period timeframe.

Note values are plotted on 100 MVA system base, so IR664 at 0.5 PU power represents full output of the generator rather than 50.0% output.

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[5] 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

[6] 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.

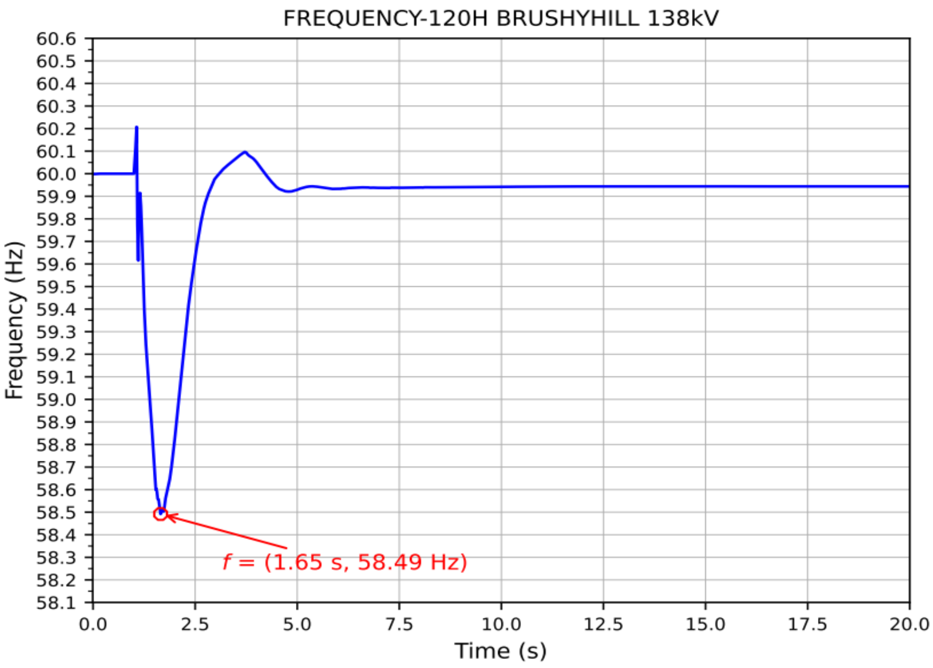

Figure 10: Underfrequency performance with IR664 discharging at 50MW ***(frequency at 120H-Brushy Hill:138kV)***

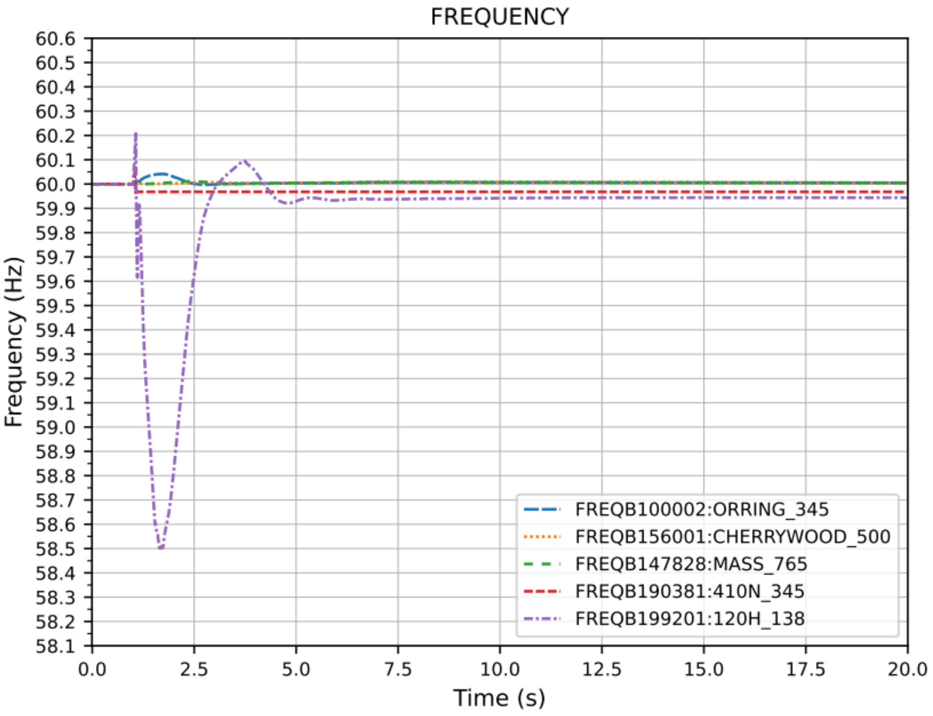

Figure 11: Underfrequency performance with IR664 discharging at 50MW ***(frequency at NS_410N, Mass, Cherrywood, Orrington, and 120H-Brushy Hill)***

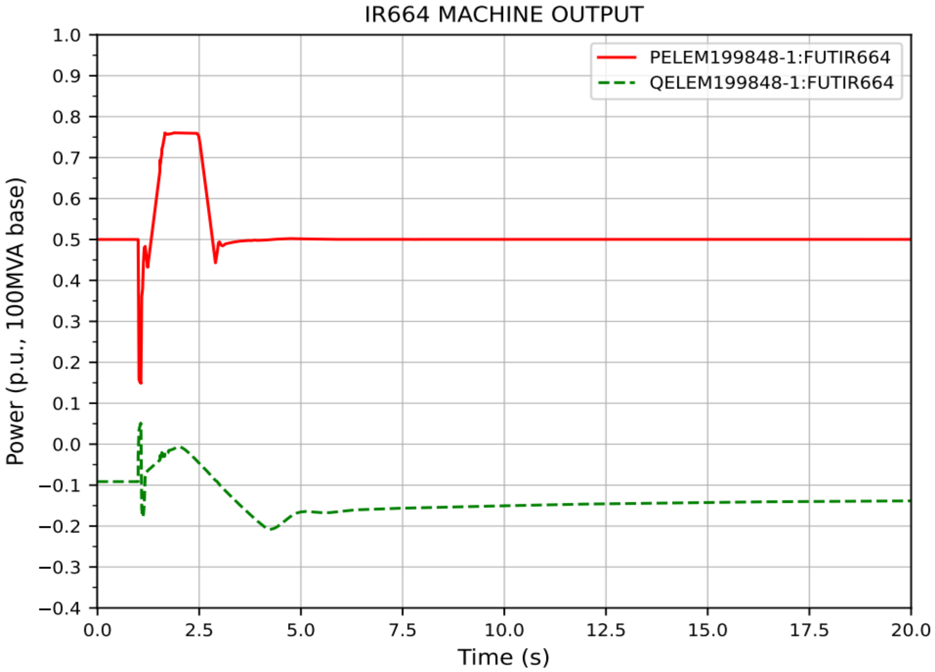

Figure 12: Underfrequency performance with IR664 discharging at 50MW

When IR664 is charging at 50MW *(sh03-4)*, simulation indicates that IR 664 provided MW support for the frequency drop and rapidly changed the output from charging to discharging as needed to alleviate the UFLS. NS Power's Stage 4 UFLS activates to stabilize system frequency by shedding 192 MW load. IR664 helps to improve the system frequency performance. The simulation results are shown in figures Figure 13, Figure 14, and Figure 15. Note values are plotted on 100 MVA system base.

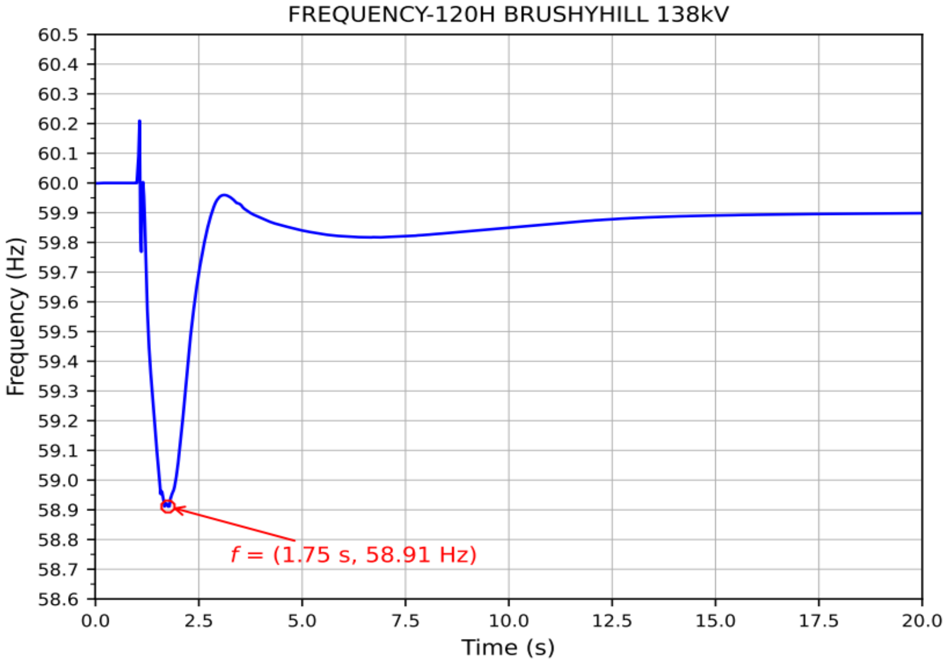

Figure 13: Underfrequency performance with IR664 charging at 50MW *(frequency at 120H-Brushy Hill:138kV)*

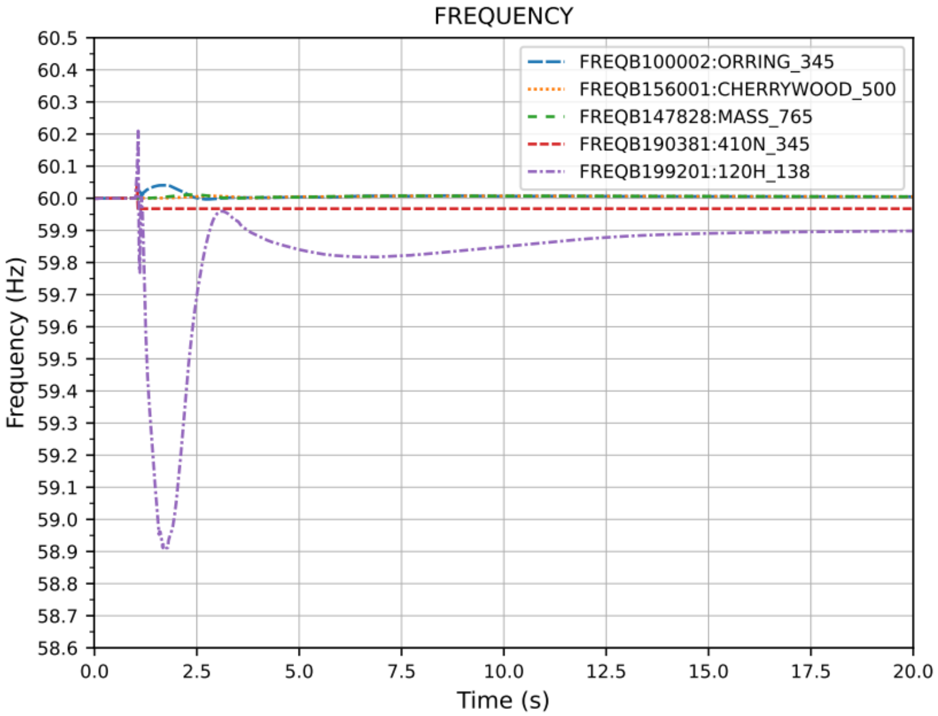

Figure 14: Underfrequency performance with IR664 charging at 50MW ***(frequency at NS_410N, Mass, Cherrywood, Orrington, and 120H-Brushy Hill)***

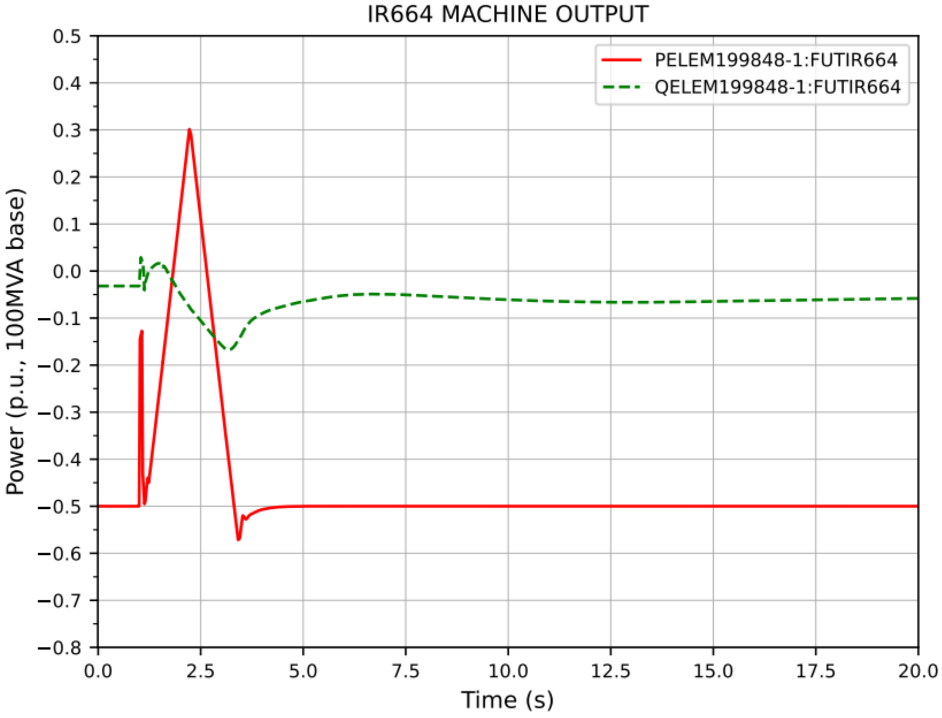

Figure 15: Underfrequency performance with IR664 charging at 50MW

3.8 Voltage ridethrough

IR664 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 IR664 138kV and 34.5kV buses under all stability base cases.

The stability plots in Figure 16 and Figure 17 demonstrate IR664 rides through the fault and stays online under both faults with IR664 discharging at 50MW. The stability plot in Figure 18 and Figure 19 demonstrate IR664 rides through the fault and stays online with IR664 charging at 50MW, as required. Results are shown in *Appendix G: Low voltage ride through*. Note values are plotted on 100 MVA system base, so IR664 at ±0.5 PU power represents full discharging/charging of the battery system rather than 50.0% output.

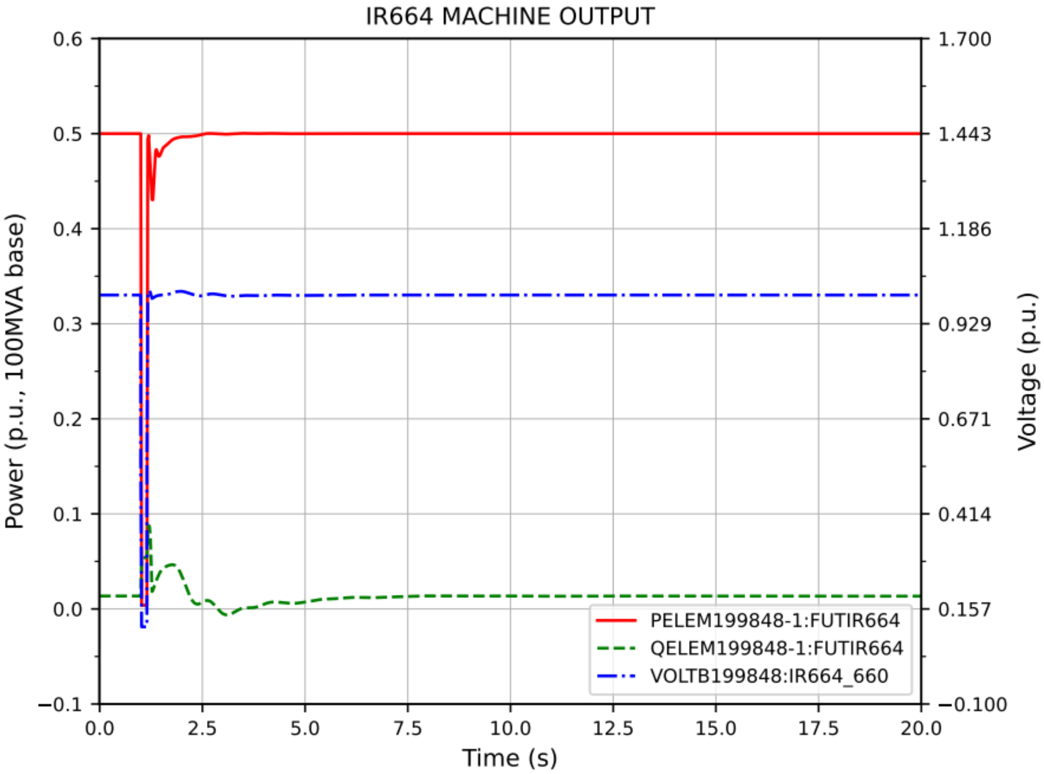

Figure 16: IR664 LVRT performance ***(HV fault, 9 cycles, discharging)***

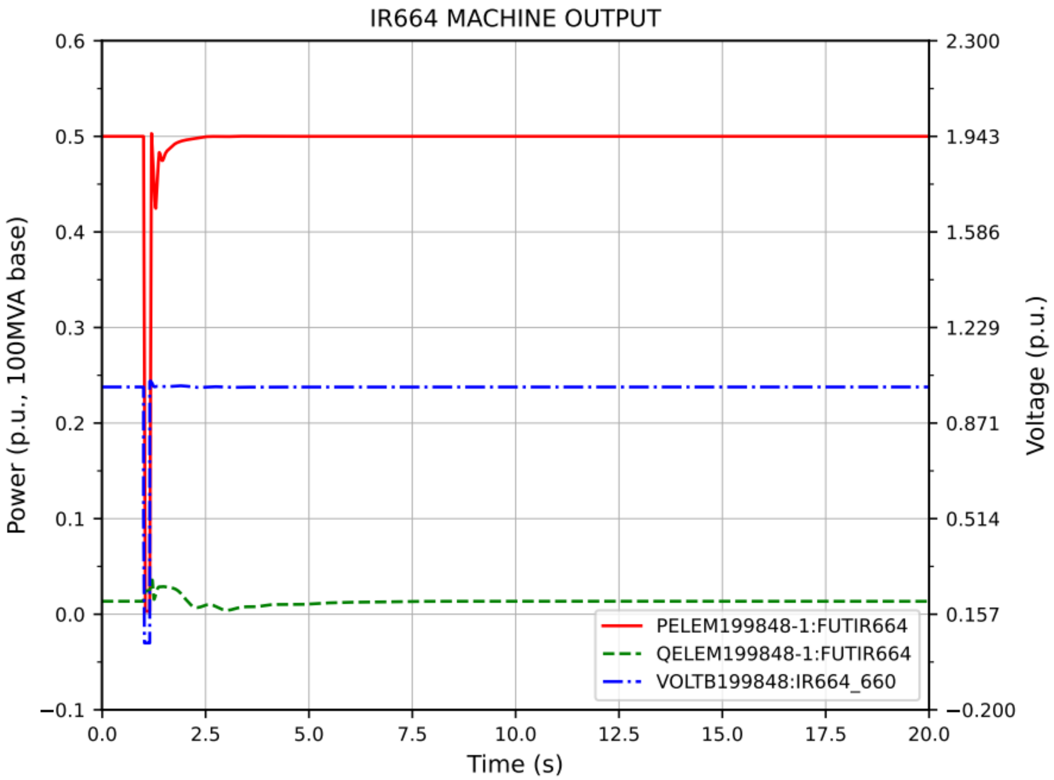

Figure 17: IR664 LVRT performance ***(MV fault, 9 cycles, discharging)***

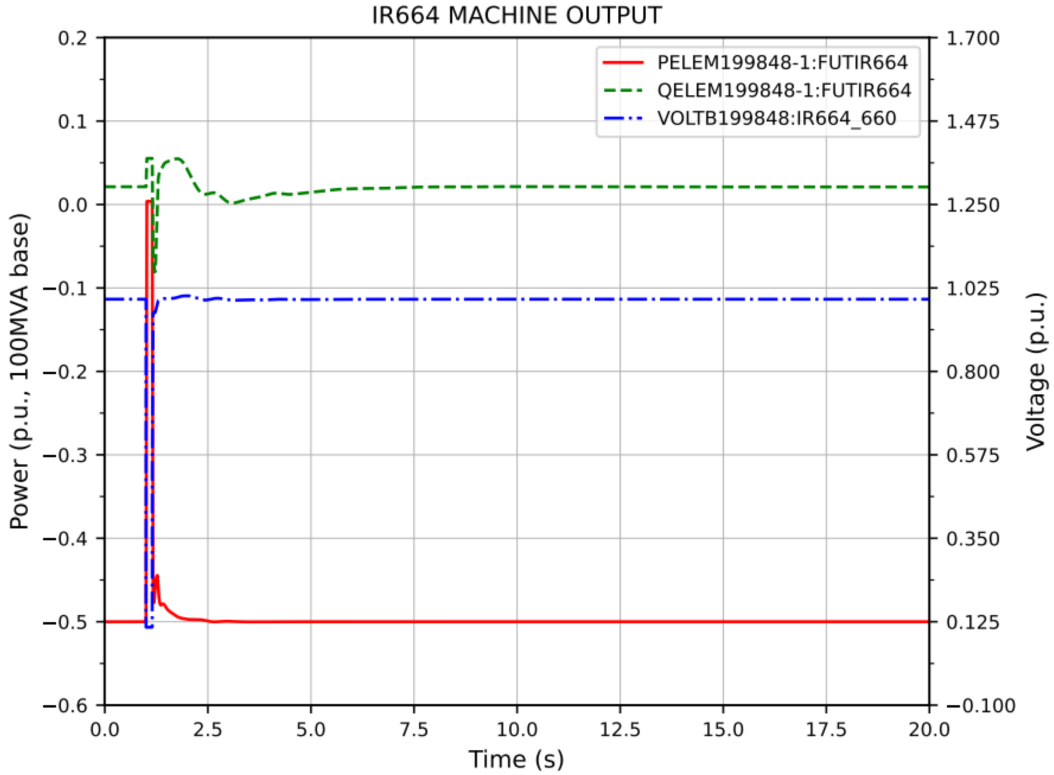

Figure 18: IR664 LVRT performance ***(HV fault, 9 cycles, charging)***

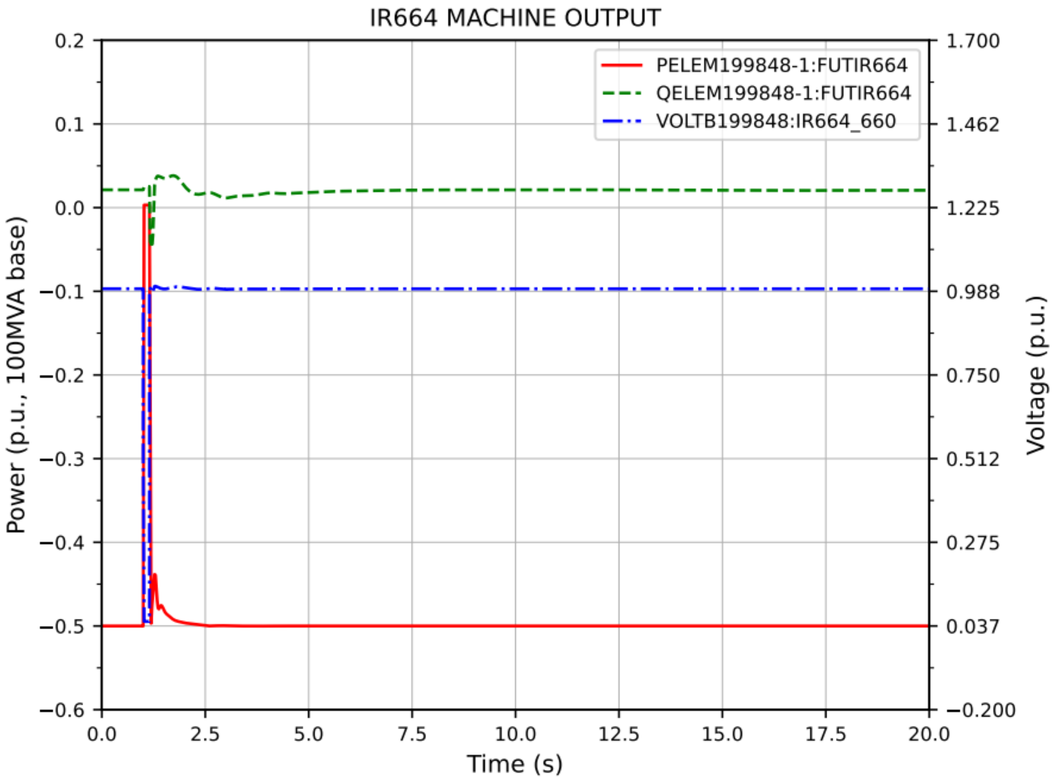

Figure 19: IR664 LVRT performance ***(MV fault, 9 cycles, charging)***

3.9 Loss factor

The loss factor for IR664 is calculated as 0.78% at IR664's generator terminal *(660V)* and 0.02% at its 138kV ICIF bus. This means system losses on peak are marginally increased when IR664 is discharging at 50.0 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 9: 2026 Loss factor

Loss Factor measured at IR664 Terminal *(660 V)*	
Description	MW
IR664 On	50.00
TC3 with IR664 On	82.39
TC3 with IR664 Off	132.00
Loss Factor Measured at IR664 Voltage Terminal	0.78%

Loss Factor Measured at POI *(99W-Bridgewater, 138kV)*	
Description	MW
IR664 On	50.00
Power measured at POI	49.62
TC3 with IR664 On	82.39
TC3 with IR664 Off	132.00
Loss Factor Measured at POI	0.02%

4.0 Re-study due to IR672 withdrawal

Due to the higher-queued project IR672's withdrawal, a re-study was performed on the steady state analysis, stability analysis and NPCC-BPS test with IR672 removed from the study and the results are reported in the following sections.

4.1 Steady state analysis

Power flow analysis was performed for cases representing system light load, summer peak load, and winter peak load conditions. IR672 was removed from the base cases in Section 3.4.1. The generation in the system was re-dispatched to represent import and export scenarios with New Brunswick for various flows associated with the existing Maritime Link transmission service reservation.

4.1.1 Base cases

The bases cases used for power flow analysis re-study are listed in Table 10: Power flow base cases.

Table 10: Power flow base cases

Case Name	NS load	IR664	Wind generation	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
c_ll01_r-1	798	0	340	231	-330	358	341	46	20	-7	33
c_ll01_r-2	798	50	340	231	-330	308	292	45	-28	-7	33
c_ll01_r-4	848	-50	340	231	-330	358	341	49	68	-7	33
c_ll03_r-1	807	0	526	231	0	163	221	37	-2	8	18
c_ll03_r-2	807	50	526	231	0	113	172	35	-50	8	18
c_ll03_r-4	857	-50	526	231	0	163	221	39	47	8	18
c_ll04_r-1	790	0	526	0	0	-38	21	37	-2	8	18
c_ll04_r-2	790	50	526	0	0	-88	-29	35	-49	8	18
c_ll04_r-4	840	-50	526	0	0	-38	21	39	47	8	18
c_ll05_r-1	790	-	559	230	-300	326	301	37	21	-1	40
c_ll05_r -2	790	50	559	230	-300	276	251	-12	20	-49	40
c_ll05_r -4	790	-50	559	230	-300	326	301	37	24	48	40
c_sh02_r-1	1256	0	526	352	-475	605	762	117	66	-22	65
c_sh02_r-2	1256	50	526	352	-475	553	712	115	18	-22	65
c_sh02_r-4	1306	-50	526	352	-475	605	762	119	114	-22	66
c_sh03_r-1	1337	0	370	-298	-300	216	155	64	24	22	22

Case Name	NS load	IR664	Wind generation	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
c_sh03_r-2	1337	50	370	-298	-300	166	106	63	-24	22	22
c_sh03_r-4	1387	-50	370	-298	-300	216	155	67	73	22	22
c_sp02_r-1	1399	0	523	352	-475	577	727	136	64	-26	74
c_sp02_r-2	1399	50	523	352	-475	525	677	134	16	-26	74
c_sp02_r-4	1454	-50	523	352	-475	577	727	138	112	-26	74
c_sp03_r-1	1433	0	291	352	-475	942	982	137	108	-26	74
c_sp03_r-2	1433	50	291	353	-475	889	932	135	60	-25	74
c_sp03_r-4	1483	-50	291	352	-475	942	982	139	156	-26	74
c_sp05_r-1	1418	0	134	0	-475	855	876	157	114	-25	74
c_sp05_r-2	1418	50	134	0	-475	801	825	155	66	-25	74
c_sp05_r-4	1468	-50	134	0	-475	855	876	159	162	-25	74
c_wp02_r-1	2135	0	365	150	-320	1069	1243	185	130	-15	87
c_wp02_r-2	2135	50	365	150	-320	1012	1190	183	81	-15	87
c_wp02_r-3	1967	0	365	151	-320	792	995	162	105	-6	73
c_wp02_r-4	2017	-50	365	150	-320	792	995	164	154	-6	74
c_wp03_r-1	2135	0	248	151	-320	1055	1183	193	144	-26	99
c_wp03_r-2	2135	50	248	150	-320	999	1131	191	96	-26	99
c_wp03_r-3	1967	0	365	150	-320	892	1088	164	130	-6	73
c_wp03_r-4	2017	-50	365	150	-320	892	1088	167	179	-6	73
c_wp04_r-1	2140	0	248	150	-320	1055	1183	212	165	-26	99
c_wp04_r-2	2140	50	248	151	-320	999	1131	210	117	-26	99
c_wp04_r-3	1972	0	248	151	-320	879	1030	187	142	-17	84
c_wp04_r-4	2022	-50	248	151	-320	879	1030	190	191	-17	85

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.
Note 4: Negative MW in the IR664 column indicates charging.
Note 5: Negative MW in NS/NB and ML columns, represent imports to NS.

4.1.2 Steady state contingencies

The steady state power flow analysis includes the contingencies listed in Table 5: Steady state contingencies.

4.1.3 Steady state evaluation

The steady state contingencies re-evaluation maintains the same conclusion that IR664 does not require Network Upgrades beyond the POI to operate at requested MW.

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

- Contingency p179 *(loss of L-4048)* can cause overvoltage at 41V-MBPP substation *(up to 1.19 p.u)* in wp02, wp03 and wp04 cases.
- Contingencies p213 *(loss of 50W-B3),* p241 *(50W-501)*, and p242 *(50W-600)* can cause overload on 9W-T63 transformer and L-6024, also cause low voltage *(down*

to 0.74 p.u) in Tusket area in ll01, sh03, sp03, sp05, wp02, wp03, and wp04 cases, which could trigger the rejection of Tusket area load by the tripping of 9W-515 *(L-5027)*.

- Contingencies p214 *(loss of 50W-B4)* p234 *(loss of L-6024)* , and p242 *(50W-600)* can overload 9W-T2 transformer, also cause low voltage *(down to 0.80 p.u)* in Tusket area and at the 23W-Clyde River; 25W-Shelburne, 30W-Souriquois, 36W-Green Harbor and 37W-Lockport substations in wp02, wp03 and wp04 cases.
- Contingency p233 *(loss of L-6020/6021)* can also cause low voltage *(down to 0.85 p.u)* at the 23W-Clyde River; 25W-Shelburne, 30W-Souriquois, 36W-Green Harbor and 37W-Lockport substations in wp02, wp03 and wp04 cases.
- Contingency p240 *(17V-611 breaker fail)* can overload 17V-T2 transformer in sp05 cases. The overloading reaches 109%.
- Contingency p245 *(43V-503)* can cause low voltage *(down to 0.89 p.u)* at the 55V-Waterville and 92V-Michelin Waterville substations in wp03 case.

All these violations are pre-existing and are not the responsibility of IR664.

4.2 Stability analysis

System design criteria requires the system to be stable and well damped in all modes of oscillations.

4.2.1 Stability base cases

One summer peak case and one winter peak case were selected as the worst-case scenarios for the re-study with contingencies associated with the substations up to two levels away from the POI. The parameters for these base cases are represented below in *Table 11: Stability base cases*.

Table 11: Stability base cases

Case Name	NS load	IR 664	Wind generation	West wind	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
c_sp05_r-2	1418	50	134	134	0	-475	801	825	155	66	-25	74
c_sp05_r-4	1468	-50	134	134	0	-475	855	876	159	162	-25	74
c_wp04_r-2	2140	50	248	248	151	-320	999	1131	210	117	-26	99
c_wp04_r-4	2022	-50	248	248	151	-320	879	1030	190	191	-17	85

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.
Note 4: Negative MW in the IR664 column indicates charging.
Note 5: Negative MW in NS/NB and ML columns, represent imports to NS.

4.2.2 Stability contingencies

The contingencies tested for the re-study are listed in *Table 12: Stability contingency list*.

Table 12: Stability contingency list

90H-605_LG	120H-710_3PH	67N-702_ LG	67N L8001_3PH*	99W-B62_3PH*
90H-606_LG	120H-715_3PH	67N-703_ LG	67N L8002_3PH	99W L6002_3PH
90H-608_LG	120H L6005_3PH	67N-704_ LG	67N L8003_3PH*	99W L6006_3PH
90H-609_LG	120H L6010_3PH	67N-705_ LG *	17V-612_LG	99W L6025_3PH
90H L6003_3PH	120H L6011_3PH	67N-706_ LG	17V-B63_3PH	99W L6531_3PH
90H L6004_3PH	120H L6016_3PH	67N-710_ LG	17V L5016_3PH	99W L7008_3PH*
90H L6008_3PH	120H L6051_3PH	67N-711_ LG	9W-B53_3PH	99W L7009_3PH*
90H L6009_3PH	120H L7008_3PH	67N-712_ LG	9W L5535_3PH	DCT L6005_L6010_LLG
103H-600_LG	120H L7018_3PH	67N-713_ LG	9W L6021_3PH	DCT L6010_L6011_ LLG
103H-608_ LG	1N-600_LG	67N-811_ LG *	9W L6021_LG	DCT L6005_L6016_ LLG
103H-881_LG	1N-601_ LG	67N-811_T82_ LG *	9W L6024_3PH	DCT L7003_L7004_ LLG *
103H-681_LG	1N-613_ LG	67N-813_ LG	50W-B2_3PH	DCT L7008_L7009_ LLG
103H L6008_3PH	1N-B61_3PH	67N-814_ LG*	50W-B3_3PH	DCT L7009_L8002_ LLG
103H L6016_3PH	1N-B62_3PH	67N L7003_3PH*	50W-B4_3PH	DCT L7009_L8002_A_ LLG
103H L6033_3PH	1N L6001_3PH	67N L7001_3PH	99W-606_3PH*	* Indicates RAS/AAS
103H L8002_3PH	1N L6503_3PH	67N L7005_3PH*	99W-625_3PH*	
120H-622_3PH	1N L6613_3PH	67N L7018_3PH	99W-631_3PH*	
120H-628_3PH	67N-701_LG	67N L7019_3PH*	99W-B61_3PH*	

4.2.3 Stability evaluation

PSS®E plotted output files for each contingency with IR664 in service and IR672 out of service are presented in Appendices X. All contingencies were found to be stable and well-damped.

4.3 NPCC-BPS

Both steady state and stability BPS testing was re-evaluated using the Spring Light Load, Summer Peak and Winter Peak case shown in *Table 13: BPS base cases*.

Table 13: BPS base cases

Case Name	NS load	IR664	Wind generation	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
c_ll01_r-2	798	50	340	231	-330	308	292	45	-28	-7	33
c_ll01_r-4	848	-50	340	231	-330	358	341	49	68	-7	33
c_ll04_r-2	790	50	526	0	0	-88	-29	35	-49	8	18
c_ll04_r-4	840	-50	526	0	0	-38	21	39	47	8	18
c_sh02_r-2	1256	50	526	352	-475	553	712	115	18	-22	65
c_sh02_r-4	1306	-50	526	352	-475	605	762	119	114	-22	66
c_sh03_r-2	1337	50	370	-298	-300	166	106	63	-24	22	22
c_sh03_r-4	1387	-50	370	-298	-300	216	155	67	73	22	22
c_sp02_r-2	1399	50	523	352	-475	525	677	134	16	-26	74
c_sp02_r-4	1454	-50	523	352	-475	577	727	138	112	-26	74

Case Name	NS load	IR664	Wind generation	NS/NB	ML	CBX	ONI	Valley import	Western import	Valley export	Western Valley import
c_sp05_r-2	1418	50	134	0	-475	801	825	155	66	-25	74
c_sp05_r-4	1468	-50	134	0	-475	855	876	159	162	-25	74
c_wp02_r-2	2135	50	365	150	-320	1012	1190	183	81	-15	87
c_wp02_r-4	2017	-50	365	150	-320	792	995	164	154	-6	74
c_wp04_r-2	2140	50	248	151	-320	999	1131	210	117	-26	99
c_wp04_r-4	2022	-50	248	151	-320	879	1030	190	191	-17	85

The steady state test was conducted by dispatching the new facility at requested MW output, then disconnecting it. Post-contingency results revealed no voltage violations or thermal overloads outside the local area.

The stability test was performed by placing a 3-phase fault at the 99W 138 kV bus for 10 second, assuming all local protection out of service. Appendix Z: Re-study BPS results demonstrates the BPS test results remain the same for IR664 with IR672 removed, it does not have adverse impact outside the local area, confirming the transmission facilities associated with IR664 are not classified as NPCC BPS.

5.0 Requirements & cost estimate

The following facility changes will be required to connect IR664 as NRIS to NSPI transmission system at the POI of 99W-B62:

- Transmission Provider's Interconnection Facilities *(TPIF)* Upgrades:
  - A 138 kV breaker, associated switches, and substation modifications at 99W-Bridgewater.
  - Transmission line exit re-routing at 99W-Bridgwater to accommodate IR664's facility.
  - Protection modifications at 99W-Bridgewater.
  - Modifications to existing 99W-Bridgewater RTU.

- IC Interconnection Facility *(ICIF)*:
  - The facility must meet NSPI's TSIR as published on the NSPI OASIS site. The following requirements are items of note from the TSIR.
  - Facilities to meet ±0.95 power factor requirement when delivering rated output *(50 MW)* at the 138 kV bus. Rated reactive power shall be available through the full range of real power output, from zero to full power.
  - 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 plant 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 IR664 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.
- 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.
- 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.
- 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%.
- Voltage ride through capability to meet the requirements in Section 2.3.9: Voltage ride-through.
- Operation at ambient temperatures as low as -30ºC.
- 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)*.
- Facilities for NSPI to execute high speed rejection of generation and load *(transfer trip)*. The plant may be incorporated in SPS runback or load reject schemes.

The cost estimate as shown in *Table 14: NRIS cost estimate* is high level non-binding in 2023 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 IC's substation, interconnection facilities and generating facility are not included. It does not include additional costs to be identified by the subsequent Facility Study, either. The Interconnection Facilities Study will provide a more detailed cost estimate.

Table 14: NRIS cost estimate

	NRIS	
	TPIF	**Estimate**
I	Terminal at 99W-Bridgewater *(breaker, switches, ...)*	$ 1,250,000
II	Transmission line re-routing at 99W-Bridgewater *(L6002)*	$ 375,000
III	Protection modifications	$ 378,000
IV	RTU modifications	$ 15,000
	Sub-total	**$ 2,018,000**

Determined costs	
Subtotal	$ 2,018,000
Contingency *(10%)*	$ 202,000
Total of determined cost items	$ 2,220,000

Item	**To Be Determined costs**	**Estimate**
I	Findings pending the release of Part 2 of the SIS *(EMT analysis)*.	TBD

6.0 Conclusion & recommendations

6.1 Summary of technical analysis

Technical analysis, including short circuit, power factor, voltage flicker, steady state, stability, and protection and control analysis was performed using utility best practices, NSPI, NPCC, and NERC criteria.

IR664 short circuit contribution does not require any uprating of existing breakers in the transmission system. The short circuit analysis shows that the maximum short circuit levels are far below 5,000 MVA for 138 kV with IR664 added into the power system at POI. The minimum short circuit level at IR664 34.5 kV bus, with L7008 out of service, is 355 MVA, which equates to a SCR of 7.1.

IR664 meets and exceeds the leading and lagging power factor requirement based on the preliminary information supplied. The IC confirmed the BESS inverters can provide ±50.0 MVAr reactive power when delivering capped power at ±50.0 MW and have full ±50.0 MVAr reactive power capability at 0 MW real power. This should be re-evaluated once the detailed design information on transformer impedances and collector circuit design are finalized.

IR664 does not require any major Network Upgrades at 99W-Bridgewater and beyond to operate at requested MW capability under NRIS provided the Western Valley Transmission System is operated within historical limits. No issues were identified in the steady state or stability analysis that are attributed to IR664.

The facilities associated with IR664 are not categorized as NPCC BPS as IR664 does not affect the BPS status of existing facilities. IR664 also does not qualify as NERC BES based on project size.

IR664 Under Frequency Ride Through capability was tested under dynamic simulation. The facility remained connected when system frequency deviation caused Under Frequency Load Shedding *(UFLS)* relays to activate. While charging, IR664 also assisted in frequency recovery by momentarily switching to discharging while system frequency was below nominal.

IR664 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 IR664 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 IR664 in service. The calculated loss factor is 0.78% at IR664's generator terminal *(660V)* and 0.02% at its 138kV ICIF bus. This means system losses on peak are marginally increased when IR664 is discharging at 50 MW.

Due to the higher-queued project IR672's withdrawal from the Queue, steady state analysis, stability analysis, and NPCC-BPS test was re-studied with IR672 removed from the study. No issues were identified in the steady state or stability analysis that are attributed to IR664. IR664 does not affect the BPS status of existing facilities.

It is concluded that the incorporation of the proposed facility into the NS Power transmission 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.

6.2 Summary of expected facilities

To accommodate IR664's 99W-B62 POI, the total high level non-binding estimated cost in 2023 Canadian dollars for the Transmission Provider's Interconnection Facilities *(TPIF)* is $2,220,000, which includes 10% contingency but excludes HST. The costs of 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 to be identified by the subsequent Facility 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 right of way shall be registered in NSPI's name.

The non-binding construction tine estimate of NSPI Transmission Provider Interconnection Facilities is two years, but to be confirmed by the Facility Study.