System Impact Study Report
Report GIP-IR598-SIS-R1

Generator Interconnection Request #598
2.52 MW Tidal Generating Facility
Cumberland County, NS

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Transmission Planning
Nova Scotia Power Inc.

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Executive Summary

This report presents the results of a System Impact Study (SIS) for a proposed 2.52 MW tidal turbine generating facility interconnected to the NSPI transmission system at the 37N-Parsboro substation via existing interconnection facilities located at the 90N-FORCE substation. The study analysed the impact the proposed development would have on the NSPI power grid.

Due to the proposed capacity of this Interconnection Request (IR#598), an expedited study process was permitted in accordance with Section 2.5 of the Generator Interconnection Procedures that removed stability analysis from the report scope. In addition, Section 7.4 of the GIP permits the use of previous study results where practicable in the SIS analysis. As a result, the following analysis results from IR#542, a higher queued tidal project having the same Point of Interconnection, were applied to this IR#598: Steady state analysis, and Bulk Power System (BPS) determination.

The report scope also included the following analysis specific to IR#598: Short circuit analysis and its impact on circuit breaker ratings; Power factor requirement at the Point of Interconnection (POI); Voltage flicker; Incremental system Loss Factor; Impact on any existing Special Protection Systems (SPSs); and Islanding potential.

The study results show that IR#598 will not adversely impact the interrupting capability of any existing circuit breakers and is assumed to meet the NSPI requirements for voltage flicker at the POI based on the site short circuit level and on the typical characteristics of inverter/converters. The minimum Short circuit ratio was calculated to be 32 at the 90N-FORCE substation 13.8 kV bus and it is the responsibility of the IC that the generating facility controls are stable under such conditions. IR#598 provides adequate reactive power to meet the Generator Interconnection Procedure (GIP) requirements and has no impact on any existing Special Protection Systems. The system loss factor for this facility was found to be 3.57%.

Study results utilized from IR#542 show that increased generation associated with IR#598 will not have any significant adverse impact on the local transmission system. No thermal loading violations were found under normal states and single contingency conditions. In addition, the Point of Interconnection at substation 37N-Parrsboro is not classified as part of the Bulk Power System, nor it classified as a Bulk Electric System element. There is a risk of this generating facility being islanded with NSPI customers for certain contingencies and as such, an anti-islanding scheme is required.

The proposed Generating facility must also meet the requirements of Sections 7.1 – 7.4, and 7.6 of the NSPI Transmission System Interconnection Requirements (TSIR) document, version 1.1 for asynchronous generation (which includes inverter-based energy conversion associated with tidal facilities).

There are no additional Network Upgrades (NU) or Transmission Providers Interconnection Facilities (TPIF) required to accommodate the connection of IR#598 to the FORCE substation 13.8kV bus. The NU and TPIF associated with the FORCE facility were previously built and are

currently in service, although commissioning work requiring generation at 90N-FORCE remains to be completed. The final cost for NSPI's work to provide the 69kV interconnection at 37N-Parrsboro was as follows:

- **TPIF Actual Costs: $1,402,630 (HST excluded)**
- NU Actual Costs: $ 268,182 (HST excluded)
- Total Actual Cost: $1,670,812 (HST excluded)

The Interconnection Facilities and Network upgrades that were common to projects IR#516, IR#517, and IR#542 will also be shared by IR#598. As NU costs are refundable under the GIP, IR#598 is not responsible to contribute towards those costs. IR#598 is the fourth project to utilize the common TPIF, and is therefore responsible for 1/4 of the TPIF costs. IR#598 is one of three active projects utilizing the TPIF, and is therefore responsible for 1/3 of the remaining commissioning costs for the 69kV supply, which is estimated at $8,696 plus HST ($2,899 plus HST each). As such, the costs attributed to IR#598 for the shared usage of the TPIF infrastructure total $350,658 + $2,899 + $53,033 (HST) = **$406,590**.

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1.0 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR) for Network Resource Interconnection Service (NRIS) to Nova Scotia Power Inc. (NSPI) for a proposed 2.52 MW tidal generating facility interconnected to the NSPI transmission system. However, the IC signed a System Impact Study (SIS) Agreement for a study of the 2.52 MW tidal generating facility taking Energy Resource Interconnection Service (ERIS) with an in-service date of 2022-12-01 and this report is the result of that Agreement.

This IR has been designated by the NSPI System Operator as Interconnection Request #598 and will be referred to as IR#598 throughout this report. Two other higher queued tidal generating facilities (IR#516 and IR#542) share the same Point of Interconnection as IR#598 and the required Transmission Providers Interconnection Facilities and Network Upgrades identified in this report are utilized by all three projects.

1.1 Scope

The Point of Interconnection (POI) for IR#598 is the 69kV substation 37N-Parrsboro. IR#598 will be connected to the Nova Scotia Power System through the 69/13.8 kV substation owned by Fundy Ocean Research Center for Energy (FORCE) but controlled by NSPI under a Facilities Operation Agreement. The FORCE substation is connected to 37N-Parrsboro through the 10 km line L-5550, which is built to 138 kV design standards but currently operated at 69 kV.

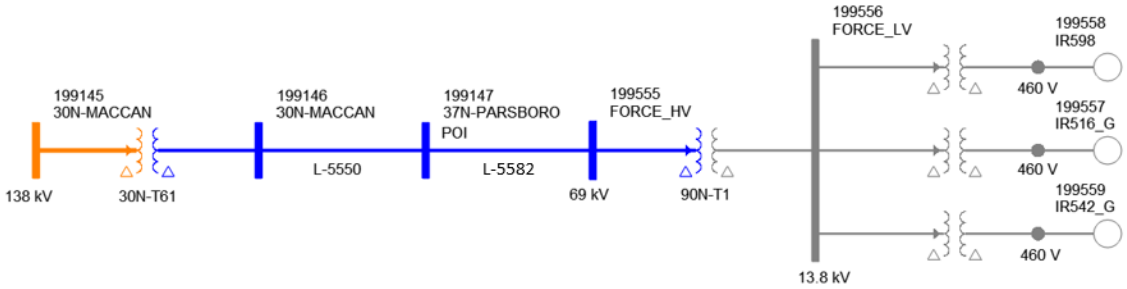

Figure 1: Interconnection One Line Diagram

1.2 Expedited Process

In their application, the interconnection Customer requested that:

> *NSPI give consideration to, and approve, the implementation of the procedures associated with section 2.5 of the GIP document (Expedited Process for Small Generating Facilities). This request was approved and includes the following changes to the SIS scope of work:*
> - *Forego of the Interconnection Feasibility Study*
> - *Combine the Interconnection System Impact Study and the Interconnection Facilities Study*
> - *Eliminate the requirement for coordination with Affected Systems*

- *Modification of the Interconnection System Impact Study scope to exclude stability analysis.*

Based on the capacity of IR#598, this request was granted by the NSPSO and is reflected in this report.

1.3 Previous Studies

Section 7.4 of the GIP requires that the Transmission Provider utilize the results of previous studies if practicable in the SIS analysis. It states:

> ***7.4 Interconnection System Impact Study Procedures***
> *The Transmission Provider shall coordinate the Interconnection System Impact Study with any Affected System that is affected by the Interconnection Request pursuant to Section 3.5 above. The Transmission Provider shall utilize existing studies to the extent practicable when it performs the study...*

The following previous studies are considered relevant to the IR#598 SIS.

IR#516:
IR#516 was submitted in December of 2014 as a 5MW Network Resource Interconnection Service (NRIS) tidal generating facility interconnected to the NSPI transmission system via the 69kV 37N-Parrsboro and 90N-FORCE substations. SIS Report GIP_IR516_SIS_R0 was completed in July of 2015, and the summary is attached in Appendix A of this report. No system issues were identified in the SIS report.

The IR#516 Generator interconnection and operating Agreement (GIA) is currently being amended to reduce the facility capacity from 5MW to 1.26MW.

IR#517:
IR#517 was submitted in December of 2014 as a 4MW NRIS tidal generating facility interconnected to the NSPI transmission system via the 69kV 37N-Parrsboro and 90N-FORCE substations. SIS Report GIP-IR517-SIS-R0 was completed in July of 2015, and the summary is attached in Appendix B of this report. The SIS for IR#517 included the proposed IR#516 NRIS generation (5MW) in its analysis and no system issues were identified in the SIS report.

IR#517 was placed into default and eventually withdrawn from the Queue in November of 2019.

IR#542:
On September 9, 2016, IR#542 was submitted as a 5.58MW NRIS tidal generating facility interconnected to the NSPI transmission system via the 69kV 37N-Parrsboro and 90N-FORCE substations. SIS Report GIP-IR542-SIS-R0 was completed on May 10, 2017, and the summary is attached in Appendix C of this report.

The SIS for IR#542 included IR#516 NRIS generation (5MW) and IR#517 (4MW) NRIS generation in its analysis for a total of 14.48MW NRIS generation at the FORCE substation. The relevant results of the report were as follows:

- Increases in short circuit levels were within the capability of the associated breakers in the vicinity of 37N-Parrsboro.
- IR#542 generation will not have any significant adverse impact on the local transmission.
- IR#542 caused no thermal loading violations under normal states and single contingency conditions.
- IR#542 caused no stability issues.
- There is a risk of this generating facility being islanded with NSPI customers for certain contingencies. As a result, an anti-islanding scheme is required.

On January 21, 2020, the Interconnection Customer for IR#542 requested that the following technical changes be made:

1. Generator: the size/output capacity of each generator was changed to 70kW, with 6 generators per platform and a platform supply voltage of 6.6kV.

2. Step-up Transformer: A step up transformer unit (6.6kV to 13.8kV) was added to the cable collector circuit and located on shore within the 90N-FORCE substation facility.

3. Generator Support Structure: Generator support structures were updated to a surface mounted floating platform structure anchored to the sea floor. Each floating platform is rated for 6x70kW=420kW, with a total of 9 floating platforms being installed for a facility capacity of 3.78MW.

A Materiality Study showed that changing the generator technology and output from 5.58MW to 3.78MW did not constitute a Material Change under the GIP, as shown in Appendix D. These changes were subsequently implemented and the capacity of IR#542 was reduced to 3.78MW.

These three projects show that NRIS generation totalling 14.48MW at 90N-FORCE has previously been studied at the SIS level with no adverse system impacts determined. Since the original IR#542 SIS was completed, the proposed generation at 90N-FORCE has been reduced from 14.58MW to 5.04 MW following the reduction of IR#516 from 5MW to 1.26MW; the withdrawal of the IR#517 (4MW); and the reduction of IR#542 from 5.58MW to 3.78MW.

The addition of 2.52MW for IR#598 will bring the total generation at 90N-FORCE back up to 7.56MW, half of what has previously been studied with no significant system impacts.

1.4 Combined T/D Advanced Stage IR Queue

The Combined T/D Advanced Stage Interconnection Request Queue (Queue) is posted on the NSPI OASIS site at https://www.nspower.ca/oasis/generation-interconnection-procedures. A copy of the October 15, 2021 version in shown in Figure 2.

Combined T/D Advanced Stage Interconnection Request Queue

Publish Date: *Friday, October 15, 2021*

Nova Scotia POWER An Emera Company

Queue Order*	IR #	Request Date DD-MMM-YY	County	MW Summer	MW Winter	Interconnection Point Requested	Type	Inservice date DD-MMM-YY	Revised Inservice date	Status	Service Type	IC Identity
1 -T	426	27-Jul-12	Richmond	45	45	47C	Biomass	01-Jan-17	01/09/2018	GIA Executed	NRIS	N/A
2 -T	516	05-Dec-14	Cumberland	5	5	37N	Tidal	01-Jul-16	31/05/2020	GIA Executed	NRIS	N/A
3 -T	540	28-Jul-16	Hants	14.1	14.1	17V	Wind	01-Jan-18	31/10/2023	GIA Executed	NRIS	N/A
4 -T	542	26-Sep-16	Cumberland	3.78	3.78	37N	Tidal	01-Jan-19	01/11/2021	GIA Executed	NRIS	N/A
5 -D	557	19-Apr-17	Halifax	5.6	5.6	24H	CHP	01-Sep-18		SIS Complete	N/A	N/A
6 -D	569	26-Jul-19	Digby	0.6	0.6	509V-302	Tidal	01-Mar-21	30/07/2021	GIA Executed	N/A	N/A
7 -D	568	21-May-19	Cumberland	2	2	22N-404	Solar	01-Sep-20	01/09/2021	GIA Executed	N/A	N/A
8 -D	566	16-Jan-19	Digby	0.7	0.7	509V-301	Tidal	31-Jul-19	29/01/2021	GIA Executed	N/A	N/A
9 -T	574	27-Aug-20	Hants	58.8	58.8	L-6051	Wind	30-Jun-23		FAC Complete	NRIS	N/A
10 -D	595	11-Mar-21	Halifax	0.1	0.1	1H-454	Battery	11-Jan-21		SIS Complete	N/A	N/A
11 -T	598	13-May-21	Cumberland	2.52	2.52	37N	Tidal	01-Dec-22		SIS in Progress	NRIS	N/A
12 -D	604	07-Jun-21	Cape Breton	0.45	0.45	11S-303	Solar	15-Jan-22		SIS in Progress	N/A	N/A
13 -D	603	31-May-21	Cumberland	0.4	0.4	22N-404	Solar/Battery	16-Feb-22		SIS in Progress	N/A	N/A
14 -D	600	27-May-21	Halifax	0.6	0.6	99H-312	Solar/Battery	02-Mar-22		SIS in Progress	N/A	N/A
		Totals:		139.65	139.65							

Figure 2: Combined T/D Advanced Stage Interconnection Request Queue

The Queue shows that IR#542, the last SIS completed at 90N-FORCE, occupies position 4. The Queue position for IR#598 is 11.

The two largest projects in the Queue are identified in positions 3 (IR#540) and 9 (IR#574). Both of these projects are in Hants County and are electrically remote from transmission in the Amherst / Parrsboro area. While the IR#540 and IR#574 generation additions will impact generation dispatch, they have no material impact on the IR's associated with the 90N-FORCE substation.

The projects in Queue positions 5-8, and 10 are all small distribution connected projects that also have no material impact on the Parrsboro projects.

1.5 System Network Upgrades

For all IR's currently in the Queue, SIS analysis models have included the transmission system upgrades needed for the Maritime Link and its associated Transmission Service Request TSR-400 for export to NB. These include upgrades to 101S-Woodbine substation; the replacement of line L-6513 with line L-6613; the separation of lines L-8004 and L-7005 on a double circuit tower at the Canso crossing; the 345kV breaker node swap at 67N-Onslow; and the upgrading of line thermal ratings for L-6511 and L-7019. No other material system changes have been made since these studies have been completed.

As no material changes have been made to the NS transmission system models in the period between IR#516 and IR#598, and as none of the projects between IR#516 and IR#598 materially impact the Amherst/Parrsboro area, study results associated with IR#516, IR#517, and IR#542 can be applied to IR#598. Therefore, this report utilizes the following SIS analysis from the IR#542 SIS:

- Steady state analysis to determine any thermal overload of transmission elements or voltage criteria violation
- Bulk Power System (BPS) determination for the substation

The report scope also includes the following items that are specific to IR#598:

- Short circuit analysis and its impact on circuit breaker ratings
- Power factor requirement at the Point of Interconnection (POI)
- Voltage flicker
- Incremental system Loss Factor
- Impact on any existing Special Protection Systems (SPSs)
- Islanding potential

This report provides the costs associated with the connection of the generation facility to the NSPI transmission system.

1.6 Assumptions

On May 3, 2021, the Interconnection Customer submitted IR#598 to the System Operator inclusive of the following technical data:

1. Generator capacity: Schottel 3-ph Tidal Turbine, Model SIT 250, 70kW
2. Generator Power Factor: +/- 0.85
3. Generator voltage: 460V
4. # of generators per platform: 6
5. Platform capacity: 420kW
6. # of generator platforms: 6

7. Total facility capacity (6 x 6 x 70kW): 2.52MW
8. Generator Power Converter: Power converter is being upgraded/aligned with the currently available power electronics technology.
9. FORCE substation transformer: 21/28/35 MVA 69kV – 13.8kV, Grounded Wye - Grounded Wye with 4.16kV Delta tertiary; +/- 10% taps in 2.5% steps; Z1=7.25%, X1/R1=18.
10. Platform Transformers: 500 kVA, 13.8kV – 480/277V, Dyn1 transformer located on platform. This transformer is connected to the 90N-FORCE 13.8kV circuit supplied via a breaker in the FORCE switch room.
11. Generator Support Structure: Surface mounted floating platform structure anchored to the sea floor.
12. The Point of Interconnection (POI) is at the 37N-Parrsboro 69 kV bus.
13. NSPI's transmission line ratings as posted on NSPI's Intranet, including any projected line upgrades for the periods under study.
14. It is assumed that IR#598 generation meets IEEE Standard 519 limiting total harmonic distortion (all frequencies) to a maximum of 5% with no individual harmonic exceeding 1%.

2.0 Technical Model

The proposed generating facility consists of six floating platforms each containing one 13.8kV – 480/277V, 500 kVA step down transformer and 6x70kW Schottel 3-phase tidal turbine generators capable of generating maximum platform power of 420kW at a 0.85 power factor. The Platforms are connected in series at 13.8kV and connect to the FORCE substation via 13.8 kV sub-sea cables prior to being stepped up to 69kV.

The PSS®E model for the study analysis is shown in Figure 3 below. The equivalent generator step-up transformer (480V/13.8 kV) was modeled with an impedance of 6% on 3 MVA. The interconnection transformer was modeled to have 7.25% impedance on the 21 MVA rating with an X/R ratio of 25.

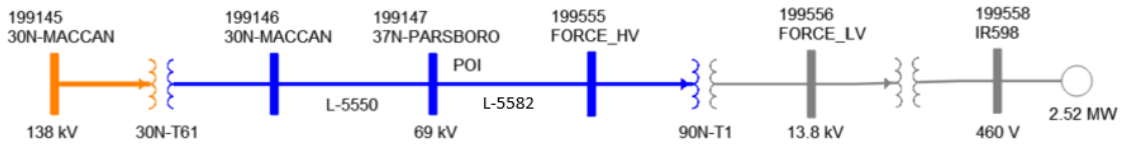

Figure 3: Interconnection One Line Diagram

2.1 System Data

The 2016 NSPI 10 Year Energy and Demand Forecast report dated 2016-05-02 was the source of data used to develop the base case modelling for Load Flow cases associated with IR#542. The winter peak demand studied in that report, including, and excluding Demand Side Management (DSM) effects, is shown in Table 1.

Table 1: Study Years Load Forecast

Forecast Year	Base Case	Net System Peak Demand (MW), with Future DSM Effects	Net System Peak Demand (MW), before Future DSM Effects
2016	Winter Peak 2019	2170	2214

Figure 2 of the NSPI 2021 Ten Year System Outlook Report, shown in Figure 4 below, shows that the forecasted system *Coincident Peak Demand with Future DSM Program Effects* in 2021 was 58 MW (2.7%) higher than the 2170 MW value forecasted in 2016 for Winter Peak 2019. This increase in load is not sufficient to materially impact the results of the IR#542 analysis, and as such, those results can be applied to IR#598.

Figure 2: Coincident Peak Demand with Future DSM Program Effects

Year	Interruptible Contribution to Peak (MW)	Demand Response (reduction in Firm Peak only, MW)	Firm Contribution to Peak (MW)	System Peak (MW)	Growth (%)
2011	265	-	1,903	2,168	2.5
2012	141	-	1,740	1,882	-13.2
2013	136	-	1,897	2,033	8.0
2014	83	-	2,036	2,118	4.2
2015	141	-	1,874	2,015	-4.9
2016	98	-	2,013	2,111	4.8
2017	67	-	1,951	2,018	-4.4
2018	80	-	1,993	2,073	2.7
2019	111	-	1,949	2,060	-0.6
2020	96	-	1,954	2,050	-0.5
2021*	155	-	2,073	2,228	8.6
2022*	158	-4	2,062	2,225	-0.1
2023*	162	-12	2,065	2,240	0.7
2024*	162	-24	2,060	2,247	0.3
2025*	169	-36	2,053	2,257	0.5
2026*	170	-39	2,049	2,258	0.0
2027*	169	-39	2,046	2,254	-0.2
2028*	169	-39	2,044	2,251	-0.1
2029*	169	-38	2,044	2,251	0.0
2030*	168	-38	2,047	2,253	0.1
2031*	168	-37	2,057	2,262	0.4

*Forecast value

Figure 4: 2021 10 Year System Outlook Report Figure 2

2.2 Generating Facility

The proposed generating facility consists of six generating platforms each with six 70kW generators capable of generating maximum power of 420kW per platform for a total capacity of 2.52 MW.

Generator voltage is 460V (Yg), stepped up to 13.8kV (D) via one 500kVA Dyn1 transformer located on each generator platform. A 13.8kV collector circuit runs between platforms and back to the FORCE transformer 90N-T51, which is rated 69kV – 13.8kV, 21/28/35 MVA with positive sequence impedance of 7.25%. A single Line Diagram showing IR#516, IR#542, and IR#598 is attached in Appendix E to this report.

The proposed generators are classified as Type 4, with fully rated AC-DC-AC inverter. It is assumed to be equipped with a SCADA-based central regulator which controls the individual generator reactive power output to maintain constant voltage or constant power factor at the Interconnection Facility substation.

2.3 Transmission System Interconnection Requirements

The proposed Generating facility must meet the requirements of Sections 7.1 – 7.4, and 7.6 of the NSPI Transmission System Interconnection Requirements (TSIR) document, version 1.1 for asynchronous generation (which includes inverter-based energy conversion associated with tidal facilities). The TSIR is posted to the NSPI OASIS web-site at https://www.nspower.ca/oasis/standards-codes, and includes requirements for the following:

- Steady State and Frequency Ranges
- Grounding requirements
- Voltage Ride-through
- Frequency Variations
- Islanded operation
- Reactive power Requirements
- Power Quality
- Automatic Voltage regulation
- Synchronizing Facilities (not required)
- Black Start Capability (not required)
- Remedial Action Schemes (also known as Special Protection Schemes)
- Modelling Data
- Curtailment
- Short Circuit Ratio
- Active Power Control

Of particular note, the generating facility must meet the voltage ride-through requirements of Figure 5 and as per NERC Standard PRC-024-2 Attachment 2, and shall be capable of operating reliably for frequency variations per NERC Standard PRC-024 Attachment 1 (Over-Frequency curve) and NERC Standard PRC-006-NPCC-2 (Eastern Interconnection underfrequency generator tripping curve) as shown in Figure 6.

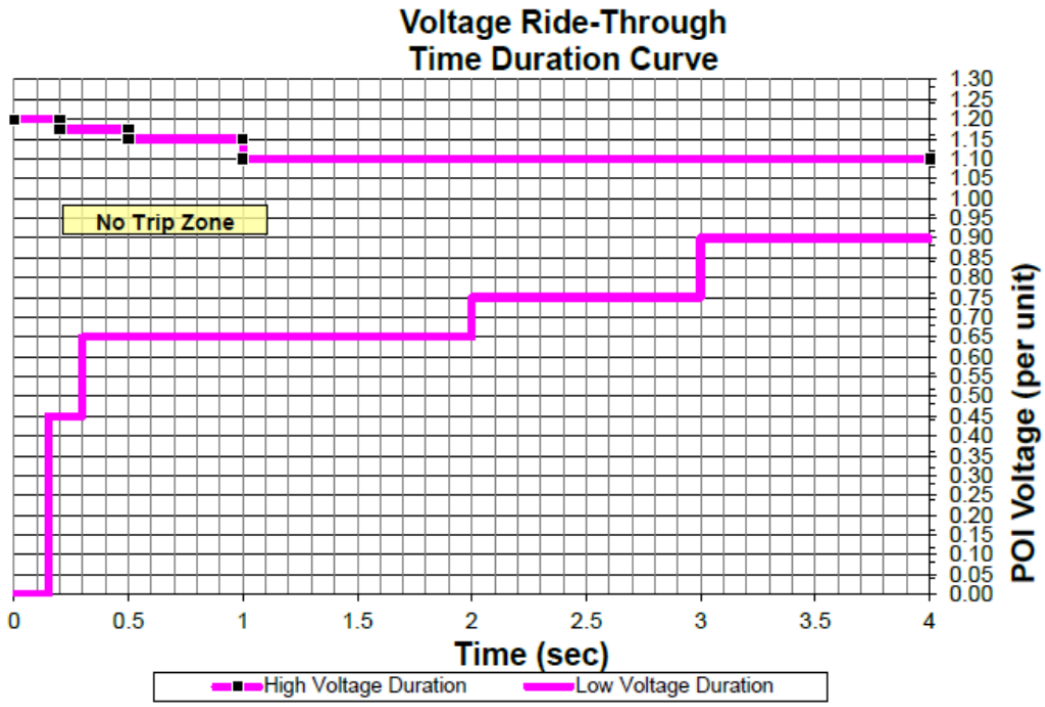

Figure 5: Voltage Ride-through requirements

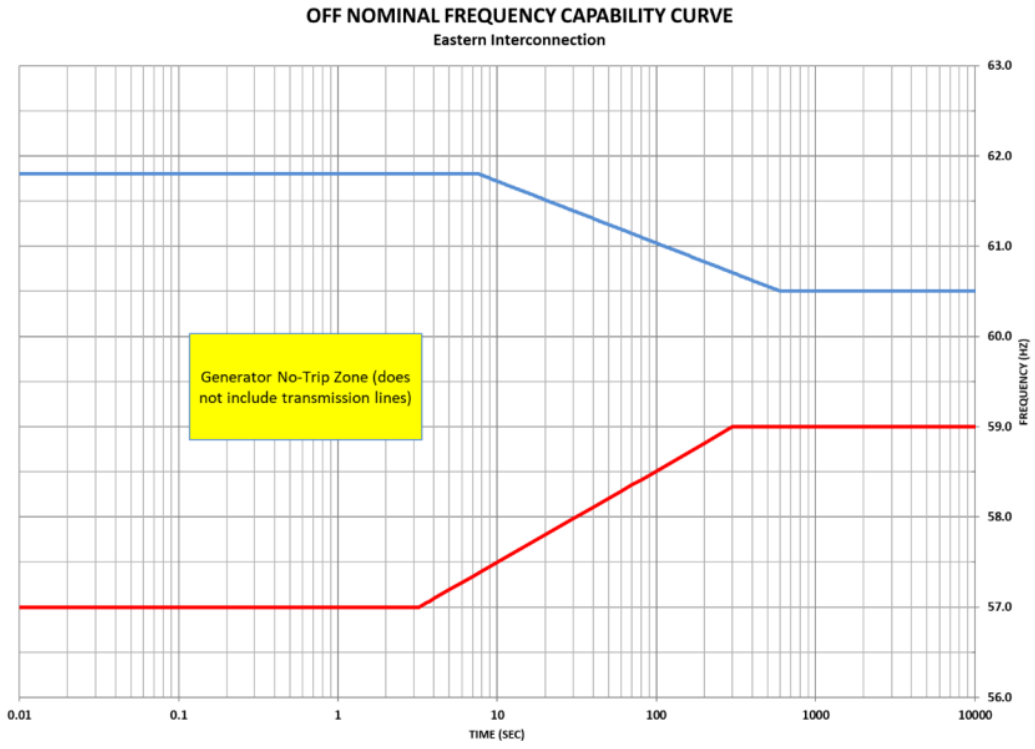

Figure 6: Off-Nominal Frequency Operation Requirements

2.4 System Model and Methodology

Testing and analysis for IR#598 was conducted using the following criteria, software packages and/or modelling data.

2.4.1 Short Circuit

ASPEN OneLiner Version 14.5, classical fault study, 3LG and flat voltage profile at 1 per unit voltage was used to assess before and after short circuit conditions. The expected 2021 system configurations were studied. Each combination was run with IR#598 in service and out of service and a comparison made between the two.

2.4.2 Power Factor

The GIP requires a net power factor of ±0.95 measured at the POI. PSS®E R34 was used to simulate high and low system voltage conditions to determine the machine capability in delivery/absorption of reactive power (vars).

2.4.3 Loss Factor

Loss factor is calculated by running the load flow using a winter peak base case with and without IR#598 while keeping 91H-Tufts Cove generation as the Nova Scotia Area Interchange bus. The loss factor for IR#598 will be the differential MW displaced or increased at 91H-Tufts Cove generation calculated as a percentage of IR#598 nameplate 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 Open Access Transmission Tariff (OATT). It should be noted, however, that the purpose of loss factor is limited to the evaluation of alternative Interconnection Requests (size and location) under specific test conditions. The impact of any particular IR varies with its output and hourly system conditions and its impact on overall system losses is not quantifiable in advance.

In addition to the previous items, this report utilizes the following SIS analysis from the IR#542 SIS in accordance with Section 7.4 of the Generator Interconnection Requirements.

2.4.4 Steady State

Steady State analysis results for IR#542 were used for IR#598. The IR#542 analysis was completed using Python scripts within PSS®E software version 33.7. The scripts simulated a wide range of single contingencies, with the output reports summarizing bus voltages or branch flows that exceed established limits. System modifications and additions were modeled and contingencies that would best provide a measure of system reliability were tested in accordance with NSPI and NPCC design criteria. Load Flow analysis was run for the contingencies on each of the bases cases listed in Section 3.8, with IR#542 in and out of service to determine the impact of the proposed facility on the reliability of the NSPI grid.

2.4.5 Bulk Power System

BPS substations are subjected to stringent requirements for redundant and physically separated protective relay and tele-protection systems. Determination of BPS status for IR542 was in accordance with NPCC criteria document A-10 Classification of Bulk Power System Elements, December 01, 2009 revision. The A-10 test requires steady state and stability testing for each base case.

For the bus to be designated BPS, testing must demonstrate significant adverse impact outside the local area. For the steady state test, no BPS equipment is permitted to be thermally loaded beyond its emergency rating or cause violation of system voltage criteria outside the local area. For the stability test, the interconnected power system outside the local area must remain stable and well damped.

3.0 Technical Analysis

3.1 Short Circuit

The NSPI design criteria for maximum system fault capacity (three phase, symmetrical) is 5,000 MVA on 138kV and 3,500 MVA on 69kV. Short circuit analysis was performed using Aspen OneLiner V14.5, classical fault study, 3LG and flat voltage profile at 1 per unit voltage. The short-circuit levels in the area before and after this development are provided in Table 2.

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

Location	IR598 not in service	IR598 in service
Maximum Generation, all transmission facilities in service		
30N-Maccan, 69 kV	382	385
37N-Parrsboro, 69 kV (POI)	175	178
FORCE Substation 69 kV	150	153
FORCE Substation 13.8 kV	103	106
Minimum Generation: NB - Pt Lepreau, Bel; NS - ML, TR6, LG1, PA		
30N-Maccan, 69 kV	364	367
37N-Parrsboro, 69 kV (POI)	167	170
FORCE Substation 69 kV	142	145
FORCE Substation 13.8 kV	96	99
Minimum Conditions, Min Generation, 30N-T61 out of service		
30N-Maccan, 69 kV	207	209
37N-Parrsboro, 69 kV (POI)	125	127
FORCE Substation 69 kV	110	113
FORCE Substation 13.8 kV	81	84

All 69kV circuit breakers at 30N-Maccan are rated at 3500 MVA. Therefore IR#598 will not impact the circuit breakers at this substation.

The minimum fault level is expected when 30N-T61 is out of service and 74N-T61 is supplying the Springhill / Maccan 69kV system and generation in Nova Scotia and New Brunswick is low, which can occur in light load conditions. Under these conditions, the SCR (Short Circuit Ratio, a measure of system strength relative to the size of the IR#598 generation) is calculated to be 32 (81 MVA / 2.52 MW) at the FORCE 13.8 kV bus.

3.2 Power Factor

The facility must be capable of operation at 0.95 pu lagging to 0.95 pu leading net power factor within the range of NSPI system voltage between 0.95-1.05 pu measured at the POI, at all production levels up to the full rate load of 2.52 MW.

The 69/13.8 kV Interconnection Facility transformer has an impedance of 7.25% on 21 MVA rating. Impedance of the 13.8 kV cable is not modeled. The generator transformer (480V/13.8 kV) was modeled to have an impedance of 6% on 3 MVA. According to the IC, the IR#598 70kW generators are each capable of operating at ± 0.85 power factor, and therefore can each provide ± 43.4 Kvar at the rated active power. This corresponds to a total facility capacity of 2.52 MW and ± 1.56 Mvar.

When IR#598 is generating at its rated output of 2.52 MW and delivering 1.56 Mvar, the power factor at the POI is +0.85 which meets the GIP requirement as seen in figure 7. Note that a generator operating with a lagging power factor is producing vars, while one operating with a leading power factor is consuming vars.

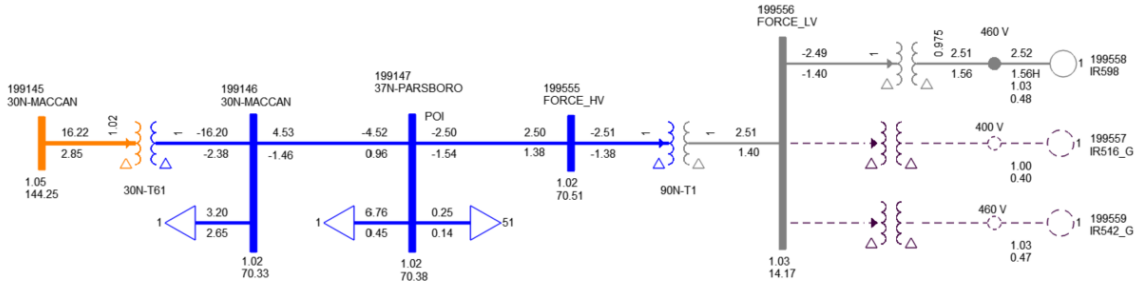

Figure 7: Lagging Power Factor

When IR#598 is generating at its rated output of 2.52 MW and absorbing 1.56 Mvar, the power factor at the POI is -0.84 which meets the GIP requirement as seen in figure 8.

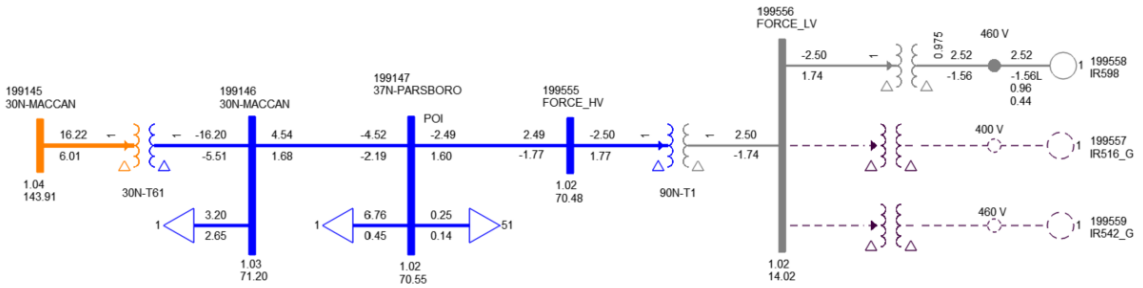

Figure 8: Leading Power Factor

3.3 Loss Factor

The loss factor for IR#598, calculated as per the methodology described in Section 2.4.3, is 3.57%. This means that system losses during the hour of system peak are increased by 0.09 MW when IR#598 is operating at full load. For this preliminary loss factor analysis, losses associated with IR#598 transformers and collector circuits are ignored.

Table #3: Loss factor	
IR#598 Rating (MW)	2.52
Tufts Cove 3 with IR#598 on (MW)	120.73
IR#598 MW + TC3 MW	123.25
TC3 with IR#598 off (MW)	123.16
Delta (MW)	0.09
Loss Factor (Delta / IR#598 Rating)	3.57%

3.4 Voltage Flicker and Harmonics

Generator data was not provided to enable the calculation of voltage flicker. However, voltage flicker is not expected to be a concern for the IR#598 inverter based generators. Flicker caused by the generators at the POI must not exceed a Short-term flicker severity (P_{st}) of 0.35 or a long-term flicker severity (P_{lt}) of 0.25.

The generator is expected to meet IEEE Standard 519 limiting Total Harmonic Distortion (THD) (all frequencies) to a maximum of 5%, with no individual harmonic exceeding 1%.

3.5 Impact on Existing Special Protection Systems (SPS)

The IC facilities connected to the NSPI transmission system via the FORCE substation are not included in any existing Special Protection Systems.

3.6 Islanding Potential

IR#598 will be interconnected to the 37N-Parrsboro 69 kV bus, which is connected to the 30N-Maccan 138/69 substation. 30N-Maccan can be electrically connected to 74N-Springhill 69 kV through normally open line L-5029 when 30N-T61 or 74N-T61 is out of service.

Whenever line L-5550 or transformer 30N-T61 trips, IR#598 would be electrically islanded with NSPI customers in the Maccan/Parrsboro area. In order to avoid this situation, a transfer trip signal is required from 30N-Maccan to isolate IR#598 for the above described events. Similarly, when the Maccan 69 kV system is supplied from 74N-Springhill, a transfer trip signal is required from 74N to isolate IR#598 for transformer 74N-T61 or line L-5029 trips. The transfer trip signal will trip the 13.8 kV breakers at the FORCE substation and will transmit the status of the breakers back to 37N-Parrsboro and 30N-Maccan or 74N-Springhill. Breaker status is required for the auto-reclosing of lines L-5029, L-5550 and L-5582 to restore FORCE substation following a transient fault.

3.7 Underfrequency Operation

Nova Scotia is connected to the rest of the North American power grid by a 345 kV line (L-8001) and two 138 kV lines (L-6535 and L-6536) to New Brunswick. Under certain import conditions, if L-8001 trips or NB trips L-3025 or L-3006, an 'Import Power Monitor' SPS will cross-trip L-6613 at 67N-Onslow to avoid thermally overloading and prevent uncontrolled separation. The Nova Scotia system is then islanded and relies on under frequency load shedding (UFLS) schemes to shed load across Nova Scotia to make up the generation deficiency and restore balance. Once this SPS operates, the load and generation in northern Nova Scotia are disconnected from the Nova Scotia system.

IR#598 is required to remain online and not trip under this scenario. Other contingencies in New Brunswick and New England can also result in an under-frequency islanded situation in Nova Scotia. IR#598's generators connected to the NSPI system must meet the requirements of NPCC for setting any under-frequency protective device as shown in Section 2.3, Figure 6.

3.8 Steady State

The following steady state analysis results were taken from report GIP_IR542_SIS_R0. Section 1.2 of this IR#598 report demonstrates the basis for accepting these results for IR#598.

3.8.1 Steady State

The base cases used for the load flow analysis are listed in Table 4.

Table #4: Steady-State Base Cases

Case Name	Description	NS Load	IR#542	NS-NB	CBX	ONI
WIN-IR542-OFF	Winter Peak 2019	2170	OFF	15	880	1005
WIN-IR542-ON	Winter Peak 2019	2170	5.6	15	875	1000
LL-IR542-OFF	Light Load 2019	705	OFF	235	415	520
LL-IR542-ON	Light Load 2019	705	5.6	235	410	515
SUM-IR542-OFF	Summer Peak 2019	1450	OFF	-205	405	455
SUM-IR542-ON	Summer Peak 2019	1450	5.6	-205	400	450

Note 1: all values are MW.
Note 2: CBX (Cape Breton Export), ONS (Onslow South) and ONI (Onslow Import) are defined Interconnection Reliability Interfaces

3.8.2 Steady-State Contingencies

The steady state load flow analysis includes the contingencies listed in Table 5.

Table #5: List of Contingencies for Steady-State

No.	CONTINGENCY	CAUSE OF EVENT	TRIPS	LOCATION
S01	1N-600	Breaker fail	6001,6503,6513,6527,1N-T1, 1N-T4,1N-T65,1N-C61	1N-Onslow 138 kV
S02	1N-613	Breaker fail	6503,6513, 1N-T1, 1N-T65	1N-Onslow 138 kV
S03	L6513/L6613	Line Fault	6513/6613	Onslow-Springhill
S05	L8001	Line Fault	8001	Onslow-Memramcook
S06	L6514	Line Fault	6514	Springhill-Maccan
S07	L6536	Line Fault	6536	Springhill- Memramcook
S08	L6551	Line Fault	6551	Maccan-Amherst
S09	L6535	Line Fault	6535	Amherst- Memramcook

3.8.3 Steady-State Evaluation

The addition of IR#542 generation at 37N-Parrsboro will not have any significant adverse impact on the local transmission. All the 69 kV transmission lines in the vicinity are capable of handling the increased generation due to IR#542.

NSPI is connected to New Brunswick Power using three tie lines: L-8001 operated at 345 kV and L-6535 & L-6536 are operated at 138 kV. Line L-6513 operated at 138 kV connects L-6535 and L-6536 to 1N-Onslow. Hence, L-6513 is a crucial line during high transfers between the two utilities. It was found that that during light system load conditions (system load less than 1000 MW) with summer line ratings in effect, where NSPI is importing close to 100 MW from NBP with the Import Power Monitor SPS not armed, the loss of L-8001 results in a thermal overload of L-6513 (close to 110% of the summer line rating). However, this issue will not exist with the scheduled replacement of line L-6513 with higher rated line L-6613 prior to the in-service date of IR#542 in 2019. It is to be noted that if the L-6513 upgrade/replacement project is canceled or delayed, it will adversely impact IR#542.

With the exception of communications and protection modifications, IR#542 does not require Network Upgrades beyond the POI to operate at full output during the steady state conditions under NRIS.

Note that Line L-6613 was built as planned and is currently in service. Line L-6513 has since been removed from service.

3.9 Bulk Power / Electric System Analysis

The following Bulk Power System (BPS) and Bulk Electric System (BES) analysis results were taken from report GIP_IR542_SIS_R0. Section 1.2 of this IR#598 report demonstrates the basis for accepting these results for IR#598.

> *Bulk Power System substations are subject to stringent requirements for redundant and physically separated protective relay system and tele-protection systems by NPCC of which NSPI is a member. Bulk Power System testing was performed in accordance with the A-10 methodology described in Section 2.3.*
>
> *The steady state test was conducted with the new facility disconnected in the base cases. Post contingency results indicate no voltage violations or thermal overloads outside the local area. The NPCC A-10 Criteria document does not require rigorous testing at all buses. Section 1, bullet 2 of that document states:*
>
> > *"Application of this methodology may be omitted at buses that can be logically excluded from the bulk power system based on study results at other buses tested using this methodology."*
>
> *In the case of IR#542, the closest BPS element is the 1N-Onslow 138kV bus. IR#542 is electrically remote from the closest BPS substation. Hence, it was concluded that an A-10 dynamics test was not necessary to declare 37N-Parrboro as a non-BPS substation.*
>
> *Because IR#542 is interconnected with the NSPI 69kV transmission system, it is not part of the Bulk Electric System as defined by NERC. Because the short circuit level will remain below 1500 MVA, the IC facilities are considered to be "Electrically Remote" in accordance with the NSPI System Design Criteria.*

It should be noted that the NPCC A-10 Classification of Bulk Power System Elements Methodology standard was revised in March of 2020 and the methodology for determining BPS status was updated. However, as no changes to the FORCE interconnection facilities are required for IR#598, and as these facilities have been in service supplied via the 69kV system since 2016, the BPS assessment from IR#542 remains valid and is used also for IR#598.

The NPCC implementation plan for the revised A-10 standard requires that system testing in accordance with the revised A-10 methodology be performed on all NSPI facilities within 5 years from the date the revised A-10 is approved. NSPI has scheduled this testing for 2022, but no change in the BPS status for the FORCE substation or associated berth holders is anticipated.

3.10 Stability Assessment

As noted in Section 1.2 of this report, the scope of the SIS was modified in accordance with Section 2.5 of the GIP: *Expedited Process for Small Generating Facilities*, to exclude Stability Analysis.

4.0 Requirements and Cost Estimate

IR#598 will share use of the following facility additions that were required to interconnect the IR#516, IR#517, and IR#542 facilities to the NSPI system via 37N-Parrsboro:

- A 138 kV breaker (operated at 69kV) and associated switches at the POI (37N-Parrsboro)
- Protection & Control for the new 69 kV line, Remote terminal Unit (RTU) and a control building at 37N-Parrsboro.
- Protection & Control upgrades at 30N-Maccan and 74N-Springhill to incorporate anti-islanding scheme
- Modification or upgrades to protection relays on L-5550 at 30N-Maccan and on L-5029 and 74N-Springhill to include directional relaying.
- Addition of a licensed 900MHz radio system, with attached SEL-2506 Remote I/O devices for tele-protection.

These additions were installed in 2016 and are currently in service. IR#598 is responsible to make a capital contribution towards 1/4 of the Transmission Providers Interconnection Facilities (TPIF) costs plus 1/3 of the remaining commissioning costs.

In addition, IR#598 must be equipped with the following:

- A centralized controller capable of maintaining constant voltage or constant power factor at the Transmission Provider's Interconnection Facilities substation 69 kV bus (90N – FORCE Tidal substation). The set-point for this controller will be delivered via the NSPI SCADA system.
- When not at full output, the facility shall offer over-frequency and under-frequency control with a deadband of ±0.2 Hz and a droop characteristic of 4%. The active power controls shall also have the capability to react to continuous control signals from the NSPI SCADA system's Automatic Generation Control (AGC) system to control tie-line fluctuations as required.
- The ability to interface with the NSPI SCADA and communication systems to provide the control communication, metering, and other items to be specified in the Facility Study.
- Sufficient reactive power support to maintain a net power factor at the 69kV IC bus.
- Low Voltage Ride Through capability to meet the requirements of Section 7.4.1 of the TSIR.
- Frequency ride-through capability to meet the requirements of Section 7.4.2 of the TSIR
- Voltage flicker and harmonics characteristics as described in this SIS.

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

There are no additional Network Upgrades (NU) or Transmission Providers Interconnection Facilities (TPIF) required to accommodate the connection of IR#598 to the FORCE substation 13.8kV bus. The NU and TPIF associated with the FORCE facility were previously built and are currently in service, although commissioning work requiring generation at 90N-FORCE remains to be completed. The final cost for NSPI's work to provide the 69kV interconnection at 37N-Parrsboro was as follows:

- TPIF Actual Costs: $1,402,630 (HST excluded)
- NU Actual Costs: $ 268,182 (HST excluded)
- Total Actual Cost: $1,670,812 (HST excluded)

It should be noted that Interconnection Facilities and Network upgrades associated with IR#516, IR#517, and IR#542 will be shared by IR#598. IR#598 is responsible for 1/4 of the TPIF costs and 1/3 of the remaining commissioning testing for the 69kV supply which is estimated at $8,696 plus HST. As such, the costs attributed to IR#598 for the shared usage of the TPIF infrastructure total to $350,658 + $2,899 + $53,033 (HST) = **$406,590**.

5.0 Conclusions and Recommendations

Technical analysis, including short circuit, power factor, voltage flicker, and steady state analysis was performed. NSPI and NPCC planning criteria were applied.

The study results show that:

- IR#598 will not adversely impact the interrupting capability of any existing circuit breakers and is assumed to meet the NSPI requirements for voltage flicker at the POI based on the site short circuit level and on the typical characteristics of inverter/converters.
- The minimum Short circuit ratio was found to be 32 at the 90N-FORCE substation 13.8 kV bus - it is the responsibility of the IC that the generating facility controls are stable under such conditions.
- IR#598 provides adequate reactive power to meet the Generator Interconnection Procedure (GIP) requirements
- IR#598 has no impact on any existing Special Protection Systems.
- The system loss factor for this facility was found to be 3.57%.

Relevant study results utilized from IR#542 show that:

- Increased generation associated with IR#598 will not have any significant adverse impact on the local transmission system.
- No thermal loading violations were found under normal states and single contingency conditions.

- The Point of Interconnection at substation 37N-Parrsboro is not classified as part of the NPCC Bulk Power System, nor it classified as a NERC Bulk Electric System element.
- There is a risk of this generating facility being islanded with NSPI customers for certain contingencies and as such, an anti-islanding scheme is required.

The proposed Generating facility must meet the requirements of Sections 7.1 – 7.4, and 7.6 of the NSPI Transmission System Interconnection Requirements (TSIR) document, version 1.1 for asynchronous generation (which includes inverter-based energy conversion associated with tidal facilities).

There are no additional Network Upgrades (NU) or Transmission Providers Interconnection Facilities (TPIF) required to accommodate the connection of IR#598 to the FORCE substation 13.8kV bus. The NU and TPIF associated with the FORCE facility were previously built and are currently in service, although commissioning work requiring generation at 90N-FORCE remains to be completed. The final cost for NSPI's work to provide the 69kV interconnection at 37N-Parrsboro was as follows:

- **TPIF Actual Costs: $1,402,630 (HST excluded)**
- NU Actual Costs: $ 268,182 (HST excluded)
- Total Actual Cost: $1,670,812 (HST excluded)

The Interconnection Facilities and Network upgrades associated with projects IR#516, IR#517, and IR#542 will also be shared by IR#598. As NU costs are refundable under the GIP, IR#598 is only responsible for 1/4 of the TPIF costs, and 1/3 of the remaining commissioning testing for the 69kV supply which is estimated at $8,696 plus HST. As such, the costs attributed to IR#598 for the shared usage of the TPIF infrastructure total $350,658 + $2,899 + $53,033 (HST) = **$406,590**.