System Impact Study Report
Report GIP-IR656-SIS-R1

Generator Interconnection Request #656
4.0 MW Tidal Generating Facility
Cumberland County, NS

Principal Investigator
John Charlton, P. Eng.

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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 4.0 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#656), 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 such, the Steady state analysis results and Bulk Power System (BPS) determination from IR#542, a higher queued tidal project having the same Point of Interconnection, were applied to IR#656

The report scope also included the following analysis specific to IR#656: 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#656 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 20 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#656 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 4.00%.

Study results utilized from IR#542 show that increased generation associated with IR#656 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#656 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 subsequent projects IR#598, IR#647, and this IR#656. As NU costs are refundable under the GIP, IR#656 is not responsible to contribute towards those costs. IR#656 is the sixth project to utilize the common TPIF and is therefore responsible for 1/6 of the TPIF costs. As such, the cost responsibility for IR#656 for the shared usage of the TPIF infrastructure totals $233,772 + $35,066 (HST) = **$268,838,** unless the right to a Capital Contribution refund is waived by those Interconnection Customers who previously contributed to these TPIF.

IR#656 is one of five active projects utilizing the TPIF and is therefore responsible for 1/5 of the remaining commissioning costs for the 69 kV supply, which is estimated at $8,696 plus HST ($1,739 plus HST each), and also for 1/5 of future maintenance and replacement costs associated with the TPIF.

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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 4.0 MW tidal generating facility interconnected to the NSPI transmission system. The IC subsequently signed a System Impact Study (SIS) Agreement for a study of the 4.0 MW tidal generating facility taking Network Resource Interconnection Service (NRIS) and this report is the result of that Agreement.

This IR has been designated by the NSPI System Operator as Interconnection Request #656 and will be referred to as IR#656 throughout this report. Four other higher queued tidal generating facilities (IR#516, IR#542, IR#598, and IR#647) share the same Point of Interconnection as IR#656 and the required Transmission Providers Interconnection Facilities and Network Upgrades identified in this report will be utilized by all five projects.

1.1 Scope

The Point of Interconnection (POI) for IR#656 is the 69 kV substation 37N-Parrsboro. IR#656 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-5582, which is built to 138 kV design standards but currently operated at 69 kV as shown in Figure 1.

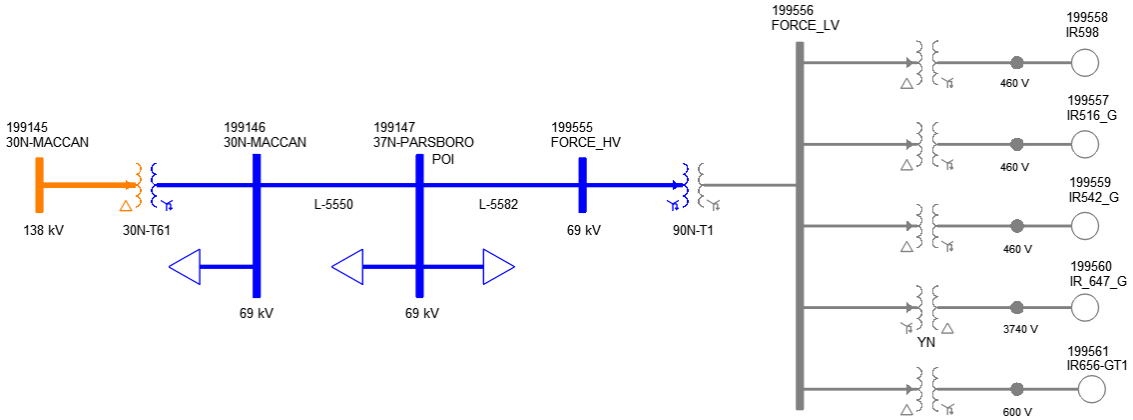


Figure 1: Simplified Interconnection One Line Diagram

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 and location of IR#656, 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#656 SIS.

- **IR#516:**
  IR#516 was submitted in December of 2014 as a 5 MW Network Resource Interconnection Service (NRIS) tidal generating facility interconnected to the NSPI transmission system via the 69 kV 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) was amended on November 9, 2021 to reduce the facility capacity from 5 MW to 1.26 MW following the determination that the change was not a material change under the GIP.

- **IR#517:**
  IR#517 was submitted in December of 2014 as a 4 MW NRIS tidal generating facility interconnected to the NSPI transmission system via the 69 kV 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 (5 MW) 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 5.58 MW NRIS tidal generating facility interconnected to the NSPI transmission system via the 69 kV 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 (5 MW) and IR#517 (4 MW) NRIS generation in its analysis for a total of 14.48 MW 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 70 kW, with 6 generators per platform and a platform supply voltage of 6.6 kV.

  2. Step-up Transformer: A step up transformer unit (6.6 kV to 13.8 kV) 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 6 x 70 kW = 420 kW, with a total of 9 floating platforms being installed for a facility capacity of 3.78 MW.

  A Materiality Study showed that changing the generator technology and output from 5.58 MW to 3.78 MW 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 3.78 MW.

- **IR#598:**
  On May 3, 2021, IR#598 was submitted as a 2.52 MW NRIS tidal generating facility interconnected to the NSPI transmission system via the 69 kV 37N-Parrsboro and 90N-FORCE substations. SIS Report GIP-IR598-SIS-R1 was completed on February 4, 2022, and the summary is attached in Appendix E of this report.

IR #598 relied on the SIS results from IR #542 in accordance with the terms of Section 7.4 of the GIP.

- **IR#647:**
  On May 3, 2021, IR#647 was submitted as a 1.5 MW NRIS tidal generating facility interconnected to the NSPI transmission system via the 69 kV 37N-Parrsboro and 90N-FORCE substations. SIS Report GIP-IR647-SIS-R1 was completed on July 29, 2022, and the summary is attached in Appendix F of this report.

  IR #647 relied on the SIS results from IR #542 in accordance with the terms of Section 7.4 of the GIP.

NRIS generation totalling 14.48 MW 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 14.58 MW to 9.06 MW following the reduction of IR#516 from 5 MW to 1.26 MW; the withdrawal of IR#517 (4 MW); the reduction of IR#542 from 5.58 MW to 3.78 MW; the submission of IR#598 (2.52 MW); and the submission of IR#647 (1.5MW).

The addition of a further 4.0 MW for IR#656 will bring the total generation at 90N-FORCE up to 13.06 MW, approximately 90% of what has previously been studied with no significant system impacts. In addition, Section 1.4 of this report shows that there have been no material additions to the system in Northern NS since the time of the original study for IR #516.

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 September 2, 2022 version in shown in Figure 2.

The Queue shows that IR#647, the last SIS completed at 90N-FORCE, occupies position 15. The Queue position for IR#656 is 18.

The two largest projects in the Queue ahead of IR#656 are identified in positions 3 (IR#540) and 8 (IR#574). Both 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 remaining projects ahead of IR#656 in Queue positions 5-8, 10-14, and 16-17 are all small projects that also have no material impact on the Parrsboro projects.

Projects appearing after IR#656 are lower in the Queue order and are therefore not included in the analysis associated with IR#656.

Combined T/D Advanced Stage Interconnection Request Queue

Publish Date: *Friday, September 2, 2022*

Queue Order*	IR #	Request Date DD-MMM-YY	County	MW Summer	MW Winter	Interconnection Point Requested	Type	Inservice date DD-MMM-YY	Revised Inservice date	Status	Service Type	IC Identity
1 -T	426	27-Jul-12	Richmond	45	45	47C	Biomass	01-Jan-17	9/1/2018	GIA Executed	NRIS	NSPI
2 -T	516	05-Dec-14	Cumberland	5	5	37N	Tidal	01-Jul-16	5/31/2020	GIA Executed	NRIS	N/A
3 -T	540	28-Jul-16	Hants	14.1	14.1	17V	Wind	01-Jan-18	10/31/2023	GIA Executed	NRIS	N/A
4 -T	542	26-Sep-16	Cumberland	3.78	3.78	37N	Tidal	01-Jan-19	6/30/2025	GIA Executed	NRIS	N/A
5 -D	557	19-Apr-17	Halifax	5.6	5.6	24H	CHP	01-Sep-18		SIS Complete	N/A	N/A
6 -D	569	26-Jul-19	Digby	0.6	0.6	509V-302	Tidal	01-Mar-21	2/24/2022	GIA Executed	N/A	N/A
7 -D	566	16-Jan-19	Digby	0.7	0.7	509V-301	Tidal	31-Jul-19	4/30/2022	GIA Executed	N/A	N/A
8 -T	574	27-Aug-20	Hants	58.8	58.8	L-6051	Wind	30-Jun-23		GIA Executed	NRIS	N/A
9 -T	598	13-May-21	Cumberland	2.52	2.52	37N	Tidal	01-Dec-22		GIA Executed	NRIS	N/A
10-D	604	07-Jun-21	Cape Breton	0.45	0.45	11S-303	Solar	15-Jan-22		GIA Executed	N/A	N/A
11-D	603	31-May-21	Cumberland	0.4	0.4	22N-404	Solar/Battery	16-Feb-22		GIA Executed	N/A	N/A
12-D	600	27-May-21	Halifax	0.6	0.6	99H-312	Solar/Battery	02-Mar-22		GIA Executed	N/A	N/A
13-T	597	07-May-21	Queens	33.6	33.6	50W	Wind	31-Aug-23		SIS in Progress	NRIS	N/A
14-T	629	20-Sep-21	Cumberland	0.5	0.5	7N	Solar	28-Sep-21		SIS in Progress	ERIS	N/A
15-T	647	06-Oct-21	Cumberland	1.5	1.5	37N	Tidal	31-Dec-23		SIS in Progress	NRIS	N/A
16-D	653	19-Jan-22	Halifax	0.09	0.09	24H-406	Solar	30-Oct-22		SIS in Progress	N/A	N/A
17-D	654	16-Feb-22	Halifax	0.125	0.125	127H-413	Solar	20-Sep-22		SIS in Progress	N/A	N/A
18-T	656	28-Mar-22	Cumberland	4	4	37N	Tidal	31-Dec-22		SIS in Progress	NRIS	N/A
19-T	672	05-Aug-22	Hants	33.4	33.4	L-5060	Wind	02-Dec-24		SIS in Progress	NRIS	N/A
20-T	661	26-Jul-22	Kings	50	50	92V	Battery	15-Mar-24		SIS in Progress	NRIS	NSPI
21-T	662	26-Jul-22	Halifax	50	50	132H	Battery	15-Dec-24		SIS in Progress	NRIS	NSPI
22-T	663	26-Jul-22	Colchester	50	50	1N	Battery	15-Jun-24		SIS in Progress	NRIS	NSPI
23-T	664	26-Jul-22	Lunenburg	50	50	99W	Battery	15-Dec-23		SIS in Progress	NRIS	NSPI
24-T	670	05-Aug-22	Colchester	97.98	97.98	L-7005	Wind	28-Feb-26		SIS in Progress	NRIS	NSPI
25-T	671	05-Aug-22	Halifax	88.96	88.96	L-6004	Wind	28-Feb-26		SIS in Progress	NRIS	NSPI
26-T	669	04-Aug-22	Cumberland	99	99	L-6613	Wind	31-Dec-25		SIS in Progress	NRIS	N/A
27-T	668	03-Aug-22	Antigonish	94.4	94.4	L-7003	Wind	01-Dec-25		SIS in Progress	NRIS	N/A
28-T	618	21-Jul-21	Guysborough	130.2	130.2	L-6515	Wind	01-Jan-25		SIS in Progress	NRIS	N/A
29-T	673	09-Aug-22	Hants	33.6	33.6	L-6054	Wind	31-Dec-24		SIS in Progress	NRIS	N/A
30-T	675	10-Aug-22	Queens	112.5	112.5	50W	Wind	01-Dec-24		SIS in Progress	NRIS	N/A
		Totals:		1067.41	1067.4							

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

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 345 kV 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#656, and as none of the projects between IR#516 and IR#656 materially impact the Amherst/Parrsboro area, study results associated with IR#516, IR#517, IR#542, IR#598, and IR#647 can be applied to IR#656. 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#656:

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

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

1.6 Assumptions

On March 28, 2022, the NSPI System operator received the Interconnection Request IR#656 inclusive of the following technical data:

1. Generator Capacity: 0.392 kW (435 kVA @ 0.9 pf)
2. Platform Capacity: 2 x 0.392 kW = 0.784 kW limited to 500 kW
3. Generator voltage: 600/347 VAC
4. Generator Power Converter PQ Capability: +/- 0.86pf at 80% real power generation
5. FORCE substation transformer: 21/28/35 MVA 69 kV – 13.8 kV, Grounded Wye - Grounded Wye with 4.16 kV Delta tertiary; +/- 10% taps in 2.5% steps; Z1=7.25%, X1/R1=18.
6. Generator Transformers: 8 x 500/667 kVA, 13.8 kV – 600/347 V, Delta (HV) – Grounded Wye (LV), +/- 5% taps in 2.5% steps; Z1=4.5%, X1/R1=3.1, connected to the 90N-FORCE 13.8 kV circuit 314 via a breaker in the FORCE switch room and subsea cable collector system.
7. The Point of Interconnection (POI) is at the 37N-Parrsboro 69 kV bus.
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 IR#656 generation meets IEEE Standard 519 limiting total harmonic distortion (all frequencies) to a maximum of 5% with no individual harmonic exceeding 3%.

2.0 Technical Model

The proposed generating facility consists of eight generator platforms connected via subsea cable, each housing a single 13.8 kV–600/347 V, 500/667 kVA step down transformer and two 435 kVA 3-phase tidal turbine generators capable of generating 400 kW each at 0.9 power factor, and their associated Energy Converters (AC-DC, DC-AC, AC-AC). The platform generation output is capped at 500kW and is connected to a single 13.8 kV subsea collector circuit supplied by the 69kV-13.8kV FORCE substation (Breaker 90N-314, Berth D).

The PSS®E model for the study analysis is shown in Figure 3 below. A single equivalent generator step-up transformer (600/347 V – 13.8 kV) was modeled with an impedance of 4.5% on 4.0 MVA and an X/R ratio of 3.1. The FORCE interconnection transformer was modeled to have 7.25% impedance on the 21 MVA rating with an X/R ratio of 18.

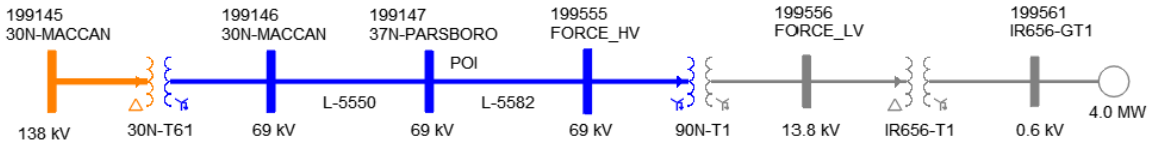


Figure 3: Interconnection One Line Diagram

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 2022 Ten Year System Outlook Report, shown in Figure 4 shows that the forecasted system *Coincident Peak Demand with Future DSM Program Effects* in 2022 was 2165 MW, 5 MW (0.23%) lower than the 2170 MW value forecasted in 2016 for Winter Peak 2019.

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 (%)
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	94	-	1,875	1,968	-4.0
2022*	144	-	2,021	2,165	10.0
2023*	146	-4	2,035	2,185	0.9
2024*	146	-12	2,057	2,215	1.4
2025*	152	-24	2,076	2,253	1.7
2026*	154	-36	2,101	2,291	1.7
2027*	153	-39	2,133	2,326	1.5
2028*	153	-39	2,170	2,361	1.5
2029*	153	-39	2,207	2,398	1.6
2030*	152	-38	2,243	2,434	1.5
2031*	152	-38	2,289	2,479	1.9
2032*	152	-37	2,342	2,532	2.1

*Forecast value

Figure 4: 2022 10 Year System Outlook Report Figure 2

This decrease 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#656.

2.2 Generating Facility

The proposed generating facility consists of eight generation platforms each supported by two pontoons. A waterwheel located between the pontoons is the prime mover for two permanent magnet induction generators (one located in each pontoon) each of which is paired with an energy converter system capable of generating maximum power of 404 kW. Each platform is regulated to limit real power to 500 kW, for a total facility capacity of 8 x 500 kW = 4.0 MW.

The generation platform voltage is 600/347 V, which is then stepped up to 13.8 kV via one 500/667 kVA transformer having an impedance of 4.5% and X/R ratio of 3.1. A 13.8kV subsea cable collector system is utilized to transmit the generation back to the 13.8kV bus located at the 90N-FORCE substation via the Berth D Breaker 90N-314. The FORCE transformer 90N-T51 is rated 69 kV – 13.8 kV, 21/28/35 MVA with positive sequence impedance of 7.25%. A single Line Diagram showing the 90N FORCE substation is attached in Appendix F to this report.

The proposed generator system is classified as Type 4, with fully rated energy converters. A SCADA-based central regulator is provided to regulate power factor and to set curtailment levels issued by the NSPSO.

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.

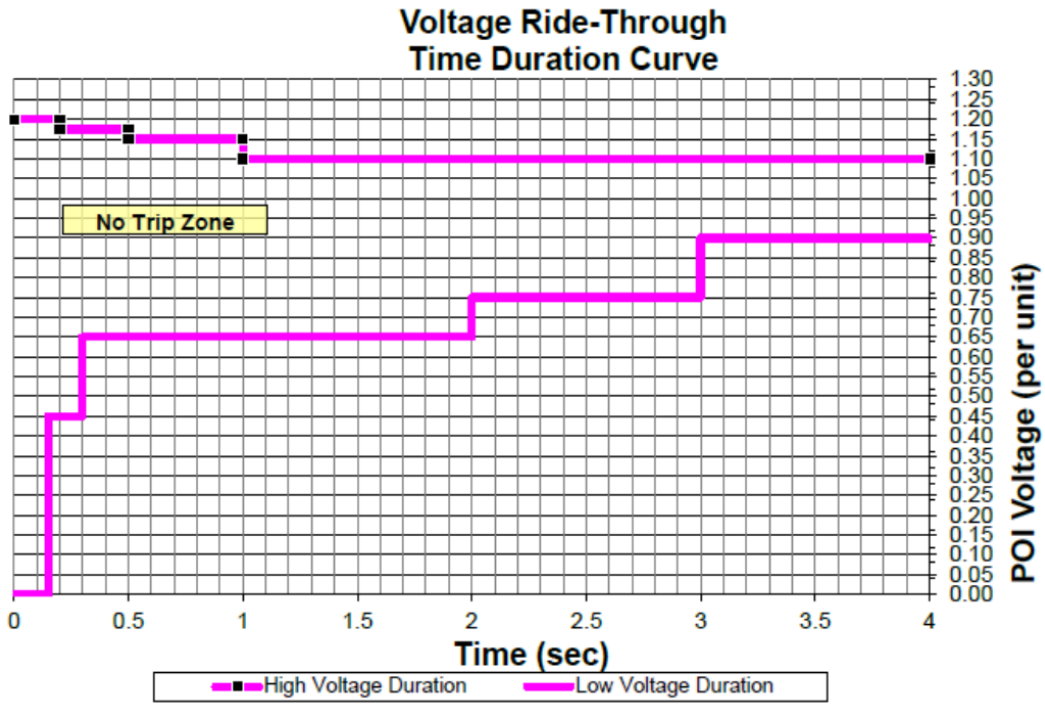


Figure 5: Voltage Ride-through requirements

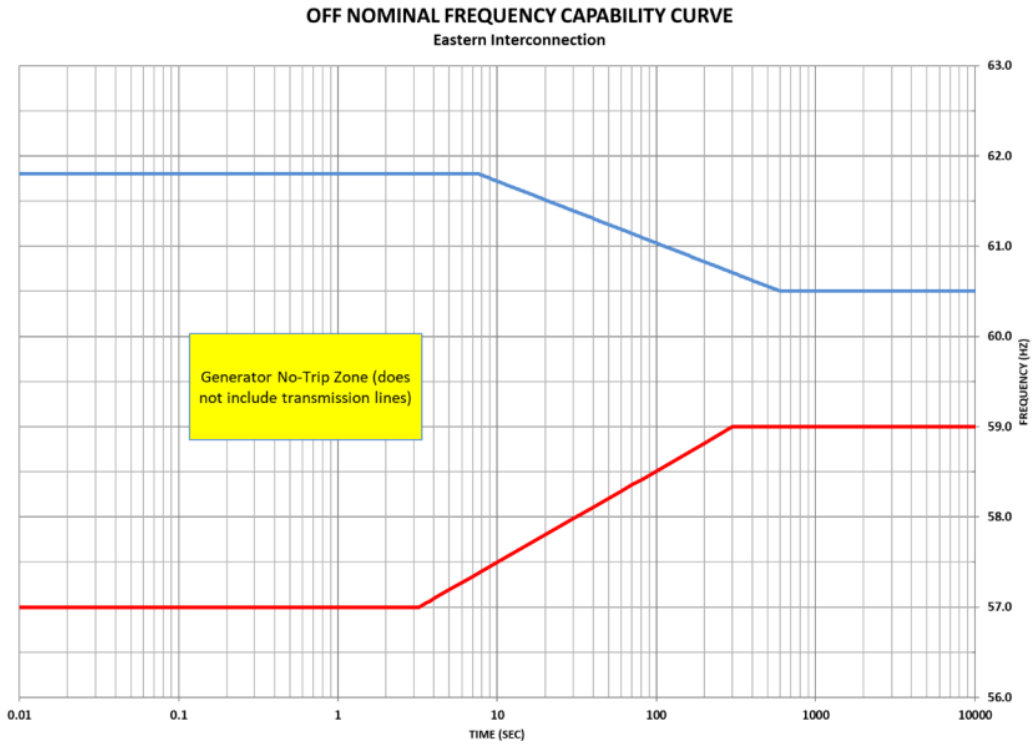


Figure 6: Off-Nominal Frequency Operation Requirements

2.4 System Model and Methodology

Testing and analysis for IR#656 was conducted using the following criteria, software packages and/or modelling data.

2.4.1 Short Circuit

ASPEN OneLiner Version 15.6, 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 2022 system configurations were studied. Each combination was run with IR#656 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 HV terminals of the generator plant interconnection transformer. 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#656 while keeping 91H-Tufts Cove generation as the Nova Scotia Area Interchange bus. The loss factor for IR#656 is the differential MW displaced or increased at 91H-Tufts Cove generation calculated as a percentage of IR#656 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#656. 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 V15.6, 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	IR656 not in service	IR656 in service
Maximum Generation, all transmission facilities in service		
30N-Maccan, 69 kV	390	394
37N-Parrsboro, 69 kV (POI)	180	185
FORCE Substation 69 kV	155	160
FORCE Substation 13.8 kV	108	114
Minimum Generation: NB; NS - ML, TR6, LG1, PA		
30N-Maccan, 69 kV	357	362
37N-Parrsboro, 69 kV (POI)	165	171
FORCE Substation 69 kV	141	147
FORCE Substation 13.8 kV	95	101
Minimum Conditions, Min Generation, 30N-T61 out of service		
30N-Maccan, 69 kV	205	210
37N-Parrsboro, 69 kV (POI)	124	129
FORCE Substation 69 kV	110	115
FORCE Substation 13.8 kV	80	86

All 69kV circuit breakers at 30N-Maccan are rated at 3500 MVA. Therefore IR#656 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 69 kV 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#656 generation) is calculated to be 20 at the FORCE 13.8 kV bus.

3.2 Power Factor

The facility must 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.

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 transformers (13.8 kV – 600/347 V) were modeled to have an impedance of 4.5% on 4.0 MVA. According to the machine PQ curves provided by the IC, the IR#656 400 kW generators and associated energy converters are capable of operating between +0.86 to 1.0 power factor (and -0.86 to 1.0 power factor) under fixed power factor control at 80% generator output per Figure 7 below.

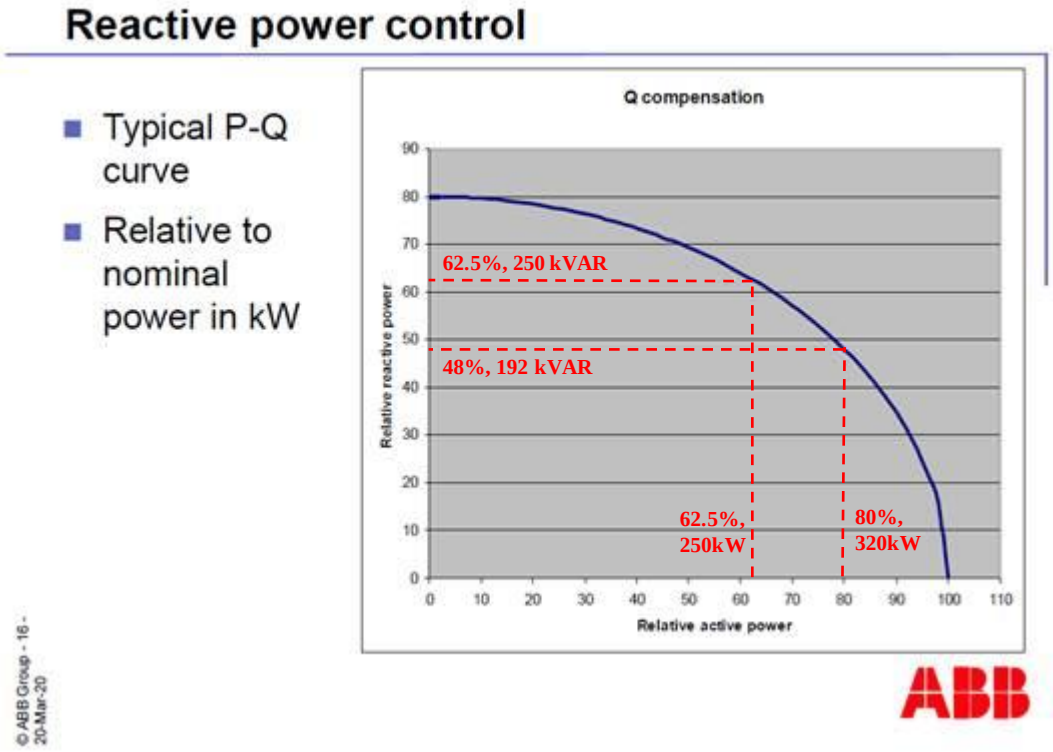


Figure 7: IR 656 – Typical ACS-800/ACS-880 PQ Curve

The PQ curve shown is typical for both the ACS 800 and ACS 880 models. Although the energy converters don't have the ability to provide the full range of +/-0.95 at full rated power, each of the eight platforms has two 400kW generators with regulation limiting the platform output to 500kW. This means that each generator will only be operating at approximately 250 kW, or 62.5% of its real power rating. As a result, there will be 250 kVAR of reactive power available on each unit to enable the facility to meet the +/- 0.95pf requirement at the HV terminals of the generator interconnection transformer.

With the generators all operating at 62.5% real power, each platform can produce 2 x 250kW = 500kW of real power, and 2 x 250kVAR = 500kVAR of reactive power for a total of 4.0 MW and 4.0 MVar with all eight platforms in service. When IR#656 is generating at its rated output of 4.0 MW and delivering 4.0 MVAR, the power factor at the HV terminals of the interconnection transformer is +0.72 which easily meets the GIP requirement as seen in figure 8. Note that a generator operating with a lagging power factor is producing vars, while one operating with a leading power factor is consuming vars.

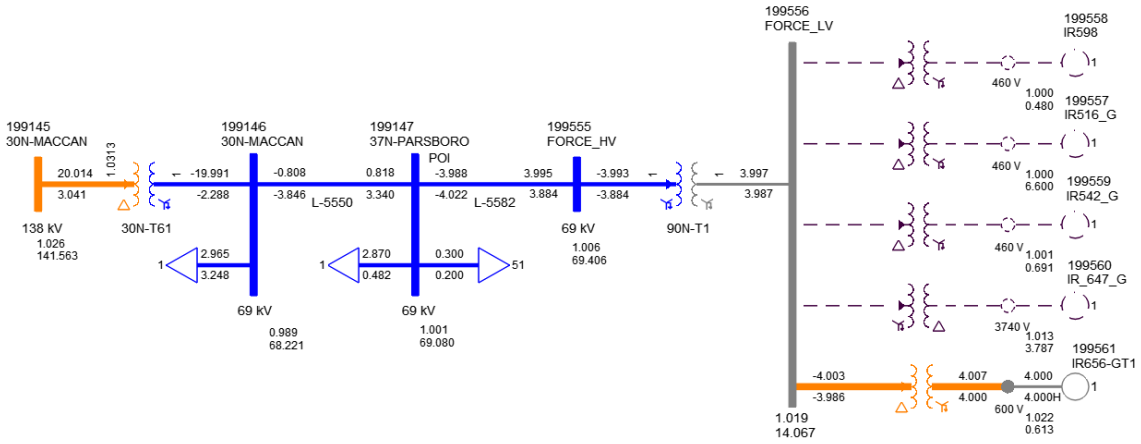


Figure 8: Lagging Power Factor

When IR#656 is generating at its rated output of 4.0 MW and absorbing 4.0 MVAR, the power factor at the POI is -0.69 which easily meets the GIP requirement as seen in figure 9.

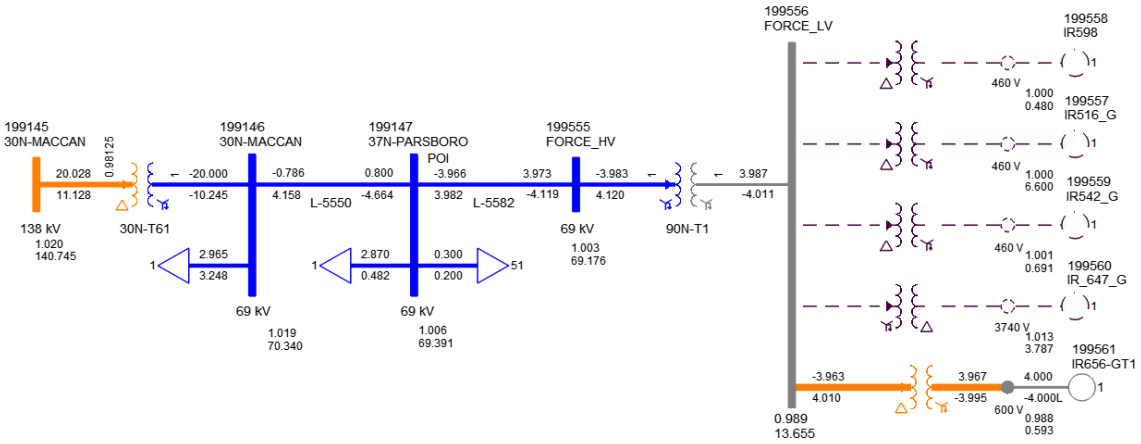


Figure 9: Leading Power Factor

3.3 Loss Factor

The loss factor for IR#656, calculated as per the methodology described in Section 2.4.3, is 4.00%. This means that system losses during the hour of system peak are increased by 0.16 MW when IR#656 is operating at full load. For this loss factor analysis, losses associated with IR#656 transformers and collector circuits are ignored.

Table #3: Loss factor	
IR#656 on (MW)	4.00
Tufts Cove 3 on (MW)	124.33
IR#656 MW + TC3 MW	128.33
Tufts Cove 3 MW with IR#656 off	128.17
Delta (MW)	0.16
Loss Factor (Delta / IR#656 Rating)	4.00%

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#656 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 3%.

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#656 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#656 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#656 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#656 for transformer 74N-T61 or line L-5029 trips. The transfer trip signal will trip the 69kV breaker 90N-501

at the 90N-FORCE substation and 90N 13.8kV Switchgear Bus undervoltage protection then opens each of the 13.8kV breakers. The status of the breakers is transmitted 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 thermal 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#656 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#656'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 1.3 of this IR#656 report demonstrates the basis for accepting these results for IR#656.

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 1.3 of this IR#656 report demonstrates the basis for accepting these results for IR#656.

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#656, 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#656.

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#656 will share use of the following facility additions that were required to interconnect the IR#516, IR#517, IR#542, IR#598, & IR#647 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. In addition, IR#656 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). 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#656 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 69 kV 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#647, and this IR#656. IR#656

is the sixth project to utilize the common TPIF and is therefore responsible for 1/6 of the TPIF costs. As such, the cost responsibility for IR#656 for the shared usage of the TPIF infrastructure totals $233,772 + $35,066 (HST) = **$268,838,** unless the right to a Capital Contribution refund is waived by those Interconnection Customers who previously contributed to these TPIF.

IR#656 is one of five active projects utilizing the TPIF and is therefore responsible for 1/5 of the remaining commissioning costs for the 69 kV supply, which is estimated at $8,696 plus HST ($1,739 plus HST each), and also for 1/5 of future maintenance and replacement costs associated with the TPIF.

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#656 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 20 at the 90N-FORCE substation 13.8 kV bus for IR#656 - it is the responsibility of the IC that the generating facility controls are stable under such conditions.
- IR#656 provides adequate reactive power to meet the Generator Interconnection Procedure (GIP) requirements.
- IR#656 has no impact on any existing Special Protection Systems.
- The system loss factor for this facility was found to be 4.00%.

Relevant study results utilized from IR#542 show that:

- Generation associated with IR#656 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# 656 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, IR#647, and IR#656. IR#656 is the sixth project to utilize the common TPIF and is therefore responsible for 1/6 of the TPIF costs. As such, the cost responsibility for IR#656 for the shared usage of the TPIF infrastructure totals $233,772 + $35,066 (HST) = **$268,838,** unless the right to a Capital Contribution refund is waived by those Interconnection Customers who previously contributed to these TPIF.

IR#656 is one of five active projects utilizing the TPIF and is therefore responsible for 1/5 of the remaining commissioning costs for the 69 kV supply, which is estimated at $8,696 plus HST ($1,739 plus HST each), and also for 1/5 of future maintenance and replacement costs associated with the TPIF.

Appendix A: IR#516 Executive Summary

System Impact Study Report

Executive Summary

This report presents the results of a System Impact Study (SIS) for a proposed 5 MW tidal turbine generating facility interconnected to the NSPI transmission system. The study analysed the impact the proposed development would have on the NSPI power grid. System studies, including short circuit, power factor, voltage flicker, steady state, stability, Bulk Power System analysis, under-frequency operation, low voltage ride through and loss factor were performed. NSPI and NPCC planning criteria were applied.

This tidal facility will be interconnected to the 69kV substation 37N-Parrsboro. Transmission line L-5550 serves to transmit power from the 30N-Maccan substation to the 37N-Parrsboro substation and is designed to 138kV specifications but it is presently operated at 69kV. Therefore, transmission facility upgrades associated with the generator interconnection must also be built to 138kV standards to accommodate future system upgrades to 138kV in this area. One new 69kV circuit breaker will be required at 37N-Parrsboro substation complete with associated switches and protection. These facilities must be designed to be capable of future 138kV operation.

The increase in short circuit levels are within the capability of the associated breakers in the vicinity of 37N-Parrsboro. There are no concerns with regard to increased short circuit levels. Reactive power capability of the generating facility was not provided by the IC. This SIS estimates that, proposed generating facility should be capable of delivering approximately 1.8 MVAR and absorbing 1.4 MVAR of reactive power. Voltage flicker was not calculated due to insufficient generator data. However, the IC is expected to meet NSPI's requirement for voltage flicker and harmonic distortion.

Increased generation from this newly proposed generation facility will not have any significant adverse impact on the local transmission. No thermal loading violations were found under normal states and single contingency conditions. Stability analysis was not performed as a dynamic model for the generator was not available at the time of the study. However, this 5 MW of inverter based generation is not expected to cause system instability. Interconnecting substation 37N-Parrsboro is not classified as part of the Bulk Power System. IC is required to meet the requirements of Low Voltage Ride Through and Under Frequency operation. The system loss factor for this facility is -2%. This SIS identifies a risk of this generating facility being islanded with NSPI customers for certain contingencies. Hence, an anti-islanding scheme needs to be installed.

The total high level estimated cost for Interconnection Costs and Network Upgrades is $1,650,000. As there are two generating facilities utilizing these interconnection facilities and Network Upgrades (IR #516 and IR #517), both IC's will share these costs equally ($825,000 each). However, should IR#517 not proceed, then IR #516 will become responsible for the entire amount. The Facility Study will provide a more detailed cost estimate. All costs of associated facilities required at the Interconnection Customer's substation and generating facility are in addition to this estimate.

Appendix B: IR#517 Executive Summary

System Impact Study Report

Executive Summary

This report presents the results of a System Impact Study (SIS) for a proposed 4 MW tidal turbine generating facility interconnected to the NSPI transmission system. The study analysed the impact the proposed development would have on the NSPI power grid. System studies, including short circuit, power factor, voltage flicker, steady state, stability, Bulk Power System analysis, under-frequency operation, low voltage ride through and loss factor were performed. NSPI and NPCC planning criteria were applied.

This tidal facility will be interconnected to the 69kV substation 37N-Parrsboro. Transmission line L-5550 serves to transmit power from the 30N-Maccan substation to the 37N-Parrsboro substation and is designed to 138kV specifications but it is presently operated at 69kV. Therefore, transmission facility upgrades associated with the generator interconnection must also be built to 138kV standards to accommodate future system upgrades to 138kV in this area. One new 69kV circuit breaker will be required at 37N-Parrsboro substation complete with associated switches and protection. These facilities must be designed to be capable of future 138kV operation.

The increase in short circuit levels are within the capability of the associated breakers in the vicinity of 37N-Parrsboro. There are no concerns with regard to increased short circuit levels. Reactive power capability of the generating facility was not provided by the IC. This SIS estimates that, proposed generating facility should be capable of delivering approximately 1.5 MVAR and absorbing 1.2 MVAR of reactive power. Voltage flicker was not calculated due to insufficient generator data. However, the IC is expected to meet NSPI's requirement for voltage flicker and harmonic distortion.

Increased generation from this newly proposed generation facility will not have any significant adverse impact on the local transmission. No thermal loading violations were found under normal states and single contingency conditions. Stability analysis was not performed as a dynamic model for the generator was not available at the time of the study. However, this 4 MW of inverter based generation is not expected to cause system instability. Interconnecting substation 37N-Parrsboro is not classified as part of the Bulk Power System. IC is required to meet the requirements of Low Voltage Ride Through and Under Frequency operation. The system loss factor for this facility is -2.5%. This SIS identifies a risk of this generating facility being islanded with NSPI customers for certain contingencies. Hence, an anti-islanding scheme needs to be installed.

The total high level estimate for Interconnection Costs and Network Upgrades is $1,650,000. As there are two generating facilities utilizing these interconnection facilities and Network Upgrades (IR #516 and IR #517), both IC's will share these costs equally ($825,000 each). However, should IR#516 not proceed, then IR #517 will become responsible for the entire amount. The Facility Study will provide a more detailed cost estimate. All costs of associated facilities required at the Interconnection Customer's generating facility are in addition to this estimate.

Appendix C: IR#542 Executive Summary

System Impact Study Report

Executive Summary

This report presents the results of a System Impact Study (SIS) for a proposed 5.58 MW tidal turbine generating facility interconnected to the NSPI transmission system. The study analysed the impact the proposed development would have on the NSPI power grid. System studies, including short circuit, power factor, voltage flicker, steady state, stability, Bulk Power System analysis, under-frequency operation, low voltage ride through and loss factor were performed. NSPI and NPCC planning criteria were applied.

This tidal facility will be interconnected to the 69kV substation 37N-Parrsboro. Transmission line L-5550 serves to transmit power from the 30N-Maccan substation to the 37N-Parrsboro substation and is designed to 138kV specifications but it is presently operated at 69kV. Therefore, transmission facility upgrades associated with the generator interconnection must also be built to 138kV standards to accommodate future system upgrades to 138kV in this area. One new 69kV circuit breaker will be required at 37N-Parrsboro substation complete with associated switches and protection. These facilities must be designed to be capable of future 138kV operation.

The increase in short circuit levels are within the capability of the associated breakers in the vicinity of 37N-Parrsboro. IR#542 provides adequate reactive power to meet the Generator Interconnection Procedure (GIP) requirement. Voltage flicker was not calculated due to insufficient generator data. However, the IC is expected to meet NSPI's requirement for voltage flicker and harmonic distortion.

Increased generation from this newly proposed generation facility will not have any significant adverse impact on the local transmission. No thermal loading violations were found under normal states and single contingency conditions.

IR#542 was not found to cause issues with the stability of the interconnected system. IR#542 was found to comply with the Low Voltage Ride Through requirements, and remained on-line through simulated under frequency islanding events. Interconnecting substation 37N-Parrsboro is not classified as part of the Bulk Power System. The system loss factor for this facility is 5%. This SIS identifies a risk of this generating facility being islanded with NSPI customers for certain contingencies. Hence, an anti-islanding scheme needs to be installed.

The total high level estimated cost for Transmission Provider's Interconnection Facilities and Network Upgrades is $1,650,000. Two other higher queued tidal generating facilities (IR #516 and IR #517) are also located in the same area as IR #542 and the required Transmission Providers Interconnection Facilities identified in this report will be utilized by all three projects. All three IC's will share these costs equally ($550,000 each). All costs of associated facilities required at the Interconnection Customer's Interconnection Facilities and generating facility are in addition to this estimate.

Appendix D: IR#542 Addendum Summary

Addendum Summary

This report represents an Addendum to Report GIP-IR542-SIS-R0, which concerns a 5.58MW Tidal Generating Facility interconnected to the transmission system via the 69kV 37N-Parrsboro substation.

On January 21, 2020, the Interconnection Customer requested the following changes to their Interconnection request (IR) 542:

- A turbine change from 15 Tocardo 372 kW units to 54 Schottel 70 kW units (Type 4 generators with AC-DC-AC inverter technology similar to that of the Tocardo units)
- A reduction in capacity from 5.58 MW to 3.78 MW
- A new generator voltage of 460V, with 500kVA, 460V-6.6kV Dyn1 collector circuit step-up transformers and a plant 6.6kV–13.8kV Dyn1 GSU step-up transformer to accommodate interconnection with the FORCE substation 13.8kV Feeder 311

The above changes are deemed to be "not material". This report addendum documents the modifications to each section of report GIP-IR542-SIS-R0, by section number, required as a result of these changes.

Appendix E: IR#598 Executive Summary

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**.

Appendix F: IR#647 Executive Summary

Executive Summary

This report presents the results of a System Impact Study (SIS) for a proposed 1.5 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#647), 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, was applied to the IR#647 Steady state analysis, and Bulk Power System (BPS) determination.

The report scope also included the following analysis specific to IR#647: 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#647 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 54 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#647 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 3.33%.

Study results utilized from IR#542 show that increased generation associated with IR#647 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#647 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 subsequent project IR#598 and IR#647. As NU costs are refundable under the GIP, IR#647 is not responsible to contribute towards those costs. IR#647 is the fifth project to utilize the common TPIF, and is therefore responsible for 1/5 of the TPIF costs. IR#647 is one of four active projects utilizing the TPIF, and is therefore responsible for 1/4 of the remaining commissioning costs for the 69kV supply, which is estimated at $8,696 plus HST ($2,174 plus HST each). As such, the costs attributed to IR#647 for the shared usage of the TPIF infrastructure total $280,526 + $2,174 + $42,405 (HST) = **$325,105.**

Appendix G: IR#656 1-Line Diagram

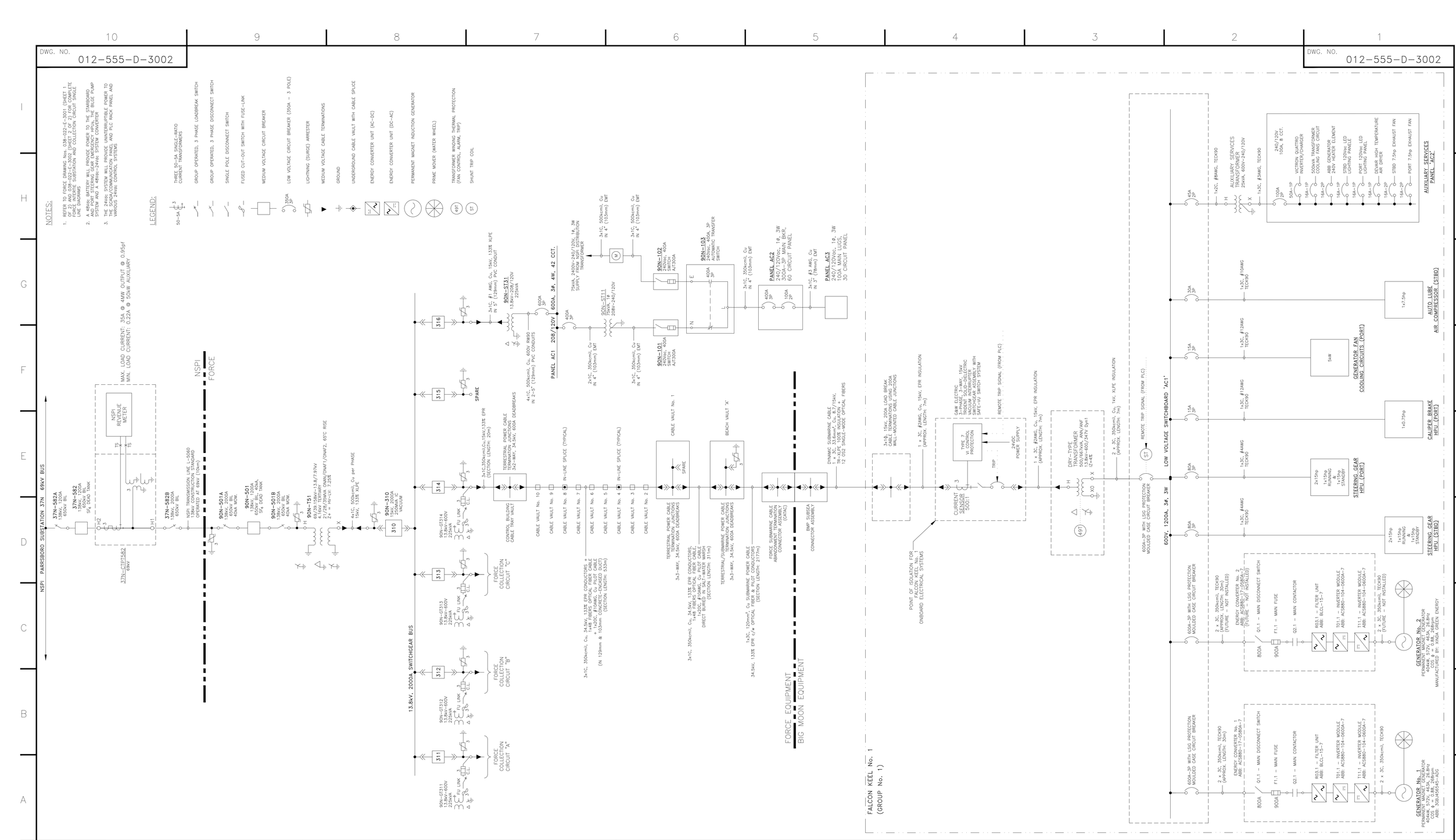
DWG. NO. 012-555-D-3002

NOTES:

1. REFER TO FORCE DRAWING Nos. 038-022-E-3001 (SHEET 1 OF 2) AND 038-022-E-3002 (SHEET 2 OF 2) FOR COMPLETE INTERTIE SUBSTATION AND COLLECTION CIRCUIT SINGLE LINE DIAGRAMS.
2. A 48Vdc BATTERY WILL PROVIDE POWER TO THE STARBOARD AND PORT STEERING GEAR EMERGENCY HPUs, THE BILGE PUMP AND THE SCADA/COMMUNICATION CONTROL SYSTEMS.
3. THE 24Vdc SYSTEM WILL PROVIDE UNINTERRUPTIBLE POWER TO THE SCADA/COMMUNICATION PANEL AND PLC RACK PANEL AND VARIOUS 24Vdc CONTROL SYSTEMS

LEGEND:

- 50-5A : THREE 50-5A SINGLE-RATIO CURRENT TRANSFORMERS
- GROUP OPERATED, 3 PHASE LOADBREAK SWITCH
- GROUP OPERATED, 3 PHASE DISCONNECT SWITCH
- SINGLE POLE DISCONNECT SWITCH
- FUSED CUT-OUT SWITCH WITH FUSE-LINK
- MEDIUM VOLTAGE CIRCUIT BREAKER
- 350A 3P : LOW VOLTAGE CIRCUIT BREAKER (350A – 3 POLE)
- LIGHTNING (SURGE) ARRESTER
- MEDIUM VOLTAGE CABLE TERMINATIONS
- GROUND
- UNDERGROUND CABLE VAULT WITH CABLE SPLICE
- ENERGY CONVERTER UNIT (AC–DC)
- ENERGY CONVERTER UNIT (DC–AC)
- PERMANENT MAGNET INDUCTION GENERATOR
- PRIME MOVER (WATER WHEEL)
- TRANSFORMER WINDING THERMAL PROTECTION (FAN CONTROL, ALARM, TRIP)
- SHUNT TRIP COIL



								A05	2022–07–13	———	ISSUED FOR REFERENCE WITH nspi FACILITIES STUDY AGREEMENT FORM	R.F.M.
								A04	2022–06–28	———	GENERAL REVISIONS	R.F.M.
								A03	2021–12–09	———	GENERAL REVISIONS	R.F.M.
								A02	2021–05–10	———	REVISED & ISSUED WITH ENERGY LOSS REPORT No. 012–555–1–21	R.F.M.
PROTECTION, CONTROL AND METERING INTERTIE SUBSTATION SINGLE LINE DIAGRAM (SHEET 1 OF 2)	038–022–E–3001							A01	2021–04–14	———	ISSUED FOR CLIENT REVIEW	R.F.M.
PROTECTION, CONTROL AND METERING COLLECTION SYSTEM SINGLE LINE DIAGRAM (SHEET 2 OF 2)	038–022–E–3002												
REFERENCE DRAWINGS	DWG. NO'S	NO.	DATE	LOCATION	REVISIONS	MADE BY	NO.	DATE	LOCATION	REVISIONS	MADE BY		

STRUM ENGINEERING ASSOCIATES LTD.
DARTMOUTH & SYDNEY, NOVA SCOTIA

DRAWN:	CHECKED:	PROJECT MANAGER:
P.M.	R.F.M.	R.F.M.
SCALE: N.T.S.	QUALITY CONTROL:	

CLIENT: BIG MOON POWER CANADA CORPORATION, DARTMOUTH, NOVA SCOTIA

TITLE: BIG MOON TIDAL POWER PROJECT
FALCON KEEL No. 1 (GROUP No. 1)
FORCE CIRCUIT 90N–314 – BERTH 'D'
OVERALL SINGLE LINE DIAGRAM

DATE: 2021–04–12 | DWG. No. 012–555–D–3002 | Rev. A05

ACAD FILE: 0125553002 – Overall Single Line Diagram – Berth 'D'.DWG