Interconnection Feasibility Study Report
GIP-IR579-FEAS-R1

Generator Interconnection Request 579
250 MW Battery Energy Storage System Facility
Pictou County, NS

2021-04-16

Control Centre Operations
Nova Scotia Power Inc.

Executive summary

This Feasibility Study report (FEAS) presents the results of a Feasibility Study Agreement for the connection of a 250 MW Battery Energy Storage System (BESS) facility interconnected to the NSPI system under Energy Resource Interconnection Service (ERIS).

This project is listed as Interconnection Request #579 in the NSPI Interconnection Request Queue and will be referred to as IR579 throughout this report. The proposed Commercial Operation Date is 2022/12/28.

The Interconnection Customer (IC) identified a 138 kV bus at 50N-Trenton as the Point of Interconnection (POI). This BESS facility will be interconnected to the POI via a ~700 m long 138 kV transmission line from the Point of Change of Ownership (PCO).

There are two long-term firm Transmission Service Reservations (TSR) in the System Impact Study (SIS) stage in the Transmission Service Queue with a requested in-service date of 2025/01/01. These are TSR411 (800 MW from NB to NS) and TSR412 (500 MW from NL to NS) and are expected to alter the configuration of the Transmission System in Nova Scotia As a result, the following notice has been posted to the OASIS site[1]:

> *Effective January 19th, 2021, please be advised that the completion of advanced-stage Interconnection Studies under the Standard Generator Interconnection Procedures (GIP) may be delayed pending the outcome of the Transmission Service Request (TSR) 411 and 412 System Impact Studies, which are expected to identify significant changes to the NSPI transmission system. The expected completion date for these studies is December 31, 2021. Feasibility Studies initiated prior to the completion of these TSR System Impact Studies will be performed based on the current system configuration.*

There are no concerns regarding increased short circuit levels or voltage flicker. The increase in short circuit level is still within the capability of associated breakers. The minimum short circuit level at the facility’s high side bus is 718 MVA.

Voltage flicker will not be an issue based on test data from a 50 Hz system. Voltage flicker for a 60 Hz system will be examined when data is made available for the SIS to confirm NSPI's requirements are met.

[1] OASIS Generation Interconnection Procedures; https://www.nspower.ca/oasis/generation-interconnection-procedures

The project design must meet NSPI requirements for voltage ride-through, frequency ride-through, reactive power range, and voltage control. Harmonics must meet the Total Harmonic Distortion requirements in IEEE 519.

Supplementary reactive power support for IR579 is required as it is unable to meet NSPI's ±0.95 net power factor (PF) requirements at the facility's 138 kV bus. The Tesla Powerstages selected for IR579 have current-limited, bi-directional inverters capable of four-quadrant operation at nominal voltage; however, they are only capable of >0.99 PF at full output. Net power factor requirements are met when IR579's output levels are just below 221 MW. Supplementary reactive power support will be further investigated in the System Impact Study. One option would be operating lower than the output level stated above.

The 50N-Trenton POI for IR579 is not classified as NPCC BPS or NERC BES. Complete NPCC BPS status will be determined in the System Impact Study's (SIS) transient testing. Portions of IR579's ICIF (padmount units, low side and high side buses of the substation step-up transformers, the substation step-up transformers, and equipment up to the 50N-Trenton 138 kV bus) will have NERC BES status due to its aggregate rating and must comply with applicable NERC reliability standards.

The preliminary loss factor is calculated as 9.74% while discharging at the 50N-Trenton 138 kV bus POI. This preliminary loss factor excludes losses associated with the TPIF, ICIF transformer, and generation facility.

The Transmission System has insufficient firm capacity to accommodate IR579 at its full 200 MW charge and 250 MW discharge rates under peak stressed conditions. At the time of this study, the maximum rates for IR579 during peak stressed periods, without Network Upgrades, is 41 MW charging and 30 MW discharging.

Charging scenarios were evaluated during light load and summer peak conditions, however winter charging was only evaluated during winter off-peak conditions following the day's winter peak. For example, if winter peak occurred at 18:00, charging was assumed to be from 23:00 - 06:00.

The necessary Network Upgrades required for ERIS operation are:

- P&C modifications at 50N-Trenton.

The present preliminary non-binding cost estimate for interconnecting IR579 to the 50N-Trenton 138 kV bus as an Energy Resource, at the reduced charge/discharge rates stated earlier, is $2,377,287, which does not include any To Be Determined costs associated with SIS stability analysis. $2,157,287 of this amount is the TPIF costs, with the remainder as the Network Upgrade costs. These estimates include a 10% contingency. This estimate will be further refined in the SIS and Facilities (FAC) studies.

Note that the proposed transmission path from the POI to PCO requires more detailed engineering to provide a more accurate cost estimate due to the congestion and sharp turns in the proposed right of way. It is the customers responsibility to provide a suitable right of way for the transmission line. The necessary easements shall be registered in NSPI’s name with the with the appropriate land registration office.

The estimated time to construct the Network Upgrades and TPIF for ERIS operation is 18-24 months after the receipt of funds.

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1.0 Introduction

This Feasibility Study report (FEAS) presents the results of a Feasibility Study Agreement for the connection of a 250 MW Battery Energy Storage System (BESS) facility interconnected to the NSPI system under Energy Resource Interconnection Service (ERIS).

This project is listed as Interconnection Request #579 in the NSPI Interconnection Request Queue and will be referred to as IR579 throughout this report. The proposed Commercial Operation Date is 2022/12/28.

The Interconnection Customer (IC) identified a 138 kV bus at 50N-Trenton as the Point Of Interconnection (POI). This BESS facility will be interconnected to the POI via a ~700 m long 138 kV transmission line from the Point of Change of Ownership (PCO). Figure 1 shows the approximate geographic location of the proposed IR579 site.

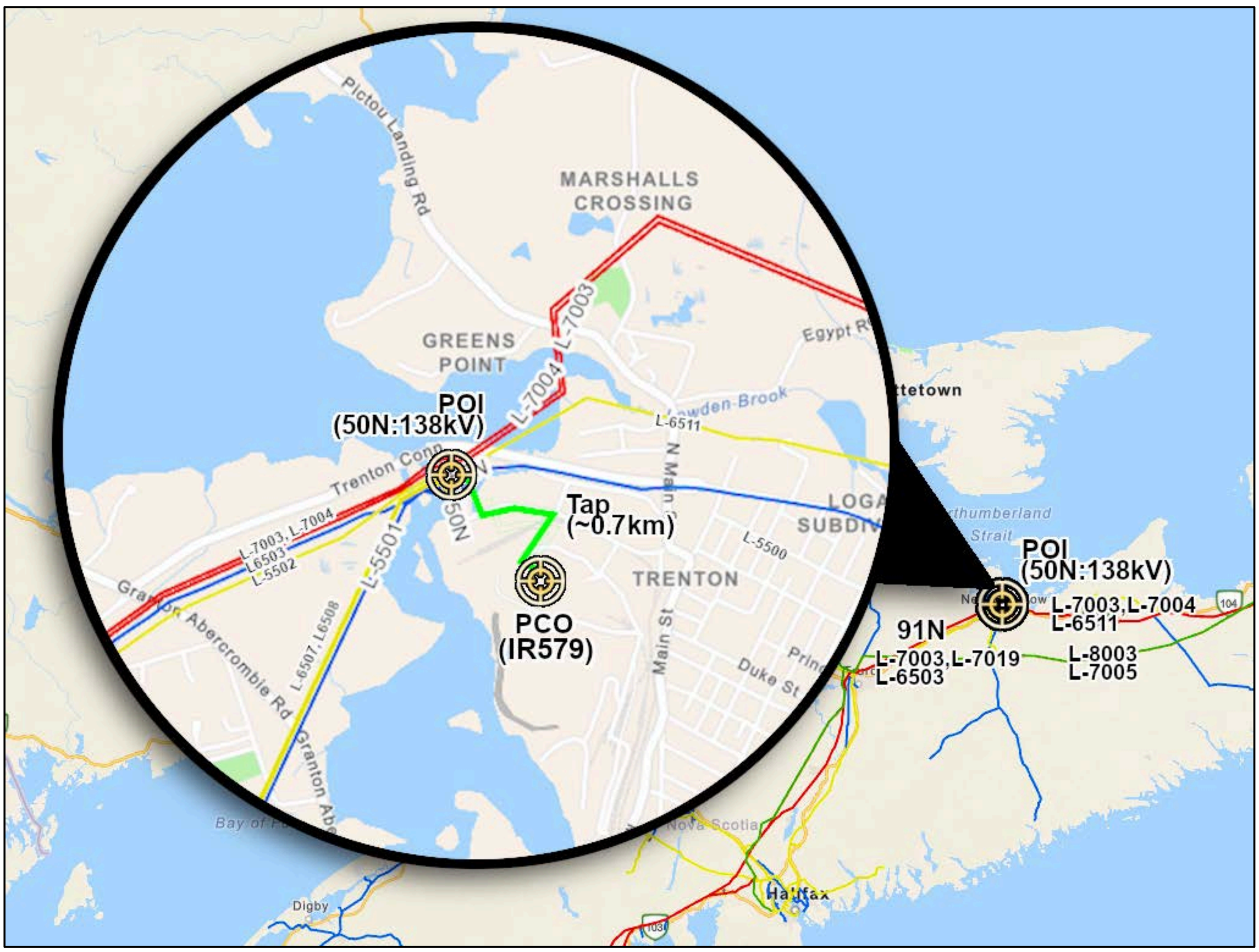

Figure 1: IR579 approximate geographic location

2.0 Scope

This Interconnection Feasibility Study's (FEAS) objective is to provide a preliminary evaluation of system impact and a high-level non-binding cost estimate of interconnecting the new BESS facility to the NSPI Transmission System at the designated location based on single contingency criteria. This assessment will identify potential impacts on transmission element loading, which must remain with their thermal limits. Any potential voltage criteria violations will be identified and addressed. Circuit breakers must be upgraded if the proposed facility increases the short-circuit duty of any circuit breakers beyond their rated capacity.

The scope of the FEAS includes modelling the power system in normal state, with all transmission elements in service, under anticipated load and generation dispatch. A power flow and short circuit analysis will be performed to provide the following preliminary information:

- Identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection and any network upgrades necessary to address the short circuit issues associated with the IR.
- Identification of any thermal overload or voltage limit violations resulting from the interconnection and identify the necessary network upgrades to allow full output of the proposed facility with respect to NPCC & NERC standards.
- Description and high-level non-binding estimated cost of and time to construct the facilities required to interconnect the generating facility to the transmission system.

This FEAS does not include a complete determination of facility changes/additions required to increase the system transfer capabilities that may be required to the transmission system to meet the design and operating criteria established by NSPI, the Northeast Power Coordinating Council (NPCC), and the North American Electric Reliability Corporation (NERC). These requirements will be determined by a more detailed analysis in the subsequent interconnection System Impact Study (SIS). An Interconnection Facilities Study (FAC) follows the SIS in order to ascertain the final cost estimate to the interconnect the generating facility.

3.0 Assumptions

This FEAS is based on technical information provided by the IC. The Point Of Interconnection (POI) and configuration is studied as follows:

1. Energy Resource Interconnection Service (ERIS) per section 3.2 of the Generation Interconnection Procedures (GIP).
2. Commercial Operation date: 2022/12/28.

3. The Interconnection Facility consists of 4,708 Tesla Powerstages, capped at 250 MW. These Powerstages are grouped in blocks of 22 per Tesla Megapack, with two Megapacks per padmount unit, connected to the medium voltage bus through a single 3.0 MVA generator step-up transformer. The padmount units are distributed between two 85/115/140 MVA substation step-up transformers.
4. The feeder circuit impedance was assumed to be negligible, due to the short distance *(padmounts were spaced at 17 m),*
5. The IC identified the POI at a 138 kV bus at the 50N-Trenton substation. The IC has indicated the ICIF will be connected to the POI via a 700 m line built to 138 kV standards using 1272 ACSR Bittern conductor. 1272 ACSR Bittern is too heavy for standard NSPI structures, and as such 1113 ACSR Beaumont rated at 100ºC was assumed for this study More detailed preliminary engineering is required at a later stage to determine the final conductor specification.
6. Preliminary data was provided by the IC for the two substation step-up transformers and padmount transformers.
   6.1. Each substation step-up transformer was modelled as a 138 kV (wye) - 34.5 kV (delta) transformer rated at 85/115/140 MVA, with a positive sequence impedance of 12.0% at 80 MVA and 35.0 X/R ratio.
   6.2. The padmount transformers were modelled as an equivalent transformer based off 14 34.5 kV (delta) - 0.48 kV (grounded wye) 3.0 MVA transformers, with a 5.75% positive impedance at 3.0 MVA and 10.8 X/R ratio.
7. The Tesla PowerStages are the 480 VAC, 70 kVA nameplate variant, with a 1.200 fault current, from the Tesla Application Note supplied by the IC.
8. The max BESS charge capacity is 200 MW and discharge capacity is 250 MW. The BESS facility can supply the full discharge capacity for 4 hours.
9. Discharging occurs in light load, summer peak, and winter peak conditions.
10. Charging occurs in light load and summer peak conditions. During the winter season, charging only occurs in minimal load conditions several hours after winter peak.
11. The two substation step-up transformers have capacity to support the proposed Megapack distribution.
12. The FEAS analysis is based on the assumption that IRs higher in the Generation Interconnection Queue and OATT Transmission Service Queue that have a completed System Impact Study, or have a System Impact Study will proceed, as listed in Section 4.0: Project queue position.

4.0 Project queue position

All in-service generation is included in this FEAS.

As of 2021/02/18, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are committed to this study's base cases:

- IR426: GIA executed
- IR516: GIA executed
- IR540: GIA executed
- IR542: GIA executed
- IR557: SIS complete
- IR569: GIA executed
- IR568: GIA executed
- IR566: GIA executed
- IR574: SIS in progress

The following projects have been submitted to the Transmission Service Request (TSR) Queue:

- TSR 411: Accepted application
- TSR 412: Accepted application

The two TSRs have an expected 2025 in service date and system studies to determine required upgrades to the NS transmission system are currently in progress. As a result, the following notice has been posted to the OASIS site[2]:

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5.0 Short circuit

IR579 will not impact 50N-Trenton and neighbouring breaker's interrupting capability (at least 3,500 MVA) based on this study's short circuit analysis.

Short circuit analysis was performed using PSS/e 34.7, classical fault study, flat voltage profile at 1.0 PU voltage, and 3LG faults. The short circuit levels in the area before and after this development are provided in Table 1: *Short circuit levels, 3-ph, in MVA.*

[2] OASIS Generation Interconnection Procedures; https://www.nspower.ca/oasis/generation-interconnection-procedures

Table 1: Short circuit levels, 3-ph, in MVA

Location	IR579 not in service	IR579 in service	Post % increase
2022, max generation, all facilities in service			
POI (50N-Trenton):138	2,991	3,276	10%
IF:138	2,841	3,127	10%
2022, min generation, all facilities in service			
POI (50N-Trenton):138	1,426	1,715	20%
IF:138	1,391	1,682	21%
2022, min generation, L6503 out of service			
POI (50N-Trenton):138	1,169	1,458	25%
IF:138	1,145	1,436	25%
2022, min generation, 79N-T81 out of service			
POI (50N-Trenton):138	727	1,016	40%
IF:138	718	1,008	40%

Further short circuit analysis will be performed in the SIS and will also examine Short Circuit Ratio (SCR) under minimum short circuit level conditions.

6.0 Voltage flicker & harmonics

The IC supplied manufacturer test data for a 50 Hz system, with P_{st} and P_{lt} values meeting NSPI's voltage flicker requirements. Voltage flicker for a 60 Hz system will be examined when data is made available for the SIS. A summary of the results is listed in Table 2: Flicker requirements.

Table 2: Flicker requirements

	P_{st}	P_{lt}
NSPI's requirements	≤ 0.25	≤ 0.35
Manufacturer-supplied 50 Hz test data *(12 samples)*	Max: 0.17 Min: 0.12 Avg: 0.14 90th: 0.17	0.14

The generator must meet IEEE Standard 519-2014 limiting voltage Total Harmonic Distortion *(all frequencies)* to no higher than 1.5% with no individual harmonic exceeding 1.5% on 138 kV.

7.0 Thermal limits

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

The base cases used in this study are shown in Table 3: Base case dispatch. Transmission connected wind generation facilities were typically dispatched at approximately 40%, with some low and high wind scenarios included. Three scenarios for each case were examined for the Light Load (LL), Summer Peak (SP), and Winter Peak (WP) cases:

- IR579 off.
- IR579 charging up to its max 200 MW capacity.
- IR579 discharging up to its max 250 MW capacity; though there were several cases in which it was dispatched under reduced output due to insufficient firm capacity on the Transmission System.

Charging scenarios were evaluated during light load and summer peak conditions, however winter charging was only evaluated during winter off-peak conditions following the day's winter peak. For example, if winter peak occurred at 18:00, charging was assumed to be from 23:00 - 06:00.

NS generation is primarily composed of Network Resource (NR) generation. NR designation requires the aggregate of NR generation facilities' full capacity in the local area to be delivered to the aggregate of load on the NSPI Transmission System under peak stressed conditions. Alternatively, Energy Resource (ER) generation is eligible to deliver energy using existing firm or non-firm capacity on an "as available" basis. IR579 was submitted to study ERIS operation.

The POI for IR579 is at a facility that constitutes part of the Onslow Import (ONI) transmission interface. This can also have interactions with the Cape Breton Export (CBX) transmission interface. Both the ONI and CBX have Interconnection Reliability Operating Limits associated with them. IR579's output also affects the Onslow South (ONS) transmission interface. This interface represents generation coming into Metro area with a portion heading towards the Western NS.

The above mentioned interfaces (CBX, ONI, and ONS) have insufficient firm capacity to accommodate IR579 at its full output under stressed conditions; even with neighbouring Energy Resource Interconnection Service (ERIS) generation curtailed. Note 4 in Table 3 indicates the maximum output levels that were possible under the various dispatches.

At the time of this study, the maximum rates for IR579 during peak stressed periods, without Network Upgrades, is 41 MW charging and 30 MW discharging. Various element overloads at rates beyond these are listed in Table 4 and the existing line ratings are shown in Table 5 and Table 6.

Table 3: Base case dispatch

Case	NS load	IR579	Wind[3]	NS/NB	Maritime Link	CBX[2]	ONI[2]	ONS[2]	M @ H[2]	H fr[2]
LL01-1	767	-	196	500	-475	537	642	107	240	323
LL01-2	967	-200	196	500	-475	691	620	85	324	379
LL01-3	767	250	102	500	-475	540	863	328	254	328
LL02-1	767	-	29	-	-330	350	365	310	156	255
LL02-2	967	-200	29	-	-330	469	365	310	217	318
LL02-3[4]	767	52	26	-	-330	350	413	358	158	257
LL03-1	767	-	196	-200	100	3	64	232	-7	82
LL03-2	967	-200	196	-200	100	81	18	186	31	121
LL03-3[4]	767	145	172	-200	100	-61	111	280	-36	53
SP01-1	1,469	-	196	500	-475	1,039	1,223	626	555	498
SP01-2	1,669	-200	196	500	-475	1,149	1,129	532	605	551
SP01-3[4]	1,469	64	172	500	-475	1,039	1,263	666	559	502
SP02-1	1,469	-	469	500	-475	818	1,097	546	436	352
SP02-2	1,669	-200	469	500	-475	1,001	1,073	522	529	458
SP02-3[4]	1,469	240	324	500	-475	818	1,269	718	448	364
SP03-1	1,469	-	196	500	-	731	933	336	427	298
SP03-2	1,604	-200	196	500	-	905	901	303	518	393
SP03-3	1,404	250	196	500	-	730	1,171	574	435	306
SP04-1	1,469	-	196	-	-475	662	712	622	358	263
SP04-2	1,604	-200	196	-	-475	864	712	622	468	341
SP04-2b[4]	1,444	-41	196	-	-475	750	766	677	406	305
SP04-3[4]	1,404	235	127	-	-475	662	939	849	366	271
SP05-1	1,469	-	196	-300	-475	452	459	667	247	216
SP05-2	1,669	-200	196	-300	-475	583	459	668	322	257
SP05-3[4]	1,609	100	172	-300	-475	452	533	742	252	221
SP06-1	1,469	-	196	-300	100	204	423	631	151	89
SP06-2	1,669	-200	196	-300	100	406	422	631	247	181
SP06-3	1,469	250	115	-300	100	206	641	850	164	101
WP01-1	2,192	-	323	330	-330	1,024	1,222	744	573	476
WP01-2	1,433	-200	294	330	-330	753	821	426	413	270
WP01-3[4]	2,192	103	263	330	-330	1,024	1,265	787	580	484
WP02-1	2,192	-	294	150	-330	1,068	1,231	936	606	511
WP02-2	1,433	-200	294	150	-330	527	604	392	275	228
WP02-3[4]	2,192	69	258	150	-330	1,068	1,264	969	610	515
WP03-1	2,192	-	196	-	-330	976	1,111	941	550	454
WP03-2	1,433	-200	196	-	-330	472	492	416	260	168
WP03-3[4]	2,192	30	196	-	-330	976	1,140	970	551	455
WP04-1	2,192	-	196	-100	-330	864	1,032	938	487	389
WP04-2	1,433	-200	196	-100	-330	419	469	492	223	186
WP04-3[4]	2,192	60	167	-100	-330	864	1,063	968	491	393
WP05-1	2,192	-	489	330	-	915	1,138	691	532	426
WP05-2	1,575	-200	489	330	-	490	606	273	255	246
WP05-3[4]	2,192	198	429	330	-	915	1,271	823	542	437

Note 1: All values are in MW.
Note 2: CBX (Cape Breton Export) and ONI (Onslow Import) are Interconnection Reliability Operating Limit (IROL) defined interfaces. ONS (Onslow South), "M @ H" (Mainland at Hastings), and "H fr" (Hastings from 88S, 5S, & 2S) are System Operating Limit (SOL) defined interfaces.
Note 3: Wind refers to transmission connected wind only.

Note 4: Cases with IR579 not at full capacity are highlighted in yellow.
Note 5: LL: Light Load, SP: Summer Peak, WP: Winter Peak.

The SIS will further investigate the following identified issues regarding ERIS operation of IR579 with the existing Transmission System SPS' (Special Protection Systems):

1. Group 5 (low level) and Group 6 (high level) SPS' operation is impacted by IR579 while charging. The ONI transmission interface is presently measured at Onslow, however when IR579 is charging, the Cape Breton end will have higher generation levels to serve its load. As a result, not enough generation may be rejected during an incident that activates these SPS'.
2. While discharging, IR579 will impact the CBX transmission interface by offsetting Cape Breton generation targeted for rejection in some dispatches. At present, incidents on the 345 kV system at 79N-Hopewell and/or 67N-Onslow may not reject enough generation with the introduction of IR579.

These SPS issues can be resolved by revising the Group 5 and Group 6 SPS' associated with the CBX and ONI interfaces. These are Type 1 SPS' and must be thoroughly studied, presented to NPCC, and approved by NPCC before changes can be implemented.

Table 4: Overloaded elements

#	Element	Cases	Notes
1	Transformer 79N-T81	SP02, SP03, SP06	These cases have high transfers from 50N-Trenton to 1N-Onslow along L6503. Contingencies disrupting this path caused overloads on 79N-T81's transformers as high as 123% over its emergency rating.
2	138 kV lines L6503a & L6503b (1N/51N/50N)	SP02, SP03, SP06, WP05	Contingencies that disrupted flows on L8003 caused overloads on these lines as high as 129% over its emergency rating. L6503a and L6503b constitute the path from 50N-Trenton to 1N-Onslow, with the 49N-Michelin Granton plant separating the two. L6503a is presently near its limit for upgraded capacity. The conductor is already built for a maximum operating temperature of 100°C which provides an emergency summer/winter rating of 352 MW/ 399 MW. This is still insufficient to handle all contingencies that would overload this path.
3	138 kV lines L6507 & L6508 (50N/79N)	SP02, SP03	This case has flows on L6507 and L6508 beyond 50% of their rating. Contingencies affecting either of these lines will cause flows on the other to reach as high as 105% over emergency rating as these lines run in parallel between 50N-Trenton and 79N-Hopewell.
4	138 kV line L6511 (50N/93N)	SP02, SP04, SP06	Contingencies that disrupt the CBX corridor overload this line as high as 101% over emergency rating. L6511, L6552, and L6515 are line segments which form the path from 50N-Trenton to 2C-Hastings.
5	138 kV line L6515 (4C/2C)	SP01, SP02, SP03, SP03, SP04, SP05, SP06, WP01	Contingencies that disrupt the CBX corridor caused overloads as high as 123% on this line.
6	138 kV line L6552 (93N/4C)	SP02, SP03, SP04, SP06	Contingencies that disrupt the CBX corridor caused overloads as high as 129% on this line.

Table 5: Transmission line ratings

NSPI Transmission Line Ratings — Last Updated: 2020-09-01

LINE	STATION	CONDUCTOR Type	Maximum Operating Temp. (Celsius)	SUMMER RATING 25 DEG (MVA)	WINTER RATING 5 DEG (MVA)	BREAKER 100% Name-plate	SWITCH 100% Name-plate	CT RELAYING Ratio	CT RELAYING R.F.	CT RELAYING MVA	CT FULL SCALE METERING Ratio	CT FULL SCALE METERING R.F.	CT FULL SCALE METERING MVA	TRIP MVA
L-6503a	50N Trenton	ACSR 1113 Beaumont	100	320	363	287	287	1000	2	287	1000	1	554	589
	49N/51N Michelin Granton						404				NA			
L-6503b	51N Michelin Granton	ACSR 1113 Beaumont	85	287	335		404				NA			
	1N Onslow					478	287	1200	2.5	717	1200	1	665	449
L-6507	50N Trenton	AACSR 795 Drake	75	216	261	287	287	1200	2	574	1200	1	346	652
	79N Hopewell					478	287	1200	2	574	1200	1	346	652
L-6508	50N Trenton	ACSR 795 Drake	75	216	261	278	278	1200	2	574	1200	1	346	652
	79N Hopewell					478	287	1200	2	574	1200	1	346	652
L-6511	93N Glen Dhu	ACSR 556.5 Dove	60	140	184	478	478	800	2	382	800	2	441	895
	50N Trenton					287	287	600	2	287	800	1	231	895

Table 6: Transmission line ratings (continued)

NSPI Transmission Line Ratings

Last Updated: 2020-09-01

LINE	STATION	CONDUCTOR				BREAKER	SWITCH	CURRENT TRANSFORMER						TRIP MVA
		Type	Maximum Operating Temp. (Celsius)	SUMMER RATING 25 DEG (MVA)	WINTER RATING 5 DEG (MVA)	100% Name-plate	100% Name-plate	RELAYING			FULL SCALE METERING			
								Ratio	R.F.	MVA	Ratio	R.F.	MVA	
L-6515	2C Pt. Hastings	ACSR 556.5 Dove	50	110	165	287	287	600	2	287	600	1	173	560
	4C Lochaber Rd.					191	143	600	2	287	600	1	173	752
L-6552	4C Lochaber Road	ACSR 556.5 Dove	50	110	165	191	143	600	2	287	600	1	173	1470
	93N Glen Dhu					478	478	800	2	382	800	2	441	1470
L-7003	3C Pt. Hastings EHV	ACSR 556 Dove	60	233	307	797	797	500	2	398	1000	1	462	533
	67N Onslow EHV					797	797	500	2	398	1000	1	462	468
L-7004	3C Pt. Hastings EHV	ACSR 556 Dove	60	233	307	797	797	500	2	398	1000	1	462	533
	91N Dalhousie Mountain					797	797	800	2	600	800	1	368	600
L-7019	91N Dalhousie Mountain	ACSR 556 Dove	70	273	345	797	797	800	2	956	800	1	368	600
	67N Onslow EHV					797	797	500	2	398	1000	1	462	469

8.0 Voltage control

NSPI requires ±0.95 net power factor (PF) requirement at the HV terminals of the ICIF substation in addition to producing/absorbing reactive power at all production levels up to its full rated output.

IR579's Tesla Powerstages use current-limited, bi-directional inverters, capable of full four-quadrant operation at nominal voltage; however, they are only capable of >0.99 PF at full output. As a result, supplementary reactive support will be required at the low voltage terminals of the substation step-up transformers to meet NSPI's requirements. The power capability curve for a single Powerstage is shown in Figure 2: Single Powerstage power capability curve.

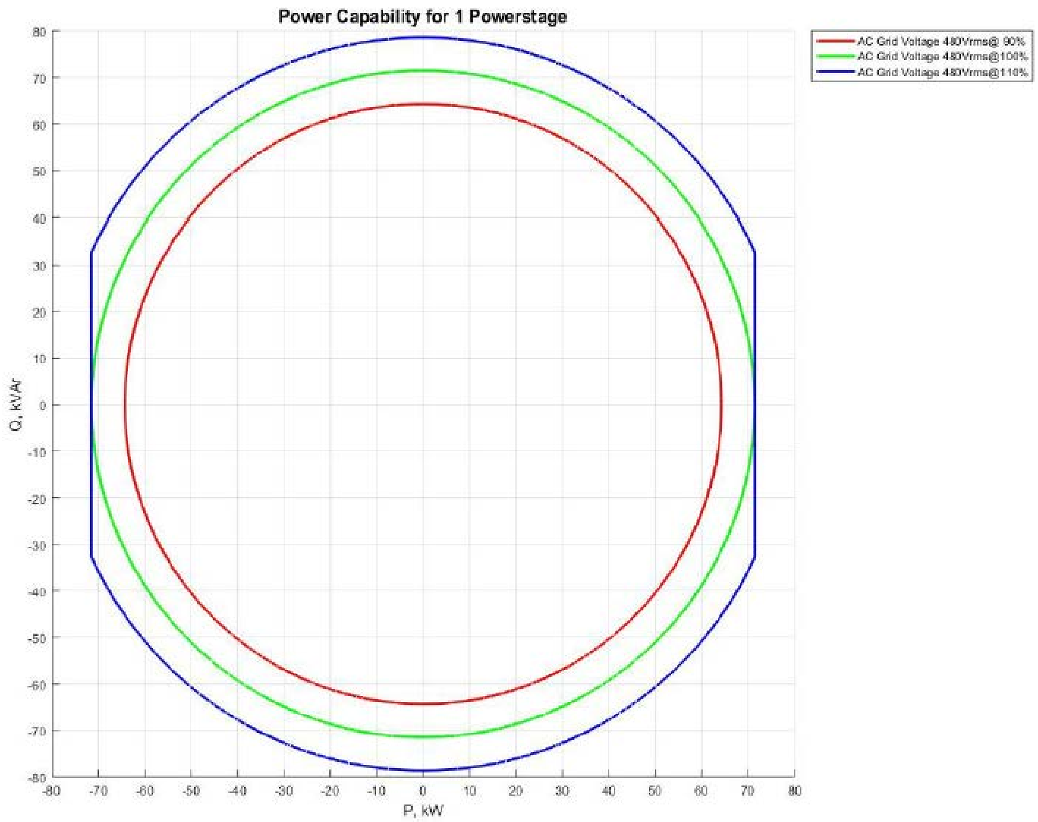

Figure 2: Single Powerstage power capability curve[3]

Net power factor requirements for supplying VARs are met when the batteries are operating just below 221.0 MW *(116.87 MVAR supplied from the machine with 71.50 MVAR calculated at the high side of the substation step-up transformers).* Table 7 lists the power factor calculated at the high side of the substation step-up transformers for output levels from 223 MW to 218 MW, in 0.5 MW increments.

[3] Tesla Megapack Interconnection Data; Supplied by the IC.

Table 7: Power factor at battery output levels 223 MW - 218 MW

Machine terminals		High side of ICIF (supplying VARs)			High side of ICIF (absorbing VARs)			Net power factor requirements met?
MW	MVAR	MW	MVAR	pf	MW	MVAR	pf	
223.00	113.01	221.12	67.30	0.957	219.49	-182.07	0.770	no
222.50	113.99	220.62	68.37	0.955	218.99	-182.37	0.768	no
222.00	114.96	220.12	69.43	0.954	218.50	-182.67	0.767	no
221.50	115.92	219.63	70.47	0.952	218.00	-182.96	0.766	no
221.00	116.87	219.13	71.50	0.951	217.51	-183.26	0.765	no
220.50	117.81	218.63	72.53	0.949	217.01	-183.55	0.764	yes
220.00	118.74	218.14	73.54	0.948	216.52	-183.84	0.762	yes
219.50	119.67	217.64	74.54	0.946	216.02	-184.12	0.761	yes
219.00	120.58	217.14	75.53	0.944	215.52	-184.40	0.760	yes
218.50	121.48	216.65	76.51	0.943	215.03	-184.68	0.759	yes
218.00	122.38	216.15	77.48	0.941	214.53	-184.96	0.757	yes

Supplementary reactive power support will be further investigated in the System Impact Study. One option would be operating lower than the output level stated above.

A centralized controller will be required, which continuously adjusts the individual battery reactive power output within the plant capability limits and regulates the voltage at the low voltage terminal of the substation step-up transformers. The voltage controls must be responsive to voltage deviations, be equipped with a voltage setpoint control, and have facilities that will slowly adjust the setpoint over several (5-10) minutes to maintain reactive power within the individual batteries' capabilities. Details of the specific control features, control strategy, and settings will be reviewed and addressed in the SIS.

The NS Power System Operator must have manual and remote control of the voltage setpoint and the reactive setpoint of this facility to coordinate reactive power dispatch requirements.

This facility must have voltage ride-through capability as detailed in Figure 2 of NERC Standard PRC-024-2 Attachment 2. The SIS will examine the battery/plant capabilities and controls in detail to specify options, controls, and additional facilities that are required to achieve low voltage ridethrough.

9.0 System security

The NSPI Transmission System is required to meet NPCC[4] Bulk Power System (BPS) and NERC[5] Bulk Electric System (BES) performance requirements. Depending on their

[4] Northeastern Power Coordination Council.
[5] North American Electric Reliability Corporation.

BPS/BES classification, new and existing facilities may also be required to meet more stringent requirements for the safe and reliable operation of the power system.

NPCC BPS criteria is performance based, and currently the 138 kV bus at 50N-Trenton is not designated NPCC BPS. The SIS will complete NPCC BPS determination for IR579 and if the BPS status of any existing NSPI substations is impacted.

NERC BES criteria uses a bright line approach with specific inclusions and exclusions[6]. Portions of IR579's ICIF (padmount units, low side and high side buses of the substation step-up transformers, the substation step-up transformers, and equipment up to the 50N-Trenton 138 kV bus) are classified as BES under BES inclusions I2 and I4 and must comply with associated NERC performance and reliability requirements. Figure 3 shows the relevant NERC BES inclusions and Table 8 summarizes the current BPS/BES status of neighbouring system elements.

I2. Generating resource(s) including the generator terminals through the high-side of the step-up transformer(s) connected at a voltage of 100 kV or above with:
   a) Gross individual nameplate rating greater than 20 MVA. Or,
   b) Gross plant/facility aggregate nameplate rating greater than 75 MVA.

I4. Dispersed power producing resources that aggregate to a total capacity greater than 75 MVA (gross nameplate rating), and that are connected through a system designed primarily for delivering such capacity to a common point of connection at a voltage of 100 kV or above. Thus, the facilities designated as BES are:
   a) The individual resources, and
   b) The system designed primarily for delivering capacity from the point where those resources aggregate to greater than 75 MVA to a common point of connection at a voltage of 100 kV or above.

Figure 3: NERC BES inclusions I2 and I4

Table 8: Current BPS & BES classification of neighbouring elements

Neighbouring element classification	NPCC BPS	NERC BES
L6503	yes	yes
L6507	yes	yes
L6508	yes	yes
L6511	no	no
50N-G5 (Trenton 5) & 50N-GT5	no	yes
50N-G6 (Trenton 6) & 50N-GT6	no	yes

[6] Glossary of Terms Used in NERC Reliability Standards; https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf

NS must carry sufficient reserve to cover first contingency loss of its largest generation units. A single breaker connection will add another condition for the NS[7]. IR579 introduces new max online generation continencies, which requires an increase in system reserve (synchronous, 10-minute, and 30-minute). These new contingencies are described below:

1. Sudden loss of IR579 while at full discharge (250 MW).
2. Bus fault where the POI is, while Trenton 6 is at max generation and IR579 is at full discharge (157 MW + 250 MW = 407 MW).

The SIS will also examine the transient response for breaker failure of 50N-604. This is a tie breaker that will result in the loss of 560 MW of generation if Trenton 5, Trenton 6, and IR579 is at full output (Trenton 5: 153 MW + Trenton 6: 157 MW + IR579: 250 MW).

10.0 Expected facilities required for interconnection

The following facilities are required to interconnect IR579 to the NSPI Transmission System via the 138 kV bus at 50N-Trenton under ERIS with the maximum charge and discharge rates detailed in Section 7.0: Thermal limits:

1) Network Upgrades:
    a) P&C modifications at 50N-Trenton.
2) Transmission Provider's Interconnection Facilities (TPIF):
    a) A 138 kV breaker, associated switches, and substation modifications.
    b) A 138 kV transmission line built to NSPI standards from the 50N-Trenton 138 kV bus to the IR579 substation.
    c) Control and communications between the ICIF and the NSPI SCADA and protection system.
3) Interconnection Customer's Interconnection Facilities (ICIF):
    a) Facilities to provide ±0.95 power factor when delivering rated output (250 MW) at the 138 kV bus when voltage is operating between ±5% of nominal. Rated reactive power shall be available through the full range of real power output, from zero to full power.
    b) Centralized controls for voltage setpoint control for the low side of the substation step-up transformers. Fast acting control is required and will include a curtailment scheme, which will limit/reduce total load/output from the facility, upon receipt of a telemetered signal from NSPI's SCADA system.

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[7] NPCC Directory #5: *Reserve*

c) Control systems allowing NSPI to have supervisory and control of this facility via the centralized controller. This will permit the NS Power System Operator to raise/lower the voltage setpoint, change the status of reactive power controls and change the real/reactive power remotely. NSPI will also have remote manual control of the load curtailment scheme.

d) 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.

e) Real-time telemetry will include MW, MVAR, bus voltages, curtailment state, and state of charge.

f) Voltage ridethrough capability as detailed in Figure 2 of NERC Standard PRC-024-2 Attachment 2. As well as operation within NSPI's continuous nominal voltage range (0.95 to 1.05 PU voltage) and during stressed (contingency) conditions (0.90 to 1.10 VPU).

g) Frequency ridethrough capability in accordance with NERC Standards PRC-024 and PRC-006-NPCC-2. The facility shall have the capability of riding through a rate of change of frequency of 4 Hz/s as well as continuous operation in the 59.5 Hz to 60.5 Hz frequency range.

h) 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 rejection schemes.

i) The facility must use equipment capable of closing a circuit breaker with minimal transient impact on system voltage and frequency (matching voltage within ±0.05 PU and phase angle within ±15º).

j) The facility must maintain operation at ambient temperatures as low as -30ºC.

10.1 Estimated Network Upgrades for IR579 at full charge/discharge rate

Due to existing insufficient firm capacity on the transmission corridor between Onslow and Cape Breton, significant Network Upgrades are required to permit IR579 operation at full charge/discharge rates at peak stressed conditions.

This report studied IR579 as ERIS. Under this scope, the Network Upgrades to allow full output of IR579 are identified below. However, as stated in Section 7.0: Thermal limits, IR579 can forgo the Network Upgrades if it is operated at the restricted output. Conversely, if IR579 was studied under NRIS, the following upgrades for full charge/discharge rates will be explored in greater detail in the SIS:

1. Transformer 79N-T81 overload:

   1.1. Expand the 79N-Hopewell substation to include a ring bus and additional 345 - 138 kV transformer. This will also require changes to the Group 5 and Group 6 SPS, pending NPCC approval.

2. 138 kV lines L6503a and L6503b overload:
    2.1. Additional transmission capacity must be added at/near 50N-Trenton to handle overloads on this transmission path since L6503a is near its max upgradable rating (the conductor is already built at 100°C max operating temperature).
    2.2. Replace two existing 1,200 A line switches at 1N-Onslow with 1,700 A line switches.
    2.3. Replace two existing 1,200 A line switches at 50N-Trenton with 1,700 A line switches.
    2.4. Replace the existing 1,200 A breaker at 50N-Trenton for L6503a with a 1,700 A breaker.
3. 138 kV lines L6507 and L6508 overload:
    3.1. Uprate L6507 conductor from 75°C to 100°C (approx. 22 km).
    3.2. Uprate L6508 conductor from 75°C to 100°C (approx. 22 km).
4. 138 kV line L6511 overload:
    4.1. Uprate conductor from 60°C to 70°C (approx. 37 km).
5. 138 kV line L6515 overload:
    5.1. Uprate conductor from 50°C to 70°C (approx. 51 km).
    5.2. Replace eight existing 600 A line switches at 4C-Lochaber Rd with 1,000 A line switches.
6. 138 kV line L6552 overload:
    6.1. Uprate conductor from 50°C to 70°C (approx. 19 km).
    6.2. Line switch upgrades are covered in the L6515 line overload work.

11.0 NSPI Interconnection Facilities and Network Upgrades cost estimate

The present day high level, non-binding cost estimate, excluding HST, for Energy Resource Interconnection Service to IR579 at the reduced charging/discharging rates stated in Section 7.0 is shown in Table 9: ERIS cost estimate. This estimate assumes there is adequate space for new equipment and modifications. This does not include any TBD costs to address any stability issues identified at the SIS stage, based on dynamic analysis.

Note that the proposed TPIF requires more detailed design work that is not in scope for this FEAS. Below are a few issues that could significantly impact the estimate for this project:

- The requirement for easements and structure relocations.

- The proposed conductor, 1272 ACSR Bittern, is not a standard NPSI conductor size and may require reinforced structures. 1113 ACSR Beaumont was used for estimation purposes in this project.
- The 50N-Trenton substation is congested and issues with implementation may be discovered. No major issues were found in this preliminary review, however detailed design could potentially find issues resulting in increased scope.

Table 9: ERIS cost estimate

Item	Network Upgrades	Estimate
I	P&C modifications at 50N-Trenton.	$200,000
	Sub-total	**$200,000**

	TPIF	Estimate
I	Modifications at 50N-Trenton, including a new 138kV breaker, switches and associated equipment.	$1,200,000
II	Transmission line from 50N-Trenton to the PCO.	$470,311
III	P&C relaying equipment.	$100,000
IV	NSPI supplied RTU.	$59,171
V	Teleprotection and SCADA communications via overhead fibre from 50N-Trenton.	$131,688
	Sub-total	**$1,961,170**

Determined costs	
Subtotal	$2,161,170
Contingency (10%)	$216,117
Total of determined cost items	$2,377,287

Item	To Be Determined costs	Estimate
I	Preliminary engineering estimation for the transmission line from 50N-Trenton to the PCO.	TBD (SIS)
II	System additions to increase IR579 output capability as listed in Section 10.1: Estimated Network Upgrades for IR579 at full charge/discharge[1].	TBD (SIS)
III	Impacts to the Group 5 and Group 6 SPS.	TBD (SIS)

Note 1: Typical thermal rating upgrades are around $150,000 / km at the 138 kV voltage level.

The estimated time to construct the Network Upgrades and Transmission Provider's Interconnection Facilities is 18-24 months after receipt of funds.

12.0 Loss factor

The Loss Factor utilized in this study is based on the peak load hour of the Nova Scotia transmission and distribution system and is used only for comparison purposes.

Loss factor is calculated by running the winter peak load flow case with and without the new facility in service, while keeping 91H-Tufts Cove as the NS Area Interchange bus. This methodology reflects the load centre in and around 91H-Tufts Cove. A negative loss factor reflects a reduction in system losses.

A constrained output, 30 MW, was used for loss factor analysis instead of the IR579's full capacity because there is insufficient transmission capacity. When IR579 is at its full output at winter peak, existing corridors (Onslow Import and Onslow South) will be loaded beyond their limits.

With IR579 in service at its constrained output (30 MW), the loss factor is calculated as 9.74% at the POI. This preliminary loss factor excludes losses associated with the TPIF, substation step-up transformers, and generation facility.

Table 10: 2022 loss factor while discharging

	Discharging (MW)
IR578 @ POI	30.00
TC3 w/ IR578	72.98
TC3 w/o IR578	100.14
Delta	2.84
2022 loss factor	9.47%

13.0 Preliminary scope of subsequent SIS

The SIS will be conducted in accordance with the GIP with the assumption that all appropriate higher-queued projects will proceed, and the facilities associated with those projects are installed. It will provide a more comprehensive assessment, based on NSPI, NPCC, and NERC criteria, of the technical issues and requirements to interconnect the proposed facility as requested.

The assessment will consider, but not be limited, to the following:

- Contingency analysis for both steady state and system stability.
- Ride-through and operation following a contingency (n-1 operation).
- The minimum transmission additions/upgrades that are necessary to permit operation of this generating facility, under all dispatch conditions, for relevant first contingencies.
- Options and ancillary equipment that the customer must install to control flicker, voltage and ensure that the required ride-through capability.
- Identify guidelines and restrictions applicable following a first contingency (curtailments, etc.).
- Loss Factor.

- Determination of BPS designation.
- Changes to SPS schemes required for operation of this generating facility
- Under-frequency load shedding.
- Facilities that the customer must install to meet the GIP requirements.

Parameters for a generic model must be supplied by the Interconnection Customer for transient analysis in PSS/e.

Any changes to SPS schemes required for operation of this generating facility, in addition to existing generation and facilities that can proceed before this project, will be determined by the SIS as well as any required additional transmission facilities. The determination will be based on NERC[8] and NPCC[9] criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

A thorough assessment will be provided to ensure that the facilities will meet applicable NSPI, NPCC and NERC transmission design criteria.

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[8] NPCC Directory #1: *Design and Operation of the Bulk Power System*
[9] NERC Reliability Standard TPL-001-4: *Transmission Operations*