Interconnection Feasibility Study Report
GIP-IR602-FEAS-R1

Generator Interconnection Request 602
78 MW Wind Facility
Victoria County, NS

2021-10-05

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 78 MW wind generation facility interconnected to the NSPI system as Network Resource Interconnection Service *(NRIS)*.

This project is designated as Interconnection Request #602 in the NSPI Interconnection Request Queue and will be referred to as IR602 throughout this report. IR602's proposed Commercial Operation Date is 2023/12/01.

The Interconnection Customer *(IC)* selected L6537, 0.6 km from the 5S-Glen Tosh substation as the Point Of Interconnection *(POI)*. The IC's substation will be located immediately adjacent to the POI using a direct line tap with transfer trip protection. This will be confirmed in the SIS, when NPCC BPS categorization testing is performed.

There are two relevant long-term firm Transmission Service Reservations *(TSR)* in the System Impact Study *(SIS)* stage with a requested in-service 2025/01/01 date in the Transmission Service Queue. These are TSR411 *(800 MW from NB to NS)* and TSR412 *(500 MW from NFLD 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.*

Based on the information provided by the IC, this feasibility assessment presents the following findings:

- There are no concerns regarding increased short circuit levels. The increase in short circuit level is still within the capability of neighbouring breakers. The minimum short circuit level at the Interconnection Facility's *(IF)* high side bus is 311 MVA with L6537 open ended at the 5S-Glen Tosh substation. The IC should discuss wind turbine design with Vestas for low Short Circuit Ratio *(SCR)* as this scenario results in a calculated 3.99 SCR at IR602's high side bus.

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

- Voltage flicker will be examined when data is made available for the SIS. Type 4 wind turbines, like the Vestas V162 used in this IR, are not expected to introduce significant voltage flicker under minimum generation conditions.
- Power factor correction for IR602 is required to meet NSPI's ±0.95 net power requirements at the IF 138 kV bus. This is in situations when the wind facility is operating near max output and full reactive power is required.
- Portions of IR602 are categorized as NERC Bulk Electric System *(BES)* under NERC BES inclusion criteria I4. This includes its generating resources and the portions where its generating resources aggregate to ≥75 MVA.
- Presently L6537 is categorized as BPS however complete transient and steady-state testing in the System Impact Study *(SIS)* stage will determine if the POI is categorized as BPS. If the POI is categorized as BPS, the interconnection method will be re-assessed.
- The preliminary loss factor is calculated as 21.28% with IR602 modelled in the winter peak case with Wreck Cove running at near full output. When Wreck Cove is offline, the loss factor is 11.39%.

This study's power flow analysis identified transmission contingencies inside Nova Scotia which would violate thermal loading criteria. The necessary Network Upgrades required for NRIS operation are:

- L6537 *(2C-Hastings/67C-Whycocomagh Tap, 55.6 km)*: Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537
- L6537 *(67C-Whycocomagh Tap/104S-Baddeck, 25.3 km)*: Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537
- L6537 *(104S-Baddeck/IR602 POI, 12.4 km)*: Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537
- L6537 *(IR602 POI/5S-Glen Tosh, 0.6 km)*: Build new 138kV line parallel to L6537 with Dove 80˚C to replace L6537
- L6538 *(5S-Glen Tosh/3S-Gannon Road, 34.5 km)*: Build new 138kV line parallel to L6538 with Drake 90˚C to replace L6538
- Upgrade 2C-Hastings metering from 231 MVA full scale limit
- Replace two 800 A breakers at 5S-Glen Tosh with 2,000 A breakers
- Upgrade 5S-Glen Tosh metering from 231 MVA full scale limit

The preliminary non-binding cost estimate for interconnecting IR602 to L6537 as Network Resource is $73,986,000. $1,100,000 of this amount is the TPIF costs, with the remainder as the Network Upgrade costs. These amounts include a 10% contingency. This estimate will be further refined in the SIS and Facility *(FAC)* studies.

The estimated time to construct the Network Upgrades and TPIF for NRIS operation is 24-36 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 78 MW wind generation facility interconnected to the NSPI system as Network Resource Interconnection Service (NRIS).

This project is listed as Interconnection Request #602 in the NSPI Interconnection Request Queue and will be referred to as IR602 throughout this report. The proposed Commercial Operation Date is 2023/12/01.

The Interconnection Customer *(IC)* identified L6537 as the Point Of Interconnection *(POI)*, 0.6 km from the 5S-Glen Tosh substation. This wind generation facility will be interconnected to the POI from the Point of Change of Ownership *(PCO)* via a 75 m long 138 kV transmission line. Figure 1 shows the approximate geographic location of the proposed POI and Figure 2 shows the approximate electrical location.

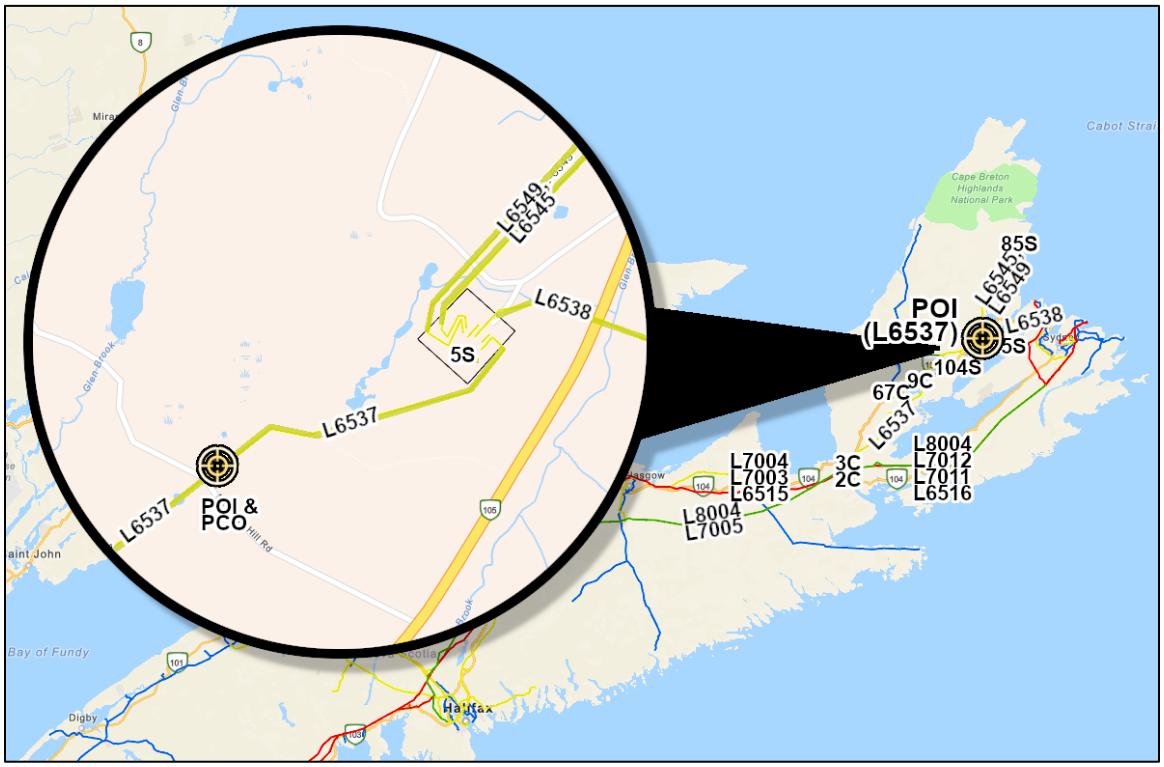

Figure 1: IR602 approximate geographic location

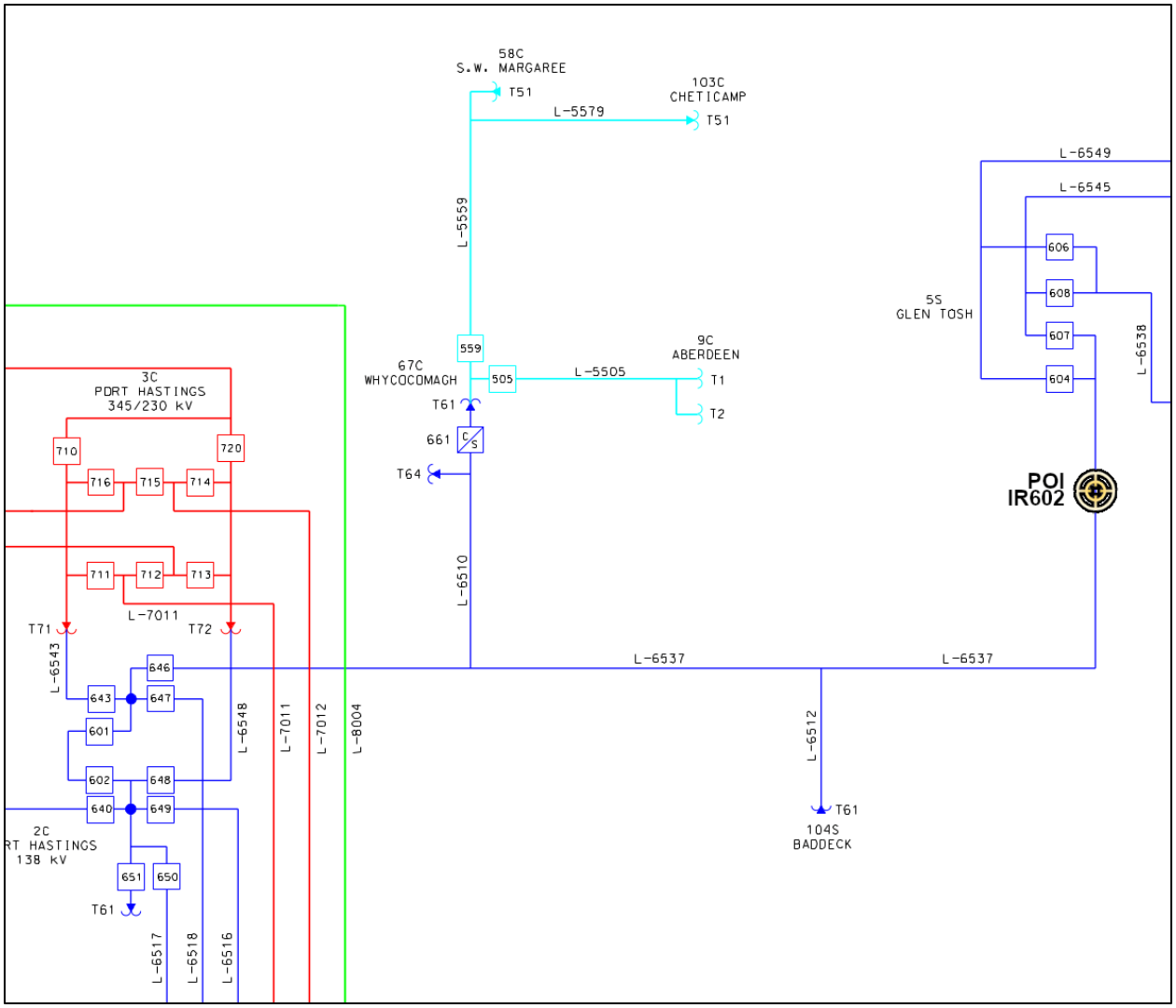

Figure 2: IR602 Point Of Interconnection

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 wind generation facility to the NSPI Transmission System at the designated location based on single contingency criteria.

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.
- 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 with 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. Network Resource Interconnection Service *(NRIS)* per section 3.2 of the Generation Interconnection Procedures *(GIP)*.
2. Commercial Operation date: 2023/12/01.
3. The Interconnection Facility consists of 13 Vestas V162-6.0 MW wind energy converters, totalling 78 MW. These are modelled as Type 4 inverter based generators, split between two collector circuits.
4. The IC identified the POI at L6537, a 138 kV line, approximately 0.6 km from the 5S-Glen Tosh substation. IR602 will be interconnected via a direct line tap with Transfer Trip protection.
5. The ICIF *(Interconnection Customer Interconnection Facility)* substation will be located adjacent and connected to the POI via 75 m of 556 ACSR Dove conductor.
6. Preliminary data was provided by the IC for the substation step-up transformer and generator step-up transformers.
   6.1. The substation step-up transformer is modelled as one 138 kV - 34.5 kV transformer rated at 54/72/90 MVA, with a positive sequence impedance of 7% and 20 X/R ratio. The transformer has a grounded wye-delta-wye winding configuration with ±10% fixed taps.
   6.2. The generator step-up transformers were modelled as an equivalent transformer based off 13 *(thirteen)* 34.5 kV - 0.720 kV 7.0 MVA transformers, with a 9.9% positive sequence impedance and an assumed 13.0 X/R ratio.
7. An assumed collector circuit layout is used, based off the site plan included in the application, since a detailed collector circuit design was not provided. Note the plant's

net real and reactive power measured at the POI will be impacted by losses through the transformers and collector circuits.

8. 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.
9. Cape Breton generation was displaced by IR602.
10. The transmission line ratings for L6537, L6538, and L6539 as listed in Table 1.

Table 1: Transmission line ratings

NSPI Transmission Line Ratings Last Updated: 2021-08-27

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-6537	5S Glen Tosh	ACSR 556.5 Dove	60	140	184	191	287	800	2	382	800	1	231	293
	2C Pt. Hastings					287	287	600	2	287	800	1	231	495
L-6538	5S Glen Tosh	Spec. Galv. Steel/ ACSR 556.5 Dove	50	110	165	191	287	600	2	287	600	1	173	114
	3S Gannon Rd.					353	287	600	2	287	600	1	173	555
L-6539	3S Gannon Rd	ACSR 556.5 Dove	100	215	242	287	287	600	2	287	600	1	173	659
	2S Victoria Junction					191	287	600	2	287	400	1	115	768

4.0 Project queue position

All in-service generation is included in this FEAS.

As of 2021/09/03, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are included in 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: FAC in progress
- IR595: SIS complete

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

- TSR 400: System upgrades in progress
- TSR 411: SIS in progress
- TSR 412: SIS in progress
- TSR 413: Accepted application

TSRs 411 and 412 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

IR602 will not impact neighbouring breaker's interrupting capability based on this study's short circuit analysis. Analysis was performed using PSS/e 34.8, classical fault study, flat voltage profile at 1.0 PU voltage, and 3LG faults.

The maximum design interrupting capability of the neighbouring 138 kV circuit breakers is at least 5,000 MVA. The Vestas V162 PSS/e User Manual specified the wind turbine generators contribute a maximum of 1.2 PU during a fault. The short circuit levels in the area before and after this development are provided in Table 2: *Short circuit levels, 3-ph, in MVA*.

The IC should discuss wind turbine design with Vestas for low SCR *(Short Circuit Ratio)* levels. Minimum fault levels occur when L6537 is open at the 5S-Glen Tosh end. In this

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

scenario, the SCR is calculated to be 3.99 at the high voltage terminals of IR602's substation step-up transformer. The SCR is 7.45 when all transmission elements are in service. The SCR will be lower at the generator terminals due to losses associated with the substation step-up transformer, collector circuit, and generator step-up transformers.

The SCR may change when a more detailed collector circuit design is submitted. This study used an assumed collector circuit layout, that followed roads on the geographic site layout.

Table 2: Short circuit levels, 3-ph, in MVA

Location	IR602 not in service	IR602 in service	Post % increase
2023, max generation, all facilities in service			
2C-Hastings:138 kV bus	2,558	2,569	0%
67C-Whycocomagh:138 kV bus	1,012	1,032	2%
104S-Baddeck:138 kV bus	1,114	1,156	4%
5S-Glen Tosh:138 kV bus	1,311	1,383	5%
IR602-hv:138 kV bus	1,299	1,371	6%
IR602-mv:34.5 kV bus	484	565	17%
2023, min generation, all elements in service			
2C-Hastings:138 kV bus	1,254	1,296	3%
67C-Whycocomagh:138 kV bus	617	660	7%
104S-Baddeck:138 kV bus	578	637	10%
5S-Glen Tosh:138 kV bus	581	653	12%
IR602-hv:138 kV bus	581	653	12%
IR602-mv:34.5 kV bus	332	412	24%
2023, min generation, L6537 open at 2C-Hastings			
2C-Hastings:138 kV bus	1,218	1,238	2%
67C-Whycocomagh:138 kV bus	267	305	14%
104S-Baddeck:138 kV bus	324	381	18%
5S-Glen Tosh:138 kV bus	364	436	20%
IR602-hv:138 kV bus	362	434	20%
IR602-mv:34.5 kV bus	247	327	33%
2023, min generation, L6537 open at 5S-Glen Tosh			
2C-Hastings:138 kV bus	1,218	1,280	5%
67C-Whycocomagh:138 kV bus	446	514	15%
104S-Baddeck:138 kV bus	345	416	21%
5S-Glen Tosh:138 kV bus	364	366	0%
IR602-hv:138 kV bus	311	383	23%
IR602-mv:34.5 kV bus	222	302	36%

6.0 Voltage flicker & harmonics

Voltage flicker will be examined when data is made available for the SIS. However, Type 4 wind turbines, like the Vestas V162's used in IR602, are not expected to introduce significant voltage flicker under minimum generation conditions.

NS Power's voltage flicker requirements are:

- $P_{st} \leq 0.25$
- $P_{lt} \leq 0.35$

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

The steady state contingencies evaluated in this study indicate IR602 requires significant Network upgrades beyond the POI to operate at its full 78 MW capacity under NRIS.

Base cases used in this study are listed in Table 3: *Base case dispatch*. They were selected to examine conditions in which Cape Breton and mainland corridors were stressed as well as transmission in the surrounding area. Generation dispatch also reflected import and export scenarios expected from flows associated with the Maritime Link Transmission Service Reservation.

Table 3: Base case dispatch

Case name	NS load	IR status	Wind	NS/NB	ML	CBX	ONI	ONS	East end exp @ Sydney	Hastings fr	Highlands exp	Mainland @ Hastings
sp01-1	1,401	-	122	330	-475	971	1,006	572	207	401	-4	524
sp01-2	1,401	78	200	330	-475	971	1,006	572	131	334	-4	533
sp02-1	1,548	-	122	-	-475	841	883	782	284	516	115	432
sp02-2	1,548	78	200	-	-475	841	883	782	209	450	115	440
sp03-1	1,372	-	344	330	-475	868	822	426	92	343	144	477
sp03-2	1,363	78	422	330	-475	868	822	426	19	276	144	484
sp04-1	1,545	-	122	-	-475	749	796	695	344	590	173	353
sp04-2	1,545	78	200	-	-475	749	796	695	271	524	173	361
sp05-1	1,538	-	122	-	-475	727	775	674	335	460	163	377
sp05-2	1,538	78	200	-	-475	727	775	674	261	394	163	385
sp06-1	1,554	-	122	-	-475	758	805	704	235	494	85	376
sp06-2	1,554	78	200	-	-475	758	805	704	160	428	85	384
wp01-1	2,310	-	175	150	-320	912	1,120	791	425	497	201	499
wp01-2	2,310	78	253	150	-320	912	1,120	791	352	431	201	506
wp02-1	2,210	-	72	150	-320	998	1,119	790	425	482	201	569
wp02-2	2,210	78	150	150	-320	999	1,119	790	352	416	201	577
wp03-1	2,370	-	235	150	-320	851	1,063	792	425	512	201	453
wp03-2	2,370	78	313	150	-320	851	1,063	792	352	447	201	460
wp04-1	2,310	-	75	-	-475	1,004	1,109	930	379	563	201	547
wp04-2	2,310	78	153	-	-475	1,004	1,109	930	306	497	201	555
wp05-1	2,201	-	75	-	-475	1,002	1,107	929	273	480	201	569
wp05-2	2,201	78	153	-	-475	1,003	1,107	929	200	415	201	576
wp06-1	2,370	-	75	-	-475	992	1,102	924	430	606	201	527
wp06-2	2,370	78	153	-	-475	992	1,102	924	357	540	201	535
wp07-1	2,093	-	75	-	-475	1,005	1,150	972	273	481	201	572
wp07-2	2,093	78	153	-	-475	1,005	1,150	972	200	416	201	579
wp08-1	2,198	-	75	-	-475	1,013	1,158	980	386	568	201	554
wp08-2	2,198	78	153	-	-475	1,013	1,158	980	313	502	201	562
wp09-1	2,210	-	66	150	-475	1,150	1,239	910	425	560	201	644
wp09-2	2,210	78	144	150	-475	1,150	1,239	910	352	494	201	651

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.
Note 3: Wind refers to only transmission connected wind.

The addition of IR602 operating at full output in most cases with the 85S-Wreck Cove plant at moderate to high levels resulted in overloads of L6537 or L6538's 110% seasonal ratings. The maximum overloads are listed in Table 4: Maximum overloads.

IR602 is situated on one of the two paths that generation from the 85S-Wreck Cove hydro plant can follow. These lines are L6537 *(IR602's POI)* and L6538, which both have 5S-Glen Tosh as one of their endpoints.

L6537, the line selected for IR602's POI, runs from 2C-Hastings:138 kV to 5S-Glen Tosh with 67C-Whycocomagh and 104S-Baddeck tapped in between.

L6538 presently has an SPS *(Special Protection System)* that uses protective overcurrent relays to prevent conductor damage, primarily at its Bras d'Or Lake crossing. With IR602 at its full output, pre-contingency flows in over half of the cases exceed present L6538's max 114 MVA capability. Presently, flows above the 114 MVA require reduction in line flow, typically by reducing Wreck Cove, or the SPS will trip a unit, followed by tripping L6538 breakers at 5S-Glen Tosh if flows are still above 114 MVA.

Table 4: Maximum overloads

Line	Line segment	Max overload % *(above 110%)*	Case	Contingency
L6537	104S-Baddeck / IR602	Summer: 162% Winter: 137%	Summer: SP04-2 Winter: WP01-2	Summer: 5S_L-6538 Winter: 5S_L-6538
L6538	5S-Glen Tosh / 3S-Gannon Rd	Summer: 194% Winter: 202%	Summer: SP04-2 Winter: WP01-2	Summer: 2C-B61 Winter: 2C-B61

In order to accommodate IR602, as NRIS generation, while maintaining existing corridor flows, the system will require the significant Network Upgrades listed in Table 5: IR602 Network Upgrades.

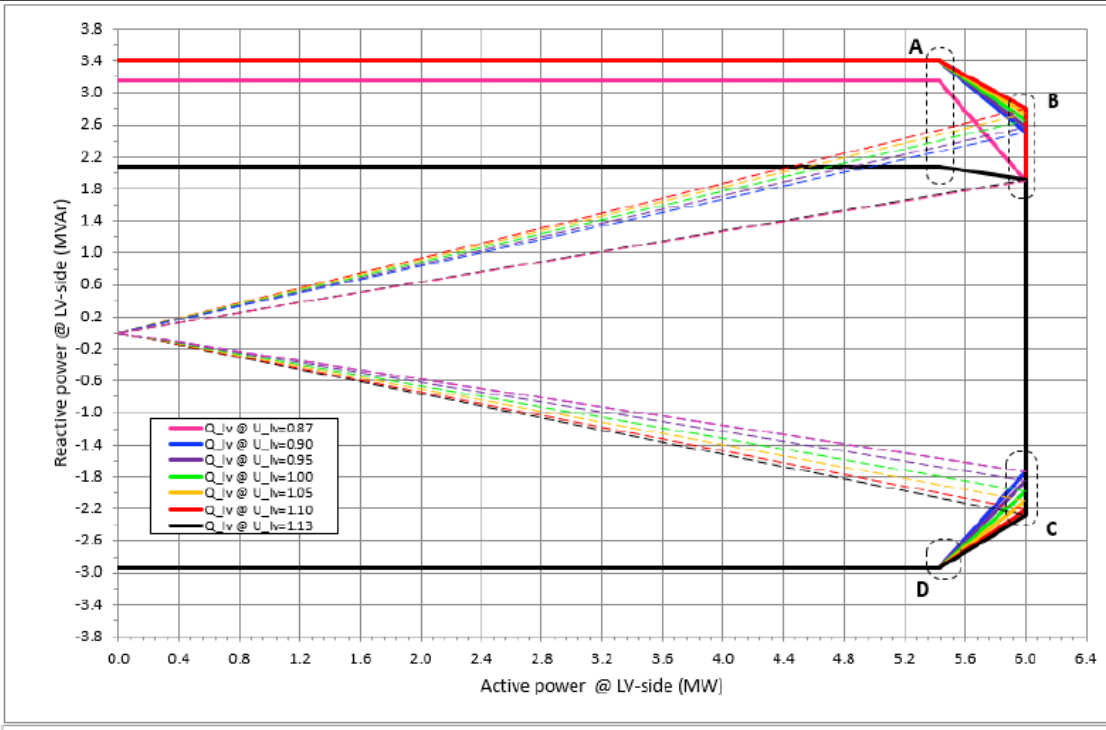
Table 5: IR602 Network Upgrades

Line	Segment	Length (km)	Upgrades
L6537	*2C-Hastings / 67C-Whycocomagh Tap*	55.6	• **Line**: Build new line parallel to L6537 to go from Dove @ 60°C to Drake @ 90°C max operating temperature. • **Metering**: Upgrade metering from present 231 MVA full scale limit.
L6537	*67C-Whycocomagh Tap / 104S-Baddeck*	25.3	• **Line**: Build new line parallel to L6537 to go from Dove @ 60°C to Drake @ 90°C max operating temperature.
L6537	*104S-Baddeck / IR602 POI*	12.4	• **Line**: Build new line parallel to L6537 to go from Dove @ 60°C to Drake @ 90°C max operating temperature.
L6537	*IR602 POI / 5S-Glen Tosh*	0.6	• **Line**: Build new line parallel to L6537 to go from Dove @ 60°C to Dove @ 80°C max operating temperature. • **Breaker**: Replace two existing 5S-Glen Tosh 800 A breakers with 2,000 A breakers. • **Metering**: Upgrade metering from present 231 MVA full scale limit.
L6538	*5S-Glen Tosh / Bras d'Or Lake crossing / 3S-Gannon Rd*	34.5	• **Line**: Build new line parallel to L6537 to go from Dove @ 50°C to Drake @ 90°C max operating temperature.

8.0 Voltage control

IR602 requires power factor correction to meet NS Power's ±0.95 net power factor requirement at the HV terminals of the ICIF substation.

Using the Vestas reactive power capability, shown in Figure 3: *Vestas V162 6.0 MW reactive power capability*, various levels were calculated and are displayed in Table 6: *Power factor analysis results*.



		Coordinates								Power factor	
	Point:	A		B		C		D		B (Capacitive)	C (Inductive)
	Coordinate:	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)		
	Reactive power [kVAr] @ LV side @ U_lv = 0.87 p.u. voltage	5.430	3.160	6.000	1.900	6.000	-1.739	5.430	-2.933	0.953	0.960
	Reactive power [kVAr] @ LV side @ U_lv = 0.90 p.u. voltage	5.430	3.400	6.000	2.503	6.000	-1.739	5.430	-2.933	0.923	0.960
	Reactive power [kVAr] @ LV side @ U_lv = 0.95 p.u. voltage	5.430	3.400	6.000	2.584	6.000	-1.856	5.430	-2.933	0.918	0.955
	Reactive power [kVAr] @ LV side @ U_lv = 1.00 p.u. voltage	5.430	3.400	6.000	2.664	6.000	-1.987	5.430	-2.933	0.914	0.949
	Reactive power [kVAr] @ LV side @ U_lv = 1.05 p.u. voltage	5.430	3.400	6.000	2.736	6.000	-2.093	5.430	-2.933	0.910	0.944
	Reactive power [kVAr] @ LV side @ U_lv = 1.10 p.u. voltage	5.430	3.400	6.000	2.807	6.000	-2.213	5.430	-2.933	0.906	0.938
	Reactive power [kVAr] @ LV side @ U_lv = 1.13 p.u. voltage	5.430	2.000	6.000	1.916	6.000	-2.283	5.430	-2.933	0.952	0.935

Figure 3-2: Reactive power capability

Figure 3: Vestas V162 6.0 MW reactive power capability[3]

As seen in Table 6, IR602 does not meet NS Power's ±0.95 net power factor requirement when producing VARs while operating at its max real power output. The Vestas technical bulletin's reactive power capability, shown in Figure 3, shows that the reactive power

[3] Vestas Performance Specification V162-6.0 MW, Document no: 0098-0840 V04, 2021/04/14.

capability is slightly reduced as real power output reaches its max *(regions A-B, and C-D)*.

Table 6: Power factor analysis results *(@ 1.0 VPU)*

Breakpoints on Vestas reactive capability curve	IR602 output				Measurements at the HV terminals of the ICIF substation				Meets net 0.95 pf requirement ?
	MW	MVAR	MVA	pf	MW	MVAR	MVA	pf	
A	70.59	44.20	83.29	0.848	68.24	24.36	72.46	0.942	Yes
B	78.00	34.63	85.34	0.914	75.32	12.58	76.37	0.986	No
C	78.00	-25.83	82.17	0.949	75.64	-45.57	88.31	0.857	Yes
D	70.59	-38.13	80.23	0.880	68.14	-58.58	89.86	0.758	Yes

The net power factor will be re-evaluated when detailed information on the transformers and collector circuit is provided in the SIS stage.

A centralized controller will be required, which continuously adjusts the individual generator reactive power output within the plant capability limits and regulates the voltage at the low voltage terminal of the ICIF transformer. 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 NSPI 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 the NS Power Transmission System Interconnection Requirements *(TSIR)*[4]. The SIS will examine the 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

Transmission System Elements may be required to meet NPCC[5] BPS *(Bulk Power System)* or NERC[6] BES *(Bulk Electric System)* requirements.

NPCC BPS categorization is performance based. At the time of this study, the POI line L6537, is categorized NPCC BPS and NERC BES. The complete determination on

[4] NS Power Transmission System Interconnection Requirements; https://www.nspower.ca/oasis/standards-codes
[5] Northeastern Power Coordination Council.
[6] North American Electric Reliability Corporation.

segment for IR602's POI *(between 104S-Baddeck tap and 5S-Glen Tosh)* will be performed in the SIS, during the complete transient and steady-state testing[7]. Regardless of BPS categorization, IR602's protection systems must comply with NPCC Directory 4: System Protection Criteria.

NERC BES criteria is bright-line based and portions of IR602 will be categorized as NERC BES, due to BES inclusion criteria I4. The IR602 facilities categorized BES are:

- The individual generating resources *(ex: generators, generator-step-up transformers, ...)*.
- Portions where the generating resources aggregate to ≥75 MVA *(ex: 34.5 kV bus, substation step-up transformer, ...)*

Table 7 summarizes the BPS & BES classification of neighbouring elements and Figure 4 contains the details of BES Inclusion criteria I4.

Table 7: BPS & BES classification of neighbouring elements

Neighbouring element classification	NPCC BPS	NERC BES
IR602	no*	partial
5S-Glen Tosh 138 kV bus	no*	no
9C-Aberdeen 138 kV	no*	no
67C-Whycocomagh 138 kV	no*	no
L6537	yes	yes
2C-Hastings 138 kV bus	yes	yes

* Complete analysis will be performed in the SIS

Unless modified by the lists shown below, all Transmission Elements operated at 100 kV or higher and Real Power and Reactive Power resources connected at 100 kV or higher
...
• 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 4: Appliable NERC BES inclusion criteria I4

As mentioned in Section 7.0, L6538 *(5S-Glen Tosh / 3S-Gannon Rd)* presently has an SPS *(Special Protection Scheme)* designed to protect L6538, specifically the portion that spans that Bras d'Or Lake. At present, flows are restricted to 114 MVA, before action is

[7] Regional Reliability Reference Criteria A-10: *Classification of Bulk Power System Elements*; NPCC.

taken to reduce flows to prevent damage to the conductor. The SIS will examine options for increasing the limitation on this line in greater detail.

10.0 Expected facilities required for interconnection

The following facilities are required to interconnect IR602 to the NSPI system via the to be rebuilt 138 kV line L6537 as NRIS:

1) Network upgrades:

- L6537 *(2C-Hastings/67C-Whycocomagh Tap, 55.6 km)*: Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537
- L6537 *(67C-Whycocomagh Tap/104S-Baddeck, 25.3 km)*: Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537
- L6537 *(104S-Baddeck/IR602 POI, 12.4 km)*: Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537
- L6537 *(IR602 POI/5S-Glen Tosh, 0.6 km)*: Build new 138kV line parallel to L6537 with Dove 80˚C to replace L6537
- L6538 *(5S-Glen Tosh/3S-Gannon Road, 34.5 km)*: Build new 138kV line parallel to L6538 with Drake 90˚C to replace L6538
- Upgrade 2C-Hastings metering from 231 MVA full scale limit
- Replace two 800 A breakers at 5S-Glen Tosh with 2,000 A breakers
- Upgrade 5S-Glen Tosh metering from 231 MVA full scale limit

2) Transmission Provider's Interconnection Facilities *(TPIF)*:

a) Direct line tap with Transfer Trip off L6537, 0.6 km from 5S-Glen Tosh.

b) Control and communications between the ICIF and the NSPI SCADA and protection systems.

3) Interconnection Customer's Interconnection Facilities *(ICIF)*:

a) Facilities to provide ±0.95 power factor when delivering rated output *(78 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 ICIF transformer. Fast acting control is required and will include a curtailment scheme, which will limit/reduce total output from the facility, upon receipt of a telemetered signal from NSPI's SCADA system.

c) NSPI to have supervisory and control of this facility, via the centralized controller. This will permit the NSPI System Operator to raise/lower the voltage setpoint, change the status of reactive power controls, change the real/reactive

power remotely. NSPI will also have remote manual control of the load curtailment scheme.

d) When curtailed, the facility shall offer over-frequency and under-frequency control with ±0.2 Hz deadband and 4% droop characteristic. The active power controls shall also 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, wind speed, and wind direction.

f) Meet the requirements detailed in the NS Power Transmission System Interconnection Requirements *(TSIR)*[8]. Among them is voltage ride-through capability per section 7.4.1 and frequency ride-through per section 7.4.2.

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

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

i) Operation at ambient temperatures as low as -30ºC.

j) The facility must meet NSPI's TSIR *(Transmission System Interconnection Requirements)* as published on the NSPI OASIS site[9].

11.0 NSPI Interconnection Facilities and Network Upgrades cost estimate

The high level, non-binding, cost estimate, excluding HST, for IR602's Network Resource Interconnection Service is shown in Table 8: *NRIS cost estimate*.

This estimate assumes the following:

1. Prolonged outages to L6537 and L6538 result in significant curtailment to the 85S-Wreck Cove generating station's capacity. This capacity is heavily relied on for operations and significant cost would be incurred to replace its capacity with other units. To avoid this, new lines that would eventually replace the existing L6537 and L6538 would be built in parallel and cut over once complete.

[8] NS Power Transmission System Interconnection Requirements; https://www.nspower.ca/oasis/standards-codes

[9] NSPI OASIS site; https://www.nspower.ca/oasis/standards-codes

2. It is feasible to increase L6538's rating by reconductoring and uprating to Drake with max operating temperature of 90°C. Detailed engineering in later study stages may present significant challenges associated with the Bras d'Or water crossing.
3. NPCC BPS testing does not change the categorization of the segment of L6537 that IR602 interconnects at. Complete BPS testing will be performed at the SIS stage.
4. This does not include any TBD costs to address any stability issues identified at the SIS stage, based on dynamic analysis.

Table 8: NRIS cost estimate

Item	Network Upgrades	Estimate
I	L6537 *(2C-Hastings/67C-Whycocomagh Tap, 55.6 km)* Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537	$27,800,000
II	L6537 *(67C-Whycocomagh Tap/104S-Baddeck, 25.3 km)* Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537	$12,650,000
III	L6537 *(104S-Baddeck/IR602 POI, 12.4 km)* Build new 138kV line parallel to L6537 with Drake 90˚C to replace L6537	$6,200,000
IV	L6537 *(IR602 POI/5S-Glen Tosh, 0.6 km)* Build new 138kV line parallel to L6537 with Dove 80˚C to replace L6537	$300,000
V	L6538 *(5S-Glen Tosh/3S-Gannon Road, 34.5 km)* Build new 138kV line parallel to L6538 with Drake 90˚C to replace L6538	$17,250,000
VI	Upgrade 2C-Hastings metering from 231 MVA full scale limit	$30,000
VII	Replace two 800 A breakers at 5S-Glen Tosh with 2,000 A breakers	$2,000,000
VIII	Upgrade 5S-Glen Tosh metering from 231 MVA full scale limit	$30,000
	Sub-total	**$66,260,000**

	TPIF	Estimate
I	Direct line tap with Transfer Trip off L6537, 0.6 km from 5S-Glen Tosh	$500,000
II	Teleprotection and SCADA communications	$500,000
	Sub-total	**$1,000,000**

Determined costs	
Subtotal	$67,260,000
Contingency (10%)	$6,726,000
Total of determined cost items	$73,986,000

Item	To Be Determined costs	Estimate
I	Preliminary engineering estimation for the L6537 transmission line upgrades.	TBD (SIS)
II	Preliminary engineering estimation for the L6538 transmission line upgrades.	TBD (SIS)

The estimated time to construct the Network Upgrades and Transmission Provider's Interconnection Facilities is 24-36 months after receipt of funds.

12.0 Loss factor

With IR602 in service, the loss factor is calculated as 21.28% with Wreck Cove generating station at near full output, when Wreck Cove generation station offline, the loss factor is 11.39%. The data and calculation is detailed in Table 9: *IR602 loss factor data* and Equation 1: *IR602 loss factor calculation*, respectively.

Table 9: IR602 loss factor data

Whole WF modelled	w/ Wreck Cove @ full output	w/ Wreck Cove offline
IR602 *(MW)*	78.00	78.00
TC w/ IR602 *(MW)*	329.70	383.80
TC w/o IR602 *(MW)*	391.10	452.91
Delta *(MW)*	16.60	8.89
2023 loss factor	21.28%	11.39%

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.

Equation 1: IR602 loss factor calculation

$$loss\ factor = \frac{(IR602_{nameplate} + TC_{w/\ IR602}) - TC_{w/o\ IR602}}{IR602_{nameplate}}$$

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 SIS will consider, but not be limited, to the following:

- Correct models of the entire facility from the POI to the IC substation, collector circuits, and machines.
- Facilities the IC must install to meet the GIP and NSPI TSIR *(Transmission System Interconnection Requirements)* requirements.

- Minimum transmission additions/upgrades necessary to permit operation of this facility, under all dispatch conditions, meeting NPCC and NERC criteria.
- Changes to SPS schemes for operation of this facility.

Nova Scotia Power
Transmission System Operations
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