Interconnection Feasibility Study Report
GIP-IR572-FEAS-R0

Generator Interconnection Request 572
48 MW Wind Generating Facility
Hants County, NS

2020-09-25

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

This report presents the results of a Feasibility Study Agreement for the connection of a 48MW wind generation facility interconnected to the NSPI system as Network Resource Interconnection Service.

The facility will be connected via an approximately 2 km 138kV spur line to a single-breaker tap off L-6054, a 138kV transmission line running between the 101V-MacDonald Pond and 43V-Canaan Rd substations.

There are no concerns regarding increased short circuit levels. The increase in short circuit levels are within the capability of the associated breakers.

Voltage flicker should not be a concern for this project. Calculated voltage flicker from the supplied Enercon E-126 EP3 voltage flicker coefficients was within the required limit.

The wind facility must meet the Total Harmonics Distortion provisions of IEEE 519.

The following Transmission Providers Interconnection Facilities are required to interconnect IR572:

- $907,000: A single-breaker substation at the L6054 POI, complete with control building, protection systems, control and communication between the POI switching station and NSPI SCADA system (land not included).
- $204,000: Structures to turn L6054 into the new switching station.
- $1,000,000: A 2km, 138kV spur line from the single-breaker substation to the proposed IC substation.
- $211,100: 10% contingency.

The preliminary non-binding cost estimate for the NRIS facilities described above is $2,322,100.

The ERIS facility cost is the same as NRIS, since no network upgrades are required.

The above cost estimates do not account for any additional upgrades identified in the SIS stage of this project.

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1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request (IR) to Nova Scotia Power, Inc. (NSPI) for a proposed 48MW wind generation facility interconnected to the NSPI system via L-6054, a 138kV transmission line between the 101V-MacDonald Pond and 43V Canaan Rd. substations. The Point of Interconnection (POI) is approximately 11.6km from 101V-MacDonald Pond.

Figure 1: IR572 approximate locations (subsequent studies will determine precise locations)

The IC signed a Feasibility Study Agreement to study the connection of their proposed generation facility for Network Resource Interconnection Service (NRIS). This report is the result of that study agreement.

This project is listed as IR # 572 in the NSPI Interconnection Request Queue and will be referred to as IR572 throughout this report.

2 Scope

The objective of this Interconnection Feasibility Study (FEAS) is to provide a preliminary evaluation of the system impact and high-level non-binding cost estimate of interconnecting the new generation facility to the NSPI transmission system at the requested location. The assessment will identify potential impacts on transmission element loading, which must remain within their thermal limits. Any potential violations of voltage criteria will be identified and addressed. If the new proposed generation increases the short-circuit duty of any circuit breakers beyond their rated capacity, the circuit breakers must be upgraded. Single contingency criteria are applied.

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

- Preliminary 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.
- Preliminary 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.
- Preliminary 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 is based on a power flow and short circuit analysis and 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 Assumptions

This FEAS is based on the technical information provided by the IC. The POI and configuration are studied as follows:

- NRIS interconnection request.
- 48MW wind generation facility, with 12 x 4MW Enercon E-126 EP3 FT WECs. Generator terminal voltage is 400V.
- The generation technology used must meet NSPI reactive power capability requirement of 0.95 capacitive to 0.95 inductive at the high voltage terminals of the IC substation Generation Step-Up (GSU) transformer. It is also required to provide high-speed Automatic Voltage Regulation to maintain constant voltage at the high voltage terminals of the Interconnection Facilities.
- The IC identified their POI to the NSPI transmission system as the 138kV transmission line L-6054, approximately 11.6km from the 101V-MacDonald Pond substation.
- L-6054 is constructed from 556.5 Dove ACSR conductor, designed for a max 75°C operating temperature. Its max seasonal ratings are summer 174MVA and winter 210MVA.
- The POC will be located approximately 2km from the POI. As such, a single-breaker substation at the POI and a transmission line from the POI to the IC's substation is required.
- The IC step-up transformer is a 138-34.5-4.16kV Y-Y-D transformer, rated at 33/44/55MVA, with a 6.5% impedance and 27.3 X/R ONAN; buried tertiary winding; +/-10% fixed taps; 34.5kV collector voltage.

This FEAS assumes that projects ahead of the project, in the Advanced Stage Interconnection Request Queue (Queue) will proceed as listed in Section 4: Project Queue Position.

4 Project Queue Position

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

As of 2020/08/10, the following projects are higher queued in the Advanced Stage Interconnection Request Queue and are committed to the study base cases:

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

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

- TSR409: SIS in progress
- TSR410: SIS in progress

The application for these TSRs are in the System Impact Study stage for an in-service date in 2025. As such, they will not be included in this FEAS. However, a subsequent SIS will include parallel scenarios with and without the TSRs in effect.

If any of the higher-queued projects included in this FEAS are subsequently withdrawn from the Queue, the results of this FEAS may require updating or a re-study may be necessary.

5 Short Circuit

The NSPI design criteria for maximum system fault capacity (3-phase RMS, symmetrical) is 5,000MVA on the 138kV system.

Short circuit analysis was performed using ASPEN OneLiner v14.4 for a classical fault study, 3LG and flat voltage profile at 1 VPU. The short-circuit levels in the area before and after this development are provided in Table 1:

Table 1: Short-circuit levels, 3-phase MVA

Location	IR572 in service	IR572 not in service
Maximum generation, all transmission facilities in service		
POI (IR572 tap on L-6054)	1,251	1,148
101V-MacDonald Pond, 138kV	1,275	1,203
43V-Canaan Rd, 138kV	1,266	1,200
Minimum conditions, low generation, all transmission facilities in service		
POI (IR572 tap on L-6054)	959	838
101V-MacDonald Pond, 138kV	965	873
43V-Canaan Rd, 138kV	954	869
Minimum conditions, low generation, L-6054 OOS (101V to POI) OOS		
POI (IR572 tap on L-6054)	589	466
101V-MacDonald Pond, 138kV	611	606
43V-Canaan Rd, 138kV	710	589
Minimum conditions, low generation, L-6054 OOS (43V to POI) OOS		
POI (IR572 tap on L-6054)	620	497
101V-MacDonald Pond, 138kV	724	606
43V-Canaan Rd, 138kV	598	593

IR572 will not exceed the interrupting capability of the 138kV circuit breakers at the substations (43V-Canaan Rd/101V-MacDonald Pond) adjacent to it.

6 Voltage Flicker and Harmonics

The voltage flicker coefficients were supplied in an Enercon E-126 EP3 wind turbine test report by the IC. The calculated voltage flicker at the POI using IEC Standard 61400-21 under normal and minimum generation conditions are provided in Table 2.

Table 2: Calculated voltage flicker

Maximum generation	
All transmission facilities in service	0.05
101V-MacDonald Pond to POI OOS	0.10
Minimum generation	
All transmission facilities in service	0.07
101V-MacDonald Pond to POI OOS	0.11

The values are well within the $P_{st} \leq 0.25$ limit; hence, voltage flicker should not be a concern for this project.

The generator is expected to meet IEEE Standard 519 limiting Total Harmonic Distortion (all frequencies) to a maximum of 5%, with no individual harmonic exceeding 1%. It is the generating facility's responsibility to ensure that this requirement is met as this FEAS cannot make this assessment.

7 Thermal limits

The study area includes the West and Valley zones, which has a mix of small hydro, tidal, wind, and gas turbine generation. Under winter load conditions, load exceeds local generation capacity and power is imported along 138kV lines from 120H-Brushy Hill and a 69kV line from 90H-Sackville. In light-load and high-generation conditions, that often occur in spring and summer, the flows can reverse, causing power to be exported from the West and Valley regions.

Basecases were selected to reflect conditions under varying amounts of low/high area load vs historic area generation. This approach was chosen because portions of the Valley transmission system would already experience overloads if the entire area hydro and wind plants were simultaneously operated at maximum capacity under system light load.

Table 3: Basecase dispatches (MW)

Case name	NS load	IR 572	West hydro	West wind	NS/NB	NS/NL	CBX	ONI	Valley import	West import	Valley export	Western valley imp
LL_01-1	860	-	9	-	330	-500	571	694	82	73	-21	49
LL_01-2	860	48	9	48	330	-500	541	645	36	71	-21	49
LL_02-1	1,129	-	88	171	330	-500	532	619	-14	-25	47	-20
LL_02-2	1,129	48	88	219	330	-500	484	573	-59	-27	47	-20
SP_01-1	1,284	-	125	180	330	-500	785	791	39	5	40	4

Case name	NS load	IR 572	West hydro	West wind	NS/NB	NS/NL	CBX	ONI	Valley import	West import	Valley export	Western valley imp
SP_01-2	1,284	48	125	228	330	-500	736	744	-6	4	40	4
SP_02-1	1,249	-	2	-	330	-500	955	1,008	154	140	-43	89
SP_02-2	1,249	48	2	48	330	-500	901	958	107	138	-43	89
SP_03-1	1,469	-	103	181	330	-500	883	916	37	12	32	10
SP_03-2	1,469	48	103	229	330	-500	832	869	-9	10	32	10
SP_04-1	1,155	-	73	155	330	-500	740	751	34	-11	24	9
SP_04-2	1,155	48	73	203	330	-500	691	704	-11	-13	24	9
WN_01-1	1,732	-	137	184	150	-320	758	960	101	83	31	32
WN_01-2	1,732	48	137	232	150	-320	708	912	55	82	31	32
WN_02-1	1,921	-	52	164	150	-320	841	1,028	189	155	-24	97
WN_02-2	1,921	48	52	212	150	-320	789	979	143	153	-25	97
WN_03-1	1,705	-	28	36	150	-320	853	1,057	221	178	-59	128
WN_03-2	1,705	48	28	84	150	-320	800	1,006	175	176	-59	128

It should be noted, that as listed in Section 4: Project Queue Position, there are projects higher in the queue whose study results are not sufficiently defined for the project to be included into the basecases for this FEAS. The addition of these projects may impact transmission system capacity for the West/Valley zones.

There may be limitations placed on IR572's output due to forced line outages or maintenance requiring system elements, like transmission lines, to be taken out of service. Best efforts will be made to coordinate maintenance activities to avoid restrictions on IR572 generation output.

Loss factor was calculated according to the Open Access Transmission Tariff system loss calculation methodology, which reflects the load centre in and around 91H-Tufts Cove. Calculations were performed running the load flow using winter peak base case with and without IR572 while keeping 91H-Tufts Cove generation as the NS Area Interchange bus.

The loss factor for IR572, shown in Table 4: Year 2023 loss factor, is the differential MW displaced/increased at 91H-Tufts Cove generation calculated as a percentage of IR572 nameplate MW rating during peak system loading. For this preliminary loss factor analysis, losses associated with IR572 transformers and collector circuits are ignored.

Table 4: Year 2023 loss factor

Year 2023	MW
IR572, 12 machines	48.00
TC3 w/ IR572	43.63
TC3 w/o IR572	91.02
Delta	-0.61
2023 loss factor	1.28%

Loss calculations will be further refined in the SIS.

8 Voltage Control

The GIP requires the facility to be capable of operation between 0.95 leading and lagging PF, measured at the HV terminals of the IC substation step-up transformer, at all production levels up to its full rated 48 MW output.

Based on IR572's submitted data, the wind machines can operate to 0.889 power factor, and the load flow analysis shows that IR572 is able to meet the power factor requirement for absorbing and delivering VARs at the GSU transformer's 138kV HV terminals.

When IR572 delivers its maximum VARs, the power factor at the GSU's 138kV side is +0.948. As such, additional power factor correction will not be required.

A centralized controller will be required which continuously adjusts individual generator reactive power output within the plant capability limits and regulates the voltage at the 138kV bus of the Interconnection Facility. The voltage controls must be responsive to voltage deviations at the connection point, be equipped with a voltage set-point control, and also have facilities that will slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual generators 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 set-point and the reactive set-point of this facility to coordinate reactive power dispatch requirements.

This facility must have low-voltage ride-through capability in accordance with FERC Order 661a[1]. The SIS will examine the generator/plant capabilities and controls in detail specify any options, controls and additional facilities that are required to achieve low-voltage ride-through.

9 System Security

Neither 43V-Canaan Rd or 101V-MacDonald Pond, the terminating substations for L6054, are currently designated Bulk Power System (BPS). The SIS will determine if IR572 will require BPS designation or if the BPS status of any existing NSPI substations are impacted by the addition of IR572 to the system.

[1] Post-transition Period LVRT Standard; “Interconnection for Wind Energy”, Federal Energy Regulatory Commission, Docket RM05-4-001; Order No. 661-A December 12, 2005.

The SIS will determine any facility changes required to maintain system stability in compliance with NSPI, NPCC, and NERC standards and in keeping with good utility practice.

10 Expected Facilities Required for Interconnection

The following facilities are required to interconnect IR572 to the NSPI system via L-6054:

10.1 NRIS

1) **Required Transmission Provider's Interconnection Facilities (TPIF)**
   TPIF are defined in the Generator Interconnection Procedures (GIP) as all facilities and equipment owned, controlled, or operated by the Transmission Provider from the Point of Change of Ownership to the Point of Interconnection. TPIF are sole use facilities and are built and operated at the sole expense of the Interconnection Customer per Section 11.2 of GIP, Appendix 6.

   The TPIF required for IR-572 are as follows:
   a) Develop a single-breaker switching substation at the POI with L-6054:
      i) One 138kV circuit breaker and associated switches.
      ii) Control building and protection systems.
      iii) Control and communications between the POI switching substation and the NSPI SCADA system.
      iv) Structures to turn L-6054 into the new switching station.
      v) Any conductor required to connect the wind farm POI will use 556 Dove ACSR conductor, rated at 100°C conductor temperature.
   b) Construct 2km of 138kV, 556 ACSR line between the new 138kV single breaker switching station at the POI and the POC at the IR572 IC substation.

2) **Required Interconnection Customer's Interconnection Facilities (ICIF)**
   ICIF are defined in the GIP as all facilities and equipment that are located between the Generating Facility and the Point of Change of Ownership. ICIF are built and operated at the sole expense of the Interconnection Customer per Section 11.1 of GIP, Appendix 6.

   The ICIF required for IR-572 are as follows:
   a) IC Substation, inclusive of step-up transformer (138-34.5-4.16kV Y-Y-D, rated at 33/44/55MVA, with a 6.5% impedance and 27.3 X/R ONAN; buried tertiary winding; +/-10% fixed taps; 34.5kV collector voltage)
   b) 34.5kV collector circuits
   c) Facilities to provide 0.95 leading and lagging power factor when delivering rated output (48 MW) at the 138kV bus when the voltage at that point is operating between 95% and 105% of nominal.

d) Centralized controls. These will provide centralized voltage set-point controls and reactive power set-point controls acting to control the voltage on the 138kV system and reactive output of the machines. Responsive (fast-acting) controls are required. The controls will also include a curtailment scheme which will limit or reduce total output from the facility, upon receipt of a telemetered signal from NSPI's SCADA system. The controller will also limit the load ramp rate of the facility to within limits set by NSPI and/or telemetered from NSPI's SCADA system.
e) NSPI to have supervisory and control of this facility's reactive output, via the centralized controller. This will permit the NSPI Operator to raise or lower the voltage set-point and change the status of any reactive power controls remotely. NSPI will also have remote manual control of the load curtailment scheme.
f) Low voltage ride-through capability in accordance with FERC Order 661a.
g) Real-time monitoring via a Remote Terminal Unit (RTU) of the interconnection substation and facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined by SIS.

10.2 ERIS

1. **Required Transmission provider's Interconnection Facilities (TPIF)**
   For ERIS generation, the single breaker switching station described in Section 10.1.1.a and the 2km line to the IC POI described in Section 10.1.1.b are required.
2. **Required Interconnection Customer's Interconnection Facilities (ICIF)**
   2.1. The ICIF for ERIS generation is the same as for the NRIS generation in Section 10.1.2

11 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

High-level estimates (non-binding), excluding taxes and future to be determined costs associated with stability analysis of the SIS, for interconnecting IR572 as NRIS are included in Table 5: NRIS cost estimates. There are no required Network Upgrades.

Table 5: NRIS cost estimates

Item	TPIF	Estimate
i	2km 138kV, 556ACSR spur line to POI	$1,000,000
ii	Single breaker substation, land not included	$502,000
iii	L6054 transmission tap	$204,000
iv	Communications	$405,000

Determined costs	
Subtotal	$2,111,000
Contingency (10%)	$211,100

Total of determined cost items	$2,322,100

Cost items to be determined in SIS	
System additions to address stability and security limitations	TBD

NSPI estimates the time required to construct the above facilities at 12-24 months assuming all easements and permits are provided and complete.

These prices do not include engineering, permits, right of way, clearing, switching to isolate sections of line, survey or any additional easements or permits for water crossings etc. that may not be in place.

12 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, catering to, at a minimum, the first contingencies listed below.
- 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 requirements of the GIP.

The SIS must determine the facilities required to operate this facility at full capacity, withstand the contingencies as defined by NPCC/NERC and identify any restrictions that must be placed on the system following a first contingency loss. The SIS will be conducted with the assumption that all projects higher queued will proceed and the facilities associated with those projects are installed.

The SIS will consider, at a minimum, winter, summer and seasonal light load basecases which stress western Valley import and export under load and hydro conditions that can reasonably be expected to occur. Analysis will include basecase variations for hydro, tidal and wind at maximum and minimum generating levels for the specific season.

In each case, accommodations for the addition of wind generation will be made to the dispatch by changing the unit commitment, ensuring enough capacity is available to export excess generation from western NS. The assumptions regarding load following and unit commitment will be noted.

At a minimum, the assessment of first contingency loss of the following elements will be required:

- L-6012, 43V to 17V
- 90H-B1
- 90H-B2
- 17V-B2
- 17V-B63
- L-6013, 43V to 51V
- L-6015, 43V to 51V
- 43V-B61
- 43V-B62
- 43V-B51
- L-5025, 51V to 11V, SPS as required
- 51V-B51, SPS as required
- 51V- B52, SPS as required
- 51V-B61
- 51V-B62
- 11V-B51, SPS as required
- L-5026, 13V to 11V
- L-5531, 13V to 15V
- L-5532, 13V to 3W
- L-5533, 13V to 77V
- 13V-B51
- 3W-B53
- L-5535, 9W to 15V
- L-6024, 9W to 50W
- 9W-B52
- 9W-B53
- L-5541, 50W to 3W
- 101W Load
- L-6004A, 43V to IR372
- L-6004B, IR372 to 90H
- IR372 Gen

To complete this assessment, a stability assessment of the following first contingencies, as a minimum, will be assessed:

- 3Φ fault on 90H-B1
- 3Φ fault on 90H-B2
- 3Φ fault on L-6013, 43V & 51V
- 3Φ fault on L-6015, 43V & 51V
- 3Φ fault on 43V-B61
- 3Φ fault on 43V-B62
- 3Φ fault on 43V-B51
- 3Φ fault on L-5025, SPS as required, 51V
- 3Φ fault on 51V-B51, SPS as required
- 3Φ fault on 51V-B61
- 3Φ fault on 11V-B51, SPS as required
- 3Φ fault on L-5026, 13V
- 3Φ fault on 9W-B52
- 3Φ fault on 9W-B53
- 3Φ fault on L-6004A, 43V & IR372
- 3Φ fault on L-6004B, IR372 & 90H
- SLG fault on separate phases of each circuit for DCT L-7008][L-7009 with associated protection systems action
- SLG fault on L-6004, IR to 43V at 43V with adjoining breaker failure
- SLG fault on L-6004, IR to 90HV at 90H with adjoining breaker failure

After determining the changes/additions that are required to facilitate this interconnection, “N-1” operation will be assessed. The objective is to determine the operating restriction or curtailments that must be enforced to ensure secure operation of the system.

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