Interconnection Feasibility Study Report
GIP-IR379-FEAS-R1

Generator Interconnection Request 379

109.5 MW Wind Generating Facility

South Canoe Lake, NS

Mar. 2, 2012

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

This report presents the results of a Feasibility Study Agreement to study the connection of a 109.5 MW wind generation facility interconnected to the NSPI system via 138kV line L-6004 as Network Resource Interconnection Service, with Energy Resource Interconnection Service studied concurrently. The study performed a steady state analysis of the impact the proposed development would have on the NSPI power grid.

The increase in short circuit levels are within the capability of the associated breakers. There are no concerns with regard to increased short circuits levels.

Using the flicker coefficient supplied by GE for the 1.5sle, results indicate voltage flicker should not be a concern for this project.

The machine data provided in the Interconnection Request indicates the facility will be unable to supply sufficient VArs to meet the 0.95 leading power factor requirement. Additional capacitive support will be required, either with a series of capacitor banks or through a change in turbine model for the proposed facility.

The proposed facility will impact the ratio of power flow on the 69 and 138kV lines in western Nova Scotia. There is an infrequent combination of events described in *Section 7: Thermal Limits* which could require the curtailment of the full output of IR379 for one to two hour events in some years.

For NRIS the following facility changes are required to interconnect IR379 to the NSPI system via L-6004:

i. Protection, communication and control: $351,000.
ii. New 13km 138kV line from generating facility to POI: $3,640,000
iii. A 138kV three breaker ring bus substation is required at the POI on L-6004. The IC substation can share the same site, provided there is a common fence separating the two substations: $4,629,000.
iv. Uprating of line L-5535 and L-5541: $7,000,000.

The preliminary, non-binding estimated cost for NRIS facilities for the proposed interconnection, including 10% contingency, is $17,285,400.

For an ERIS connection, the line uprating would not be required and the preliminary, non-binding estimated cost for ERIS facilities for the proposed interconnection, including 10% contingency, is $9, 584,400.

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1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request to Nova Scotia Power Inc. (NSPI) for a proposed 109.5 MW wind generation facility interconnected to the NSPI system via 138kV line L-6004. The IC signed a Feasibility Study Agreement to study the connection of their proposed generation for both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS). This report is the result of that study agreement

The project is listed as Interconnection Request (IR) 379 in the NSPI Interconnection Request Queue, and will be referred to as IR379 throughout this report.

2 Scope

The objective of this Interconnection Feasibility Study (FEAS) is to provide a preliminary evaluation of the system impact and the high-level non-binding cost estimate of interconnecting the new generating facility to the NSPI transmission system at the designated location. The assessment will identify potential impacts on the loading of transmission elements, which must remain within their thermal limits. Any potential violations of voltage criteria will be identified and addressed. If the proposed new 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 modeling 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 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 facilities required to interconnect the Generating Facility to the transmission system, the time to construct such facilities
- For ERIS, identify the maximum output allowed without requiring the additional Network Upgrades. Transmission interfaces limits will not be exceeded to avoid Network Upgrades.

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 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 of the technical implications of this development 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 interconnect the generating facility.

3 Assumptions

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

- POI is the 138kV line L-6004, approximately 26 km from 43V-Canaan Road.
- A three breaker ring bus substation will be required at the POI.
- The Transmission Providers Interconnection Facilities would include the 13km transmission line from the 3 breaker sing bus substation to the IC's substation.
- New 138kV transmission line would be constructed with 556ACSR.
- 109.5 MW wind farm comprised of 73 – 1.5 MW General Electric 1.5 sle wind turbines.
- The generation technology used must meet NSPI requirement for reactive power capability of 0.95 capacitive to 0.95 inductive at the HV terminals of the IC Substation Step Up transformer. The generator is assumed to be specified for 34.5 kV at a rated power factor of 0.95 for both lagging and leading. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the generator terminals during and following system disturbances as determined in the subsequent System Impact Study.
- The step-up transformers are assumed as 21/41/63 MVA (x2), Y-Y-D, 138kV to 34.5kV, impedance of 9 % (on ONAN Base).
- ERIS and NRIS service type as per section 3.2 of the GIP
- This feasibility study is based on the assumptions that the projects that are ahead of this project in the Generation Interconnection Queue (Queue) and have sufficiently defined SIS results available will proceed as listed in Section 4.

4 Project Queue Position

All in-service generation facilities are included in the FEAS

The following projects are higher queued in the Advanced Stage Interconnection Request Queue or Transmission Service Request Queue and are committed to the study base cases.

- IR #8 GIA executed
- IR #45 GIA executed
- IR #56 GIA executed
- IR #151 GIA executed
- TSR100 SIS in progress
- IR #219 GIA executed
- IR #227 GIA in progress
- IR #225 GIA in progress
- IR #234 FAC in progress

The following have an SIS in progress. However the results are not sufficiently defined for the project to be included into the basecases for this FEAS.

- TSR400
- IR #131
- IR #360
- IR #362

The following IRs either have SIS Agreements complete, but have not yet met the GIP SIS progression milestones, or have Feasibility Study Agreements complete and are not committed to the FEAS base cases:

- IR #67
- IR #68
- IR #117
- IR #126
- IR #128
- IR #149
- IR #163
- IR #213
- IR #222
- IR #235
- IR #238
- IR #241
- IR #242
- IR#314
- IR#356
- IR361
- IR364
- IR365
- IR366
- IR367
- IR368
- IR369
- IR372
- IR373
- IR374
- IR375
- IR376
- IR377
- IR378

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.

While TSR100, IR225 and IR234 are higher queued than IR379, they have later in-service dates – 2016, 2017 ad 2017 respectively. Therefore the analysis for this FEAS will be performed twice – for 2014 when this project is expected to be in-service and for 2017 when the higher queued TSR 100, IR225 and IR234 are in-service.

5 Short Circuit

The NSPI design criteria for maximum system fault capacity (three phase rms symmetrical) is 5,000 MVA and 3,500 MVA on the 138kV and 69 kV system respectively.

Short circuit analysis was performed using Aspen OneLiner V11.6, classical fault study, 3LG and flat voltage profile at 1 V(pu). The short-circuit levels in the area before and after this development are provided in Tables 1 and 2.

Table 1: Short-Circuit Levels, Three-phase MVA for 2014

Location	IR379 in service	IR379 not in service
Maximum generation, all transmission facilities in service		
POI (IR379 tap on L-6004)	1319	1098
43V-Canaan Road, 138kV	1277	1166
90H-Sackville, 138kV	3650	3509
Minimum Conditions, low Generation, L-6004, 90H to 43V out of service		
POI (IR379 tap on L-6004)	697	476
43V-Canaan Road, 138kV	877	682
90H-Sackville, 138kV	2240	2152

Table 2: Short-Circuit Levels, Three-phase MVA for 2017

Location	IR379 in service	IR379 not in service
Maximum generation, all transmission facilities in service		
POI (IR379 tap on L-6004)	1327	1107
43V-Canaan Road, 138kV	1285	1176
90H-Sackville, 138kV	3745	3606
Minimum Conditions, low Generation, L-6004, 90H to 43V out of service		
POI (IR379 tap on L-6004)	720	500
43V-Canaan Road, 138kV	927	733
90H-Sackville, 138kV	2406	2328

There are no concerns with regard to increased short-circuit levels.

6 Voltage Flicker

The wind turbine supplier, GE, provided the voltage flicker coefficients for the 1.5sle wind turbine.

Based on the information provided, the calculated voltage flicker values at the POI using IEC Standard 61400-21 methodology are provided in Table 3:

Table 3: Calculated Voltage Flicker	
Maximum Generation	
All transmission facilities in service	0.062
POI to 90H out of service	0.127
Minimum Generation	
All transmission facilities in service	0.075
POI to 90H out of service	0.144

The values are below the allowable P_{st} limit of 0.25, 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%.

7 Thermal Limits

To examine the impact of IR379 on the NSPI system, base cases were selected to stress overall system and local conditions.

As can be seen in Figure 1, on the following page, line L-6004 is one of two 138kV lines from the central NS to 43V-Canaan Road which in turn has two 138kV lines into 51V-Tremont. From 51V-Tremont, a single 69kV line, L-5025 continues towards 13V-Gulch.

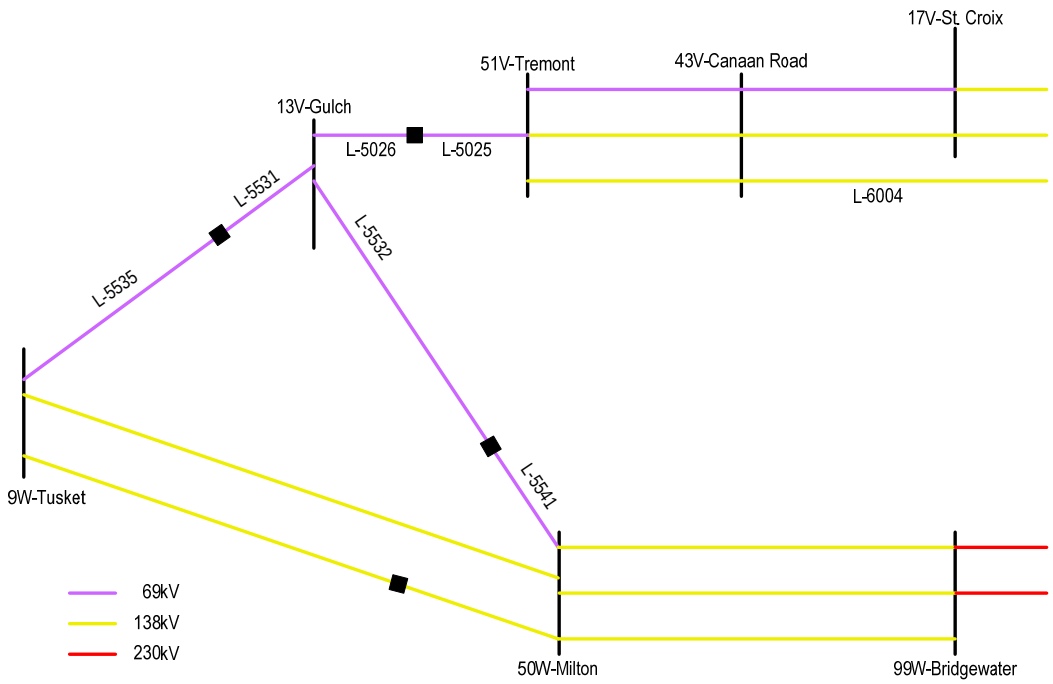

Figure 1: Western Nova Scotia Transmission System

Western Nova Scotia has a mix of hydro, wind, tidal and gas turbine generation nicely interspersed along the 69kV lines between 51V-Tremont, 50W-Milton and 9W-Tusket. Under winter load conditions, load exceeds the available generation and power is imported via 138kV lines into 9W-Tusket and 51V-Tremont. The addition of IR379 poses no additional constraints to the NSPI system under these conditions.

Under reduced load conditions in spring and summer, western Nova Scotia can export power when specific dispatch conditions exist. The addition of generation on L-6004 changes the ratio of power on the lines leaving the 69kV generation pocket. Specifically, it forces more of the flow from the 69kV towards the 9W-Tusket and 50W-Milton substations.

If Hydro is running above 50% under light to medium load and the tidal and wind plants are generating, there is no remaining capacity on the western 69kV NSPI system. This combination of events, requires must run water conditions for the hydro systems in conjunction with the tidal and wind facilities in the area at close to full output. In drier years, this combination of events will not occur. In years with heavy rainfall there may be occasional events of up two hours duration when the tidal plant is at full output and wind is on full. Keep in mind that the tidal plant requires tides (twice a day) and lunar cycle (once a month) for maximum output. During this occurrence of events, loss of line L-5541 can produce overloads of up to 136% of Normal Rating for L-5535. Loss of 9W-B53 can produce overloads of up to 118% for line L-5541. Loss of 3W-B53 produces

overloads of up to 118% to L-5535 and loss of 5535 would produce overloads up to 111% to L-5541.

The infrequent combination of events described above, would curtail the full output of IR379 for one to two hour events in some years. To run at full output without restriction under system normal conditions would require the uprating of the 64km line L-5535 from Sissiboo to Carleton and the 6.3km line L-5541 from 50W-Milton to 4W-Lower Great Brook. Without a field survey, the estimated cost to uprate these lines is approximately $7,000,000. If the survey indicated a full rebuild of the line was required to get the required upratings, the cost would be considerably more.

It should also be noted, as listed in *Section 4: Project Queue Position*, that 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 projects west of Halifax will impact the capacity available on transmission system in western NS.

For a transmission line or other system element out of service due to forced outage or maintenance, there could be limitations on the output of the proposed facility.

Loss factor was calculated according to the methodology used in the calculation of system losses for Open Access Transmission Tariff (OATT) which reflects the load centre in and around 91H-Tufts Cove. Loss factor was calculated by running the load flow using winter peak base case with and without IR379 while keeping 91H-Tufts Cove generation as the Nova Scotia Area Interchange bus. The loss factor for IR379 is the differential MW displaced or increased at 91H-Tufts Cove generation calculated as a percentage of IR379 name plate MW rating.

Table 4: Loss Factor

2014	**MW**
73 machines	109.5
TUC3 without IR379 generating	104.8
TUC3 with IR generating	0
Delta	4.7
2014 Loss Factor	4.29%
2017	**MW**
73 machines	109.5
TUC3 without IR379generating	104.2

Table 4: Loss Factor	
TUC3 with IR generating	0
Delta	5.3
2017 Loss Factor	4.84%

Loss calculations may be further refined in the SIS.

8 Voltage Control

The facilities included with this installation must be such that the facility is capable of providing both lagging and leading power factor of 0.95, measured at the HV terminals of the IC substation step-up transformer, at all production levels up to the full rate load of 109.5MW. 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 voltage. The voltage controls must be responsive to voltage deviations at the terminals of the Interconnection Facility substation, be equipped with a voltage set-point control, and also have the ability to slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual generators capabilities. The details of the specific control features, control strategy and settings will be reviewed and addressed in the SIS, as will the dynamic performance of the generator and its excitation.

The NSPI system Operator must have manual and remote control of the voltage set-point and reactive power output from this facility to coordinate system reactive power requirements.

The machines specified by the IC can absorb sufficient VArs to meet the lagging 0.95 power factor criteria. However, at the specified capability, the proposed facility does not meet the requirement to deliver 0.95 leading power factor at high voltage bus. It can deliver 0.95 at the low voltage bus but with the VArs absorbed by the collector circuits and intervening transformers, cannot deliver sufficient VArs at the 138kV bus. Additional capacitive support will be required to meet the 0.95 leading power factor criteria. This can be achieved with a series of capacitor banks or a change in turbine model for the proposed facility.

This facility must also have low voltage ride-through capability as per Appendix G to the Standard Generator Interconnection and Operating Agreement. The SIS will state specific options, controls and additional facilities that are required to achieve this.

9 System Security/Stability Limits

Neither 43V-Canaan Road nor 90H-Sackville, the terminating substations for L-6004, are currently designated Bulk Power System (BPS). The SIS will determine if IR379 substation will require BPS designation or if the BPS status of any existing NSPI substation is impacted by the addition of IR379 to the system.

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 facility changes are required to interconnect IR379 to the NSPI system via L-6004:

A new 13km 138kV transmission line from the generating facility to the POI substation. A 138kV three breaker ring bus substation is required at the POI on L-6004. The IC substation can share the same site, provided there is a common fence separating the two substations.

This project will require the installation of an MDR-8000 radio link from the new South Canoe Substation site to 428V-Hemlock Hill Radio site, as well as a new radio link from 428V-Hemlock Hill to 425V-Newtonville Radio to increase capacity to meet the communications requirements for this project. This solution provides communications for voice, data, and Ethernet as well as tele-protection to the following sites: 43V-Canaan Rd and 90H-Sackville.

The estimate assumes that the construction of a new building, which provides a spot for a 23" cabinet with front and back access. Also note that there will be new radio licensing fees of ~$400/year for the South Canoe to 428V-Hemlock Hill radio link. The location of the tower at South Canoe has been approximated and a site visit will be required when this project is ready to go ahead to verify a location that will work with the new substation and other site conditions. The new tower will require Land Use Authority and Public Consultation as per Industry Canada’s requirements in CPC-2-0-03. A geotechnical survey of the location, as well as a frequency interference study and a tower analysis (for 425V-Newtonville and 428V-Hemlock Hill) will be required as well; this is included in the estimate. Also included in the estimate are tower upgrades for 428V-Hemlock Hill site as a result of the new dishes that will be installed at that location. These numbers may change when the additional loading is fully scoped.

11 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 109.5 MW wind energy as NRIS onto the 138 kV system are included in Table 5.

Table 5: Cost Estimates

	Cost Items	Estimate
NSPI Interconnection Facilities		
i	Communications, protection and control	$445,000
ii	New 13km 138kV line from generating facility to POI	$3,640,000
Network Upgrades		
iii	138kV Three Breaker Ring Bus Substation	$4,629,000
iv	Uprating of lines L-5535 and L-5541	$7,000,000
	Contingency 10%	$1,571,000
	Total	$17,285,400
Cost Items To Be Determined in SIS		
	System Additions to address Stability and Security Limitations	TBD

The preliminary non-binding cost estimate for interconnecting IR379 via a line tap to L-6004 as NRIS would be $17,285,400, including a contingency of 10%. The IC is required to fund items iii and iv which are eligible for reimbursement per Section 11.4.1 of the GIA.

A ERIS interconnection would not require item iv, line uprating for L5535 and L-5541. The preliminary non-binding cost estimate for interconnecting via a line tap to L-6004 as ERIS would be $9,585,400, including a contingency of 10%.

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 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 that sufficient capacity is available to export excess generation from western NS. The assumptions regarding load following and unit commitment will be noted. .

At a minimum, to complete the assessment of first contingency, loss of the following elements will be assessed:

- 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 IR379
- L-6004B, IR379 to 90H
- IR379 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 & IR379
- 3Φ fault on L-6004B, IR379 & 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.