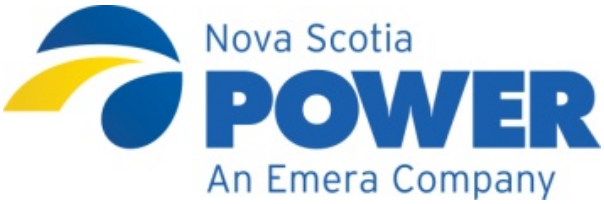

Interconnection Feasibility Study Report
GIP-IR377-FEAS-R1

Generator Interconnection Request 377

40 MW Wind Generating Facility

Renfrew, NS

Mar. 6, 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 40 MW wind generation facility interconnected to the NSPI system via 230kV line L-7001 as Energy Resource Interconnection Service. 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.

As no flicker coefficient values were received for the proposed turbines, generic values were used. Results indicate voltage flicker should not be a concern for this project.

Thermal limits analyses indicate no concerns with the addition of this project to the NSPI system. Under system normal conditions, feasibility study results indicate the proposed facility will be able to run at full output of 40MW when replacing generation to the north or east of Onslow.

Both 67N-Onslow and 120H-Brush Hill, the terminating substations for L-7001, are currently designated Bulk Power System (BPS). The SIS will determine if IR377 substation will require BPS designation or if the BPS status of any existing NSPI substation is impacted by the addition of IR377 to the system.

Generator interconnection to the NSPI system requires the facility to be capable of providing both lagging and leading power factor of 0.95, measured at the HV terminals of the IC substation step-up transformer. As the customer Interconnection Request indicated a machine power factor of approximately 1, additional capacitive/reactive will be required. This will be further addressed in the SIS when machine data is made available. No details or costs associated with this requirement are addressed in this Feasibility Study.

The following facility changes are required to interconnect IR377 to the NSPI system via L-7001:

i. A 230kV three breaker ring bus substation is required at the POI on L-7001. The IC substation can share the same site, provided there is a common fence separating the two substations: $5,895,000.
ii. Protection, communication and control: $693,000.

The preliminary, non-binding estimated cost for facilities for the proposed interconnection, including 10% contingency, is $7,246,800.

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1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request to Nova Scotia Power Inc. (NSPI) for a proposed 40 MW wind generation facility interconnected to the NSPI system via 230kV line L-7018 with the alternate point of interconnection to 230kV line L-7001. The IC signed a Feasibility Study Agreement to study the connection of their proposed generation under Energy Resource Interconnection Service (ERIS). This report is the result of that study agreement

The project is listed as Interconnection Request (IR) 377 in the NSPI Interconnection Request Queue, and will be referred to as IR377 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.
- 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) indicated by the customer was one of three 230kV lines from 67N-Onslow to 120H-Brushy Hill. Lines L-7018 and L-7001 were closest to the new facility. L-7018 is built to 345kV standard to allow for future upgrade to 345kV operating voltage. This would require the Interconnection substation to be capable of operating at 345kV at some future date. Therefore, the Alternate POI L-7001 was chosen as the POI for study. The POI and configuration is studied as follows:

- POI is the 230kV line L-7001, approximately 16 km from 120H-Brushy Hill.
- A three breaker ring bus substation will be required at the POI.
- The Transmission Providers Interconnection Facilities would include any transmission line from the 3 breaker ring bus substation to the IC's substation. This study assumes that both the three breaker ring bus substation and the IC substation are located adjacent to L-7001 and as such would share the same site with a common fence separating the two substations.
- 40 MW wind farm comprised of 20 x 2.0 MW RePower MM92 wind turbines. Generic data has been used for modelling purposes for the MM92 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. 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 transformer assumed as 31/50 MVA,230kV(wye) to 34.5kV(wye),Delta tertiary, impedance of 9 % (on ONAN Base), ± 5% offload.

- ERIS 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 and are committed to the study base cases.

- IR8 GIA executed
- IR45 GIA executed
- IR56 GIA executed
- IR151 GIA executed
- TSR100 SIS in progress
- IR219 GIA executed
- IR227 GIA in progress
- IR225 GIA in progress
- IR234 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
- IR131
- IR360
- IR362

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:

- IR67
- IR68
- IR117
- IR126
- IR128
- IR149
- IR163
- IR213
- IR222
- IR235
- IR238
- IR241
- IR242
- IR314
- IR356
- IR361
- IR364
- IR365
- IR367
- IR368
- IR369
- IR372
- IR373
- IR374
- IR375
- IR378
- IR379
- IR380

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 IR377, 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 10,000 MVA and 5,000 MVA on the 230kV and 138kV 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	IR377 in service	IR377 not in service
Maximum generation, all transmission facilities in service		
POI (IR377 tap on L-7001)	2827	2744
120H-Brushy Hill, 230kV	3566	3496
67N-Onslow, 230kV	4248	4193
Minimum Conditions, low Generation, L-7001, POI to 120H out of service		
POI (IR377 tap on L-7001)	1306	1181
120H-Brushy Hill, 230kV	2456	2411
67N-Onslow, 230kV	3253	3135

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

Location	IR377 in service	IR377 not in service
Maximum generation, all transmission facilities in service		
POI (IR377 tap on L-7001)	2982	2856
120H-Brushy Hill, 230kV	3765	3662
67N-Onslow, 230kV	4655	4573
Minimum Conditions, low Generation, L-7001, POI to 120H out of service		
POI (IR377 tap on L-7001)	1327	1244

Table 2: Short-Circuit Levels, Three-phase MVA for 2017		
120H-Brushy Hill, 230kV	2671	2644
67N-Onslow, 230kV	3706	3626

As no reactance information was included for the wind turbines, they were modeled with an estimated reactance for a Type 2 machine. The results will be refined, based on the actual machine parameters, in the SIS.

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

6 Voltage Flicker

Due to the lack of flicker coefficient information provided for the RePower MM92 machine, this study assumed pessimistic values for a Type 2 machine. The calculated voltage flicker at the POI using IEC Standard 61400-21 under normal conditions and under minimum generation conditions are provided in Table 3 below.

Table 3: Calculated Voltage Flicker	
Maximum Generation	
All transmission facilities in service	0.043
POI to 120H out of service	0.092
Minimum Generation	
All transmission facilities in service	0.055
POI to 120H out of service	0.101

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 IR377 on the NSPI system, base cases were selected to stress overall system and local conditions.

Line-L7001 is part of the Onslow South (ONS) interface which has associated constraints and limits. ONS is the corridor south from Onslow with flows typically out of Onslow. This corridor supplies additional generation to the Halifax load centre and the western portion of the province, as needed.

As an ERIS proposal, IR377 will be dispatched as long as there is transfer capacity available in the existing constrained interfaces within the Nova Scotia transmission system. As ONS interface already has constraints, this FEAS was conducted with IR377 replacing generation east or north of 67N-Onslow whenever ONS is at limit. For the purpose of this study either a thermal plant east of Onslow was displaced or the excess generation placed on the tie line to New Brunswick.

Thermal limits analyses indicate no concerns with the addition of this project to the NSPI system.

Loss factor was calculated according to the methodology used in the calculation of system losses for Open Access Transmission Tariff which reflects the load centre in and around 91H-Tufts Cove. Calculations were performed by running the load flow using winter peak base case with and without IR377 while keeping 91H-Tufts Cove generation as the Nova Scotia Area Interchange bus. The loss factor for IR377, shown in Table 4, is the differential MW displaced or increased at 91H-Tufts Cove generation calculated as a percentage of IR377 name plate MW rating.

Table 4: Loss Factor

2014	**MW**
20 machines	40
TUC3 with IR377 generating	149.1
TUC3 without IR generating	110
Delta	0.9
2014 Loss Factor	2.25%
2017	**MW**
20 machines	40
TUC3 with IR377 generating	148.8
TUC3 without IR generating	110
Delta	1.2
2017 Loss Factor	3.0%

Loss calculations may be further refined in the SIS.

8 Voltage Control

The information submitted with IR377 indicates the machines with have a power factor of approximately 1. The GIP requires the installation to 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 40MW. 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 34.5 kV 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.

To meet the ± 0.95 power factor requirement, the IC facility will require reactive and capacitive support. 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.

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

Both 67N-Onslow and 120H-Brushhill, the terminating substations for L-7001, are currently designated Bulk Power System (BPS). The SIS will determine if IR377 substation will require BPS designation or if the BPS status of any existing NSPI substation is impacted by the addition of IR377 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.

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10 Expected Facilities Required for Interconnection

The following facility changes are required to interconnect IR377 to the NSPI system via L-7001:

A 230kV three breaker ring bus substation is required at the POI on L-7001. 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 IR377 new site to 82V-Elmsdale Substation. This solution provides communications for voice, data, and Ethernet; as well as 'A' tele-protection to the following connected sites: 120H-Brushy Hill Substation and 67N-Onlslow 138kV Substation. For 'B' teleprotection new under-build, track resistant jacketed, 12-fiber cable will be required on L-7001, to run back to 120H-Brushy Hill.

The estimate assumes that the construction of a new building, which provides a spot for a 23" cabinet with front and back access, in our substation at IR377 will be included with other parts of the project. Also note that there will be radio licensing fees of ~$400/year for the IR377 to 120H-Brushy Hill substation link. The location of the towers at IR377 and 82V-Elmsdale have 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 towers will require Land Use Authority and Public Consultation as per Industry Canada's requirements in CPC-2-0-03. A geotechnical survey of the locations, as well as a frequency interference study will be required; this is included in the estimate. This estimate does not include any upgrades that may be required on L-7001 to accommodate under-build fiber.

11 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 40 MW wind energy as ERIS onto the 230kV system are included in Table 5.

Table 5: Cost Estimates

	Cost Items	Estimate
NSPI Interconnection Facilities		
i	Protection, Communication and Control	$693,000
Network Upgrades		
ii	230kV Three Breaker Ring Bus Substation	$5,895,000
	Contingency 10%	$658,800

Table 5: Cost Estimates		
	Total	$7,246,800
Cost Items To Be Determined in SIS		
	System Additions to address Stability and Security Limitations	TBD

The preliminary non-binding cost estimate for interconnecting IR377 via a line tap to L-7001 as ERIS would be $7,246,800 including a contingency of 10%. The IC is required to fund item ii which will be eligible for reimbursement per Section 11.4.1 of the GIA.

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 ONS, and other NSPI constrained interface. Analysis will include basecase variations for constrained interfaces at median and strained flow levels.

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 meet the peak load. 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-8001, 67N to ME with any associated SPS action
- L-8002, 67N to 103H
- L-7019, 67N to 91N
- L-7002, 67N to 120H
- L-7018, 67N to 120H
- 67N-T81
- 67N-T71
- 67N-811 with any associated SPS action
- 67N-812 with any associated SPS action
- 67N-813
- 67N-814 with any associated SPS action
- 67N-815 with any associated SPS action
- 67N-701
- 67N-702
- 67N-703
- 67N-704
- 67N-705
- 67N-706
- 67N-710
- 67N-711
- 67N-712
- 67N-713
- L-6513, 1N to 74N
- L-6503, 1N to 51N
- L-6001, 1N to 108H
- L-7008, 120H to 99W
- L-7009, 120H to 99W
- L-6005, 120H to 90H
- L-6010, 120H to 90H
- L-6011, 120H to 17V
- L-6051, 120H to 17V
- L-6016B, 120H to 137H
- 120H-T71
- 120H-710
- 120H-711
- 120H-712

- 120H-713
- 120H-714
- 120H-715
- 120H-716
- 120H-720
- 120H-621
- 120H-622
- 120H-623
- 120H-624
- 120H-625
- 120H-626
- 120H-627
- 120H-628
- 120H-629
- L-6008, 103H to 90H
- L-6016A, 103H to 137H
- L-6033, 103H to 1H
- L-6038, 103H to 129H
- 103H-T81
- 103H-B61
- 103H-B62
- DCT L-7009][L-8002
- DCT L-6011][L-6010
- DCT L-6010][L-6005
- DCT L-6005][L-6016
- DCT L-7008][L-7009
- DCT L-7008][L-7009 w tripping
- L-7001A, 120H to IR377
- L-7001B, IR377 to 67N
- IR377 Bus

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

- 3Φ fault on L-8001, 67N to ME with any associated SPS action
- 3Φ fault on L-8002, 67N & 103H
- 3Φ fault on L-7002, 67N & 120H
- 3Φ fault on L-7018, 67N & 120H
- 3Φ fault on 67N-T81
- 3Φ fault on 67N-T71
- 3Φ fault on L-7008, 120H to 99W
- 3Φ fault on L-7009, 120H to 99W
- 3Φ fault on L-6005, 120H to 90H

- 3Φ fault on L-6010, 120H to 90H
- 3Φ fault on L-6011, 120H to 17V
- 3Φ fault on L-6051, 120H to 17V
- 3Φ fault on L-6016B, 120H to 137H
- 3Φ fault on 120H-T71
- 3Φ fault on 120H-710
- 3Φ fault on 103H-T81
- 3Φ fault on 103H-B61
- 3Φ fault on L-7001A, 120H to IR377
- 3Φ fault on L-7001B, IR377 to 67N
- 3Φ fault on IR377 Bus
- SLG fault on separate phases of each circuit for DCT L-7009][L-8002
- SLG fault on separate phases of each circuit for DCT L-6011][L-6010
- SLG fault on separate phases of each circuit for DCT L-6010][L-6005
- SLG fault on separate phases of each circuit for DCT L-6005][L-6016
- SLG fault on separate phases of each circuit for DCT L-7008][L-7009 with associated protection systems action
- SLG fault on L-8003 with failure of 67N-811, SPS action as needed
- SLG fault on L-8002 with failure of 67N-812, SPS action as needed
- SLG fault on L-8002 with failure of 67N-813
- SLG fault on L-8001 with failure of 67N-814, SPS action as needed
- SLG fault on L-8001 with failure of 67N-815, SPS action as needed
- SLG fault on L-7002 with failure of 67N-701
- SLG fault on L-7002 with failure of 67N-702
- SLG fault on L-7001 with failure of 67N-704
- SLG fault on L-7018 with failure of 67N-713
- SLG fault on L-7002 with failure of 120H-711
- SLG fault on L-7001 with failure of 120H-714

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.