Interconnection Feasibility Study Report
GIP-IR461-FEAS-R0

Generator Interconnection Request 461

16.45 MW Wind Generating Facility

St. Croix, NS

October 09, 2013

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 16.45 MW wind generation facility interconnected to the NSPI system via 69 kV bus 17V-B1 as Network 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.

Flicker calculation was performed based on the data sheets received from Interconnection Customer for the proposed turbines. Results indicate that voltage flicker should not be a concern for this project.

The proposed facility will not have any adverse impact on transmission system loading. Hence, upgrades to the existing NSPI transmission system is not required accommodate the additional generation.

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 0.94. Preliminary study based on the assumptions indicate additional requirement of 2.60 MVAR of reactive power. This will be further addressed in the SIS when collector circuit impedance is made available. No details or costs associated with this requirement are addressed in this Feasibility Study.

For NRIS the following Transmission Provider's Interconnection Facilities are required to interconnect IR461 to the NSPI system via 17V-B1:

i. A 69kV breaker is required at the POI on bus 17V-B1. Approximately 6 km of 69 kV transmission line needs to be built between the POI and the 1R461 substation: $2,225,000.
ii. Communication: $122,000.

The preliminary, non-binding estimated cost for NRIS facilities for the proposed interconnection, including 10% contingency, is $2,609,000.

Table of Contents

Page

List of Tables

1 Introduction

The Interconnection Customer (IC) submitted an Interconnection Request to Nova Scotia Power Inc. (NSPI) for a proposed 16.45 MW wind generation facility interconnected to the NSPI system via bus 17V-B1. The IC signed a Feasibility Study Agreement to study the connection of their proposed generation for Network Resource Interconnection Service (NRIS). This report is the result of that study agreement

The project is listed as Interconnection Request (IR) 461 in the NSPI Interconnection Request Queue, and will be referred to as IR461 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.

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 69kV bus 17V-B1
- A single breaker will be required at the POI.
- IC's substation is approximately 6km from POI.
- 16.45 MW wind farm comprised of 7 x 2.35 MW Enercon E92 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. 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 interconnection facility transformers are assumed as 2x69kV (wye) to 23kV (wye), 6/10 MVA, impedance of 7% (on ONAN Base).
- No data was provided for the generator step-up transformers, so typical impedance of 6% on a base rating of 2.5 MVA was assumed.
- 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.

- IR #8 GIA executed
- IR #56 GIA executed
- IR #227 GIA executed

- IR #372 FAC in progress
- IR #379 FAC in progress
- TSR #400 SIS completed

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.

- IR #426

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#356
- IR#361
- IR#370
- IR #371
- IR #375
- IR #380
- IR#428

In addition to the above transmission IRs, approximately 46 MWs of distribution connected IRs have GIA executed. If any of the higher-queued transmission 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 (three phase rms symmetrical) are 5,000 MVA and 3,500 MVA on the 138kV and 69 kV system respectively.

Short circuit analysis was performed using Aspen OneLiner V11.8, classical fault study, 3LG and flat voltage profile at 1 per unit. Short circuit current data was assumed as typical for a Type 4 machine. The short-circuit levels in the area before and after the development of IR461 are provided in Table 1.

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

Location	IR461 in service	IR461 not in service
Maximum generation, all transmission facilities in service		
IR461 Sub, 69kV side of Transformer	601	589
17V-St.Croix, 69kV (POI)	832	820
17V-St.Croix, 138kV	1815	1807
Minimum Conditions, low Generation, 17V-T63 out of service		
IR461 Sub, 69kV side of Transformer	452	441

Table 1: Short-Circuit Levels, Three-phase MVA		
17V-St.Croix, 69kV (POI)	570	558
17V-St.Croix, 138kV	1708	1700

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

6 Voltage Flicker

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 2: Calculated Voltage Flicker	
Maximum Generation	
All transmission facilities in service	0.020
17V-T63 of service	0.025
Minimum Generation	
All transmission facilities in service	0.021
17V-T63 of service	0.027

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 IR 461 on the NSPI system, 2015 winter peak base case and 2014 light load case were selected.

17V-St.Croix has two 138kV transmission lines connected to 120H-Brushy Hill and one 138 kV line connected to 43V-Canaan Road. There are two auto transformers connecting between the 138 and 69 kV substations at 17V-St. Croix. In addition to the loads and generations, 17V-St. Croix 69 kV substation is also connected to 43V-Canaan Road via the 69kV transmission system.

Generally, the load on the 69 kV loop between 17V-St.Croix and 43V-Canaan Road is higher than the collective generation and the power flows from 138 kV system to 69 kV system. This would still be the case for the winter peak with the

addition of IR 461. The addition of IR461 poses no additional constraints to the NSPI system under winter peak conditions.

During the infrequent conditions of light load and high generation typically in the spring season, generation in the 69 kV loop can be higher than the load. This surplus energy will flow back in to 138 kV system and most of it will flow back to Metro via 138 kV transmission lines. The rest of the energy flowing back to the 69 kV system on the West is insignificant and hence will not stress the constrained transmission lines L-5532 and L-5535 above their limit. Hence, addition of IR 461 will not have any negative impact on loading any NSPI transmission equipment. For this preliminary loss factor analysis, losses associated with IR461 transformers and collector circuits are ignored.

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 IR461 while keeping 91H-Tufts Cove generation as the Nova Scotia Area Interchange bus. The loss factor for IR461, shown in Table 3, is the differential MW displaced or increased at 91H-Tufts Cove generation calculated as a percentage of IR461 name plate MW rating. . For this preliminary loss factor analysis, losses associated with IR461 transformers and collector circuits are ignored.

Table 3: Loss Factor

2015	MW
7 machines	16.45
TUC3 with IR376 generating	99.4
TUC3 without IR generating	116.7
Delta	-0.85
2015 Loss Factor	-5.17%

Loss calculations will be further refined in the SIS.

8 Voltage Control

The information submitted with IR461 indicates the machines have a power factor of 0.94. 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 16.45 MW. 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 capacitive support. Based on the assumed collector circuit and IR461 transformer impedances, study indicates the need for a capacitor bank (or equivalent) of size 2.6 MVAR. 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

17V-St. Croix is currently not designated Bulk Power System (BPS). The SIS will determine if IR461 substation will require BPS designation or if the BPS status of any existing NSPI substation is impacted by the addition of IR461 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 IR461 as NRIS to the NSPI system via 17V-B1:

A 69kV breaker connected to the existing bus 17V-B1. The existing 69 kV substation may need to be expanded to accommodate the new breaker. A new 69 kV transmission line approximately 6 km required to be built to connect to the IR 461 Interconnection Facility Both the 69kV breaker and the new radial transmission line will be designated as Transmission Provider’s Interconnection Facilities (TPIF), which are fully funded by the Interconnection Customer.

This project will require the installation of a new 900MHz licensed radio link from the new IR461 site to the existing 17V St Croix site and a radio/mux combo

to provide capability for Transfer Trip and SCADA. Traffic other than tele-protection will be cross-connected at 17V-St. Croix and brought back to NSPI Control Centre. The radio link will also be designated as Transmission Provider's Interconnection Facilities.

11 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities for interconnecting 16.45 MW wind energy as NRIS onto the 69 kV system are included in Table 4. There are no required Network Upgrades.

Table 4: Cost Estimates

	Cost Items	Estimate
NSPI Interconnection Facilities		
i	Communication	$122,000
ii	69 kV Breaker at 17V-St.Croix	$750,000
iii	69 kV transmission from 17V-St. Croix to IR 461	$1,500,000
	Contingency 10%	$237,000
	Total	$2,609,000
Cost Items To Be Determined in SIS		
	System Additions to address Stability and Security Limitations	TBD

The preliminary non-binding cost estimate for interconnecting IR461 via a new 69 KV line tap to 17V-St.Croix as NRIS would be $2,609,000 including a contingency of 10%, but not including future *to be determined* costs associated with the stability analysis of the SIS.

12 Preliminary Scope of Subsequent SIS

The SIS will be conducted in accordance with the RGIP 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, biomass and wind at maximum and minimum generating levels for the specific season.

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

- 17V-B2
- 17V-B63
- L-6012, 43V to 17V
- L-6011, 120H to 17V
- L-6051, 120H to 17V
- 120H-B61
- 120H-B61
- 17V-T2
- 17V-T63
- L-6013, 43V to 51V
- L-6015, 43V to 51V
- 43V-B61
- 43V-B62
- 20V-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
- 9W-B52
- 9W-B53
- L-5541, 50W to 3W

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

- 3Φ fault on 17V-B2
- 3Φ fault on 17V-B63
- 3Φ fault on 17V-B51
- 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 20V-B51
- 3Φ fault on 120H-B61
- 3Φ fault on 120H-B62
- 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

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.