# Interconnection Feasibility Study Report
# GIP-082-FEAS-R2

**System Interconnection Request #82**
**45 MW Wind Generating Facility**
**Colchester County (L-5040)**

August 17, 2007

Control Centre Operations
Nova Scotia Power Inc.

# Executive Summary

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed 45 MW wind generation facility interconnected to the NSPI 69kV transmission line L-5040 between 1N-Onslow and 4N-Tatamagouch, approximately 25 km from 1N-Onslow near the 68N-West Earltown switching station.

No significant concerns regarding short-circuit level, voltage flicker, or voltage control were found, provided that the project design meets NSPI requirements for low-voltage ride-through, reactive power range and voltage control system.

The Interconnection Customer's generating facility is rated at higher than the nominal summer rating of the conductor used for L-5040, and can approach the rating of the switch at the 1N-Onslow end of the circuit. The line must be surveyed to better determine the actual thermal rating. This should be done in the System Impact Study, where remedial action such as operational constraints or equipment upgrades can be examined.

It is assumed that the Interconnection Customer's facility substation is located at the Point of Interconnection, and therefore the non-binding cost estimate excludes any 69kV spur line that might be required.

The direct cost of interconnection is estimated to be $1,980,000.

This project is not significantly influenced by other projects ahead in the Interconnection Request queue.

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# 1 Introduction

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed 45 MW wind generation facility interconnected to the NSPI 69kV transmission line L-5040 between 1N-Onslow and 4N-Tatamagouch, approximately 25 km from 1N-Onslow near the 68N-West Earltown switching station. The Interconnection Request is for Energy Resource Interconnection Service (ERIS).The Interconnection Customer signed a Feasibility Study Agreement to study the connection of their proposed generation to the NSPI transmission system. This report is the result of that Study Agreement.

This project is listed as #82 in the NSPI Interconnection Request Queue, and will be referred to as IR #82 throughout this report.

# 2 Scope

The Interconnection Feasibility Study (FEAS) report shall provide the following information:

i. Preliminary identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection;

ii. Preliminary identification of any thermal overload or voltage limit violations resulting from the interconnection;

iii. Preliminary description and non-bonding estimated cost of facilities required to interconnect the Generating Facility to the Transmission System, the time to construct such facilities, and to address the identified short circuit and power flow issues.

Subsequent to this FEAS, a System Impact Study (SIS) will examine the project in more detail in the context of Interconnection Requests ahead of this IR #82. This may include system stability issues, single contingencies and extreme contingencies, off-nominal frequency operation, low voltage ride-through, harmonic current and voltage distortion, system protection, Special Protection System interaction, Automatic Generation Control action, and islanded operation. The impacts on neighboring power systems and the requirements set by reliability authorities such as the North American Electric Reliability Council (NERC) and the Northeast Power Coordinating Council (NPCC) will be addressed in the SIS, including the Bulk Power System status of IR #82 in accordance with the NPCC A-10 Criteria[1]. The SIS may identify requirements and system upgrades that are not identified in the FEAS.

[1] NPCC Document A-10, *Classification of Bulk Power System Elements*, 2007 04 28.

# 3 Assumptions

The Point of Interconnection and configuration studied is as follows:

i. A 45 MW wind farm comprised of 15 – 3 MW Vestas V90 wind turbines using asynchronous induction generator technology. If other machines are used, the results of this analysis may require revision.

ii. Generators are assumed to operate with their own power factor correction capacitor banks. They must meet NSPI power factor requirements of 0.95 inductive to 0.95 capacitive at the high voltage terminal of the interconnection, using an auxiliary reactive power source if necessary.

iii. The Interconnection Customer provided a primary and a secondary location to interconnect with L-5040. The two alternatives locations are sufficiently close together, relative to the length of L-5040, such that only one point needs to be studied. This analysis is performed with the Point of Interconnection (POI) near West Earltown, Colchester County. This point on L-5040 is approximately 25 km from 1N-Onslow substation.

iv. The wind generating facility is located approximately in close proximity to the POI on L-5040 and will be connected via a few spans of 69kV line.

v. No information was provided regarding the transformer, therefore it is assumed that there will be one 69kV transformer with a base rating of 35 MVA and a top rating of 45 MVA. Transformer impedance assumed to be 7% (on 45 MVA ONAN base) and 5 fixed taps between -5% and +5%. Collector voltage will be at the discretion of the Interconnection Customer. It should be noted that NSPI standard distribution voltage is 25kV.

This feasibility study is based on the assumption that projects that are ahead of this project in the Generation Interconnection Request Queue will not proceed, however the potential impact of those projects will be reviewed qualitatively.

# 4 Projects with Higher Queue Positions

As of 2007 06 18 the following projects have a higher Queue Position than IR #82, and have the status indicated.

**In Service and committed generation projects**

Wind Generation – 30.5 MW – connected to L-5027 (in-service)

Wind Generation – 14.0 MW – connected to L-5573 (in-service)

Wind Generation – 20.0 MW – distribution connected (in-service)

Wind Generation – 40.0 MW – distribution connected (committed)

**Generation projects with a higher Queue position, not yet committed**

IR 008 Wind – Guysborough, L-5527B, 15 MW – FAC Complete

IR 017 Wind – Lunenburg, L-6004, 100MW – SIS in Progress

IR 023 Wind – Inverness, L-6549, 100MW – SIS in Progress

IR 042 Wind – Cape Breton, New 138kV line, 100MW – SIS in Progress

IR 044 Wind – Colchester, L-6503, 35MW – FEAS in Progress

IR 045 Wind – Cumberland, L-6535, 35MW – SIS Complete

IR 046 Wind – Colchester, L-6513, 32MW – FEAS in Progress

IR 056 Wind – Cumberland, L-5058, 60MW – FEAS in Progress

IR 067 Wind – Annapolis, L-5026, 40MW – FEAS in Progress

IR 068 Wind – Digby, L-5533, 35MW – FEAS in Progress

IR 072 Wind – Guysborough, L-6515, 100MW – FEAS in Progress

IR 079 Wind – Antigonish, L-6515, 50MW – FEAS in Progress

IR 080 Wind – Cumberland, L-5550, 30MW – FEAS in Progress

IR 081 Wind – Shelburne, L-5027, 50MW – FEAS in Progress

IR 082 Wind – Colchester, L-5040, 45MW – FEAS in Progress

There are no Interconnection Requests ahead of this project in the Queue that directly impact IR #82.

# 5 Objective

The objective of this feasibility study is to determine the primary physical requirements to interconnect 45 MW of generation 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 uprated. Single contingency criteria are applied for the Energy Resource Interconnection Service assessment.

The feasibility study does not produce a binding estimate of all costs and changes that may be required to interconnect the facility. These costs are limited to facility additions/changes that are in the immediate vicinity of the proposed generating facility and any other system costs that are foreseen at the time this report is completed.

This assessment does not include any determination of facility changes/additions required to increase system transfer capabilities that may be required to the Bulk Power System to meet the design and operating criteria established by the Northeast Power Coordinating Council (NPCC) and/or the North American Reliability Corporation (NERC) or required to maintain system stability. These

requirements will be determined by the subsequent interconnection System Impact Study (SIS).

# 6 Short-Circuit Duty

The maximum (future) expected short-circuit level on 69kV systems is 3500 MVA.
The short-circuit levels in the area before and after this development are provided in Table 6-1 below.

**Table 6-1: Short-Circuit Levels. Three-phase MVA[2]**

| Location | This project in service | This project not in service |
|---|---|---|
| **All transmission facilities in service** | | |
| 1N-Onslow B52 | 704 | 614 |
| 4N-Tatamagouche | 216 | 170 |
| 69kV Connection Point | 359 | 248 |
| **Minimum conditions[3]** | | |
| 69kV Connection Point | 357 | 246 |

The maximum short-circuit level at the POI is presently 248 MVA. Although the actual increase in short-circuit levels will be dependent on the specific type of generator installed, the increase will not be more than 111 MVA, bringing the short-circuit level to not more than 359 MVA at the POI. Under contingency operation, with generators at Trenton off-line, the short-circuit level will be approximately 357 MVA at the POI.

The interrupting capability of 69kV circuit breakers at 1N-Onslow is at least 2500 MVA which will not be exceeded by this development. The transformer fuse at 4N-Tatamagouche is rated 1045 MVA and will not be adversely affected by this project

# 7 Voltage Flicker

Because the proposed generator is based on induction generator technology, and the minimum Short Circuit Ratio at the POI is only 5.5, therefore voltage flicker is a concern for this project. It is understood that the OptiSpeed® option for the Vestas V90 is not available in Canada. The unit must also be capable of providing high-speed voltage control over a range of power factor of 0.95 inductive and capacitive at the 69kV bus, therefore it is possible that the

[2] Classical fault study, flat voltage profile.
[3] L-6503 open between 1N-Onslow and 50N-Trenton

technology used to meet this requirement will also provide voltage flicker mitigation.

# 8 Thermal Limits

Line L-5040 is constructed with 336 kcm Linnet ACSR conductor designed for maximum operating temperature of 50°C. The conductor has a thermal rating of 41 MVA summer and 60 MVA winter. However, the switch at the 1N-Onlow end of the circuit has a thermal rating of 48 MVA (summer or winter), so the transmission line is currently rated 48 MVA in winter.

Since the generation is rated higher than the summer rating of the transmission line, there is a potential need to curtail the generator output for high ambient temperature. Line L-5040 should be surveyed to verify ground clearance at the required line rating. This survey may result in a requirement for the line to be uprated.

The System Impact Study will examine alternatives to address this situation in more detail.

# 9 Voltage Control

This project, like all new generating facilities must be capable of providing both lagging and leading power factor of 0.95, measured at the 69kV terminals of the Interconnection Facility substation, at all production levels up to the full rated load of 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 69kV bus voltage. The voltage controls must be responsive to voltage deviations at the 69kV terminals of the Interconnection Facility substation, be equipped with a voltage set-point control, and also have facility that will slowly adjust the set-point over several minutes (5-10) to maintain reactive power just 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[4]. The SIS will examine the generator/plant capabilities and

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

controls in detail specify any options, controls and additional facilities that are required to achieve low-voltage ride-through.

# 10 System Security

This generating facility will increase loading on the Onslow South corridor (Truro to Halifax) by replacing generation south and west of Truro. This may require increased reactive support requirements in the Halifax area or invoke facility additions that can reduce the reactive support requirements. This will be evaluated in the SIS.

The SIS will determine the facility changes that are required to permit higher transmission loadings while maintaining compliance with NERC/NPCC standards and in keeping with good utility practices.

# 11 Expected Facilities Required for Interconnection

We expect the following facilities will be required assuming that the projects ahead of IR #82 in the Interconnection Request queue, do not proceed.

**Additions/Changes to NSPI systems**

Develop a switching substation at the POI with L-5040 (West Earltown) consisting of:

i. One 69kV circuit breaker and associated switches in a line-tap arrangement,
ii. Control building and protection schemes.
iii. Control and communications between West Earltown switching station and NSPI SCADA system,
iv. Turn L-5040 into new switching station.
v. Any conductors needed to connect the wind farm to the POI will use 336 Linnet ACSR conductor rated 100°C conductor temperature.
vi. Control and Communications between the POI and NSPI SCADA system (to be specified)

**Requirements for the Interconnection Customer's Interconnection Facility**

i. If an Interconnection Facility substation is required separate from the substation at the POI, a 69kV circuit breaker and associated switches is required.

ii. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (45 MW) all at the 69kV bus when the voltage at that point is operating between 95 and 105 % of nominal.

iii. Centralized controls. These will provide centralized voltage set-point controls and reactive power set-point controls acting to control the voltage on the 69kV system and the 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.

iv. NSPI to have control and monitoring of reactive output of this facility, via the centralized controller. This will permit the NSPI Operator to raise or lower the voltage set-point and change the status of any slow-Q controls, remotely. NSPI will also have remote manual control of the load curtailment scheme.

v. Low voltage ride-through capability in accordance with FERC Order 661a.

vi. Real-time monitoring (RTUs) of the interconnection substation and facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined by SIS.

# 12 NSPI Interconnection Facilities Cost Estimate

It is anticipated that the high level cost estimates (non-binding), excluding HST taxes, for the items identified above will be approximately:

**Table 12-1: Cost Estimates**

| | Determined Cost Items | Estimate |
|---|---|---|
| i | Develop 69kV substation (West Earltown) | $1,000,000 |
| ii | Line-tap L-5040 with 69kV switch and circuit breaker | $300,000 |
| iii | Protection, control, communication | $500,000 |
| iv | Contingency (10%) | $180,000 |
| | **Total of Determined Cost Items** | **$1,980,000** |

NSPI estimates the time required to construct the above facilities at 12-24 months provided that no more than 2 to 3 projects per year go forward, and assuming all easements and permits are provided and complete.

# 13 Issues to be addressed in SIS

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.

IR #82 can reverse flow on transformer 1N-T1 as generation exceeds load on the 69kV system (L-5028 plus L-5040). This can result in voltage coordination issues between the 1N-T1 on-load tap changer and the generators.

The assessment will consider but not be limited to the following. The facility additions/changes required to increase NSPI east to west transfers under system normal conditions (all transmission in) over the range of NSPI loads and with interruptible loads on or off. Some of the interfaces that may be constrained and should be included in the assessment are as follows.

i. Onslow South

ii. Metro reactive reserve requirements

iii. NS – NB export

## 13.1 Steady-state post-contingency analysis

All elements within acceptable voltage and thermal limits under the following single contingencies, in accordance with NPCC[5] and NERC[6] criteria.

i. Hopewell transformer 79N-T81
ii. L8003
iii. Operation with Breaker 1N-600 open
iv. Buses 1N-B51 and 1N-B52 tied together (one transformer out of service).

## 13.2 System stability for the following faults

Loss of any element without a fault

i. N/A

Three-phase fault cleared in normal time:

i. L8003 at Onslow end
ii. L8001 at import and export limits

Single-phase to ground fault cleared in backup time (Breaker Failure)

i. L8003 at Onslow with failure of 67N-812 (lose L8002)

Single-phase to ground fault on separated circuits of double-circuit tower:

i. N/A

Any changes to SPS schemes required for operation of this generating facility, in addition to existing generation and facilities that can proceed before this project, will be determined by the SIS as well as any required additional transmission facilities. The determination will be based on NERC and NPCC criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

[5] NPCC criteria are set forth in it's A-2 Document *Basic Criteria for Design and Operation of Interconnected Power Systems*
[6] NERC transmission criteria are set forth in *NERC Reliability Standards TPL-001, TPL-002, TPL-003*