Interconnection Feasibility Study Report
GIP-072-FEAS-R2

Generator Interconnection Request #72

100 MW Wind Generating Facility

Guysborough County (L-6515)

August 17, 2007

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

This Interconnection Request is for a 100 MW wind generation facility in the vicinity of the town of Canso, interconnecting with the NSPI grid at 138kV line L-6515. To avoid crossing a 345kV line and multiple 230kV lines, it is proposed that the Point of Interconnection (POI) should be near Mattie Settlement, approximately 37 km from 4C-Lochaber Road.

With all lines in service, the power from this generator (with the proposed POI) splits east and west along L-6515, and flow remains within the thermal range of the circuit. Under single contingency loss of L-8003, this project causes L-6503 to exceed the rating of the switchgear on L-6503 at 50N-Trenton, which must be uprated.

If L-6515 is open between the POI and 2C-Port Hastings, voltage control may be a problem at the Interconnection Customer's facility, and operating restrictions may be applied.

IR #72 requires the development of a 138kV substation with a three-breaker ring bus at the POI on L-6515. Approximately 77 km of 138kV transmission must be built from the POI to the Interconnection Customer's generation facility.
A non-binding estimate of the direct costs to interconnect this facility is $26,016,100.

Four IR's are ahead of IR #72 in the Interconnection Request queue that have the potential to significantly impact this project. The scope of transmission reinforcements to integrate IR #72 with due consideration to the other IR's can only be addressed in the System Impact Study

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1 Introduction

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed 100 MW wind generation facility interconnected to the NSPI 138 kV transmission line L-6515 between 100C-Cape Porcupine and 4C-Lochaber Road, approximately 37 km from 4C-Lochaber Road near Mattie Settlement. This Interconnection Request is for Network Resource Interconnection Service (NRIS). 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 #72 in the NSPI Interconnection Request queue, and will be referred to as IR #72 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 #72. 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 #72 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.

The final study will be a detailed engineering review and design, known as the Interconnection Facilities Study (FAC).

3 Assumptions

The Point of Interconnection (POI) and configuration studied is as follows:

i. 100 MW wind farm comprised of 50 – 2 MW Enercon E-70 wind turbines using IGBT (full-inverter) technology. If other machines are used, the results of this analysis may require revision.

ii. Information provided by the Interconnection Customer suggests that the generators have a rated power factor from 0.87 inductive to 0.87 capacitive. This capability will be verified during the SIS to determine if it meets the NSPI requirements of 0.95 inductive to 0.95 capacitive at the high voltage terminal of the interconnection.

iii. The Interconnection Customer did not provide a specific location to interconnect with L-6515, so this analysis is performed with the assumption that the POI is near Mattie Settlement, approximately 37 km from 4C-Lochaber Rd. This is the closest location to the proposed wind farm without the need for the spur line to cross other major transmission. And alternate POI is near Afton, 45°34'37.3"N 61°41'23.4"W, however, the spur line must cross two 230kV lines plus a 345kV line.

iv. The wind generating facility is located approximately 77 km from the POI on L-6515 (73km from the alternate POI) and will be connected via new 138 kV line.

v. There will be two 138kV-34.5kV transformers, each with a base rating of 45 MVA and a top rating of 60 MVA. Transformer Impedance assumed to be 7% (on 45 MVA ONAN base) and 5 fixed taps between -5% and +5%. Collector voltage will be 34.5 kV. It should be noted that 34.5kV is not a standard voltage for NSPI, and therefore any assistance in the way of spares, tools or operating experience will be limited.

This feasibility study is based on the assumption that projects that are ahead of IR #72 in the Generation Interconnection Request Queue (Queue) will not proceed, however the potential impact of those projects will be reviewed qualitatively.

4 Projects with Higher Queue Positions

As of July, 2007 the following projects have a higher Queue Position than IR #72, 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 #72 and projects #8, #23, #42, and #44 affect the interface known as Onslow Import. Onslow Import is presently a congested interface from time to time. If any of the projects #8, #23, #42 or #44 proceed, the results of this feasibility study must be updated to reflect the impact of increased Onslow Import flow on Project #72, and any transmission upgrades that might be required for this or other projects ahead in the queue.

5 Objective

The objective of this feasibility study is to determine the primary physical requirements to interconnect 100 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 Network 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 138 kV systems is 5000MVA.

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 (1)[2]

Location	This generating facility in service	This generating facility not in service
All transmission facilities in service		
100C-Cape Porcupine	2390	2244
4C-Lochaber Road	1157	1122
Project #72 138kV substation	675	409
POI on L-6515	1842	1662
Minimum conditions[3]		
Project #72 138kV substation	481	213
POI on L-6515	532	352

The maximum short-circuit level at the POI is presently 1662 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 180 MVA, bringing the short-circuit level to not more than 1842 MVA at the POI. Under contingency

[2] Classical fault study, flat voltage profile.
[3] L-6515 open between POI and 2C-Hastings, one Trenton generator off-line.

operation, with one generator at Trenton off and L-6515 open between the POI and 2C-Port Hastings, the short-circuit level is approximately 353 MVA at the POI. The system short circuit at the wind farm 138kV substation (wind generation off) ranges from a minimum of 213 MVA to maximum of 409 MVA.

The interrupting capability of 138 kV circuit breakers at 4C-Lochaber Road is 3500 MVA which will not be exceeded by this development. The transformer fuse at 100C-Cape Porcupine is planned to be replaced by a circuit switcher before IR #72 is scheduled for service with an interrupting duty that will not be impacted by IR #72 on its own.

7 Voltage Flicker

Although the proposed generator is an Enercon fully-inverted machine, voltage flicker could be a concern when line L-6515 is open between the POI and 2C-Port Hastings. This may result in operating restrictions if the voltage control of the wind turbines is incapable of maintaining voltage control within acceptable limits under low short circuit conditions.

8 Thermal Limits

Line L-6515 is constructed with 556 kcm Dove ACSR conductor designed for maximum operating temperature of 50°C. The line has a thermal rating of 110 MVA summer and 165 MVA winter. However, the switchgear at the 4C-Lochaber Road end of the circuit has a thermal rating of 143 MVA (summer or winter), so the transmission line is currently rated 143 MVA in winter.

With all lines in service, flow on L-6515 will not be adversely affected by IR #72. However, under single-contingency loss of L-8003, L-6503 will exceed its summer rating with IR #72 in service. Therefore the switchgear (switches, circuit breakers, current transformers) for L-6503 at 50N-Trenton must be uprated from 1200 amps to at least 1500 amps.

9 Voltage Control

This facility must be capable of providing both lagging and leading power factor of 0.95, measured at the 138 kV terminals of the Interconnection Facility substation, at all production levels up to the full rated load of 100 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 138 kV bus voltage. The voltage controls must be responsive to voltage deviations at the 138 kV terminals of the Interconnection Customer substation, must be equipped with a voltage set-point control, and also have

facility that will slowly adjust the set-point over several (5-10) minutes 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 controls in detail specify any options, controls and additional facilities that are required to achieve low-voltage ride-through.

10 System Security

The NSPI transmission system has limited east to west transfer capability. Transmission corridors between Sydney and Halifax are often operated to security limits. IR #72 increases flow across the Onslow Import interface. Generation rejection SPS's are utilized to increase system stability limits to maximize east to west power transfers. Depending on the impact of other generation additions ahead of IR #72 in the Interconnection Queue, the additional generating capacity that this facility provides may not be integrated into the NSPI system under all dispatch conditions without system upgrades.

This generating facility will also 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 #72, in the Interconnection Queue, do not proceed.

[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.

Additions/Changes to NSPI systems

i. Develop a switching substation at the POI with L-6515 (Mattie Settlement) consisting of:

ii. Three 138kV circuit breakers and associated switches in a ring-bus arrangement,

iii. Control building and protection schemes.

iv. Control and communications between Mattie Settlement switching station and NSPI SCADA system,

v. Turn L-6515 into new switching station.

vi. Build 138kV spur line from new switching station to wind farm substation (77 km) with fiber optic communication wire in the shield wire (OPGW).

vii. 556 Dove ACSR conductor rated 100°C conductor temperature.

viii. Control and Communications between the POI & NSPI SCADA system (to be specified)

ix. Uprate switchgear at Trenton end of L-6503.

Requirements for the Interconnection Customer's Interconnection Facility

i. 138 kV substation. This will include 138 kV circuit breaker and protection systems as acceptable to NSPI, a Remote Terminal Unit (RTU) to interface with NSPI's SCADA with telemetry and controls as required by NSPI.

ii. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (100 MW) all at the 138 kV 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 138 kV 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 reactive power 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 (SCADA) of the IC substation and generating facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined by SIS.

12 High Level Cost for NSPI Additions/Changes

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

Table 12-1: Cost Estimates

	Determined Cost Items	Estimate
i	Uprate L-6503 switchgear at 50N-Trenton	$200,000
ii	Develop 138kV switching substation (Mattie Settlement)	$1,000.000
iii	Three-breaker ring bus on L-6515 at Mattie Settlement	$3,600,000
iv	Build 138kV line spur from Mattie Settlement to wind farm (assume 77 km)	$19,250,000
v	Additions and changes to NSPI SPS's (NSPI costs only)	$100,000
vi	Protection, control, communication	$500,000
vii	Contingency (10%)	$2,365,100
	Total of Determined Cost Item	**$26,016,100**
	To be Determined Costs	
viii	System additions to increase east-west transfer capability	TBD (SIS)

The above estimate includes the additions/changes to NSPI systems with the exception of changes to NSPI SPS's which will not be known until the SIS is complete. All costs associated with facilities required at interconnection substation and generating facility are in addition to the above estimate. 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 (N-1 operation). The SIS will be conducted with the assumption that all projects higher-queued will proceed and the facilities associated with those projects are installed.

Because IR #72 increases east-west transmission flow, transmission losses will increase. The SIS will determine the incremental impact of IR #72 on system losses.

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 Import
ii. Cape Breton Export
iii. Onslow South
iv. Metro reactive reserve requirements
v. 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. Trenton Bus 50N-B62
iii. L-8003
iv. L-6515 (either side of Interconnection Point)
v. Operation with Breaker 50N-604 open
vi. Loss of Double-circuit tower L-7003+L-7004 near Trenton
vii. Loss of double-circuit tower line L-8004 +L-7005 at Strait of Canso.

13.2 System stability for the following faults

Loss of any element without a fault

i. L-8003

[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*

ii. L-8004
iii. 79N-T81
iv. L-6515

Three-phase fault cleared in normal time:

i. L-8003 at Hopewell end
ii. L-8003 at Onslow end
iii. High voltage side of 79N-T81
iv. L-6515 at Trenton
v. L-6515 at Onslow
vi. L-8001 at import and export limits
vii. Low voltage side of 67N-T71
viii. Onslow Bus 1N-B61
ix. Onslow Bus 1N-B62

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

i. L-8003 at Onslow with failure of 67N-812 (lose L-8002)
ii. L-6515 at Onslow with failure of 1N-600
iii. L-6515 at Trenton with failure of 50N-604

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

i. L-7003 + L-7004 at Trenton
ii. L-8004 + L-7005 at Hastings.

Any changes to SPS schemes required for operation of this generating facility, in addition to existing generation and facilities that can proceed before IR #72, 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.