Interconnection Feasibility Study Report
GIP-079-FEAS-R2

System Interconnection Request #79
50 MW Wind Generating Facility
Antigonish County (L-6515)

August 17, 2007

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed 50 MW wind generation facility interconnected to the NSPI 138 kV transmission line L-6515 between 100C-Cape Porcupine and 4C-Lochaber Road, approximately 25 km from 4C-Lochaber Road near Merland, Antigonish County..

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.

Excessive thermal loading on L-6503 at the 50N-Trenton terminal was found under single contingency conditions, and therefore the circuit breaker and associated switches and current transformers at the Trenton end of this circuit must be updated from 1200A to 2000A.

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 138kV spur line that might be required.

The direct cost of interconnection, assuming that this is the only project in the vicinity to proceed, is estimated to be **$5,940,000.00**.

Because this project can impact transmission congestion between Cape Breton and Onslow, there is the potential requirement for significant transmission reinforcement, depending on the amount of generation that is added in the vicinity. The requirement for such reinforcements will be determined in a subsequent System Impact Study.

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1 Introduction

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed 50 MW wind generation facility interconnected to the NSPI 138 kV transmission line L-6515 between 100C-Cape Porcupine and 4C-Lochaber Road, approximately 25 km from 4C-Lochaber Road near Merland, Antigonish County. The Interconnection Request is for Network Resource Interconnection Service (NRIS). The Interconnection Customer signed an Interconnection 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 #79 in the NSPI Interconnection Request queue, and will be referred to as IR #79 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 #79. 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 #79 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. 50 MW wind farm comprised of 25 – 2 MW Enercon E-82 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 Merland, Antigonish County. This point on L-6515 is approximately 25 km from 4C-Lochaber Road substation.

iv. The wind generating facility is located approximately in close proximity to the POI on L-6515 and will be connected via a few spans of 138 kV line. It should be noted, however, that L-6515 is the middle circuit of a Right of Way that is bracketed by two 230kV lines.

v. There will be one 138kV-34.5kV transformer 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 #79 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 #79, and have the status indicated.

In-service and committed generation projects

- Wind Generation - 30.5 MW - connected to L-5027 (in-service)
- Wind Generation – 15 MW – connected to L-5573 (in-service)
- Wind Generation – 20 MW - distribution connected (in-service or committed)

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

- IR #8 Wind – Guysborough County L-5527B 15 MW – FAC complete
- IR #17 Wind – Lunenburg County L-6004 100 MW – SIS in progress
- IR #23 Wind – Inverness County L-6549 100 MW - FEAS complete
- IR #42 Wind – Cape Breton County 1S 100 MW – SIS in progress
- IR #44 Wind – Colchester County L-6503 36 MW – FEAS in progress
- IR #45 Wind – Cumberland County L-6535 35 MW – FEAS in progress
- IR #46 Wind – Colchester County L-6513 32 MW – FEAS in progress
- IR #56 Wind – Cumberland County L-5058 60 MW – FEAS in progress
- IR #67 Wind – Annapolis County L-5026 40 MW – FEAS in progress
- IR #68 Wind – Digby County L-5533 35 MW – FEAS in progress
- IR #72 Wind – Guysborough County L-6515 100 MW – FEAS in progress

This IR #79 and IR #8, IR #23, IR #42, IR #44 and IR #72 affect the interface known as Onslow Import. Onslow Import is presently a congested interface from time to time. If any of the projects IR #8, IR #23, IR #42 IR #44, or IR #72 proceed, the results of this feasibility study must be updated to reflect the impact of increased Onslow Import flow on IR #79, 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 50 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 138kV systems is 5000 MVA.
The short-circuit levels in the area before and after this development are provided in Table 1 below.

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

Location	IR #79 in service	IR #79 not in service
All transmission facilities in service		
4C-Lochaber Road	2327	2244
100C-Porcupine	1170	1122
138 kV Interconnection Point	1445	1321
Minimum conditions[3]		
138 kV Interconnection Point	518	395

The maximum short-circuit level at the POI is presently 1321 MVA. Although the actual increase in short-circuit levels will be dependent on the specific type of generator installed, the increase will raise the short-circuit level to not more than 1445 MVA at the POI. Under contingency operation, with generators at Trenton off-line and L-6515 open between 2C-Port Hastings and the wind farm, the short-circuit level will be approximately 395 MVA at the POI.

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 #79 is scheduled for service with an interrupting duty that will not be impacted by IR #79 on its own.

[2] Classical fault study, flat voltage profile.
[3] L-6515 open between 2C-Hastings and Project #79 POI, one unit off-line at Trenton.

7 Voltage Flicker

The proposed generator is an Enercon fully-inverted machine. Based on the minimum Short Circuit Ratio at the POI of 7.9, voltage flicker is not a concern for IR #79 on its own.

8 Thermal Limits

Line L-6515 is constructed with 556 kcm Dove ACSR conductor designed for maximum operating temperature of 50°C. The conductor 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 transmission lines in service, flow on L-6515 will not be adversely affected by IR #79. However, loss of L-8003 results in excessive flow on L-6503 between 50N-Trenton and 51N-Michelin Tap. The switchgear at the Trenton end of L-6503 (switches, circuit breaker, current transformers) must be uprated from 1200 amps to at least 1500 amps.

9 Voltage Control

IR #79, like all new generating facilities must be capable of providing both lagging and leading power factor of 0.95, measured at the 138 kV terminals of the Interconnection Faciltity substation, at all production levels up to the full rated load of 50 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, 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

[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

The NSPI transmission system has limited east to west transfer capability. Transmission corridors between Sydney and Halifax are often operated to security limits. IR #79 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 #79 in the IR queue, significant transmission system upgrades may be required to integrate IR#79.

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 #79, in the Interconnection Request queue, do not proceed.

Additions/Changes to NSPI systems

Develop a switching substation at the POI with L-6515 (Merland) consisting of:

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

ii. Control building and protection schemes.

iii. Control and communications between Merland switching station and NSPI SCADA system,

iv. Turn L-6515 into new switching station.

v. Any conductors needed to connect the wind farm to the POI will use 556 Dove 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. Assuming the Interconnection Customer substation is in close proximity to the POI, a separate substation may not be needed.

ii. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (50 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 (RTUs) of the interconnection substation and facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined by SIS.

vii. Accessible and tree-cleared lands or Rights Of Way (ROW) acceptable to NSPI for design and construction of any required new transmission line or Transmission Provider's substation.

viii. Environmental approval for the lands or right-of-ways (if required).

12 High Level Cost Estimate 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 approximately:

Determined Cost Items

Item	Estimate
Uprate L-6503 switchgear at 50N-Trenton	$200,000
Develop 138kV switching substation (Merland)	$1,000,000
Three-breaker ring bus on L-6515 at Merland	$3,600,000
Additions and changes to NSPI SPS's (NSPI costs only)	$100,000
Protection, control, communication	$500,000
Contingency (10%)	$540,000
Total of Determined Cost Items	**$5,940,000.00**

To Be Determined Cost Items

System additions to increase east-west transfer capability	TBD (SIS)
Total	TBD

The above estimate includes the additions/changes to NSPI systems with the exception of changes to SPS's which will not be known until the SIS is complete. All costs associated with facilities required at the Interconnection Customer's own substation (if remote from POI) 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 the 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 #79 increases east-west transmission flow, transmission losses will increase. The SIS will determine the incremental impact of IR #79 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 POI)
v. Operation with Breaker 50N-604 open
vi. Loss of double-circuit tower L-7003+L-7004 at Trenton
vii. Loss of double-circuit tower line L-8004 +L-7005 at Hastings

13.2 System stability for the following faults

Loss of any element without a fault

i. L-8003
ii. L-8004
iii. 79N-T81
iv. L-6515

Three-phase fault cleared in normal time:

[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*

i. L-8003 at Hopewell end
ii. L-8003 at Onslow end
iii. High voltage side of 79N-T81
iv. L-6515 at 2C-Port Hastings
v. L-6515 at 4C-Lochaber Road
vi. L-8001 at import and export limits

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

i. L-8003 at Onslow with failure of 67N-812 (lose L-8002)

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 #79, 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.