



**Interconnection Feasibility Study Report
GIP-044-FEAS-R2**

**Generator Interconnection Request #44
36 MW Wind Generating Facility
Colchester County (L-6503)**

August 17, 2007

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed 36 MW wind generation facility interconnected to the NSPI 138 kV transmission line L-6503 between 50N-Trenton and 1N-Onslow, approximately 23 km from Onslow near Kemptown. Although the Interconnection Customer provided a Property ID for the Point of Interconnection, the indicated location is actually the Right of Way for 230kV transmission lines L-7003 and L-7004. The Point of Interconnection is adjusted to the nearest point on L-6503.

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.

Thermal overloading on L-6503 at the 1N-Onslow terminal was found under single contingency conditions, and therefore the circuit breaker 1N-623 and associated switches and current transformers must be updated from 1200A to 2000A.

It is assumed that the Interconnection Customer's facility substation is located approximately 9 km from the Point of Interconnection, and therefore the non-binding cost estimate includes a 138kV spur line.

The direct costs of interconnection, assuming that this is the only project in the vicinity to proceed, is estimated to be \$8,525,000

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 reinforcement 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 36 MW wind generation facility interconnected to the NSPI 138 kV transmission line L-6503 between 50N-Trenton and 1N-Onslow, approximately 23 km from Onslow near Kemptown. The Interconnection Request is for Network Resource Interconnection Service. 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 #44 in the NSPI Interconnection Request queue, and will be referred to as IR #44 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; and
- 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 IR in more detail in the context of Interconnection Requests ahead of this IR #44. 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 #44 in accordance with the NPCC A-10 Criteria¹. 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. 36 MW wind farm comprised of 18 – 2 MW Gamesa G87 wind turbines using Double-Fed Induction Generator (DFIG) technology. If other machines are used, the results of this analysis may require revision.
- ii. Generators have a rated power factor from 0.96 inductive to 0.98 capacitive. This does not meet NSPI requirements of 0.95 inductive to 0.95 capacitive at the high voltage terminal of the interconnection, so additional switched capacitors are required.
- iii. Although the Interconnection Customer provided a Property ID with the Interconnection Request, the property identified is the Right of Way associated with the 230kV lines L-7003 and L-7004. L-7003 is a former 138kV line that is now operated at 230kV. The ROW to line L-6503 is another 2 km from the identified Property ID, requiring the line extension to cross two 230kV lines (L-7003 and L-7004) plus the Trans-Canada Highway 104.
- iv. The wind generating facility is located approximately 9 km from the POI on L-6503 and will be connected via new 138 kV line extension.
- v. Transformer Impedance assumed at 7.5% (on ONAN Base), rated 25/34//42 MVA and 5 fixed taps between -5% and +5%. Collector voltage will be 34.5 kV.

This FEAS is based on the assumption that projects that are ahead of IR #44 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 #44, 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 #44 and IR #8, IR #23 and IR #42 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 or IR #42 proceed, the results of this FEAS must be updated to reflect the impact of increased Onslow Import flow on IR #44, and any transmission upgrades that might be required for this or other projects ahead in the queue.

5 Objective:

The objective of this FEAS is to determine the primary physical requirements to interconnect 36 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 updated. Single contingency criteria are applied for the Network Resource Interconnection Service assessment.

The FEAS 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 MVA²		
Location	IR #44 in service	IR #44 not in service
All transmission facilities in service		
50N Trenton	2776	2742
49N Granton	1790	1766
1N Onslow	2292	2240
IR #44 #44 138kV substation	1266	1172
138 kV POI	1622	1529
Minimum conditions³		
IR #44 138kV substation	678	584
138 kV POI	753	661

The maximum short-circuit level at the POI is presently 1529 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 90 MVA, bringing the short-circuit level to not more than 1622 MVA at the Interconnection Point. Under minimum conditions, with one generator at Trenton off-line and L-6503 open between the POI and 1N-Onslow, the short-circuit level approaches 678 MVA at the POI. The system short circuit at the wind farm 138kV substation (wind generation off) ranges from a minimum of 584 MVA to maximum of 1172 MVA.

The interrupting capability of 138 kV circuit breakers at 1N Onslow, 50N Trenton and 49N-Granton is 3500 MVA or higher which will not be exceeded by this development on its own.

7 Voltage Flicker

The minimum Short Circuit Ratio at the Interconnection Point is 18, therefore voltage flicker is not a concern for IR #44.

8 Thermal Limits

Line L-6503 at the Interconnection point has a thermal rating of 287 MVA summer and 335 MVA winter. However, the switchgear at the 1N-Onslow end of

² Classical fault study, flat voltage profile.

³ L-6503 open between IR #44 POI and 1N-Onslow, one unit off at Trenton

the circuit has a thermal rating of 287 MVA (summer or winter), so the transmission line is currently rated 287 MVA in winter.

With all lines in service, flow on L-6503 will not be adversely affected by IR #44. However, under single-contingency loss of L-8003, L-6503 will exceed its thermal rating with IR #44 in service. The System Impact Study will examine alternatives to address this situation in more detail, but as a minimum, circuit breaker 1N-623 and its associated switches and current transformers must be updated from 1200A to 2000A.

9 Voltage Control

IR #44, 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 Facility substation, at all production levels up to the full rated load of 36 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 661a⁴. 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. Generation rejection SPS's are utilized to increase system stability limits to maximize east to west power transfers. Depending on the impact of other

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.

generation additions ahead of IR #44 in the IR queue, significant transmission system upgrades may be required to integrate IR#44.

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

Additions/Changes to NSPI systems

Develop a switching substation at the Interconnection Point with L-6503 (Kempton) 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 Kempton switching station and NSPI SCADA system,
- iv. Turn L-6503 into new switching station.
- v. Build 138kV spur line from new switching station to wind farm substation (9 km):
- vi. 1113 Beaumont ACSR conductor rated 100°C conductor temperature.
- vii. Structures crossing under L-7003 and L-7004.
- viii. Structures crossing over Trans-Canada Highway 104.
- ix. Control and Communications between Onslow, connection point & NSPI SCADA system (to be specified)
- x. Uprate circuit breaker and switches, 1N-Onslow end of L-6503.

Requirements for the Interconnection Customer’s Interconnection Facility

- i. 138 kV substation. This will include 138 kV circuit breaker and protections as acceptable to NSPI, An RTU to interface with NSPIs SCADA with telemetry and controls as required by NSPI.
- ii. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (36 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.
- 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 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 in the range:

Table 12-1: Cost Estimates		
	Determined Cost Items	Estimate
i	Uprate L-6503 switchgear at 1N-Onslow	\$200,000
ii	Develop 138kV switching substation (Kempton)	\$1,000,000
iii	Three-breaker ring bus at Kempton	\$3,600,000
iv	Build 138kV line spur from Kempton to wind farm (assume 9 km)	\$2,250,000
v	Raise/Re-enforce L-7003 & L-7004 structures	\$100,000
vi	Additions and changes to NSPI SPSs (NSPI costs only)	\$100,000
vii	Protection, control, communication	\$500,000
viii	Contingency (10%)	\$775,000
	Total of Determined Cost Items	\$8,525,000
	To be Determined Costs	
ix	System additions to increase east-west transfer capability	TBD (SIS)

All costs associated with facilities required at interconnection substation and generating facility are in addition to the above estimate. In this case the TBD costs may exceed the total of the determined cost items above. 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.

Because IR#44 increases east-west transmission flow, transmission losses will increase. The SIS will determine the incremental impact of IR #44 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 NPCC⁵ and NERC⁶ criteria.

- i. Hopewell transformer 79N-T81
- ii. Trenton Bus 50N-B62
- iii. L-8003
- iv. L-6503 (either side of Interconnection Point)
- v. Onslow Bus 1N-B62
- vi. Operation with Breaker 50N-604 open
- vii. Operation with breaker 1N-600 open
- viii. Loss of Double-circuit tower L-7003+L-7004 at Trenton
- ix. Loss of double-circuit tower line L-8004 +L-7005 at Hastings

13.2 System stability analysis

Loss of any element without a fault

- i. L-8003
- ii. L-8004
- iii. 79N-T81
- iv. L-6503

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-6503 at Trenton

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*

- v. L-6503 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-6503 at Onslow with failure of 1N-600
- iii. L-6503 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 #44, 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.