Interconnection Feasibility Study Report

GIP-156-FEAS-R1

System Interconnection Request #156

49.5 MW Wind Generating Facility

Antigonish County (L-6511)

2009 07 23

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer submitted an Request to NSPI for a proposed 49.5MW wind generation facility interconnected to the NSPI 138kV transmission system via L-6511, which requires approximately 12km newly-constructed 138kV line from the customer generation in Antignish County.

No concern regarding short-circuit, voltage flicker or voltage control were found for this project on its own, 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-6511 between 50N Trenton and IR#114 Glen Dhu Wind Farm was found under single contingency conditions, and therefore this section of transmission line should be uprated to 166 MVA from 110 MVA.

A SVC with at least 70MVAR extra reactive power compensation should be provided at Onslow (not confirmed as optimized location) for voltage support for this project under stressed cases (winter peak condition with high transfer level on transmission corridors).

Under certain conditions of high transfers across the Cape Breton Export interface, loss of the double-circuit transmission at Strait of Canso Crossing (resulting in the simultaneous loss of L-7005 plus L-8004) can result in excessive loads on the section of L-7019 between 67N-Onslow and Dalhousie Mountain Wind Farm. This may require significant transmission reinforcement, depending on the amount of generation that is added in the vicinity; otherwise it may require operator action to curtail the output of this project. The requirement of such reinforcements will be determined in a subsequent System Impact Study.

The cost of interconnection assuming that this is the only project in the vicinity to proceed is estimated to be $47,627,800.

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1 Introduction

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed 49.5 MW wind generation facility interconnected to the NSPI 138kV transmission system via L-6511 between 50N-Trenton and 4C-Lochaber Road, approximately 7km from 4C substation. The generation site would be located in Antigonish County, and would be connected to L-6511 via a newly constructed 138kV line, approximately 12 km in length (connecting to the Interconnection Customer's substation).

The requested interconnection point was the 4C substation. However, due to the congested substation layout, a new circuit breaker with a line tap can not be installed without an extensive re-arrangement of the existing substation. Therefore a new switching substation, with a differential protection scheme on L-6511, is recommended in this report.

The Interconnection Customer signed a Feasibility Study Agreement to study the connection of their proposed generation to the NSPI transmission system, dated 2008 05 16, and this report is the result of that Study Agreement. This project is listed as Interconnection Request #156 in the NSPI Interconnection Request Queue, and will be referred to as IR #156 throughout this report.

2 Scope

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

1. Preliminary identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection;
2. Preliminary identification of any thermal overload or voltage limit violations resulting from the interconnection;
3. Preliminary description and non-binding 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.

The Scope of this FEAS includes modeling the power system in normal state (with all transmission elements in service) under anticipated load and generation dispatch conditions.

For Network Resources Integration Service (NRIS), the FEAS will identify any transmission upgrades required as the result of thermal overload, voltage violation, or equipment rating. The FEAS will attempt to provide high level cost estimates for such upgrades and direct interconnection costs.

A more detailed analysis of the technical implications of this development will be included in the System Impact Study (SIS) report. This will include system stability analysis, single contingencies (including contingencies with more than one common element), off-nominal frequency operation, off-nominal voltage operation, low voltage ride through, harmonic current distortion, harmonic voltage distortion, system protection, special protection systems (SPS), automatic generation control (AGC) and islanded operation. The impacts on neighbouring power systems and the requirements set by reliability authorities such as Northeast Power Coordinating Council (NPCC), North American Electric Reliability Corporation (NERC), and NSPI will be addressed at that time. The SIS may identify additional costs and upgrades that were not identified in this FEAS.

A separate Facilities Study will follow the SIS in order to ascertain the final cost estimate for interconnection and any transmission upgrade requirements.

3 Assumptions

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

1. 49.5 MW wind farm with 33 x 1.5MW GE Wind Turbines and NRIS service type.
2. The generation technology used must meet the NSPI requirement for reactive power capability of 0.95 capacitive to 0.95 inductive at the high voltage terminals of the Interconnection Facilities (POI). It is also required to provide high-speed Automatic Voltage Regulation to maintain constant voltage at either the high voltage or the low voltage (selectable) terminals of the Interconnection Facilities.
3. The Generation Interconnection Point is on the 138kV line L-6511, approximately 7km from the 4C-Lochaber Road substation. The wind generating facility is located approximately 12 km from the line tap.
4. No information was provided regarding the IR #156 substation transformer; therefore it is assumed that there will be one 138/34.5 kV transformer with a base rating of 45 MVA and a top rating of 60 MVA. Transformer impedance is assumed to be 8.5% (on 45 MVA ONAN base) and it is assumed the transformer has 5 fixed taps between -5% and +5%. Collector voltage will be at the discretion of the Interconnection Customer.
5. This FEAS analysis is based on the assumption that IRs higher in the Generation Interconnection Queue (Queue) will not proceed; however, in accordance with UARB Order P890, projects IR# 45, IR #82, IR #84, IR #114, IR #137/150 and IR #141 have been included in this study.

4 Projects with Higher Queue Positions

As of 2009 06 19 the following projects can proceed ahead of this project, due to their position in the Generation Interconnection Request Queue, 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 – 25MW - distribution connected (in-service)
- IR #45 Wind – Cumberland County L-6535 30 MW – GIA Tendered
- IR #82 Wind – Colchester County L-5040 45 MW – GIA Executed
- IR #84 Wind – Pictou County L-7004 50 MW – GIA Executed
- IR #114 Wind – Pictou, L-6511, 60MW – FAC in Progress
- IR #137/150 Wind – Richmond, 1C, 22MW – FAC in Progress
- IR #141 Wind – Digby, 77V, 30MW – FAC in Progress

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

- IR #8 Wind – Guysborough County L-5527B 15 MW – GIA Tendered
- IR #56 Wind – Cumberland County L-5058 34 MW – FAC in Progress
- IR #67 Wind – Annapolis County L-5026 40 MW – SIS in Progress
- IR #68 Wind – Digby County L-5533 35 MW – SIS in Progress
- IR #86 Wind – Pictou County L-7003 50MW – SIS in Progress
- IR #115 Wind – Pictou, L-7003, 120MW – SIS in Progress
- IR #117 Wind – Shelburne, L-5027, 10MW – SIS Agreement Complete
- IR #126 Wind – Cumberland, L-6513, 70MW – SIS Agreement Complete
- IR #128 Wind – Cumberland, L-6536, 40.5MW – SIS Agreement Complete
- IR #130 Wind /hydro pumped storage – Cape Breton, L-6516, 200MW – SIS Agreement Complete
- IR #131 Wind – Cape Breton, L-5580, 11.5MW – SIS Agreement Complete
- IR #140 Wind – Antigonish, L-7004, 30MW – SIS Agreement Complete
- IR #149 Wind – Cumberland, L-6536, 70MW – SIS Agreement Complete
- IR #151 Steam Turbine – Halifax, 91H, 50 MW – SIS Agreement Complete

There are various congested interfaces that will be affected by this IR #156 and also other projects which have not yet been committed, but are ahead of IR #156 in the queue, as noted below.

Interface	Projects Influencing Interface (not yet committed)
Onslow Import	IR #8, IR #86, IR #115, IR #130, IR #131, IR #140
Onslow South	IR #8, IR #56, IR #86, IR #115, IR #126, IR #128, IR#130, IR#131, IR#140, IR #149

If any of the projects ahead of IR #156 proceed, the results of this feasibility study must be updated to reflect the impact of increased interface flow on IR #156, and any transmission upgrades that might be required for this or other projects ahead in the queue.

The SIS[1] will be based on the assumption that all the projects that are ahead of this project in the Queue are in-service. Should any project that is ahead of this project be withdrawn, or changed, within the established procedures then the SIS for this project must be updated accordingly, at the Interconnection Customer's expense.

5 Objective

The objective of this feasibility study is to determine the primary physical requirements to interconnect 49.5 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 upgraded. Single contingency criteria are applied for the Network Resource Interconnection Service assessment.

This 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 a complete 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 6-1 below.

[1] This process could change depending on the decision of the UARB with regard to "NSPI Application to Amend the Generation Interconnection Procedures (GIP) - P890"

Table 6-1: Short-Circuit Levels. Three-phase MVA (1)		
Location	**IR #156 in service**	**IR #156 not in service**
All transmission facilities in service		
50N-Trenton	2866	2836
4C-Lochaber Road	1319	1215
138kV Interconnection Point	893	784
Minimum Conditions (2)		
138kV Interconnection Point	566	457

(1) Classical fault study, flat voltage profile
(2) L-6511 open between 4C-Lochaber Rd and IR #114 POI

In determining the maximum short-circuit levels with this generating facility in service the generators have been modeled as conventional machines with reactance comparable to induction machines regardless of the type of generators proposed, which provides a worst case scenario.

The maximum short-circuit level at the POI is presently 784 MVA. After installing generating units the increase will bring the short-circuit level to not more than 893 MVA at the POI. Under contingency operation, with the generator at Point Tupper off-line and the wind farm only connected to 4C-Lochaber Road (L-6511 open at 4C-Lochaber), the short-circuit level will be approximately 566 MVA at the POI.

The interrupting capability of 138kV circuit breakers at 50N-Trenton and 4C-Lochaber Road is at least 3500 MVA which will not be exceeded by this development on its own.

7 Voltage Flicker and Harmonics

The voltage flicker at the POI using IEC Standard 61400-21, and based on GE published values for GE 1.5MW machines, is 0.11 under normal conditions and 0.13 under minimum generation conditions. These are both below NSPI's required limit of 0.25 for P_{st} and 0.35 for P_{lt} at the 138kV side of the 34.5/138kV. Therefore voltage flicker should not be a concern for this project. The full System Impact Study will examine the requirements in detail.

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%.

8 Thermal Limits

Line L-6511 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. The thermal ratings of L-6511 are limited by the ground clearance. 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.

Loss of L-8003 can result in line L-6511 between 50N-Trenton and IR#114 exceeding the summer line rating with #156 in service. This section of L-6511 presently has a maximum operating temperature of 50°C which must be upgraded to at least 70°C to accommodate IR#156.

9 Voltage Limits

This project, like all new generating facilities must be capable of providing both lagging and leading power factor of 0.95, measured at the 138kV terminals of the transmission providers interconnection facilities , at all production levels up to the full rated load of 49.5 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 138kV bus voltage. The voltage controls must be responsive to voltage deviations at the connection point, be equipped with a voltage set-point control, and also have facilities 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[2]. The SIS will examine the generator/plant capabilities and controls in detail and will specify any options, controls and additional facilities that are required to achieve low-voltage ride-through.

10 System Security / Stability Limits

The NSPI transmission system has limited east to west transfer capability. Transmission corridors between Sydney and Halifax are often operated to security limits. This project increases flow across the Onslow Import interface. Generation rejection Special

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

Protection Systems[3] (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 this project in the Interconnection Request Queue, the additional generating capacity that this facility provides may not be able to be integrated into the NSPI system under all dispatch conditions without system upgrades.

Under some dispatch conditions with certain contingencies, transmission corridors become overstressed, which may require transmission system improvements such as separation of L-8004 & L-7005 which currently share common structures at the Strait of Canso. This may also require increased 70Mvar 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 this project in the Interconnection Request queue (except IR# 45, IR #82, IR #84, IR #114, IR #137/150 and IR #141) do not proceed.

Additions/Changes to NSPI systems

Develop a switching substation at the POI with L-6511 consisting of:

1. Three 138kV circuit breakers and associated switches in a ring-bus arrangement,
2. 12km newly-constructed 138kV line from POI to wind farm facilities,
3. Control building and protection systems,
4. Control and communications between the POI switching station and NSPI SCADA system,
5. Structures to detour L-6511 into the new switching station,
6. Any conductors needed to connect the wind farm to the POI will use 556 Dove ACSR conductor rated 100°C conductor temperature.

[3] Also known as Remedial Action Schemes, SPS's are defined by NPCC as "A protection system designed to detect abnormal system conditions, and take corrective action other than the isolation of faulted elements." *NPCC Document A7 - Glossary of Terms*.

Requirements for the Generating Facility

1. Facilities to provide 0.95 leading and lagging power factor at POI when delivering rated output (49.5 MW) all at the 138kV bus when the voltage at that point is operating between 95 and 105 % of nominal.
2. Centralized controls. These will provide centralized voltage set-point controls and reactive power set-point controls acting to control the voltage on the 138kV 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.
3. 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.
4. Low voltage ride-through capability in accordance with FERC Order 661a.
5. Real-time monitoring (RTU's) 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

Estimates for NSPI Interconnections Facilities are included in Table 12-1.

Table 12-1: Cost Estimates

	Determined Cost Items	Estimate
I	Transmission reinforcement on double circuit towers	$20,974,000
ii	Uprate L-6511 between 50N Trenton and IR #114 Wind Farm	$4,375,000
iii	Develop 70MVAR SVC at 1N Onslow	$8,680,000
iv	Develop new 138kV single circuit line (12km)	$4,140,000
v	Develop 138kV switching substation	$4,629,000
vi	Protection, control, communication	$500,000
vii	Contingency (10%)	$4,329,800
	Total of Determined Cost Items	$47,627,800
	To be Determined Costs	
viii	System additions to address potential stability limits	TBD (SIS)

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.

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.

1. Cape Breton Export
2. Onslow Import
3. Onslow South
4. Metro reactive reserve requirements
5. NS – NB export/import

Steady-State Post-contingency Analysis

All elements within acceptable voltage and thermal limits under the following single contingencies, in accordance with NPCC[4] and NERC[5] criteria

1. L-8004
2. Hopewell transformer 79N-T81
3. L-8003

System stability for the following faults

Loss of any element without a fault

1. L-8004
2. Hopewell transformer 79N-T81
3. L-8003
4. Circuit Breaker 67N-812 (L-8002 plus L-8003)

[4] NPCC criteria are set forth in it's A-2 Document *Basic Criteria for Design and Operation of Interconnected Power Systems*

[5] NERC transmission criteria are set forth in *NERC Reliability Standards TPL-001, TPL-002, TPL-003*

Three-phase fault cleared in normal time:

1. L-6511 at POI (lose section to IR#114)
2. L-8003 at Onslow end
3. L-8003 at Hopewell end
4. 345kV bus at Hopewell
5. L-8004 at Woodbine end
6. L-8001 at import and export limits

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

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

Single-phase to ground fault on different phases of each circuits of double-circuit tower:

1. L-8004 plus L-7005 at Canso Crossing
2. L-7003 plus section of L-6511 at Trenton

Verify Bulk Power Status of Interconnection Facility

1. Three-phase fault on IR#156 138kV bus cleared remotely in backup time.

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.

Nova Scotia Power
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