Interconnection Feasibility Study Report
GIP-083-FEAS-R2

Generator Interconnection Request #083

150MW Wind Generating Facility

Shelburne , NS

August 17, 2007

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

This report discusses the preliminary analysis of the proposed 150MW wind farm connection to L-6021 (30W-Souriquois to 9W-Tusket, 138kV). This Interconnection Request (IR) will be referred to as IR 083.

Connection point to L-6021 will be referred to as the Point-Of-Interconnection (POI). The customer's 34.5kV/138kV substation will be referred to as the Interconnection Customer (IC) substation.

Based on the preliminary analysis, it is anticipated that the following transmission system upgrades would be required if IR083 were to connect to the power system as it exists today (as if other projects ahead in the queue do not proceed):

- A new 138kV substation at the POI with 5 breakers in a breaker-and-half arrangement, complete with protections and terminations for L-6021, L-6024, and the new 138kV line to the IC substation.
- A new communication medium/path/terminal equipment for the high speed protections for the newly terminated lines.
- A 40km, 138kV line from the POI substation to the IC substation.
- A generation rejection Special Protection Scheme (SPS) to reject generation for certain single contingencies.
- Possible replacement of 30W-T62, 138kV/69kV, 15/20/25MVA transformer with a larger unit (25/33/42MVA)
- SCADA control, status, alarms, and metering at the IC substation.

Based on the information submitted by the Interconnection Customer, the assumptions used (*section* 2), the scope of the FEAS (*section* 1), and the results of this preliminary analysis, it is anticipated that the high level (non-binding) cost estimate for the above mentioned upgrades will be in the vicinity of $20.2 million, excluding HST.

This cost estimate excludes:

- Any unknown costs that will be identified by a subsequent System Impact Study (SIS) and the Interconnection Facilities Study (FAC).
- Any cost associated with the requirements for the IC Interconnection Facilities (section 11.2).

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1 Introduction

The FEAS will 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 to address the identified short circuit and power flow issues as mentioned in 1.i and 1.ii.

This FEAS does not produce a binding cost estimate for all costs and system changes that may be required to interconnect the proposed Generating Facility. The costs identified in this FEAS are non-binding, high level estimates, resulted from a very preliminary analysis of the power system in the vicinity of the proposed Generating Facility.

Subsequent to this FEAS, a System Impact Study will be required to complete all the necessary evaluations (section 13) to determine all the system impacts and system upgrades required.

Subsequent to the SIS, an Interconnection Facilities Study will be required to determine the detailed engineering cost estimates.

2. Information Provided and Assumptions

2.1 Information Provided

The FEAS was conducted based on the following information submitted by the Interconnection Customer (IC):

i. The location for the POI on L-6021 was indicated at 15.3km to 35.9km from 9W-Tusket substation. Since it is not practical to study the entire range of this distance, a midpoint of 25.6km from 9W-Tusket substation was used as the POI.

ii. The wind farm will consist of 74 wind turbines, each capable of delivering 2MW. The wind turbines will be Enercon GmbH model E-82.

iii. The IC substation will have 2 generating transformers, each will be rated 40/60/75MVA, 34.5kV/138kV. Half of wind turbines will be on one transformer and half on the other. The transformers will have fixed tap +/-2.5% per tap for 2 taps above and 2 taps below nominal to provide +/-5% range.

iv. The transformer impedance will be 7% on 40MVA base.

v. The transformer will be Grounded Wye HV, Grounded Wye LV, and Delta Tertiary.

vi. NRIS service type.

2.2 Assumptions

The FEAS includes the following assumptions:

i. The IC substation (34.5kV/138kV generating transformer substation) will be 40km away from the POI on L-6021.

ii. The E-82 will be an inverter based machine with short circuit current approximately 160% of rated current.

iii. The FEAS for IR 083 will be conducted as if it were not impacted by other IRs ahead in the queue. Refer to section 4 for the existing queue.

iv. IR083 facility will meet the reactive power requirement of 0.95 capacitive to 0.95 inductive at the high voltage terminals of the IC substation. In addition to the reactive power capability of the wind turbines, additional reactive power (static var compensation) may be required to meet this requirement.

v. IR083 facility will have an automatic voltage regulation (AVR) to maintain constant voltage at the high voltage terminals of the IC substation.

A change of any of the above items may require revision to the FEAS.

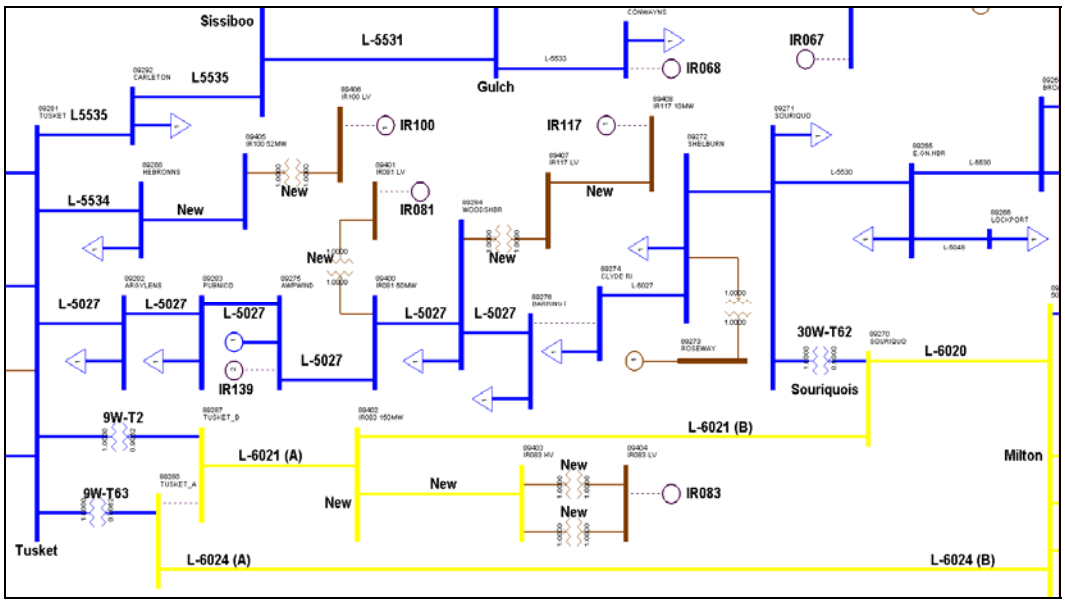
3. Existing Power System

The existing local electrical network is such that L-6021 connects 9W-Tusket and 30W-Souriquois, L-6020 connects 30W-Souriquois and 50W-Milton, and L-6024 connects 9W-Tusket and 50W-Milton.

L-6021 terminates to 9W-T2 (138kV/69kV) at 9W-Tusket.

L-6024 terminates to 9W-T63 (138kV/69kV) at 9W-Tusket.

The system one line shown below will be used for reference in the subsequent sections of this report:



NSPI's records indicate that:

L-6021	138kV, 58.7km, wood pole, H-frame, Linnet (336ACSR), Summer rating 82MVA, Winter rating 121MVA.
L-6021 Terminal	9W-Tusket: 72MVA switches, 143MVA breaker, 143MVA relay, 150MVA metering.
L-6020	138kV, 57.6km, wood pole, H-frame, Linnet, Summer rating 82MVA, Winter rating 121MVA.
L-6020 Terminal	30W-Souriquois: 143MVA relay rating. 50W-Milton: 287MVA switches and breaker, 143MVA relay, 100MVA metering at 50W-Milton.
L-6024	138kV, 111.6km, wood pole, H-frame, Drake (795ACSR), Summer rating 203MVA, Winter rating 251MVA

L-6024 Terminal	9W-Tusket: 72MVA switches, 96MVA breaker, 191MVA relay, 150MVA metering 50W-Milton: 287MVA switches, 478MVA breaker, 186MVA relay, 200MVA metering.
9W-T2	138kV/69kV, 30/40/50//56MVA transformer at 9W-Tusket
9W-T63	138kV/69kV, 33.6/44.8//56MVA transformer at 9W-Tusket
30W-T62	138kV/69kV, 15/20/25MVA transformer at 30W-Souriquois
L-5531	69kV, 24.8km, single pole, delta pin, Quail (2/0 ACSR), Summer rating 23MVA, Winter rating 34MVA.
L-5531 Terminal	Gulch: 96MVA breaker, 72MVA switches, 36MVA relay, 18 MVA metering. Sissiboo: 96MVA breaker, 48MVA switches, 24MVA relay, 36MVA metering.
L-5530	69kV, 68km, single pole, delta pin, Penguin (4/0 ACSR), Summer rating 31MVA, Winter rating 45MVA.

4. Existing Queue

The existing queue for generation Interconnection Requests as of June 18, 2007 is shown below:

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, 20MW, 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, GIA Tender
- 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 138 kV 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

5. Network Model

IR 083 was modeled as an injection of 150MW at the IC substation, 40km from the POI on L-6021. The POI was modeled at 25.6km on L-6021 from 9W-Tusket substation.

The generator was modeled with reactive power capability to control the 138kV bus voltage at the IC substation with the power factor range of +/-0.95.

L-6021 (9W-Tusket to 30W-Souriquois) was relabeled L-6021A (9W-Tusket to IR 083) and L-6021B (IR 083 to 30W-Souriquois).

L-6024 (9W-Tusket to 50W-Milton) was relabeled L-6024A (9W-Tusket to IR 083) and L-6024B (IR 083 to 50W-Milton).

PSS/E was used for load flow analysis and Aspen Oneliner was used for fault analysis.

6. Load Flow

Excluding IRs ahead in the queue, the load flow, with IR 083 150MW modeled as connected to L-6021, shows a number of issues:

6.1 System normal winter peak: Overload 30W-T62 (115%).

6.2 Loss L-6021A or 9W-T2, winter peak: Overload L-6021B (125%), L-6020 (at limit: 101%), and 30W-T62 (138%).

6.3 Loss L-6024A or 9W-T63, winter peak: Overload 30W-T62 (125%).

6.4 System normal light load: Overload on L-6021B (132%) and L-6020 (112%).

6.5 Loss L-6021A or 9W-T2, light load: Overload L-6021B (185%) and L-6020 (158%).

6.6 Loss L-6024 or 9W-T63, light load: Overload L-6021B (163%), L-6020 (140%), and L-5535 (106%).

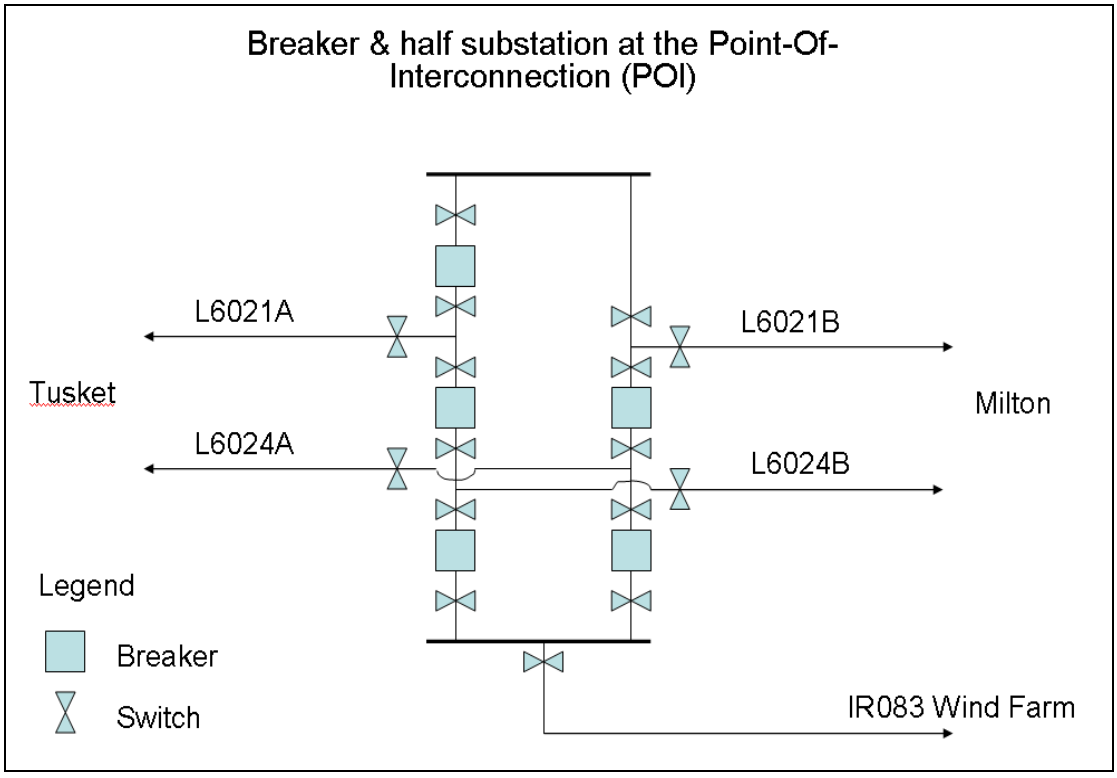
6. 7 Loss of L-6020/L-6021B or 30W-Souriquois 138kV bus, light load: Severe low voltage in the South Shore and Valley that the load flow fails to converge.

6.8 Loss of 9W-Tusket 69kV bus, light load: Overload L-6021B (183%) and L-6020 (157%).

6.9 Loss of 50W-Milton 138kV bus will overload numerous transmission lines in the Valley and South Shore and severe voltage depression in both areas.

7. Thermal Limit

Based on the preliminary analysis, it is anticipated that a breaker-and-half substation configuration will be required at the POI, as shown below:



This substation configuration will offer the advantage of avoiding overloading L-6021B and L-6020 during system normal light load, thus avoiding the cost of

upgrading these two lines for this scenario. It should also lessen the severity of a number of issues identified.

Special System Protection (SPS) will be required to reduce IR083 generation for a number of single contingencies such as loss of L-6024B, loss of L-6020/L-6021B, loss of 50W-Milton bus, and any other scenarios to be identified by the System Impact Study (SIS).

The breaker and half substation configuration at the POI will help to lessen the overload of 30W-T62 during system normal winter peak, but does not eliminate it completely. For system normal winter peak, the load flow indicates a reduction from 115% to 103%; for loss of 9W-T2 or L-6021A during winter peak, a reduction from 138% to 104%; for loss of 9W-T63 or L-6024A during winter peak, a reduction from 125% to 103%. Replacement of 30W-T62 could be a possibility depending upon whether or not this slight overload on 30W-T62 could be tolerated in winter. The nameplate of 30W-T62 shows that it has only 55deg C rise rating, not 65deg C rise. The SIS will need to conduct further load flow analysis and transformer analysis to make the determination.

8. Voltage Control

IR 083 facility must be capable of providing both lagging and leading power factor of 0.95, measured at the 138 kV terminals of the wind farm substation, at all production levels up to the full rating of 150 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 connection point, 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’s order 661a. The SIS will examine the generator/plant capabilities and controls in detail to specify options, controls and additional facilities that are required to achieve low-voltage ride-through.

9. Short circuit

The maximum design future short-circuit level on 138kV systems could be as high as 5,000MVA, hence the IC facility equipment must be provisioned for this capability.

9.1 Maximum Fault Level & Breaker Rating

The existing three phase fault level, using July 2007 base case, without any new generation, at the POI is 515MVA with X/R ratio of 4.07.

If IR083 were to connect to L-6021 and L-6024 as proposed (breaker and half arrangement), then the three phase fault level would be 901MVA with X/R ratio of 5.68 at the POI. This is based on Enercon E-82 wind turbines, which are inverter based machines, producing short circuit current approximately 160% of rated current. If the wind turbines were not Enercon E-82, then this fault level would need to be recalculated.

The maximum fault levels, based on Enercon E-82 wind turbines, would not exceed the ratings of existing breakers at NSPI's substations in the vicinity.

9.2 Minimum Fault Level & Voltage Flicker

If IR083 were to connect to L-6021 and L-6024 as proposed, then the minimum fault level (minimum generation and L-6024B outage) would be 378MVA with X/R ratio of 2.44 at the POI.

Since the short circuit ratio at the POI is low (2.5) at minimum fault level, coupled with the fact that there is already an existing 30.5MW wind farm on L-5027, it will require the SIS to determine if the voltage flicker emission will or will not be a limiting factor, depending upon the wind turbines and the technologies used.

10. System Security

Locally, in the South Shore and Valley, there are some special protection schemes (SPS) at 9W-Tusket, 51V-Tremont, and 43V-Canaan Road, and 50W-Milton substation.

The SIS will be required to examine the impact of the proposed generating facility on the local SPSs as well as other SPSs being used in the power system.

11. Expected Facility Required

Based on the scope (section 1), the assumptions (section 2), and the preliminary analysis of this FEAS, it is anticipated that the following facilities will be required.

11.1 Additions/Changes to NSPI System

i. A new 138kV breaker and half substation at the POI as per section 7, complete with protections and line terminations.

ii. A new communication medium/path/terminal equipment required for the high speed protections for L-6021A, L-6021B/L-6020, L-6024A, L-6024B, and the new 138kV line extension from the POI to the IC substation

iii. A new 40km, 138kV line extension from the POI substation to the IC substation.

iv. A new generation rejection SPS as discussed in section 7.

v. Possible replacement of 30W-T62, 138kV/69kV, 15/20/25MVA transformer with a larger unit (25/33/42MVA)

vi. SCADA control, status, alarms, and metering at IC substation

11.2 Requirements for the IC Interconnection Facilities

vii. A new 138kV substation (IC substation), including an RTU to interface with NSPIs SCADA with telemetry and controls as required by NSPI.

viii. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (150 MW) at the 138 kV bus when the voltage at that point is operating between 95% and 105 % of nominal. In addition to the reactive power capability of the wind turbines, additional reactive power (static var compensation) may be required to meet this requirement.

ix. Responsive (fast acting) 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. 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.

x. 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.

xi. Low voltage ride-through capability in accordance with FERC's order 661a.

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

xiii. Flicker meter at the IC substation.

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

xv. Environmental approval for the lands or ROW.

12. High Level Estimate on Additions/Changes to NSPI System

12.1 Cost items that are identified by the FEAS

It is anticipated that the high level cost estimates (non-binding), excluding HST taxes, for the items identified in section 11.1 will be in the vicinity of:

Item Description	Estimate
1. A new 138kV breaker and half substation at the POI as per section 7, complete with protections and line terminations.	$7.0M
2. A new communication medium/path/terminal equipment required for the high speed protections for L-6021A, L-6021B/L-6020, L-6024A, L-6024B, and the new 138kV line extension from the POI to the IC substation	$1.2M
3. A new 40km, 138kV line extension from the POI substation to the IC substation.	$10.0M
4. A new generation rejection SPS as discussed in section 7.	$0.2M
5. Possible replacement of 30W-T62, 138kV/69kV, 15/20/25MVA transformer with a larger unit (25/33/42MVA)	$1.5M
6. SCADA control, status, alarms, and metering at IC substation	$0.3M
Subtotal	$20.2M

12.2 Cost items that are unknown, yet to be determined by the SIS

To be determined by the System Impact Study (SIS)	n/a

NSPI estimates the time required to construct the above facilities at 24-36 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. System Impact Study

Subsequent to this FEAS, a System Impact Study will be required to examine this project in details in the context of, but not be limited to, the following evaluations:

- Impact on existing Special Protection Schemes
- Equipment required to meet reactive power of 0.95 capacitive to 0.95 inductive at the high voltage terminals of the IC substation
- No voltage step change more than +/- 2.5% at transmission buses
- Centralized controller and the controls for maintaining constant voltage on the high voltage terminals of the IC substation
- Stability analysis for all single contingencies
- Load flow analysis for all single contingencies (the FEAS has only analyzed limited cases preliminarily)
- Impact of IRs which are ahead of this IR in the Generation Interconnection Request Queue
- Impact on Under Frequency Load Shedding
- Off nominal frequency operation
- Off nominal voltage operation
- Low voltage ride through
- Harmonic current distortion
- Harmonic voltage distortion
- System protection
- Automatic generation control and tie lines between NS and NB
- Islanded condition
- Voltage flicker emission
- Equipment to mitigate voltage flicker if required
- Voltage/Power Factor control
- Requirements of NERC and NPCC
- Sensitivity analysis with Hydro dispatch patterns
- Sensitivity analysis with neighbouring wind farms

Subsequent to the SIS, an Interconnection Facilities study will be required to determine the detailed engineering cost estimates.