Interconnection Feasibility Study Report
GIP-100-FEAS-R2

Generator Interconnection Request #100

52MW 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 52MW wind farm connection to 16W-Hebron substation with the generation flowing to 9W-Tusket bus via L-5534. This Interconnection Request (IR) will be referred to as IR100.

16W-Hebron substation will be referred to as the Point-Of-Interconnection (POI) substation. The customer's 34.5kV/69kV 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 IR100 were to connect to the power system as it exists today (as if other projects ahead in the queue do not proceed):

- Upgrade (rebuild) L-5534 to a higher rating.
- Possible L-5534 protection upgrade at 9W-Tusket substation.
- A 69kV breaker substation at the POI, complete with line protection.
- Communication required for transfer trip from 9W-Tusket substation to the IC substation and for communication from IC substation back to NSPI's SCADA.
- A new 8km 69kV line extension from the POI to the IC substation.
- 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 cost estimate (non-binding) for the above upgrades will be in the vicinity of $4.7 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 feasibility study (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 of the POI will be at the 69kV bus at 16W-Hebron substation. The IC substation will be 8km away from the POI. Hence, it will require 8km of 69kV line extension.

ii. The wind farm will consist of 26 wind turbines, each capable of delivering 2MW. The wind turbines will be Gamesa G-87.

iii. The IC substation will have one generating transformer, rated 35/46/59MVA, 34.5kV to 69kV. The transformer 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 7.5% on 35MVA base.

v. NRIS service type.

2.2 Assumptions

The FEAS includes the following assumptions:

i. Since the specification for the Gamesa G-87 wind turbines is not available for this feasibility study, they will be modeled as induction generators with the typical fault current contribution of induction machines.

ii. The FEAS for IR100 will be conducted as if it were not impacted by other IRs ahead in the queue. Refer to section 4 for the existing queue.

iii. IR100 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.

iv. IR100 facility will have an automatic voltage regulation (AVR) to maintain constant voltage at the high voltage terminals of the IC substation.

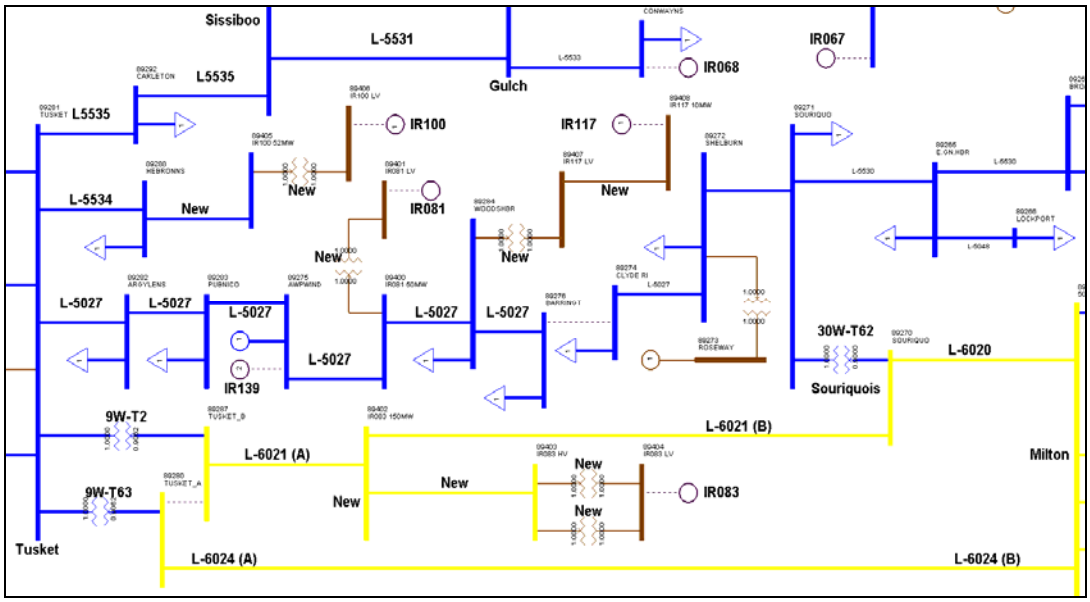
v. The transformer will be Grounded Wye HV, Grounded Wye LV, and Delta Tertiary.

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-5534 operates as a 69kV radial line from 9W-Tusket substation. 16W-Hebron substation is normally fed from L-5534, but there are times when 16W-Hebron load could be fed from L-5536 during L-5534 outage.

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



NSPI's records indicate that:

L-5534	69kV line, 8.37km, 9W-Tusket to 16W-Hebron, wood pole H-frame construction, conductor Penguin (4/0ACSR), summer rating 31MVA, winter rating 45MVA.
L-5536	69kV line, 20.5km, 9W-Tusket to Yarmouth, wood pole with a mixture of single poles and H-frames, conductors are a mixture of Quail, Penguin, and Linnet, summer rating 23MVA, winter rating 34MVA.

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
- IR 083 Wind, Shelburne, L-6021, 150MW, FEAS in Progress
- IR 084 Wind, Pictou, L-7004, 50MW, FEAS in Progress
- IR 085 Wind, Pictou, L-6511, 50MW, FEAS in Progress
- IR 086 Wind, Pictou, L-7003, 50MW, FEAS in Progress

5. Network Model

IR100 was modeled as an injection of 52MW at the IC substation, 8km from 16W-Hebron substation. The POI was modeled at 16W-Hebron 69kV bus.

The generator was modeled with reactive power capability to control the 69kV bus voltage at the IC substation with the power factor range of +/-0.95.

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

6. Load Flow

The load flow, modeling IR100 on L-5534, shows that when IR100 is at full rating, L-5534 will be overloaded (160%) from the POI back to 9W-Tusket substation during light load.

The load flow, modeled with L-5534 upgraded from Linnet (336ACSR) conductors to Dove (556ACSR) conductors, shows more desirable results. Under system normal (with all transmission elements in service), the load flow indicates that L-5534 will not be overloaded and the voltage profile will be acceptable.

7. Thermal Limit

Based on the above preliminary analysis, it is anticipated that L-5534 will require an upgrade from Linnet (336ACSR) to Dove (556ACSR) at 100deg C for the line section from 16W-Hebron back to 9W-Tusket substation (approximately 8.4km).

8. Voltage Control

IR100 facility must be capable of providing both lagging and leading power factor of 0.95, measured at the 69 kV terminals of the wind farm substation, at all production levels up to the full rating of 52 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 69 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 69kV systems could be as high as 3,500MVA, 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 on L-5534 would be 368MVA with X/R ratio of 2.78.

If IR100 were to connect to L-5534 at 16W-Hebron substation and if the Gamesa G-87 wind turbines were modeled as induction machines, then the three phase fault level would be 485MVA with X/R ratio of 3.6 at the POI. When the specification for the Gamesa G-87 or the wind turbines chosen is available, then this fault level would need to be recalculated.

The maximum fault levels, based on the above analysis, would not exceed the ratings of existing breakers at NSPI's substations in the vicinity.

9.2 Minimum Fault Level & Voltage Flicker

The minimum fault level at POI on L-5534, using July 2007 base case (minimum generation and L-6024 outage) would be 195MVA with X/R ratio of 2.1 at the POI.

If IR100 were to connect to L-5534, the short circuit ratio at the POI would be low (3.8) 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. Upgrade L-5534 to 556ACSR at 100deg C.

ii. Possible L-5534 protection upgrade at 9W-Tusket substation.

iii. A 69kV breaker substation at the POI, complete with line protection.

iv. Communication for transfer trip from 9W-Tusket substation.

v. A new 8km 69kV line extension from the POI to the IC substation.

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

11.2 Requirements for the IC Interconnection Facilities

vii. A new 69 kV 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 (52 MW) at the 69 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 69kV 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. Rebuild L-5534 to Dove, 556ACSR at 100deg C.	$1.8M
2. Possible L-5534 protection upgrade at 9W-Tusket substation.	$0.1M
3. A 69kV breaker substation at the POI, complete with line protection.	$0.8M
4. Communication for transfer trip from 9W-Tusket substation.	$0.2M
5. A new 8km 69kV line extension from the POI to the IC substation.	$1.6M
6. SCADA control, status, alarms, and metering at the IC substation.	$0.2M
Subtotal	$4.7M

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 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. 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.