Interconnection Feasibility Study Report
GIP-117-FEAS-R2

Generator Interconnection Request #117

10MW Wind Generating Facility

Shelburne , NS

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Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

This report discusses the preliminary analysis of the proposed 10MW wind farm connection to 21W-Lower Woods Harbour substation with the generation flowing to 9W-Tusket bus via L-5027. This Interconnection Request (IR) will be referred to as IR117.

21W-Lower Woods Harbour substation will be referred to as the Point-Of-Interconnection (POI). The customer's 27.6kV/69kV substation will be referred to as the Interconnection Customer (IC) substation. In the case of IR117, the IC substation will be at the POI, hence this feasibility study does not include the POI substation or any 69kV line extension.

Based on the preliminary analysis, it is anticipated that the following transmission system upgrades would be required if IR117 were to connect to the power system as it exists today (as if other projects ahead in the queue do not proceed):

- SCADA control, status, alarms, and metering at the IC substation.
- Communication required for transfer trip from 9W-Tusket substation to the IC substation and for communication from IC substation back to NSPI's SCADA.

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 upgrades will be in the vicinity of $0.5 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).
- Any 69kV line extension from the POI to the IC substation, and a 69kV breaker substation at the POI if this line extension were to be longer than 1km.

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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 for the IC substation will at the 69kV bus at 21W-Lower Woods Harbour substation. Hence, the POI substation and the IC substation will be just one substation. There will be no 69kV line extension.

ii. The wind farm will consist of 5 wind turbines, each capable of delivering 2MW. The wind turbines will be Enercon GmbH model E-82.

iii. The IC substation will have a step up transformer, rated 12MVA, 27.6kV to 69kV.

iv. ERIS service type.

2.2 Assumptions

The FEAS includes the following assumptions:

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

ii. The step up 27.6kV/69kV transformer impedance will be 5% on 12MVA base.

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

iv. The FEAS for IR117 will be conducted as if it were not impacted by other IRs ahead in the queue. Refer to section 4 for the existing queue.

v. IR117 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.

vi. IR117 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.

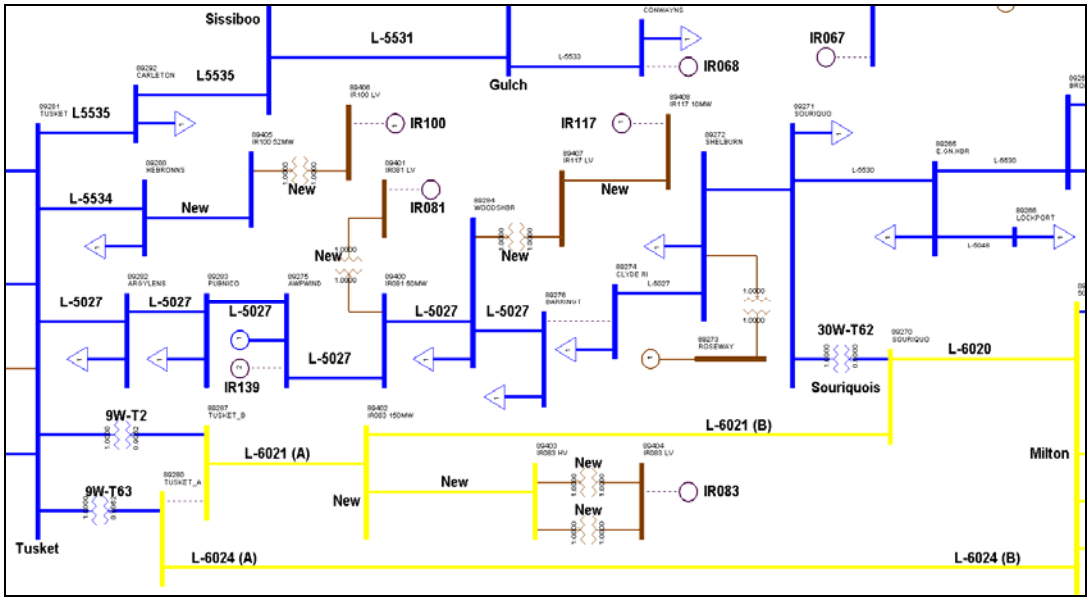
3. Existing Power System

The existing local electrical network is such that L-5027 operates as a 69kV radial line from 9W-Tusket substation. The line provides 69kV transmission feed to four load substations (19W-Central Argyle, 20W-Lower East Pubnico, 21W-Lower Woods Harbour, and 22W-Barrington Passage).

L-5027 has already a connection to a 30.5MW wind farm operating at 106W-Pubnico Point Wind Farm.

The line section between 22W-Barrington Passage substation and 23W-Clyde River substation is normally open. This FEAS will only examine the case of IR117 connected to L-5027 radially from 9W-Tusket substation (not from 30W-Souriquois substation).

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



NSPI's records indicate that L-5027 radial section 9W-Tusket substation to 22W-Barrington Passage substation is 60.21km long. The line section from 21W-Lower Woods Harbour substation to 9W-Tusket is 50.41km in length, has wood pole H-frame construction with Linnet (336ACSR) conductor. The line has a 41MVA summer rating and a 60MVA winter rating. It is also restricted by relay rating at 39MVA and metering rating at 48MVA.

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
- IR 100 Wind, Yarmouth, New 69kV line, 52MW, FEAS in Progress
- IR 114 Wind, Pictou, L-6511, 60MW, FEAS in Progress
- IR 115 Wind, Pictou, L-7003, 120MW, FEAS in Progress

5. Network Model

IR117 was modeled as an injection of 10MW at 27.6kV at 2.5km (via cable) from 21W-Lower Woods Harbour substation. The 27.6kV to 69kV step up transformer is modeled at 21W-Lower Woods Harbour substation. The generator was modeled with reactive power capability to control the 69kV bus voltage 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 preliminary analysis showed that if IR117 were to connect to the power system as it exists today (ignoring other IRs ahead in the queue), it would not cause thermal overload or large voltage step change on the transmission system in the area under system normal (all transmission elements in service).

7. Thermal Limit

No thermal overload was observed under system normal.

8. Voltage Control

IR117 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 10MW.

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-5027 would be 187MVA with X/R ratio of 4.18.

If IR117 were to connect to L-5027 at the POI (21W-Lower Woods Harbour substation) then the three phase fault level would be 200MVA with X/R ratio of 4.48. 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

The minimum fault level at POI on L-5027, using July 2007 base case (minimum generation and L-6024 outage) would be 105MVA with X/R ratio of 2.55.

If IR117 were to connect to L-5027 at the POI (21W-Lower Woods Harbour substation) then the short circuit ratio would be 10.5 at minimum fault level, so it is not anticipated that voltage flicker would be an issue.

However, there is already an existing wind farm at 106W-Pubnico Point, voltage flicker must be further analyzed in details by the SIS, depending upon the type of wind turbines and the technologies used, to determine if voltage flicker will or will not be a limiting factor.

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

ii. Communication for transfer trip from 9W-Tusket substation and SCADA communication.

11.2 Requirements for the IC Interconnection Facilities

iii. A new 69 kV substation (IC substation), including a 69kV circuit breaker complete with protection and an RTU to interface with NSPIs SCADA with telemetry and controls as required by NSPI.

iv. 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.

v. 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.

vi. 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.

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

viii. 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.

ix. Flicker meter at the IC substation.

x. 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).

xi. 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. SCADA control, status, alarms, and metering at IC substation.	$0.2M
2. Communication for transfer trip from 9W-Tusket substation and SCADA communication.	$0.3M
Subtotal	$0.5M

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.