Interconnection Feasibility Study Report

GIP-238-FEAS-R1

System Interconnection Request #238

54 MW Wind Generating Facility

Yarmouth County (9W)

2011-04-08

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer submitted an Interconnection Request for Network Resource Interconnection Service (NRIS) to NSPI for a proposed 54 MW wind generation facility at Yarmouth County. The Point of Interconnection (POI) requested by the customer is on either line L-6024 or L-6021 at 9W-Tusket substation. However the existing 9W-Tusket substation is physically congested and there is not enough room to accommodate the expansion for IR#238; therefore the recommended POI in this study is located approximately 8 km away from 9W substation on L-6021, which requires approximately 20 km of newly-constructed spur line from the wind farm at Wedgeport. A new switching station will be developed at the POI with three 138 kV circuit breakers and associated switches in a ring bus arrangement, and new structures will be required to detour L-6021 into the new switching station.

Under peak wind generation in both Western and Valley areas and light load condition during summer, when 10W-Tusket gas turbine (24 MW) is also in service, a line fault on L-6020/6021 or bus fault on 50W- Milton B3 resulting in the tripping of L-6020 could potentially cause the thermal overload of L-6024 and the 9W-T63 transformer. Similarly, under peak wind generation in the Western area during light load conditions while the generation in the Valley area is low, loss of L-6020 could cause L-5535 to be overloaded. Therefore a Special Protection System (SPS) would have to be deployed to trip or curtail the wind farm when L-6020 is tripped from the 50W-Milton end in a fault situation. The SPS will be armed whenever Tusket Gas Turbine on-line and will be activated by loss of L-6020 for any reason. The new SPS scheme would have to be presented to NPCC and would require their approval. The contingencies that should be included in the SPS will be further assessed in the SIS study as well as the arming conditions.

No concern regarding short-circuit or voltage flicker was 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. Harmonics must meet the Total Harmonics Distortion provisions of IEEE 519.

The loss factor for IR #238 is approximately 0.9% (the overall system losses increased by net 0.5 MW when IR #238 is operated at 54 MW).

The preliminary non-binding estimated cost of facilities required to interconnect the IR#238 to L-6021 is $13.4 Million including a contingency of 10%. This estimate will be further refined in the System Impact Study and the Facility Study.

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1 Introduction

The Interconnection Customer submitted an Interconnection Request (IR) for Network Resource Interconnection Service (NRIS) to NSPI for a proposed 54 MW wind generation facility interconnected to the NSPI transmission system. The Point of Interconnection (POI) requested by the Interconnection Customer (IC) is on either L-6024 or L-6021 at 9W-Tusket substation. However the existing 9W-Tusket substation is physically congested and there is not enough room to accommodate the expansion for IR#238, therefore the recommended POI in this study is located approximately 8 km away from 9W substation on L-6021, which requires approximately 20 km of newly-constructed spur line from the wind farm at Wedgeport.

The Interconnection Customer signed a Feasibility Study Agreement to study the connection of their proposed generating facility to the NSPI transmission system dated 2011-02-14, and this report is the result of that Study Agreement. This project is listed as Interconnection Request #238 in the NSPI Interconnection Request Queue, and will be referred to as IR#238 throughout this report.

2 Scope

The Interconnection Feasibility Study (FEAS) consists of a power flow and short circuit analysis. Based on this scope, the 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 limits violations resulting from the interconnection;
3. Preliminary description and high level 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.

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.

In accordance with Section 3.2.2.2 of the Standard Generation Interconnection Procedures, as approved by the UARB on February 10, 2010 (RGIP), the Interconnection Study for NR Interconnection Service shall assure that the Interconnection Customer's Generating Facility meets the requirements for NR Interconnection Service and as a general matter, that such Generating Facility's interconnection is also studied with the Transmission Provider’s Transmission System at peak load, under a variety of severely stressed conditions, to determine whether, with the Generating Facility at full output, the aggregate of generation in the local area can be delivered to the aggregate of load on the

Transmission Provider's Transmission System, consistent with the Transmission Provider's reliability criteria and procedures.

A more detailed analysis of the technical implications of this development will be included in the System Impact Study (SIS) report. The SIS includes system stability analysis, power flow analysis such as 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 and will include an assessment of the status of the Interconnection Facility as a Bulk Power System element. The SIS may identify and provide a non-binding estimate of any additional interconnection facilities and/or network upgrades that were not identified in this FEAS.

An Interconnection Facilities Study follows the SIS in order to ascertain the final cost estimate to interconnect the generating facility.

3 Assumptions

The FEAS is based on the technical information provided by the Interconnection Customer. The Point of Interconnection (POI) and configuration is studied as follows:

1. Network Resource Interconnection Service type per section 3.2 of the RGIP.
2. 54 MW wind with 18 x 3.0 MW Vestas V112 Wind Turbines.
3. The generation technology used must meet NSPI requirement for reactive power capability of 0.95 capacitive to 0.95 inductive at the HV terminals of the IC Substation Step Up transformer. The generator is assumed to be specified for 54 MW at a rated power factor of 0.9 for both lagging and leading at generator terminals. It is also required to have high-speed Automatic Voltage Regulation to maintain constant voltage at the generator terminals during and following system disturbances as determined in the subsequent System Impact Study.
4. The Interconnection Customer indicated that the generation interconnection point is on the 138 kV line L-6024 with an alternative POI on 138kV line L-6021 both at 9W-Tusket substation. However due to the physical restriction of 9W substation, the recommended POI in this study is located approximately 8 km from 9W substation on L-6021 via an approximately 20 km newly-constructed spur line from the wind farm at Wedgeport.
5. Preliminary data was provided by the Interconnection Customer for the generator step-up and IC substation step-up transformers. Modeling was conducted with a 138kV-34.5kV 39/52/64 MVA Interconnection Facility transformer with a positive

sequence impedance of 9% and an assumed X/R ratio of 7.5. The Interconnection Customer indicated that this Interconnection Facility step-up transformer has a grounded wye-delta-wye winding configuration with +/-5% off-load tap changer. The generator step-up transformer has an impedance of 8% on 3.35 MVA with +/-5% off-load tap changer and an assumed X/R ratio of 7.5.

6. The FEAS analysis is based on the assumption that IR's higher in the Generation Interconnection Queue (Queue) that have completed a System Impact Study, or that have a System Impact Study in progress will proceed. As such, IR#8, IR #45, IR#56, IR#151, IR#219, IR#227, IR#225, IR#233 and IR#234 are included in this study.

4 Projects with Higher Queue Positions

All in-service generation is included in the FEAS.

As of 2011-04-05 the following Transmission Service Requests from the Open Access Transmission Tariff are higher queued, and have the status indicated.

- TSR 100 SIS in progress
- TSR 200 SIS in progress

The following projects are higher queued in the Interconnection Request Queue, and have the status indicated.

Per GIP Section 6.2 - Interconnection Requests -included in FEAS (Committed to study Base Case)

- IR #45 Unexecuted GIA filed
- IR #8 GIA Executed
- IR #56 GIA Tendered
- IR #151 FAC in progress
- IR #219 FAC in progress
- IR #227 SIS complete
- IR #225 FAC in progress
- IR #233 SIS in progress
- IR #234 SIS in progress

Per GIP Section 6.2 – Interconnection Requests not included in FEAS

The following IRs either have SIS Agreements complete (but have not yet met the RGIP SIS progression milestones), or have Feasibility Study agreements complete. As such, they are not included in this FEAS.

IR #67	IR #68	IR #86	IR #115	IR #117	IR #126
IR #128	IR #130	IR #131	IR #140	IR #149	IR #156
IR #157	IR #163	IR #213	IR #222	IR#232	IR#235

If any of the higher-queued projects included in this FEAS are subsequently withdrawn from the Queue, the results of this FEAS may need to be updated. The re-study cost incurred as a result of the withdrawal of the higher-queued project shall be the responsibility of the Interconnection Customer that has withdrawn the higher queued project.

5 Objective

The objective of this FEAS is to provide a preliminary evaluation of the system impact and the high-level non-binding cost estimate of interconnecting the 54 MW generating facility to the NSPI transmission system 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[1] are applied for the NRIS assessments.

This FEAS is based on a power flow and short circuit analysis and 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 NPCC and 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 (design) expected short-circuit level is 5000 MVA on 138kV systems and 3500 MVA on 69kV systems. The short-circuit levels in the area before and after this development are provided below in Table 6-1.

Table 6-1: Short-Circuit Levels. Three-phase MVA (1)

Location	IR #238 in service	IR #238 not in service
All transmission facilities in service		
9W-Tusket 138kV (POI)	583	454
9W-Tusket 69 kV	562	507
30W-Souriquois 138 kV	679	609
50W-Milton 138 kV	1575	1507
Minimum Conditions		
9W-Tusket 138kV (POI)	402	275

[1] The Single Contingency Criteria is defined by NPCC in its A-7 Document, and may involve more than one transmission element.

(1) Classical fault study, flat voltage profile

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 SIS will refine the fault level based on the actual machine characteristics.

The maximum short-circuit level on 138kV bus at 9W is presently 454 MVA. After installing IR # 238 the increase will bring the short-circuit level to 583 MVA at the POI. Similarly, under summer light load conditions with certain generation units offline, the minimum short-circuit level will be approximately 275 MVA at the POI. This translates into maximum equivalent system impedance at the POI of 0.36 per unit on 100 MVA base.

The interrupting capability of the 69kV circuit breakers at 9W-Tusket is at least 2000 MVA, the interrupting capability of the 138kV circuit breakers is 4500 MVA at 30W-Souriquois and at least 3500 MVA at 50W-Milton which will not be exceeded by this development on its own.

7 Voltage Flicker and Harmonics

The generator flicker co-efficient data was not available at the time of this study. As a result, the voltage flicker analysis will be conducted during the System Impact Study. However, as the ratio of short-circuit level to generating capacity at POI under system normal condition is 10.8 (based on proposed plant rating of 54 MW), there should be no specific issues regarding voltage control and power quality due to the addition of this facility on its own.

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

This facility would be tapped off either L-6024 or L-6021 by constructing approximately 20 km of 138kV transmission line with 556 ACSR Dove conductors and maximum operating temperature of 100ºC. The proposed POI is at the 9W-Tusket substation, however the space at 9W substation is very physically congested and there is not enough room for the expansion to accommodate a new line for IR#238. There is a property located approximately 8 km away from 9W substation near L-6021/6024 that NSPI owns for the future substation development. Therefore this study recommends the development of a switching station utilizing this property as the POI. IR#238 will be integrated with the systems via three breakers and associated switches in a ring-bus arrangement. Load flow analysis indicates that L-6021 is the better option due to the performance on voltage

support and energy deliveries under certain contingencies, therefore it is recommended in this study.

The 138 kV L-6024 is constructed with 795 ACSR Drake conductors and maximum operating temperature of 70ºC with conductor thermal rating of 203 MVA in summer and 251 MVA in winter. However, the switch continuous ratings of the line terminal at 9W-Tusket restrict the L-6024 rating to 72MVA for both summer and winter. L-6021 is constructed with 336 Linnet conductors and maximum operating temperature of 50ºC with conductor thermal rating of 82 MVA in summer and 121 MVA in winter. Similarly the line rating is also limited to 72 MVA by the switch continuous ratings at the 9W-Tusket end for both summer and winter. Both 138/69kV transformers 9W-T2 and 9W-T63 are rated at maximum 56 MVA.

The total wind generation in the local Tusket area could be as high as 85 MW with IR#238 in service. Under peak wind generation at both Western and Valley areas with light load condition during summer, when 10W-Tusket gas turbine (24 MW) is also on-line, a line fault on L-6020/6021 or bus fault on 50W- Milton B3 resulting in the tripping of L-6020 could potentially cause the thermal overload of L-6024 and the 9W-T63 transformer. Similarly, under peak wind generation in the Western area and light load condition during summer while generation output in the Valley area is low, loss of L-6020 could cause L-5535 to be overloaded. Therefore a Special Protection System (SPS) would have to be deployed to trip or curtail the wind farm when L-6020 is tripped from the 50W-Milton end in a fault situation. The SPS will be armed whenever the 10W Gas Turbine on-line and will be activated by loss of L-6020 for any reason. The new SPS scheme would have to be presented to NPCC and would require their approval. The contingencies that should be included in the SPS will be further assessed in the SIS study as well as the arming conditions.

The requirement for restrictions or curtailments of this facility when operating with an element (transmission line, transformer etc) out of service (N-1 operation) will be further assessed in the SIS.

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 HV terminals of the IC Substation Step Up Transformer, at all production levels up to the full rated load of 54 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 34.5 kV bus voltage. The voltage controls must be responsive to voltage deviations at the terminals of the Interconnection Facility substation, be equipped with a voltage set-point control, and also have the ability to slowly adjust the set-point over several (5-10) minutes to maintain reactive power within the individual generators capabilities. The

details of the specific control features, control strategy and settings will be reviewed and addressed in the SIS, as will the dynamic performance of the generator and its excitation.

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 also have low voltage ride-through capability as per Appendix G to the Standard Generator Interconnection and Operating Agreement (GIA). The SIS will state specific options, controls and additional facilities that are required to achieve this.

The SIS will also examine whether a voltage control device will be required for this wind facility under contingencies as well as the options on the voltage profile control forms.

10 System Security / Stability Limits

The SIS will determine if any facility changes are required to permit the proposed higher transmission loadings while maintaining compliance with NERC/NPCC standards and in keeping with good utility practice.

11 Expected Facilities Required for Interconnection

The following facility changes are required to interconnect IR #238 onto L-6021:

Additions/Changes to POI

Develop a switching station at the POI with L-6021 consisting of:

1. Three 138 kV circuit breakers and associated switches in a ring-bus arrangement,
2. Structures to detour L-6021 into the new switching station,
3. Addition of approximate 20 km of 138kV spur line to connect the wind farm to the POI with 556 Dove ACSR conductors rated 100°C conductor temperature,
4. Modification on NSPI protection systems,
5. Control and communications between the wind farm and NSPI SCADA system (to be specified).

Requirements for the Generating Facility

1. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (54 MW) at the HV terminals of the IC Substation Step Up Transformer 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 known as a Farm Control Unit (FCU). The FCU will control the 34.5 kV bus voltage 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 remotely.
4. Low voltage ride-through capability as per Appendix G to the Standard Generator Interconnection and Operating Agreement (GIA).
5. Real-time monitoring (including a Remote Terminal Unit) of the interconnection facilities.
6. Facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined in SIS.

12 NSPI Interconnection Facilities and Network Upgrades Cost Estimate

Estimates for NSPI Interconnections Facilities and Network Upgrades for interconnecting 54 MW wind energy onto 138 kV systems are included in Table 12-1.

Table 12-1: Cost Estimates identified from FEAS scope

	Determined Cost Items	Estimate
NSPI Interconnection Facilities		
i	Build 20 km 138kV single circuit line to L-6021 from the wind farm	$ 6,900,000
ii	Control, communication and protection	$484,304
iii	Develop a Special Protection System and operating restrictions	$200,000
Network Upgrades		
iv	Develop 138 kV switching station with three circuit breaker ring bus	$4,629,000
Totals		
v	Contingency (10%)	$ 1,221,330
vi	Total of Determined Cost Items	$13,434,634
	To be Determined Costs	
vii	System additions to address potential stability limits	TBD (SIS)

The preliminary non-binding cost estimate for interconnecting IR#238 with L-6021 would be $13,434,634. Interconnection Customer is required to fund the Item iv) costs, and would be eligible for repayment in accordance with the terms of the GIA.

13 Issues to be addressed in SIS

The following provides a preliminary scope of work for the subsequent SIS. The SIS will include a more comprehensive assessment of the technical issues and requirements to interconnect generation as requested. In addition, this will include contingency analysis, system stability and ride through and operation following a contingency (N-1 operation). The SIS must determine the facilities required to operate this facility at full capacity, withstand any contingencies (as defined by the criteria appropriate to the location) and identify any restrictions that must be placed on the system following a first contingency loss. The SIS will confirm the options and ancillary equipment that the customer must install to control flicker, voltage, and ensure that the facility has the required ride-through capability. The SIS will be conducted in accordance with the RGIP with the assumption that all appropriate higher-queued projects will proceed and the facilities associated with those projects are installed.

The following outline provides the minimum scope that must be complete in order to assess the impacts. It is recognized the actual scope may deviate, to achieve the primary objectives.

The assessment will consider but not be limited to the following.

i. Facilities that the customer must install to meet the requirements of the RGIP
ii. The minimum transmission additions/upgrades that are necessary to permit operation of this Generating Facility, under all dispatch conditions, catering to the first contingencies listed.
iii. Guidelines and restrictions applicable to first contingency operation(curtailments etc)
iv. System loss impacts
v. Under-frequency load shedding impacts

To complete this assessment the following first contingencies, as a minimum, will be assessed:

- L-6024 & 9W-T63
- L-6021 & 9W-T2
- L-6020
- L-6021
- L-5027
- L-5535
- L-5532
- L-5540

- L-5541
- 9W-500
- 9W-563 (taking out B53 and L-6024)
- 9W-516 (taking out B52 and L-6021)
- 50W-600 (taking out 50W-B3 and B4)
- 50W-500 (taking out 50W-B2 and 50W-T1)
- 50W-624 (taking out L-6024, L-6025, L-6048, L-6006 and 9W-T63)
- 50W-615 (taking out L-6020, L-6047, L-6531 and 50W-T1)
- 43V-613 (taking out 43V- T61 and L-6013)
- 51V-521 (taking out L-5024 and L-6013)
- 13V-516 (taking out 13V-B51 and L5026)

To complete this assessment the dynamics of the following first contingencies, as a minimum, will be assessed:

- 3 phase fault on L-6021
- 3 phase fault on L-6020
- 3 phase fault on L-6024
- 3 phase fault on L-5535
- 3 phase fault on L-5027
- 3 phase fault at 9W-B52
- 3 phase fault at 9W-B53
- 3 phase fault at 50W-B3
- 3 phase fault at 50W-B4
- 3 phase fault at 50W-B2

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[2] and NPCC[3] criteria as well as NSPI guidelines

[2] NPCC criteria are set forth in it's Reliability Reference Directory #1 *Design and Operation of the Bulk Power System*
[3] NERC transmission criteria are set forth in *NERC Reliability Standards TPL-001, TPL-002, TPL-003*

and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.

The SIS will calculate the unit loss factor, which is a measure of the percentage of the net output of IR #238 which is lost through the transmission system. Preliminary value is calculated to be 0.9% (system losses increase by net 0.5 MW when IR #238 is operated at 54 MW).

Nova Scotia Power
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