System Impact Study
GIP-IR141-SIS-R2

Generator Interconnection Request IR141

30 MW Wind Generating Facility

Digby

Nova Scotia

Principal Investigator
Hung Huynh, P.Eng.

December 17, 2008

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnect Request (IR) number 141 proposes to install a 30 MW wind generating facility at Digby, Nova Scotia. The proposed facility will be located approximately 10 km from Nova Scotia Power Inc's (NSPI) nearest 69kV 77V-Conway substation. The proposed facility will consist of twenty GE 1.5 MW wind turbines. Each wind turbine will have its own step-up transformer to the collector system voltage of 34.5kV. The Point-Of-Interconnection will be at 77V-Conway substation.

Any newly identified system issues that arise because of IR141 addition will be discussed in this report. Any system problem that exists prior to IR141 will be pursued by Nova Scotia Power in a separate system planning study.

The System Impact Study shows the following:

- The increased fault levels do not exceed any existing breaker rating.
- The calculated voltage flicker does not exceed NSPI's required voltage flicker level.
- Dynamic simulation shows that IR141 generation will remain on line during system underfrequency condition when Nova Scotia is suddenly islanded from New Brunswick.

Also the System Impact Study finds the following new system issues due to the addition of IR141 generation facility:

1. Exceed metering rating on the following lines:
    a. L-5533 at 13V-Gulch
    b. L-5531 at 13V-Gulch
    c. L-5026 at 11V-Paradise
    d. L-5025 at 11V-Paradise and 51V-Tremont
2. Overload L-5533 (112% of summer rating) under system normal.
3. Exceed summer rating of L-5531 (145%), L-5532 (129%), L-5535 (157%), and L-5541 (115%) for the following contingencies:
    a. Loss of 11V-B51 at Paradise
    b. Loss of L-5025
    c. Loss of 51V-B51 at Tremont
4. Undervoltage violation at a number of 69kV substations near 9W-Tusket for the following contingencies:
    a. Loss of 51V-B51 at Tremont
    b. Loss of 9W-T63 at Tusket
    c. Loss of L-6024
5. Overvoltage violation at 9W-Tusket and 106W-Pubnico for the following contingencies:
    a. Loss of L-5535
    b. Loss of 15V-B51 at Sissiboo
6. L-5533 underfrequency load shedding scheme at 13V-Gulch will need to be relocated to 77V-Conway substation to avoid tripping L-5533 and hence IR141 generation during underfrequency system condition.
7. The wind turbines with rated power factor of +/-0.95 do not provide sufficient vars to meet the requirement to provide a net power factor of +/-0.95 measured at the high

voltage side of the main 34.5kV/69kV transformer at the IR141 generating facility. The SIS identifies a minimum of 6 Mvar switched capacitor bank will be required. The size of this capacitor bank will need to be confirmed and finalized at the design stage when the collector circuit design is available and the actual impedances of the main 34.5kV/69kV are known.

The System Impact Study identifies the requirement for the following system upgrades:

- Upgrade metering rating on L-5533 and L-5531 at 13V-Gulch, L-5026 at 11V-Paradise, and L-5025 at 11V-Paradise and 51V-Tremont to resolve issue 1).
- Upgrade L-5533 to resolve issue 2).
- Upgrade L-5531, L-5532, L-5535, and L-5541 rating to resolve issue 3). Since the overload of these lines only occurs during contingencies an alternative to uprating these circuits would be the installation of an SPS to curtail IR141 generation, provided that the SPS can be practically designed and NPCC (Northeast Power Coordinating Council) approval can be obtained.
- Install an SVC or D-VAR with a range of -7 Mvar reactive to +15 Mvar capacitive at the 69kV bus at 9W-Tusket to resolve issue 4) and 5). An alternative option would be to install a new 7 Mvar switched reactor, add a new 7.8 Mvar stage 1 switched capacitor bank, and convert the existing 7.2 Mvar capacitor bank to a stage 2 switched capacitor bank, with each unit having its own breaker and protection, at the 69kV bus at 9W-Tusket. The existing capacitor breaker for the 7.2 Mvar may not have the duty cycle required and may need to be upgraded. The switched shunts must be equipped with a controller that can provide the switching sequence and timing required to control the 69kV voltage at 9W-Tusket as per the results of the load flow and dynamic simulations. The reactor and capacitor banks must have interlocks to avoid switching in capacitor banks while the reactor is already energized and vice versa. The capacitor bank switching must be designed to mitigate issues associated with switching a second bank into an already energized bank.
- Relocate L-5533 underfrequency load shedding scheme which is presently at 13V-Gulch to the three 12kV distribution feeders at 77V-Conway to resolve issue 6).
- Install new 10 km of 69kV line from 77V-Conway to IR141 69kV substation to connect IR141 generation to NSPI's power system.
- Install a 69kV breaker substation complete with protection at the POI at 77V-Conway as required by NSPI's system interconnection requirement.
- Install a transfer trip from 13V-Gulch to the new 69kV breaker at the POI substation at 77V-Conway to avoid islanding IR141 generation with the customers from 77V-Conway substation.
- Install control, communication, metering, teleprotection, status, and analogues as required at IR141 and at POI substation to 13V-Gulch substation back to NSPI's SCADA at Ragged Lake Control Centre.

In addition, IR141 requires the following:

- IR141 must have a central voltage controller that can be set to control the 34.5kV or 69kV bus voltage. The voltage set point must be remotely settable by the NSPI System

Operator. All the individual wind turbines must participate in the voltage regulation to the set point.

- IR141 must have ZVRT (Zero Voltage Ride Through) or LVRT (Low Voltage Ride Through with GE option "15% voltage for 625 msecs at the point of interconnection for single and three phase faults").
- The wind turbines were studied with +/-0.95 power factor capability, so IR141 must have a switched capacitor bank connected to the 34.5kV collector bus sufficient to provide the required power factor of +/-0.95 at the 69kV side of the main 34.5kV/69kV transformer at IR141 substation. The SIS has identified a minimum of 6 Mvar size, but this needs to be finalized at the design stage when the actual impedances of the main 34.5kV/69kV transformer and the collector circuits are known.
- The wind turbines must have frequency set points selected to meet NPCC (Northeast Power Coordinating Council) requirement.
- The wind turbines must meet the IEEE Std.519-1992 for harmonic distortion.
- IR141 must be able to provide control, communication, metering, and other items to NSPI's SCADA as required and determined by the Facility Study.

After the addition of IR141 generation, L-5533 (13.19 km of 69kV line from 13V-Gulch to 77V-Conway) exceeds its summer rating under system normal hence it must be upgraded to allow IR141 generation to run at full load. This line needs to be surveyed so that the extent of work required to upgrade it can be determined. Since 77V-Conway is radial load with very limited load transfer capability, the line upgrade will need to be done with the line remains energized. There is some concern about whether this line can be re-conductored live. In the absence of the line survey information at this time, the estimate cost of a line rebuild will be included in the total system upgrade cost estimate. This will need to be confirmed by the Facility Study.

The total length of L-5531, L-5532, L-5535, and L-5541 is approximately 200 km. Since the overload of these lines occurs only during contingencies, to increase the rating of these lines by reconductoring or rebuilding may not be economically practical in this case. Since it is likely that these lines are limited by conductor to ground clearances rather than thermal rating of the conductors, it would be more practical to survey the lines and determine which spans need to be upgraded and thus estimate the cost of upgrading those spans. This option could be pursued by the Facility Study. At this time, since the information is not available, a cost estimate for an SPS is included in the total system upgrade cost estimate.

The cost estimate for installing the SVC at 9W-Tusket is about $3,000,000. Whereas the cost estimate for installing a new 7 Mvar switched reactor, adding a new 7.8 Mvar stage 1 switched capacitor bank, converting the existing 7.2 Mvar capacitor bank to a stage 2 switched capacitor bank, and adding a new controller for switching sequence and timing of these 3 devices is about $1,100,000. This lower cost option is included in the total system upgrade cost estimate.

For the time being, non-binding preliminary cost estimates (in 2008 and excluding applicable taxes) for the above mentioned system upgrades are shown on the table below:

Post_IR141 System Upgrades	Preliminary Cost Estimate ($ CAN)
1) Upgrade L-5533 metering equipment at 13V-Gulch. Upgrade L-5531 metering equipment at 13V-Gulch. Upgrade L-5026 metering equipment at 11V-Paradise. Upgrade L-5025 metering equipment at 11V-Paradise and 51V-Tremont	$15,000
2) Upgrade L-5533 rating	$2,902,000
3) Install an SPS to reject IR141 generation for loss of 11V-B51, L-5025, or 51V-B51	$200,000
4) Install a new 7 Mvar switched reactor, add a new 7.8 Mvar stage 1 switched capacitor bank, convert the existing 7.2 Mvar bank to a stage 2 switched capacitor bank, and add a new controller for switching sequence and timing of these devices.	$1,100,000
5) Relocate L-5533 underfrequency load shedding scheme which is presently at 13V-Gulch to the three 12kV distribution feeders at 77V-Conway.	$30,000
6) Build new 10 km of 69kV line from 77V-Conway to IR141	$2,200,000
7) Install a new 69kV POI substation at 77V-Conway including a 69kV circuit breaker and protection	$450,000
8) Install transfer trip from 13V-Gulch to the new 69kV breaker at the POI substation	$40,000
9) Install control, communication, metering, teleprotection, status, and analogues at IR141 and at the POI substation back to NSPI's SCADA at Ragged Lake Control Centre	$400,000
Total	$7,337,000

The Facility Study will determine the final cost estimates.

NOVA SCOTIA POWER
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Addendum (Feb 4th, 2010) to System Impact Study GIP-IR141-SIS-R2 (dated Dec 17th, 2008)

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This addendum was necessary due to a number of changes to the original system impact study GIP-IR141-SIS-R2 which was completed and dated December 17, 2008. This addendum includes the following changes:

The twenty GE 1.5 MW wind turbines will be equipped with +/- 0.9 power factor instead of +/- 0.95 power factor as per the original SIS.

The impedances for the 69 kV / 34.5 kV transformer at the wind facility are now modeled using the factory tested values instead of the estimated values used in the original SIS.

The conductors for the 69 kV transmission line from 13V-Gulch substation to 77V-Conway substation were found to be mostly 4/0ACSR instead of the published 2/0ACSR, which was used in the original SIS.

The line length of the new 69 kV transmission line from 77V-Conway substation to the wind facility is now 17.5 km instead of 10 km used in the original SIS.

The addendum study includes a typical collector circuit, where as the original SIS did not include any collector circuit as it was left to the wind facility to calculate the amount of MVAR compensation required depending upon the collector circuit design. A typical collector circuit was modelled because the wind facility has not finalized the collector circuit at the time of this addendum analysis.

The original SIS assumed that the fault contribution from the wind turbines would be equivalent to the fault level provided by induction generators. However, recent bulletin from GE for its 1.5 MW wind turbines shows that, for fault on the transmission system, the wind turbines act as current sources and provide about 2 per unit currents for 1 to 2 cycles then return to 1 per unit currents. For "close in" faults within the wind facility, the wind turbines may 'crowbar" and provide up to 5 per unit current.

The above changes were updated in the original PSS/E base cases for Light Load and Winter Peak. The addendum did not re-study the entire scope of the original SIS, only the analysis deemed necessary given the above changes for these two base cases. The result shows that:

Given the wind turbines equipped with +/-0.9 power factor, the load flow analysis shows that the wind facility will meet the GIP power factor requirement of +/- 0.95 on the 69 kV at the wind facility without additional reactive power compensation.

The revised fault levels do not exceed breaker ratings at NSPI's existing substations. The calculated voltage flicker levels at the nearest NSPI's substation with customers (77V-Conway) meet NSPI's requirement. However, if the voltage

flicker becomes a problem for NSPI's customers after the installation of the wind facility and the cause of the voltage flicker is proved to come from the wind facility operation, then the wind facility will be required to resolve the problem.

The dynamic simulation shows that the new dynamic model provides better performance in term of damping compared to the model in the original SIS, except that the wind gust model was not working and had to be disconnected for the dynamic initialization and simulation. It is surmised that this is a modelling problem and not the wind turbine performance problem.

This addendum concludes that the above changes do not constitute Material Modifications under the GIP.