Interconnection Feasibility Study Report
GIP-130-FEAS-R2

System Interconnection Request #130
200 MW Wind / Pumped Storage Hydro Generating Facility
Cape Breton County (L-7012)

August 17, 2007

Control Centre Operations
Nova Scotia Power Inc.

Executive Summary

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed combination wind and pumped storage hydro generation facility interconnected to the NSPI 138kV transmission line L-6516 between 2S-Victoria Junction and 2C-Port Hastings, near the border of Richmond County and Cape Breton County. At the Feasibility Study scoping meeting held 2007-06-26, NSPI pointed out that this project could not be accommodated on that L-6516. The Interconnection Customer agreed to change the Interconnection Request to line L-7012, a 230kV line between 3C-Port Hastings and 88S-Lingan.

No concerns regarding short-circuit level, voltage flicker, or voltage control were 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.

Excessive thermal loading on L-6503 at the 50N-Trenton terminal was found under single contingency conditions, and therefore the circuit breaker and associated switches and current transformers at the Trenton end of this circuit must be updated from 1200A to 2000A.

There is sufficient transmission capacity to accommodate this project with all transmission elements in service.

Loss of L-7012 resulted in two lines slightly exceeding their summer thermal rating, and post-contingency re-dispatch can be used.

The single contingency loss of the double-circuit tower at the Strait of Canso with the tripping of L-8004 and L-7005 produced unacceptable results in the summer, with several 230kV and one 138kV exceeding its thermal rating by 35% even after a Lingan unit is rejected by Special Protection System action. It is proposed that a new Canso Strait crossing be built to move L-7005 away from L-8004 and eliminate this contingency.

It is assumed that the Interconnection Customer's facility substation is located at the Point of Interconnection, and therefore the non-binding cost estimate excludes any 230kV spur line that might be required.

Because the Point of Interconnection at L-7012 is considered a Bulk Power System (BPS) element, it must be designed and constructed in accordance with the NPCC Bulk Power System Protection Criteria and the terminals of L-7012 at 88S-Lingan and 3C-Port Hastings must be updated to BPS compliance.

The direct cost of interconnection, assuming that this is the only project in the vicinity to proceed, is estimated to be $29,700,000.

Because this project can impact transmission congestion between Cape Breton and Onslow, there is the potential requirement for significant transmission reinforcement, depending on the amount

of generation that is added in the vicinity. The requirement for such reinforcements will be determined in a subsequent System Impact Study.

Table of Contents

Page

1 Introduction

The Interconnection Customer submitted an Interconnection Request to NSPI for a proposed combination wind and pumped storage hydro generation facility interconnected to the NSPI 138kV transmission line L-6516 between 2S-Victoria Junction and 2C-Port Hastings, near the border of Richmond County and Cape Breton County. The Interconnection Request is for Network Resource Interconnection Service (NRIS). The Interconnection Customer signed a Feasibility Study Agreement to study the connection of their proposed generation to the NSPI transmission system. This report is the result of that Study Agreement.

At the Feasibility Study scoping meeting held 2007-06-26, NSPI pointed out that the line L-6516 has a summer rating of only 110 MVA and a winter rating of 165 MVA and that this project could not be accommodated on that line. The Interconnection Customer agreed to change the Interconnection Request to line L-7012, a 230kV line between 3C-Port Hastings and 88S-Lingan. L-7012 is on the same Right of Way as L-6516.

This project is listed as Interconnection Request #130 in the NSPI Interconnection Request Queue, and will be referred to as IR #130 throughout this report.

2 Scope

The Interconnection Feasibility Study (FEAS) report shall 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, the time to construct such facilities, and to address the identified short circuit and power flow issues.

Subsequent to this FEAS, a System Impact Study (SIS) will examine the project in more detail in the context of Interconnection Requests ahead of this IR #130. This may include system stability issues, single contingencies and extreme contingencies, off-nominal frequency operation, low voltage ride-through, harmonic current and voltage distortion, system protection, Special Protection System interaction, Automatic Generation Control action, and islanded operation. The impacts on neighboring power systems and the requirements set by reliability authorities such as the North American Electric Reliability Council (NERC) and

the Northeast Power Coordinating Council (NPCC) will be addressed in the SIS, including the Bulk Power System status of IR #130 in accordance with the NPCC A-10 Criteria[1]. The SIS may identify requirements and system upgrades that are not identified in the FEAS.

3 Assumptions

The Point of Interconnection (POI) and configuration studied is as follows:

i. A 200 MW generating facility consisting of a 100 wind farm with unspecified wind turbines (potentially Enercon fully-inverted variable-speed machines) and a 100 MW pumped storage hydroelectric facility with two 50 MW General Electric synchronous machines.

ii. The generation technology used must meet NSPI requirement for reactive power capability of 0.95 capacitive to 0.95 inductive at the high voltage terminals of the Interconnection Facilities. It is also required to provide high-speed Automatic Voltage Regulation to maintain constant voltage at the high voltage terminals of the Interconnection Facilities.

iii. The POI on L-7012 is approximately 71 km from 3C-Port Hastings substation.

iv. The generating facilities are assumed to be located in close proximity to the POI on L-7012 and therefore the Interconnection Facility is also the Interconnection Customer's substation. If the Interconnection Customer's substation is located remote from the POI, then a separate 230kV transmission line spur connecting the Interconnection Customer's substation to the POI switching station is required.

v. It might not be feasible for the Interconnection Customer's substation to accommodate both the wind generation and the hydro generation if the two sites are physically separated from each other, such as the wind generation facility on the top of a hill and the hydro pumped storage at the bottom of the hill at water's edge. In that case, the cost of interconnection must be revised to reflect the multiple substations and spur lines.

vi. No information was provided regarding the transformer, therefore it is assumed that there will be one 230kV transformer with a base rating of 200 MVA and a top rating of 230 MVA. Transformer impedance assumed to be 7% (on 200 MVA ONAN base) and 5 fixed taps between -5% and +5%. Secondary voltage will be at the discretion of the Interconnection Customer.

[1] NPCC Document A-10, *Classification of Bulk Power System Elements*, 2007 04 28.

This feasibility study is based on the assumption that projects that are ahead of this project in the Generation Interconnection Request Queue will not proceed, however the potential impact of those projects will be reviewed qualitatively.

4 Projects with Higher Queue Positions

As of 2007 06 18 the following projects have a higher Queue Position than IR #130, and have the status indicated.

In Service and committed generation projects

Wind Generation – 30.5 MW – connected to L-5027 (in-service)

Wind Generation – 14.0 MW – connected to L-5573 (in-service)

Wind Generation – 20.0 MW – 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 – FAC Complete

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 138kV 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

IR 117 Wind – Shelburne, L-5027, 10MW – FEAS in Progress

IR 126 Wind – Cumberland, L-6513, 70MW – IR valid

IR 128 Wind – Cumberland, L-6536, 40.5MW – FEAS in Progress

This IR #130 and IR #8, IR #23, IR #42, IR #44, IR #72, IR #79, IR #84, IR #85, IR #114 and IR #115 affect the interface known as Onslow Import. Onslow Import is presently a congested interface from time to time. If any of the projects IR #8, IR #23, IR #42 IR #44, IR #72, IR #79, IR #84, IR #85, IR #114 or IR #115 proceed, the results of this feasibility study must be updated to reflect the impact of increased Onslow Import flow on IR #130, and any transmission upgrades that might be required for this or other projects ahead in the queue.

IR #23 and IR #42, as well as this IR #130 impact the interface known as Cape Breton Export, which is also congested from time to time. The SIS will assess the impact of projects ahead of IR #130 on both the Onslow Import and Cape Breton Export interfaces

In addition to the above transmission Interconnection Requests, there are 183 MW of distribution connected wind generation proposals ahead of this IR #130 which may have an impact on the results of this FEAS.

5 Objective

The objective of this feasibility study is to determine the primary physical requirements to interconnect 200 MW of generation 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 uprated. Single contingency criteria are applied for the Network Resource Interconnection Service assessment.

This FEAS does not produce a binding estimate of all costs and changes that may be required to interconnect the facility. These costs are limited to facility additions/changes that are in the immediate vicinity of the proposed generating facility and any other system costs that are foreseen at the time this report is completed.

This assessment does not include any 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 the Northeast Power Coordinating Council (NPCC) and/or the North American Reliability Corporation (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 (future) expected short-circuit level on 230kV systems is 10,000 MVA.

The short-circuit levels in the area before and after this development are provided in Table 6-1 below.

Table 6-1: Short-Circuit Levels. Three-phase MVA[2]		
Location	**This project in service**	**This project not in service**
All transmission facilities in service		
88S-Lingan	4251	3928
3C-Port Hastings	3290	3015
230kV Interconnection Point	2594	1900
Minimum conditions[3]		
230kV Interconnection Point	1651/1381[4]	960

The maximum short-circuit level at the POI is presently 1900 MVA. Although the actual increase in short-circuit levels will be dependent on the specific type of generator installed, the increase will bring the short-circuit level to not more than 2594 MVA at the POI. Under contingency operation, with the wind farm only connected to 3C-Port Hastings (L-7012 open at 88S-Lingan), the short-circuit level will be approximately 960 MVA at the POI. With the hydro portion of IR #130 on-line, the minimum short circuit level seen by the wind portion is 1381 MVA

The interrupting capability of 230kV circuit breakers at 67N-Onslow EHV and 3C-Port Hastings is at least 14,000 MVA (36kA) which will not be exceeded by this development on its own.

[2] Classical fault study, flat voltage profile.
[3] L-7012 is open between 88S-Lingan and Project #130 POI, with Point Tupper generator off-line
[4] All IR #130 generation on / only IR #130 hydro generation on

7 Voltage Flicker

The minimum Short Circuit Ratio at the POI is 4.8 (based on proposed plant rating of 200 MW). If the entire plant was wind generation, instead of half of the plant being hydro, this short circuit ratio would potentially be of concern. However, the Short Circuit Ratio as seen by the wind portion is 13.8 with the hydro portion of IR #130 on-line and is 9.6 with the hydro portion off, based on the wind generation rating of 100 MW. Voltage flicker is therefore not a concern for this project.

8 Thermal Limits

Line L-7012 is wood-pole Gulfport construction with 1115 kcm Beaumont ACSR, designed for maximum operating temperature of 70°C. This conductor has a thermal rating of 408 MVA summer and 504 MVA winter. Switchgear at each terminal of L-7012 are rated 797 MVA, but the lowest metering range is 398 MVA, which may require uprating.

With all lines in-service, there are no thermal limitations due to this project.

Loss of L-7012 between the POI and 3C-Port Hastings can result in lines L-7011 and L-6537 exceeding their long-term summer rating by 10% and 15% respectively. With Cape Breton Export at 600 MW (the point at which generation rejection Special Protection Systems (SPS)[5] are set), loss of L-8004 will result in several lines reaching their long-term summer thermal limit. These conditions can be handled by an automatic run-back scheme or operator action.

This IR increases flow across the Onslow Import interface, and any contingency that results on the loss of L-8003 will result in overload of L-6503. Switchgear and associated equipment at 50N-Trenton (50N-607) must be upgraded to 2000 amps.

The single contingency loss of the double-circuit tower at the Strait of Canso results in the tripping of L-8004 and L-7005. With IR #130 operating at rated load, and east-west transfers at the level where existing SPS's are armed and operate to trip one Lingan generator, this contingency causes the flow on L-7003, L-7004, and L-6515 to exceed their summer ratings by 33%, 36%, and 34% respectively, which is unacceptable. It would be required to trip all generation at IR #130 to relieve the overloads. This would mean the rejection of 350 – 500 MW of generation on Cape Breton.

[5] Also known as Remedial Action Schemes, SPS's are defined by NPCC as "A protection system designed to detect abnormal system conditions, and take corrective action other than the isolation of faulted elements." *NPCC Document A7 - Glossary of Terms.*

Three options are offered:

i. Rebuild L-7003, L-7004 and L-6515 with larger conductor or higher operating temperature:
    a. L-7004 between Route 289 and 67N-Onslow (60.88 km = $30M)
    b. L-7003 from 67N-Onslow to 3C-Port Hastings (160 km = $80 M)
    c. L-6515 from 2C-Port Hastings to 4C- Lochaber Rd (50 km = $12.5M)
    d. Total $122.5M

ii. Build new Canso Strait Crossing towers to separate L-7005 from L-8004 ($18M)

iii. Restrict IR# 130 when Cape Breton Export exceeds 500 MW (1200 hours per year).

Since the Interconnection Customer has requested NRIS, Option 3 is not applicable. Option 2 is assumed to be the most economically viable for this project.

9 Voltage Control

This project, like all new generating facilities must be capable of providing both lagging and leading power factor of 0.95, measured at the 230kV terminals of the Interconnection Facility substation, at all production levels up to the full rated load of 200 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 230kV Interconnection Facility bus voltage. The voltage controls must be responsive to voltage deviations at the 230kV terminals of the Interconnection Facility substation, be equipped with a voltage set-point control, and also have facility that will only adjust the set-point over several (5-10) minutes 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.

IR #130, including the wind generation portion of this facility must have low-voltage ride-through capability in accordance with FERC Order 661a[6]. The SIS

[6] Post-transition Period LVRT Standard; “Interconnection for Wind Energy”, Federal Energy Regulatory Commission, Docket RM05-4-001; Order No. 661-A December 12, 2005

will examine the generator/plant capabilities and controls in detail specify any options, controls and additional facilities that are required to achieve low-voltage ride-through.

10 System Security

The NSPI transmission system has limited east to west transfer capability. Transmission corridors between Sydney and Halifax are often operated to security limits. This project increases flow across the Onslow Import interface and Cape Breton Export. Generation rejection SPS's are utilized to increase system stability limits to maximize east to west power transfers. Depending on the impact of other generation additions ahead of this project in the Interconnection Request Queue, the additional generating capacity that this facility provides may not be integrated into the NSPI system under all dispatch conditions without system upgrades.

This may require increased reactive support requirements in the Halifax area or invoke facility additions that can reduce the reactive support requirements. This will be evaluated in the SIS.

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

11 Expected Facilities Required for Interconnection

We expect the following facilities will be required assuming that the projects ahead of this project in the Interconnection Request queue do not proceed.

Additions/Changes to NSPI systems

Develop a switching substation at the POI with L-7012 (near the border between Richmond and Cape Breton counties) consisting of:

i. Three 230kV circuit breakers and associated switches in a ring-bus arrangement,

ii. Control building and protection systems,

iii. Control and communications between the POI switching station and NSPI SCADA system,

iv. Structures to turn L-7012 into new switching station.

v. Any conductors needed to connect the Interconnection Customer's Interconnection Facility to the POI will use 1113 Beaumont ACSR conductor rated 100°C conductor temperature.

vi. Control and Communications between the POI and NSPI SCADA system (to be specified)

vii. Uprate switchgear at 50N-Trenton end of L-6503.

viii. Because the POI at L-7012 is considered a Bulk Power System (BPS) element, it must be designed and constructed in accordance with the NPCC Bulk Power System Protection Criteria[7], and the terminals at 88S-Lingan and 3C-Port Hastings must be uprated to BPS compliance.

ix. Move L-7005 to new Canso Strait crossing structures.

Requirements for the Interconnection Customer's Interconnection Facility

i. Facilities to provide 0.95 leading and lagging power factor when delivering rated output (200 MW) all at the 230kV bus when the voltage at that point is operating between 95 and 105 % of nominal.

ii. Centralized controls. These will provide centralized voltage set-point controls and reactive power set-point controls acting to control the voltage on the 230kV system 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.

iii. 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.

iv. Low voltage ride-through capability in accordance with FERC Order 661a.

v. Real-time monitoring (RTU's) of the interconnection substation and facilities for NSPI to execute high speed rejection of generation (transfer trip) if determined by SIS.

[7] NPCC Document A-5: *Bulk Power System Protection Criteria*

12 NSPI Interconnection Facilities Cost Estimate

It is anticipated that the high level cost estimates (non-binding), excluding HST taxes, for the items identified above will be approximately:

Table 12-1: Cost Estimates

	Determined Cost Items	Estimate
i	Uprate L-6503 terminal equipment at 50N-Trenton	$200,000
ii	Develop 230kV substation (under L-7012)	$1,500,000
iii	Develop 230kV ring bus with three circuit breakers	$6,000,000
iv	Protection, control, communication	$500,000
v	Generation run-back controls for transmission overload	$100,000
vi	Uprate L-7012 terminals to BPS	$700,000
vii	Install new towers at Canso Strait, move L-7005	$18,000,000
viii	Contingency (10%)	$2,700,000
	Total of Determined Cost Item	**$29,700,000**
	To be Determined Costs	
ix	System additions to increase east-west transfer capability	TBD (SIS)

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 Issues to be addressed in SIS

The SIS must determine the facilities required to operate this facility at full capacity, withstand the contingencies as defined by NPCC/NERC and identify any restrictions that must be placed on the system following a first contingency loss. The SIS will be conducted with the assumption that all projects higher-queued will proceed and the facilities associated with those projects are installed.

The assessment will consider but not be limited to the following. The facility additions/changes required to increase NSPI east to west transfers under system normal conditions (all transmission in) over the range of NSPI loads and with interruptible loads on or off. Some of the interfaces that may be constrained and should be included in the assessment are as follows.

i. Cape Breton Export
ii. Onslow Import
iii. Onslow South
iv. Metro reactive reserve requirements
v. NS – NB export/import

13.1 Steady-state post-contingency analysis

All elements within acceptable voltage and thermal limits under the following single contingencies, in accordance with NPCC[8] and NERC[9] criteria.

i. L-8004
ii. Hopewell transformer 79N-T81
iii. L-8003
iv. L-8003 plus L-8002
v. L-8004 plus L-7005 (not needed if L-7005 is moved)

13.2 System stability for the following faults

Loss of any element without a fault

i. L-8004
ii. Hopewell transformer 79N-T81
iii. L-8003

Three-phase fault cleared in normal time:

i. L-8003 at Onslow end
ii. L-8003 at Hopewell end
iii. L-8001 at import and export limits

[8] NPCC criteria are set forth in it's A-2 Document *Basic Criteria for Design and Operation of Interconnected Power Systems*
[9] NERC transmission criteria are set forth in *NERC Reliability Standards TPL-001, TPL-002, TPL-003*

Single-phase to ground fault cleared in backup time (Breaker Failure)

i. L-8003 at Onslow with failure of 67N-812 (lose L-8002)

Single-phase to ground fault on separated circuits of double-circuit tower:

i. L-8004 plus L-7005 at Canso Crossing (not needed if L-7005 is moved)
ii. L-7003 plus section of L-7004 at Trenton

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 and NPCC criteria as well as NSPI guidelines and good utility practice. The SIS will also determine the contingencies for which this facility must be curtailed.