ORR&RENO
ATTORNEYS AT LAW

Susan S. Geiger
sgeiger@orr-reno.com
Direct Dial 603.223.9154
Direct Fax 603.223.9054
Admitted in NH and MA

January 16, 2013

Via Hand Delivery
NH Site Evaluation Committee
c/o Jane Murray, Secretary
29 Hazen Drive, P.O. Box 95
Concord, NH 03302-0095

***Re: Antrim Wind, LLC*, SEC Docket No. 2012-01 – Ex. AWE 10A and 10B**

Dear Ms. Murray:

At the adjudicative hearings in the above-captioned docket, Exhibit AWE 10 was reserved for the ISO-NE System Impact Study. Enclosed for filing in this docket, please find an original and eight (8) copies of two documents which have been marked Exhibits AWE 10A and 10B. Also enclosed is e-mail correspondence from ISO-New England indicating that the enclosed documents were provided to Antrim Wind on January 15, 2013.

Please contact me if there are any questions about this filing.

Very truly yours,

S S Geiger

Susan S. Geiger

SSG
Enclosures

cc: Site Evaluation Committee Members (via hand delivery)
Service List (via electronic mail)

953586_1

From: <Nikolov>, "Nikolov, Stojan" <snikolov@iso-ne.com>
Date: Tuesday, January 15, 2013 3:46 PM
To: Jack Kenworthy <jkenworthy@eolian-energy.com>, Dave Forrest <dforrest@iso-ne.com>
Cc: Sean McCabe <sean@westerlywind.com>, Dan Schwarting <dschwarting@iso-ne.com>
Subject: RE: SIS Confidentiality

Jack,
Attached please find versions of both the Steady State and Stability Report that should not contain any materials that are deemed CEII.
Feel free to let me know if you have any questions or concerns.
Thanks,
Stojan

Stojan Nikolov
Project Manager – Transmission Planning Group
ISO New England, Inc
1 Sullivan Road, Holyoke, MA 01040-2751
Tel: 413-540-4769 Fax: 413-535-4156

From: Jack Kenworthy [mailto:jkenworthy@eolian-energy.com]
Sent: Monday, January 07, 2013 11:16 AM
To: Nikolov, Stojan; Forrest, David
Cc: Sean McCabe; Schwarting, Daniel
Subject: Re: SIS Confidentiality
Stojan,
Can you please advise what the status of this request is?
Thank you.
Jack

Jack Kenworthy
Chief Executive Officer
Eolian Renewable Energy LLC
155 Fleet Street
Portsmouth, NH 03801
603.570.4842 Office
603.386.6743 Fax
484.467.5315 Mobile
jkenworthy@eolian-energy.com
www.eolian-energy.com

From: <Nikolov>, "Nikolov, Stojan" <snikolov@iso-ne.com>
Date: Wednesday, December 19, 2012 1:08 PM
To: Jack Kenworthy <jkenworthy@eolian-energy.com>, Dave Forrest <dforrest@iso-ne.com>
Cc: Sean McCabe <sean@westerlywind.com>, Dan Schwarting <dschwarting@iso-ne.com>
Subject: RE: SIS Confidentiality
Jack,
I have been working internally here to resolve this issue. We are working on redacting the report (removing the parts of the report that are CEII), and as soon as we are done with this, I will send you a copy of the report that will not contain any materials that are deemed CEII.

Thanks,
Stojan

Stojan Nikolov
Project Manager – Transmission Planning Group
ISO New England, Inc
1 Sullivan Road, Holyoke, MA 01040-2751
Tel: 413-540-4769 Fax: 413-535-4156

EXHIBIT
AWE - 10A

R108-11

Steady State System Impact Study Report for Q371 Wind Project Interconnecting to Line L-163 near Jackman Substation in New Hampshire

Prepared for

ISO-NE, Inc.

Submitted by:
Baldwin P. Lam, Senior Manager
Octavio J. Gutierrez, Senior Staff Consultant
David Lovelady, Senior Consultant
Bo Gong, Senior Consultant
Mounika Kurra, Consultant

October 9, 2012, Revision 6

Siemens PTI Project Number: P/21-113619

Siemens Industry, Inc.
Siemens Power Technologies International
400 State Street • P.O. Box 1058
Schenectady, New York 12301-1058 USA
Tel: +1 (518) 395-5000 • Fax: +1 (518) 346-2777
www.siemens.com/power-technologies

SIEMENS

Revision History

Date	Rev.	Description
October 9, 2012	0	Initial draft
April 6, 2012	1	Incorporated comments received from ISO-NE and Northeast Utilities
May 7, 2012	2	Incorporated L-163 South 115 kV line upgrade information
May 10, 2012	3	Incorporated comments from ISO-NE dated 5/9/2012
May 18, 2012	4	Incorporated comments from ISO-NE dated 5/15/2012
August 24, 2012	5	Incorporated comments from ISO-NE dated 8/13/2012
October 9, 2012	6	Addressed comments from NU, as per ISO-NE email dated 10/9/12

Contents

[redacted]

[redacted]

Legal Notice

This document was prepared by Siemens Energy, Inc., Siemens Power Technologies International (Consultant), on behalf of ISO-NE with the intention of meeting the requirements of the ISO New England Transmission, Market and Services Tariff. None of Consultants, ISO-NE, nor their parent corporations or affiliates, nor any person acting in their behalf (a) makes any warranty, expressed or implied, with respect to the use of any information or methods disclosed in this document or (b) assumes any liability with respect to the use of any information or methods disclosed in this document, in either case except as set out in the aforementioned Tariff. None of Consultants or ISO-NE assumes any responsibility for any damages incurred by any entities other than those named in this Study.

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[redacted]

Executive Summary

Siemens Energy, Inc., Siemens Power Technologies International (Siemens PTI) has conducted a Steady State System Impact Study (“Study”) of Project Q371 (“the Project”) under the ISO New England (ISO-NE) Network Capability Interconnections Standard as specified in Schedule 22 of the ISO New England Tariff, PP5-6, Scope of Study for System Impact Studies under the Generation Interconnection Procedures and PP3 and the Reliability Standards for the New England Area Bulk Power Supply System, dated March 2010, on behalf of ISO-NE.

Project Description

The Project consists of eleven (11) Acciona 3.0 MW (AW3000) wind turbine generators (WTG’s) and the associated collector system. The maximum aggregated gross output of the WTG’s will be 33 MW. The Project net output at the point of interconnection (POI) is, approximately, 32 MW, once the losses in the collector system have been subtracted. The Project service load is negligible.

The proposed commercial operation date for this Project is December of 2013.

The Project will interconnect to the Public Service of New Hampshire (PSNH) system in the Town of Antrim in New Hampshire at a new 115 kV Switching Station with a [redacted] configuration, tapping the L 163 line about 6.5 miles southwards of the Jackman 115 kV Substation.

Scenarios Studied

Steady state N-1 contingency analysis was performed on peak, shoulder and minimum load conditions with all lines in service. The peak and shoulder load conditions were studied with high West to East and East to West New England interface flows, each case was also studied both with and without NEEWS (New England East West Solution) & Pittsfield/Greenfield projects modeled, to be known hereafter as “pre-NEEWS” and “post-NEEWS”, respectively.

A steady state N-1 sensitivity study with the 115 kV Greggs series reactor in service was studied. A voltage sensitivity study was also performed.

Three line-out scenarios (N-1-1) for pre and post-NEEWS conditions were studied as follows:

- The loss of the 345 kV Vernon to Northfield 381 line for shoulder load conditions with East to West flows.
- The loss of the 345 kV Ludlow-Carpenter Hill-Millbury 301/302 line for shoulder load conditions with East to West flows.
- The loss of the 115 kV Fitzwilliam to Monadnock to Bellows Falls three terminal I135N line for minimum load conditions.

The short circuit study was performed by PSNH, the Transmission Owner.

The Study results are summarized below:

N-0 Results

No thermal or voltage violations caused by the Project were found during pre-contingency conditions.

N-1 Thermal Results

N-1 thermal analysis was performed for peak and shoulder load conditions. The thermal results are summarized below:

Peak Load – Pre-NEEWS Conditions – East to West Flows

- The Q345 POI to Ashland 115 kV section of the E-115 line overloads for the [redacted] s part of prior queued project "Q345", this portion of the E-115 line will be upgraded to an LTE rating of [redacted] Therefore the Q371 Project is not required to upgrade this line. The E115 line upgrade's in-service date is December 2013, while the in-service date of the Q345 project is October 2012; the Q345 project's output may be limited under certain scenarios until this line upgrade is complete.

Shoulder Load – Pre-NEEWS and Post-NEEWS Conditions – East to West Flows

- Q371 POI to Keene 115 kV section of the L-163 line overloads for several contingencies with the highest loading caused by [redacted] the fact that an overload was found indicated the need for a transfer limit analysis to be performed. The results of this analysis can be found in the "Transfer Limit Analysis" section.

Greggs Series Reactor Sensitivity

Switching the Greggs 115 kV series reactor in service was studied to ensure that the addition of the Project did not adversely impact the system in this state.

For this study the Greggs 115 kV by-pass switch is opened forcing the current to flow through the series reactor. Both pre-NEEWS and post-NEEWS shoulder load conditions with East to West flows were tested for N-1 contingencies and monitored for any thermal and voltage impacts.

The results show that the Project does not adversely impact system operation, that is, no thermal overloads and voltage violations were found.

N-1 Voltage Results

No adverse voltage impact caused by the Project on the New England bulk power system was found.

However, for all conditions studied, post-contingency high voltages up to [redacted] were seen in simulation at the Project's WTG 12.0 kV terminals and within the 34.5 kV collector system and for post-NEEWS conditions with East to West flows low voltages occur below [redacted] within the Project. This is due to the WTG's reaching their reactive power limits of +/-1.2 Mvar trying to maintain the scheduled voltage at the POI, for contingencies that cause either low or high voltages on the 115 kV system.

In reality the reactive power output limits reduce for voltages above or below the 0.95 – 1.05 per unit range, thereby limiting such extreme voltages.

Voltage Sensitivity Analysis

This sensitivity test was performed to ensure that, with terminal voltages outside of their 0.95-1.05 per unit range, the turbines could still provide sufficient reactive power to avoid any voltage violations on the transmission system. Therefore, for this sensitivity analysis, reactive power limits of +/- 0.3 Mvar (considered conservative) were set for each WTG.

The results shown that with limited reactive power limits, no voltage violations on the New England bulk power system occur. However, the Project may not be able to hold its voltage schedule with the reactive power limits reduced.

N-1-1 Thermal Results

Shoulder Load East to West Flows

For the pre-NEEEWS conditions with the **381 (Northfield-Vernon)** line-out, area generation reduction following the line-out situation will prevent any thermal overloads occurring following a possible second contingency. For the post-NEEWS conditions less area generation reduction is required.

For the pre-NEEEWS conditions with the **301/302 (Ludlow-Carpenter Hill-Millbury)** line-out, area generation reduction following the line-out situation will prevent any thermal overloads occurring following a possible second contingency. For the post-NEEWS conditions less area generation is required.

Minimum Load

No thermal overloads were found for the **I135N (Fitzwilliam-Monadnock-Bellows Falls)** line-out case.

N-1-1 Voltage Results

For all N-1-1 line-out scenario's studied the reduced reactive power output of +/- 0.3 Mvar (considered conservative) were set for each WTG.

No adverse voltage impact caused by the Project was found with or without NEEWS for any of the line-out scenarios studied.

Transfer Limit Analysis

The analysis was performed to determine whether the Project degrades transfer capability on the New England East-West interface. Both pre-NEEWS and post-NEEWS cases were tested, and transfer limits were evaluated both with the Greggs series reactor bypassed and inserted.

In the pre-NEEWS/ Pittsfield-Greenfield system, the Project does degrade transfer capability on the East-West interface by approximately [redacted] This degradation does not appear in the post-NEEWS/Pittsfield-Greenfield system, where pre- and post-Project transfer limits are essentially equal. [redacted]

Short Circuit

The addition of the 33MW wind powered facility will not cause any PSNH Transmission breakers to become overdutied or exceed 80% of their current rating.

Final Conclusions

For pre-NEEWS/Pittsfield-Greenfield conditions, due to the thermal overload on the portion of the L163 line between the Point of Interconnection and Keene and the impact to the East-West transfer limits, this portion of the L163 115 kV line will need to be upgraded to a minimum LTE rating of [redacted] This upgrade is not required, however, because this impact is addressed by the Pittsfield-Greenfield project. In the event that the Project wishes to connect before the Pittsfield-Greenfield project is energized, without upgrading the L163S line, the Project may be subject to additional operational restrictions to address this overload on a day-to-day basis, as described in the ISO New England Transmission, Markets, and Services Tariff, section II, schedule 22, article 5.9.

[redacted]

The estimated in-service date for the Project is December 2013; if the Project does not elect to upgrade the Line L163 and elects to rely on the Pittsfield-Greenfield Project to mitigate the overload of Line L163 and impacts to thermal limits on transfers across the East-West Interface, then the project can interconnect in 2013 as planned. However, until the Pittsfield-Greenfield Project is constructed, the Project may be restricted in real-time operations to mitigate the potential overload of Line L163 and impacts to thermal transfer limits. If for reasons beyond NU's control (e.g. siting and regulatory approval) the Pittsfield-Greenfield Project is cancelled, the Project will be held responsible to upgrade the section of Line L163 from the Project's Point of Interconnection to the Keene substation.

The steady state and short circuit analyses performed show that the Project, along with the proposed thermal solutions, will not have a steady state adverse impact on the reliability or operating characteristics of the power system.

[redacted]

Interconnection Cost Estimate

NU's non-binding good faith estimate to interconnect Antrim Wind to the Public Service of New Hampshire (PSNH) system in the Town of Antrim, NH ranges between -50% $6.34 million to 200% $38 million. This estimate is based on constructing a [redacted] configuration, looping into the L163 line about 6.5 miles southwards of the Jackman 115-kV Substation.

NU's non-binding good faith estimate to uprate the L163 line for the Q371 interconnect is in the order of magnitude -50% $6.6 million to +200% $40 million.

The section of line between the POI and Keene substation requires uprate, this is approximately 19 miles in length. The scope of work will allow the line to be operated at a summer LTE temperature of 140C, resulting in a new summer LTE rating of [redacted] The uprate does not affect the impedance of the 115 kV conductors.

Section

1

Introduction

Siemens Energy, Inc., Siemens Power Technologies International (Siemens PTI) has conducted a Steady State System Impact Study ("Study") of Project Q371 ("the Project") under the ISO New England (ISO-NE) Network Capability Interconnections Standard as specified in Schedule 22 of the ISO New England Tariff, PP5-6, Scope of Study for System Impact Studies under the Generation Interconnection Procedures and PP3 and the Reliability Standards for the New England Area Bulk Power Supply System, dated March 2010, on behalf of ISO-NE.

This document presents the Steady State Study Report.

The Project consists of eleven (11) Acciona 3.0 MW (AW3000) wind turbine generators (WTG's) and the associated collector system. The maximum aggregated gross output of the WTG's will be 33 MW. The Project net output at the point of interconnection (POI) is, approximately, 32 MW, once the losses in the collector system have been subtracted. The Project service load is negligible.

The proposed commercial operation date for this Project is December of 2013.

The Project will interconnect to the Public Service of New Hampshire (PSNH) system in the Town of Antrim in New Hampshire at a new 115 kV Switching Station with a [redacted] configuration, tapping the L-163 line about 6.5 miles southwards of the Jackman 115 kV Substation.

Steady state N-1 contingency analysis was performed on peak, shoulder and minimum load conditions with all lines in service. The peak and shoulder load conditions were studied with high West to East and East to West New England interface flows, each case was also studied both with and without NEEWS (New England East West Solution) & Pittsfield/Greenfield projects modeled, to be known hereafter as "pre-NEEWS" and "post-NEEWS", respectively.

A steady state N-1 sensitivity study with the 115 kV Greggs series reactor in service was studied. A voltage sensitivity study was also performed.

Three line-out scenarios (N-1-1) for pre and post-NEEWS conditions were studied as follows:

- The loss of the 345 kV Vernon to Northfield 381 line for shoulder load conditions with East to West flows.
- The loss of the 345 kV Ludlow-Carpenter Hill-Millbury 301/302 line for shoulder load conditions with East to West flows.

- The loss of the 115 kV Fitzwilliam to Monadnock to Bellows Falls three terminal I135N line for minimum load conditions.

The analysis of transfer limit impacts due to the Project interconnection was conducted by ISO-NE.

The short circuit study was performed by PSNH, the Transmission Owner.

[redacted]

Section

2

Project Description

2.1 Project Description and Interconnection Plan

The Project consists of 11 Acciona 3.0 MW wind turbine generators (WTG's) with a maximum aggregated gross output of 33 MW. The Project net output at the point of interconnection (POI) is, approximately, 32 MW, once the losses in the collector system have been subtracted. The service load is negligible. Each WTG will be connected to the 34.5 kV underground collector system via its own 12.0/34.5 kV generator step-up transformer (GSU). A single 34.5 kV overhead line will carry the power from the underground wind turbine cables to the Project's Collector Substation where a 24 MVA 34.5/115 kV transformer will step up the voltage and connect to the Point of Interconnection (POI) at a new 115 kV [redacted] Switching Station on the L-163 line between Keene and Jackman 115 kV Substations.

The Developer provided a detailed layout showing the individual wind turbine generators and feeders. As such, the entire wind farm was explicitly modeled for the steady-state study, including each WTG, GSU, underground feeder cable and the overhead line.

For illustration purposes only, Figure 2-1 shows a simplified one-line diagram of the power system in the vicinity of the Project.

The IDEV to incorporate the Project to the PSS®E version 30 database is included in Appendix E.

[redacted]

Figure 2-1. Project Interconnection and buses nearby the Project

Figure 2-2 below illustrates the approximate geographical location of the Project and the transmission lines in the area of interest.

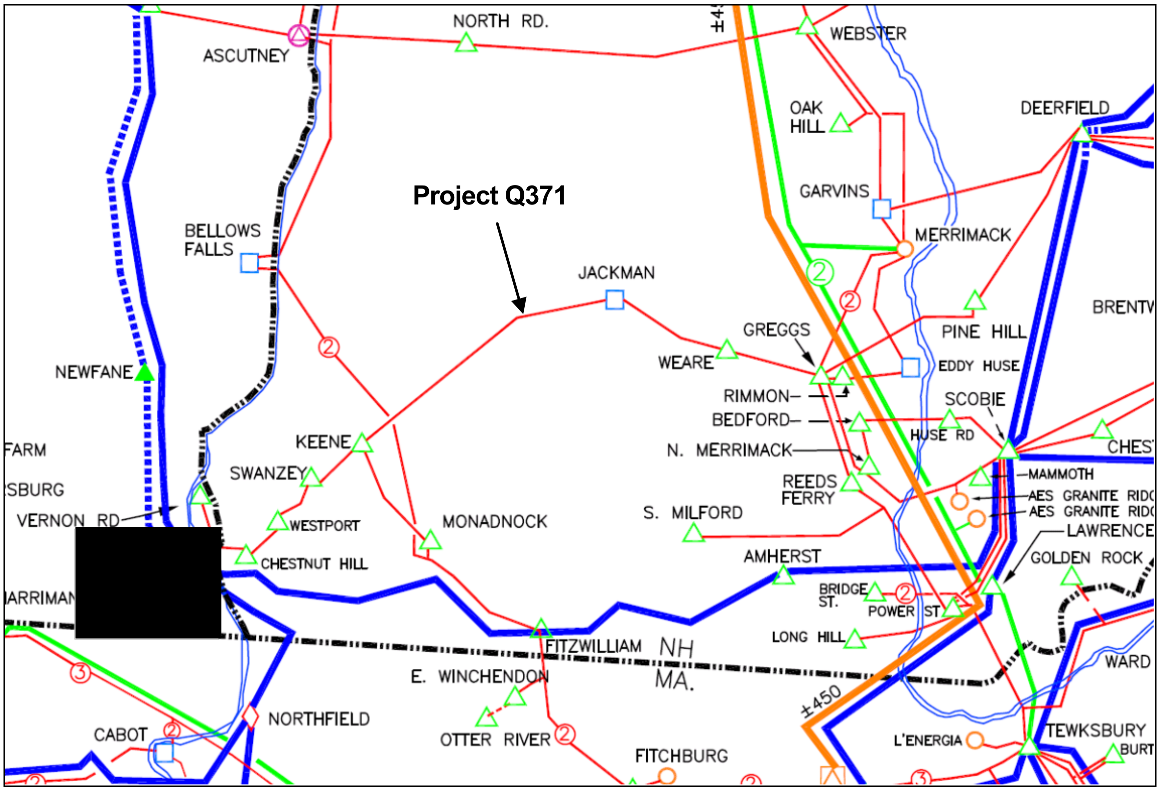

Figure 2-2. Project Geographical Location in New Hampshire

2.2 Project Data

The Project data for each wind turbine generator and the corresponding GSU are shown in Table 2-1 and Table 2-2, respectively.

Table 2-1. Wind Turbine Generator (WTG) Data

Generator Type	Doubly fed induction generator
Ratings of each Wind Turbine Generator	3.23 MVA, 12,000 V
Gross Output of each wind generator	3.0 MW
Exporting Reactive Power Limit at 3.0 MW output [1]	1.2 Mvar (0.928 power factor)
Importing Reactive Power Limit at 3.0 MW output [1]	-1.2 Mvar (0.928 power factor)
Station Service Load	When the WTG's are online, the service load is negligible.

1 – For each wind turbine, measured at the 12 kV terminals, for voltages between 0.95 – 1.05 Per unit.

Table 2-2. Wind Turbine GSU Transformer Data

Nameplate ratings (self cooled/maximum)	3.4/3.4 MVA
Voltage ratio, generator side/system side	12.0/34.5 kV
Winding connections, low voltage/high voltage	Wye grounded/Delta
Available Tap positions (set to center tap for study)	5 steps, each +/- 2.5% of nominal
Impedance, Z_1 (on self cooled MVA rating)	6.0%, X/R = 8.0
Impedance, Z_0 (on self cooled MVA rating)	6.0%, X/R = 8.0

Figure 2-3 and Figure 2-4 below show the Acciona WTG reactive power output for varying conditions. Both figures were obtained from the Acciona "AW-3000 Electrical Characteristic - DG200032-F" document provided by the Developer.

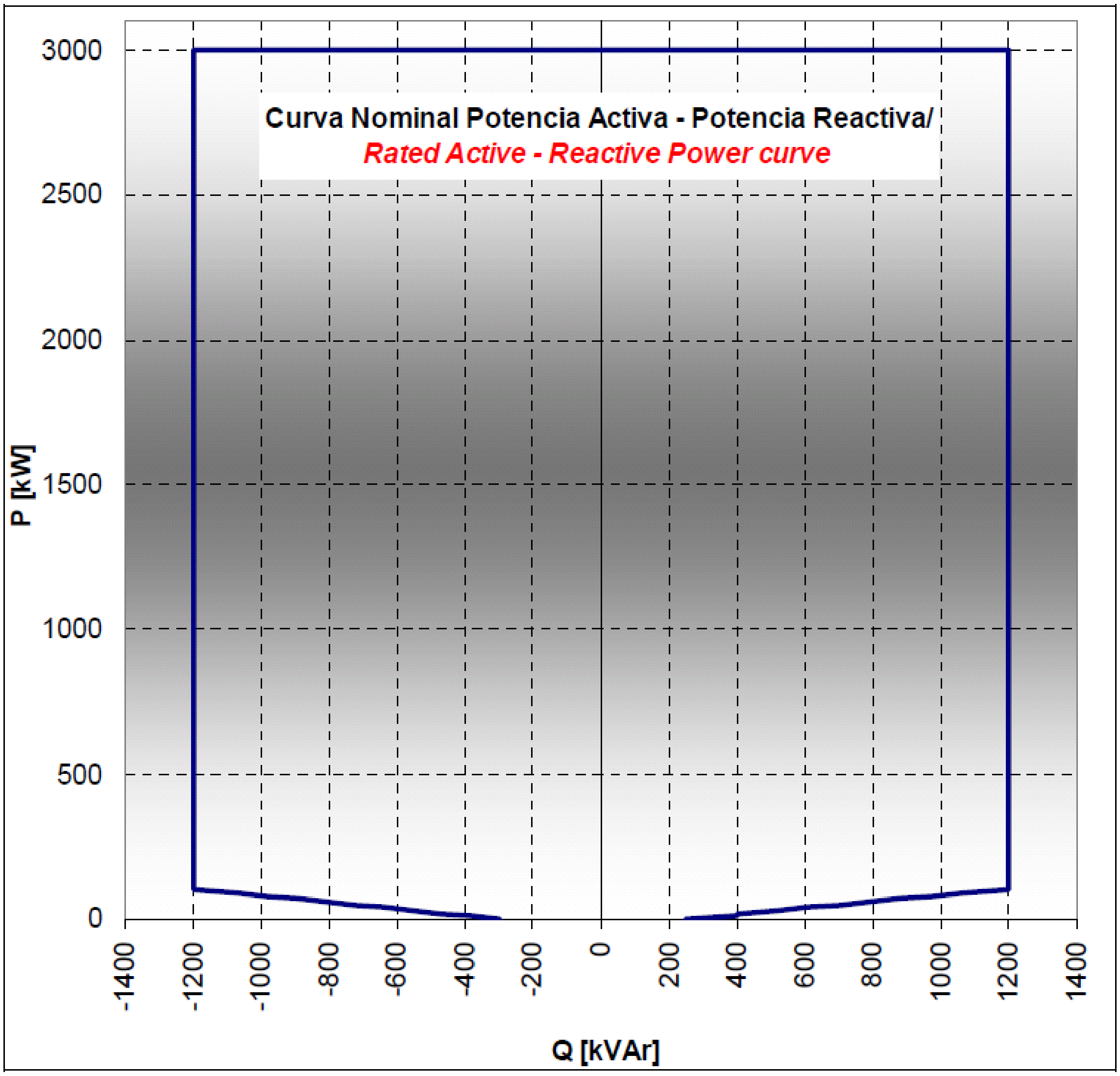

Figure 2-3. WTG Rated Active (P) vs Reactive Power (Q) Curve

Figure 2-4 below shows the reactive power output limits of each turbine reduces significantly for terminal voltages outside of the 0.95 – 1.05 per unit range.

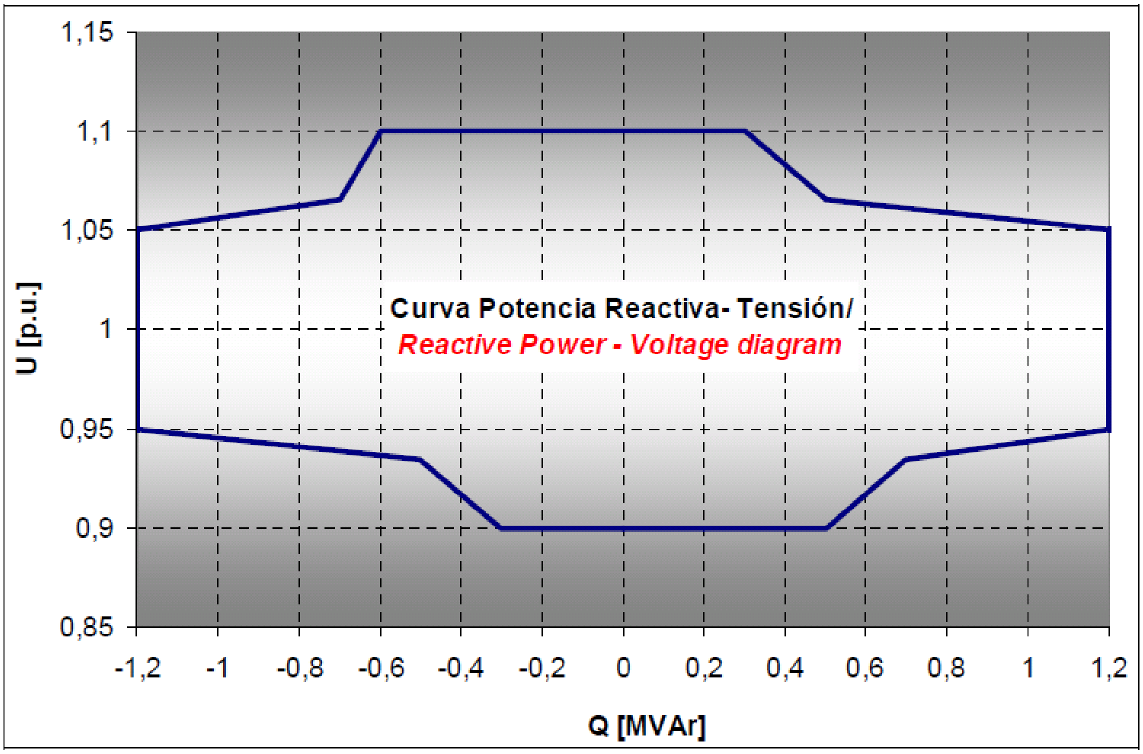

Figure 2-4. WTG Reactive Power (Q) vs Terminal Voltage (U) at Full Rated Active Power Output

The parameters of the main transformer are shown in Table 2-3 below.

Table 2-3. Main Transformer at Collector Station

Nameplate ratings (self cooled/maximum)	30/50 MVA
Voltages, High/Low voltage/Tertiary	115/34.5/13.2 kV
Winding connections, High/Low/Tertiary	Wye grounded/Wye grounded/Delta
Available Tap positions (set to center tap for study)	5 steps, each +/- 2.5% of nominal
Impedance Z_1 (% on self cooled MVA rating)	9.0 %, X/R = 26
Impedance Z_0 (% on self cooled MVA rating)	9.0 %, X/R = 26

Table 2-4 below shows the parameters of the 34.5 kV overhead line that will connect the WTG strings to the 34.5 kV Project Collector Substation, based on values calculated by the project Developer.

Table 2-4. 34.5 kV Overhead Line Feeder Data

Length (feet)	Positive Sequence – Ohms			Zero Sequence –Ohms	
	R	Xl	Xc (MOhms)	R	Xl
4,500	0.1185	0.5185	0.16548	0.2765	1.356

2.3 Present Voltage Schedule at the POI

Currently there is no specific voltage schedule at the POI as it is a new Switching Station on the L-163 line.

2.4 WTG Operating Control Mode and Voltage Schedule

The reactive power exchanged with the power system can be controlled in real time by means of the power converter within the limits defined above. This control may be local for constant reactive power or power factor operation, or remote. The remote control allows the implementation at plant-wide level of different reactive controls, most commonly:

- Field bus voltage control, to balance the field bus voltage and therefore the machine voltages. The voltage at the POI would be controlled according to a set point. This voltage is periodically sampled to determine whether the POI voltage is different from the set point, and if so, sends command signals to the turbines via SCADA to adjust their reactive power.
- Remote voltage control. In this mode, the reactive power set point to be generated by the wind farm comes directly from remote controls of system operators.
- Scheduled power factor. The power factor of the turbines is changed periodically during the day according a scheduled program usually established by the electric grid operator.

Field bus voltage control was selected by the Developer and as such was modeled for this Study.

Currently there is no specific voltage schedule at the POI as it is a new Switching Station on the L-163 line. However, to be consistent with local pre-Project voltages, the reactive power output of the WTG's will adjust to maintain a scheduled voltage of [redacted]

Table 2-5 below shows the voltage schedule maintained at the Project POI for all Study conditions.

Table 2-5 Project POI Scheduled Voltage

	Voltage Schedule
Scheduled Voltage at the POI	[redacted]

As confirmed by the WTG manufacturers Acciona, the field bus voltage control method can react to system voltage excursions at the POI by adjusting the reactive power output of each WTG within 2 seconds and can be considered similar in operation to a synchronous machine (for the steady-state time period). As such the reactive power output of the WTG's was initially modeled to move within the reactive limits of -1.2 to 1.2 Mvar during pre and post-contingency conditions to maintain the scheduled voltage at the POI.

For the Study, the total reactive power output required to maintain scheduled voltage at the POI is divided equally among each of the eleven WTG's.

[redacted]

Section

3

Study Methodology

3.1 Introduction

The Study was performed under the ISO New England (ISO-NE) Open Access Transmission Tariff (“Tariff”) Schedule 22-Standard Large Generator Interconnection Procedures (“LGIP”), and in accordance with:

- Northeast Power Coordinating Council (NPCC) Document A-2 “Basic Criteria for Design and Operation of Interconnected Power Systems”.
- Interconnection Procedures contained in Schedule 22 of the Tariff.
- ISO-NE Planning Procedure No. 3, “Reliability Standards for the New England Area Bulk Power System” (June 2009).
- ISO-NE Planning Procedure No. 5-3, “Guidelines for Conducting and Evaluating Proposed Plan Application Analyses”.
- ISO-NE Planning Procedure 5-6 (PP5-6), “Network Capability Interconnection Standard (“NCIS”)”.
- ISO-NE Operating Documents.
- Transmission Reliability Standards for Northeast Utilities (May 2008).

Pursuant to Schedule 22, the Study was performed as a Steady State System Impact Study. The Study includes the identification of:

- Any thermal overload of any transmission facility or system voltage limit violations resulting from the Project.
- Any circuit breaker or other facility short circuit capability limit that are exceeded as a result of the Project, as determined from a short circuit study conducted by Northeast Utilities.

3.2 Criteria

The analysis was performed for steady state N-0 normal conditions and N-1 contingency conditions with all lines in service, for both pre-Project and post-Project cases, to identify thermal and voltage problems that may be attributed to the Project.

[redacted]

Line-out conditions (N-1-1) were also studied. Any thermal and voltage violations were addressed by performing system adjustments i.e. generation re-dispatches, PAR adjustments, capacitor re-dispatches etc. These adjustments are recorded in this Study report.

3.2.1 Voltage Criteria

Table 3-1 shows the voltage criteria that were applied in the Study.

Table 3-1. Normal and Emergency Voltage Criteria

VOLTAGE LEVEL	BUS VOLTAGE LIMITS -% of Nominal	
	Pre-contingency	Post-contingency
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
230 kV and above	98 to 105%	95 to 105%
69 kV and 115 kV	95 to 105%	95 to 105%
Project WTG terminals and 34.5 kV collector system	95 to 108%	95 to 108%

3.2.2 Thermal Criteria

Table 3-2 shows the thermal criteria that were applied in the study.

Table 3-2. Thermal Criteria

SYSTEM CONDITION	MAXIMUM ALLOWABLE FACILITY LOADING
Pre-contingency	Normal rating
Post-contingency	Long Time Emergency Rating (LTE)

3.3 Thermal and Voltage Analysis

Power flow cases were tested for both thermal and voltage violations. The AC contingency analysis function of Siemens PTI's PSS®E Version 32 was used to compare the steady state performance of the New England interconnected system, with and without the proposed Project. Version 32 was used as it can handle larger number of contingency events compared to previous versions.

[redacted]

If the system steady state performance did not meet the study criteria, transmission reinforcement options (e.g. line upgrades, shunt compensation, etc) were recommended.

The Project is not required to upgrade the system to resolve violations for line-out conditions (N-1-1). N-1-1 testing was performed only to examine the potential impacts of line-out scenarios on the Project's operation.

3.3.1 Thermal Analysis

The pre-Project power flow base cases were adjusted to ensure there were no relevant pre-Project N-1 or N-0 overloads. During the contingency analysis, the loading of any monitored element found to be higher than 95% of LTE rating was reported.

3.3.2 Voltage Analysis

The pre-Project load flow base cases were adjusted to ensure there were no relevant pre-project voltage criteria violations. During the contingency analysis, the voltage of any monitored bus found to be outside the range of the post-contingency criteria was reported.

3.3.3 Contingencies

The list of contingencies considered in the study is presented in Appendix C. The following types of contingencies were tested:

- 345 kV and 230 kV single line contingencies
- 115 kV single line contingencies
- 345 kV, 230 kV and 115 kV multiple element contingencies
- Autotransformer contingencies
- Loss of generation

Additional contingencies created by the Project were tested with the Project in-service. These include the loss of the entire Project, the loss of wind power with remaining Project elements in-service, and new contingencies created by the addition of the new 115 kV Switching Station at the POI.

3.3.4 Monitored Elements

The Project will be located in [redacted] Facilities rated at 69 kV and above in the zones listed in Table 3-3 were monitored for possible thermal and voltage criteria violations.

Table 3-3. Monitored Zones

Zone No.	Zone Name
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

3.3.5 Power Flow Solution Options

The ACCC activity of Siemens PTI PSS®E software was used. The pre-contingency and post-contingency solution options that were used in the Study are summarized in Table 3-4 below.

Table 3-4. Power Flow Solution Options

Case	Transformer Taps	Phase Shifters	DC Taps	Switchable Shunts	Area Interchange Control
Pre-Contingency [2]	Stepping	Regulating	Regulating	Regulating	Disabled
Post-Contingency [2]	Stepping [1]	Locked at pre-contingency setting	Locked at pre-contingency setting	Enable continuous, disable discrete	Disabled

1 - The taps on the Fitzwilliam autotransformer were locked for post-contingency conditions to ensure any potential 115 kV voltage violations were not masked by changing taps.

2- For pre-contingency and post-contingency conditions, the reactive power limits of generators were observed and applied immediately at the start of the power flow solution.

Base Cases and Generation Dispatch

ISO-NE provided 6-digit power flow base cases representing 2013 peak, shoulder and minimum load conditions. The New England loads represented in the cases match the 2011 CELT forecast load levels for 2013. Additionally, generating units in New England were represented with the most updated maximum power outputs at 50°F.

4.1 Development of Base Cases

Power flow cases representing 2013 peak, shoulder and minimum load conditions were used in the Study. The peak load represents, approximately, the 2013 summer peak 90/10 load of the CELT 2011 forecast; the shoulder load is calculated as the 75% of the summer 50/50 peak load and the minimum load has a total New England load of 8500 MW.

Table 4-1 below, shows the New England (NE) loads and the transmission losses in the peak, shoulder and minimum load post-Project base cases that were considered in the Study.

The load levels include station service, non-CELT and 100% passive demand response loads (zero active demand response is modeled).

Table 4-1. NE Load and Losses for 2013 (MW)

	Load	Losses	Total
Peak	30,106	783	30,890
Shoulder	21,288	629	21,918
Minimum	9,839	206	10,045

The following approved projects and their associated upgrades were assumed in service and modeled in all base cases provided by ISO-NE:

- Closing of the Y138 line from White Lake 115 kV Substation to Saco Valley 115 kV Substation.
- 115 kV capacitors at Beebe and White Lake substations.
- Monadnock transmission project.

[redacted]

- Q166 Granite Wind project (99 MW) interconnecting on the W179 line.
- Q172 wind project (40 MW) interconnecting in Vermont on the St. Johnsbury-Irasburg line.
- Q197 wind project (50 MW), named Record Hill in the power flow cases, interconnecting in Maine to the Rumford 115 kV Substation.
- Southern Loop transmission project, including the Vernon and Newfane substations and a second 345 kV line between Vernon and Coolidge.
- Q251 Laidlaw Berlin Biomass project (65.9 MW) plus associated line rating upgrades of the following 115 kV lines caused by the project: O154 line (Paris-Lost Nation 115 kV) upgraded to [redacted] D142 line (Lost Nation to Whitefield 115 kV) upgraded to [redacted] and S136 line (Whitefield to Berlin 115 kV) upgraded to [redacted]
- Q290 wind project (18 MW), interconnecting in Maine to the Woodstock 115 kV Substation.
- Q291 Merrimack G2 up-rate to the following ratings: gross output 354 MW, gross over-excited [redacted] gross under-excited [redacted] with a service station load of [redacted]
- Q323 wind project up-rate of former project Q290 to 20 MW (increase of 2 MW) in Maine.
- Lyndonville reliability project, that adds a [redacted] Substation, a 115/34.5 kV transformer and two 12.5 Mvar capacitors. The project taps the St Johnsbury to Sheffield 115 kV line in Vermont.
- Q345 Wind Project (24 MW) interconnecting between Beebe River and Ashland Tap on the E-115 115 kV line in New Hampshire. As the Project is currently being studied, in this analysis, it is modeled as an equivalent generator and without any project upgrades.

4.1.1 Peak and Shoulder Load Cases

The base cases for this project originated from ISO-NE's MOD (Model On Demand) system, and reflect the latest system topology and ratings as of the beginning of the study. The following changes were made to the peak and shoulder load cases originally provided by ISO-NE:

- All Nuclear units in ISO-NE turned online and set to pmax for peak and shoulder load conditions, with the exception of the East to West stressed cases where Vermont Yankee nuclear generating unit is offline to stress the associated flows.
- All Northfield and Bearswamp pumped hydro units were set to generating mode in all peak load conditions and for West to East flow shoulder load conditions. For East to West flow shoulder conditions, the units are set to pumping mode.

[redacted]

- Pmax and Pgen values were corrected for multiple generating units in ISO-NE using data provided by ISO-NE on 5/24/2011 (originally for project Q297).

- Generation dispatches across the ISO-NE area were adjusted to stress the interface flows to maximum limits i.e. Orrington-South ~[redacted] etc.

- Saco PAR set to [redacted] (previously [redacted]), Bliss PAR set to [redacted] (previously [redacted]) and Phase II HVDC set to [redacted] total in the peak case, [redacted] total in the shoulder case and [redacted] total in the minimum load case, this is to match the configurations used for previous studies in this area.

- Removed project Q229 Biomass (29 MW) from all cases, as this project has since withdrawn. No upgrades are associated with this project.

- Prior queued project Q368 (18 MW) interconnecting to the Monadnock 34.5 kV distribution bus. As this project is currently being studied, in this analysis, it is modeled as an equivalent generator and without any project upgrades.

- Alexandria generating unit Pgen and Pmax in New Hampshire changed from 0 MW to 17.0 MW in all cases.

- Turned offline two of the four modeled Granite synchronous condensers and set the remaining two units to a reactive power output of [redacted] This is to match previous configurations used for previous studies in this area.

- Prior queued project wind project Q311 (63 MW) interconnecting to the 46 kV Lowell Substation in Vermont is modeled explicitly in all cases.

- Merrimack and Comerford shunt reactors and capacitors adjusted to ensure reasonable reactive power output from nearby generating units.

- For pre-NEEWS conditions, the A127 and B128 115 kV transmission lines in MA were set to “out of service” to match current operation.

- For post-NEEWS conditions, the A127 and B128 115 kV transmission lines in MA were upgraded.

- The Amherst to Fitzwilliam 345 kV line rating was updated to [redacted] to replace a temporary rating reduction which will be mitigated before the Project’s in-service date.

- Generation dispatch changes in northern NH, NH Seacoast and southern Maine were made to secure the cases including: Whitelake Jet, Comerford, Moore, generation in the Berlin loop, Schiller, Granite Ridge, Yarmouth and Westbrook. In some cases these changes resulted in several interface flows below their target limits.

4.1.2 Minimum Load Cases

To look at the worst-case scenario with respect to high voltage violations, the minimum load case was configured to minimize inter- and intra-area transfers to unload 345 kV lines and eliminate reactive losses as much as possible. Specifically, the [redacted] interfaces were set as close to 0 MW as possible given the generation available.

4.2 Project Dispatch

Table 4-2 and Table 4-3 show the Project dispatches for West to East and East to West flows, respectively.

Table 4-2. Project Dispatch (MW) for West to East flows

Unit	Pre-Project Case	Post-Project Case
Project Queue #371 (net)	0	32
Bellows Falls	49	16.33 (1 of 3 units online)

Table 4-3. Project Dispatch (MW) for East to West flows

Unit	Pre-Project Case	Post-Project Case
Project Queue #371 (net)	0	32
Merrimack G1	122.03	90.03

4.3 Generation Dispatch

The generation dispatch and interface flows in ISO-NE can be found in Table 4-4 below for all cases studied. “OOS” refers to a generating unit being “Out Of Service”.

Complete power flow case summaries can be found in Appendix A.

Table 4-4. Generation Dispatch (MW) and Interface Flows (MW) for the Pre-Project Cases

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Section

5

N-1 Thermal and Voltage Study

Thermal and voltage analyses with all lines in service (N-1 analysis) were performed to determine the thermal and voltage impacts of the Project on the performance of the power system. The peak, shoulder and minimum load scenarios described in Section 4 were evaluated with and without the Project. The minimum load scenario was included to identify any overvoltage condition caused by the Project.

Post-contingency loadings and voltages obtained for post-Project conditions were compared with the corresponding results obtained for pre-Project conditions to identify significant impacts due to the Project.

The study was performed assuming the Littleton 115-kV Reconfiguration project is in-service. This project has ISO-NE PPA approval. Therefore, contingencies associated with this project were considered.

5.1 Results for Normal Conditions (N-0)

No thermal or voltage adverse impacts were found with all lines in service and all bus voltages within the 34.5 kV collector and WTG terminals are within 0.95 – 1.05 per unit criteria.

Table 5-1 documents the active and reactive power from the Project at the POI. The maximum reactive power imported by the Project at the POI is approximately [redacted]

Table 5-1. MW and Mvar Injection from the Project at the POI

[redacted]

5.2 N-1 Thermal Results

N-1 thermal analysis was performed for peak and shoulder load conditions. Complete N-1 thermal results are included in Appendix D.1.

The results discussed in this section are for the worst thermal violation for a given element. Loadings are expressed in percent of the LTE and where appropriate, STE ratings.

[redacted]

[redacted] several 345 kV lines show pre-Project thermal overloads above LTE rating. However, as the Project's impact is less than 0.5% on these lines, these overloads can be ignored.

The results are discussed below:

5.2.1 Peak Load pre-NEEWS Conditions

Table 5-2 and Table 5-3 show the thermal results for East to West flows and West to East flows, respectively.

As shown in Table 5-2 below, the only thermal overload caused by the Project was found on the Q345 POI to Ashland 115 kV section of the E-115 line for the [redacted] The Project causes a loading of [redacted]

As part of prior queued project "Q345", this portion of the E-115 line will be upgraded to an LTE rating of [redacted] Therefore the Q371 Project is not required to upgrade this line. The E115 line upgrade's in-service date is December 2013, while the in-service date of the Q345 project is October 2012; the Q345 project's output may be limited under certain scenarios until this line upgrade is complete.

Table 5-2. Thermal Results - 2013 Peak Load, Pre-NEEWS, East to West flows

[redacted]

[redacted]

Table 5-3. Thermal Results - 2013 Peak Load, Pre-NEEWS, West to East flows

[redacted]

5.2.2 Shoulder Load pre-NEEWS Conditions

Table 5-4 and Table 5-5 show the thermal results for East to West flows and West to East flows, respectively.

As shown in Table 5-4 below the only thermal overload caused by the Project was found on the Q371 POI to Keene 115 kV section of the L-163 line for several contingencies with the highest loading caused by [redacted] The Project causes a loading of [redacted]

Section 9 describes the transfer limit analysis performed for these conditions to determine the Projects impact on existing transfer limits.

Table 5-4. Thermal Results - 2013 Shoulder Load, Pre-NEEWS, East to West flows

[redacted]

[redacted]

[redacted]

Table 5-5. Thermal Results - 2013 Shoulder Load, Pre-NEEWS, West to East flows

[redacted]

[redacted]

[redacted]

5.2.3 Peak Load post-NEEWS Conditions

Table 5-6 and Table 5-7 show the thermal results for East to West flows and West to East flows, respectively.

For both flow directions the results show the Project has no significant impact.

Table 5-6. Thermal Results - 2013 Peak Load, Post-NEEWS, East to West flows

[redacted]

Table 5-7. Thermal Results - 2013 Peak Load, Post-NEEWS, West to East flows

[redacted]

5.2.4 Shoulder Load post-NEEWS Conditions

Table 5-8 and Table 5-9 show the thermal results for East to West flows and West to East flows, respectively.

[redacted]

As shown in Table 5-8 below, the only thermal overload caused by the Project was found on the Q371 POI to Keene 115 kV section of the L-163 line in New Hampshire for several contingencies with the highest loading caused by [redacted]

Section 9 describes the transfer limit analysis performed for these conditions to determine the Projects impact on existing transfer limits.

Table 5-8. Thermal Results - 2013 Shoulder Load, Post-NEEWS, East to West flows

[redacted]

[redacted]

[redacted]

[redacted]

Table 5-9. Thermal Results - 2013 Shoulder Load, Post-NEEWS, West to East flows

[redacted]

[redacted]

5.3 N-1 Voltage Results

N-1 voltage analysis was performed for peak, shoulder and minimum load conditions. The results are discussed in this section.

As the N-1 voltage results are too large to show in the body of this report, the complete results are included in Appendix D.2.

All voltage violations shown in the results are considered pre-existing, in several cases the pre-existing voltage violations are a result of having all switched shunt capacitors and reactors locked post-contingency, whereas in reality many of these devices in New Hampshire have the capability to switch automatically to resolve the violations. Most importantly, the Project has less than 0.5% impact on all monitored bus voltages. Therefore no adverse voltage impact caused by the Project on the New England bulk power system was found.

Table 5-10 below, provides an example of the local pre-existing voltage violations and the Project's impact, which in some cases alleviates the high voltages.

[redacted]

Table 5-10. Voltage Results – Peak Load, Post-NEEWS, East to West

[redacted]

However, for all conditions studied, post-contingency high voltages above 1.08 per unit occur at the Project's WTG 12.0 kV terminals and within the 34.5 kV collector system. This is due to the WTG's reaching their reactive power exporting limits trying to maintain the scheduled voltage at the POI, for contingencies that cause low voltages on the 115 kV system. The highest voltages of up to 1.1 per unit at the WTG terminals occur for post-NEEWS conditions with West to East flows for several contingencies, as shown below in Table 5-11 for the worst cases.

However, in reality the reactive power output limits reduce for voltages above or below the 0.95 – 1.05 per unit range, thereby limiting such extreme high voltages.

Table 5-11. Voltage Results - Post-NEEWS, West to East Flow, Project WTG 12.0 kV Terminal Post-Contingency Voltages

[redacted]

For post-NEEWS conditions with East to West flows, low voltages occur at several WTG 12.0 kV terminals for several contingencies that cause high voltages on the 115 kV system. This is due to the WTG's reaching their reactive power importing limits trying to maintain the scheduled voltage at the POI.

Table 5-12 shows the voltages found for the worst cases.

Table 5-12. Voltage Results - Post-NEEWS, East to West Flow, Project WTG 12.0 kV Terminal Post-Contingency Voltages

[redacted]

Section 7 (Voltage Sensitivity Results) – discusses the issues and resolutions to the voltage problems shown in Table 5-11 and Table 5-12 above.

[redacted]

Section
6

Greggs Series Reactor Sensitivity

Switching the Greggs 115 kV series reactor in service was studied to ensure that the addition of the Project did not adversely impact the system in this state.

For this study, the Greggs 115 kV by-pass switch is opened forcing the current to flow through the series reactor. Both pre-NEEWS and post-NEEWS shoulder load conditions were tested for N-1 contingencies and monitored for any thermal and voltage impacts with same the conditions described previously in sections 3 and 4.

6.1 Results for Normal Conditions (N-0)

No thermal or voltage adverse impacts were found with all lines in service.

6.2 N-1 Thermal Results

N-1 thermal analysis was performed for pre-NEEWS and Post-NEEWS shoulder load conditions with East to West flows. Complete N-1 thermal results are included in Appendix D.3.

The results are discussed below:

6.2.1 Shoulder Load pre-NEEWS with East to West Flow Conditions

Table 6-1, below, shows the thermal results for the shoulder load pre-NEEWS case with East-West flow conditions and the Greggs reactor in service. With the Greggs series reactor in service no thermal overloads occur.

Table 6-1. Thermal Results - Shoulder Load, Pre-NEEWS, East to West flows – Greggs Series Reactor In-Service

[redacted]

[redacted]

[redacted]

6.2.2 Shoulder Load post-NEEWS with East to West Flow Conditions

Table 6-2, below, shows the thermal results for the shoulder load post-NEEWS case with East-West flow conditions and the Greggs reactor in service. With the Greggs series reactor in service no thermal overloads occur.

[redacted]

Table 6-2. Thermal Results - Shoulder Load, Post-NEEWS, East to West flows – Greggs Series Reactor In-Service

[redacted]

[redacted]

6.3 N-1 Voltage Results

N-1 voltage analysis was performed for pre-NEEWS and Post-NEEWS shoulder load conditions with East to West flows to see if switching in-service the 115 kV Greggs series reactor caused any low voltage problems.

Complete N-1 voltage results are included in Appendix D.4.

No adverse voltage impact caused by the Project with the 115 kV Greggs series reactor in-service was found.

[redacted]

Section 7

Voltage Sensitivity Analysis

As described previously in Section 5.3, high and low post-contingency voltages were found at the Project's WTG 12.0 kV terminals and within the 34.5 kV collector system. According to Figure 7-1 (also shown in Figure 2-4), the reactive power output capability is reduced for voltages outside the 0.95 – 1.05 per unit range. However, during the N-1 voltage analysis in Section 5.3, the reactive limits modeled remained at +/- 1.2 Mvar for post-contingency conditions. Due to the high collector system impedances between the WTG's and the POI, the WTG's reactive power output essentially reaches saturation for certain contingencies and will therefore reach a maximum terminal voltage and reactive power output limit before the design limit of +/-1.2 Mvar can be reached. As such, a sensitivity analysis was performed to ensure that even with reduced reactive power limits of +/- 0.3 Mvar (considered conservative) the Project causes no voltage violations on the New England bulk power system.

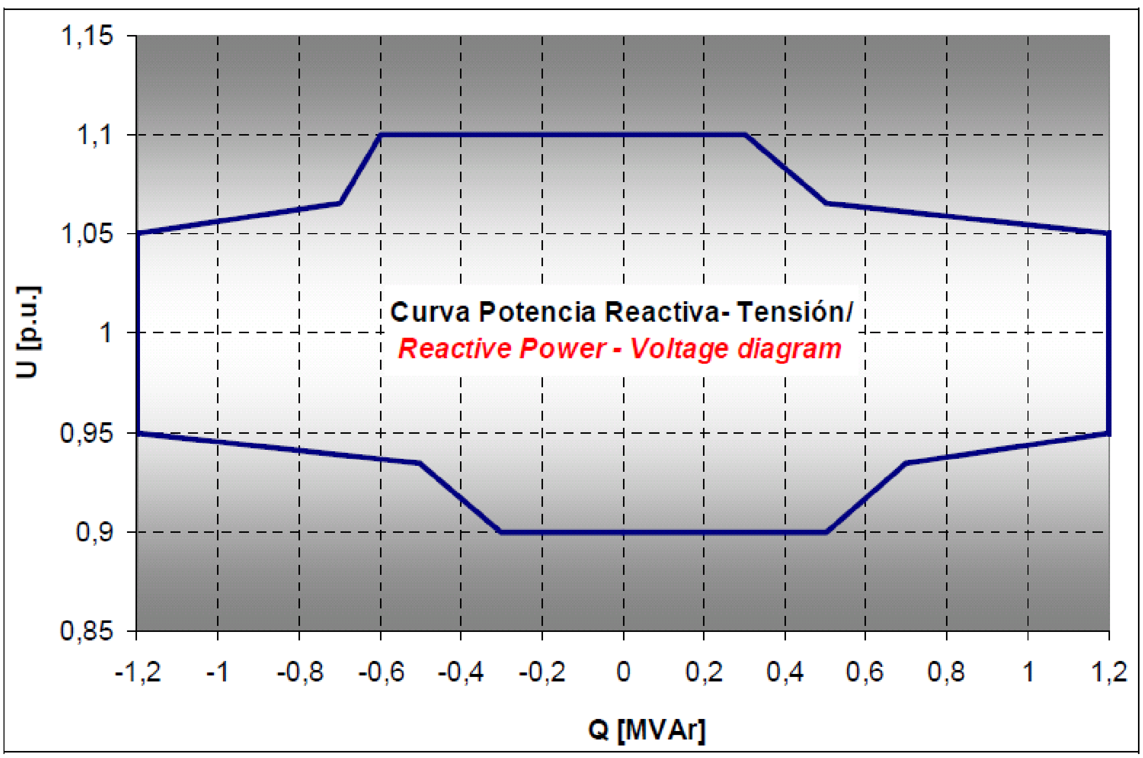

Figure 7-1. WTG Reactive Power (Q) vs Terminal Voltage (U) at Full Rated Active Power Output, taken from "AW-3000 Electrical Characteristic - DG200032-F"

[redacted]

.

For the sensitivity analysis a “low area voltages” case and a “high area voltages” case were simulated, to ensure the Project can be operated at a range of acceptable voltages. The results below, show the Project causes no adverse voltage impact to the transmission system whilst voltages within the Project’s collector system and at the WTGs terminals remain within criteria.

Table 7-1 below describes the scenarios, contingencies and case setup to perform the voltage sensitivity analysis.

Table 7-1. Voltage Sensitivity Analysis Procedure

	“115 kV High-voltage” case	**“115 kV Low-voltage” case**
Cases to test	[redacted]	[redacted]
Contingencies to test	[redacted]	[redacted]
Jackman capacitors	Online	Offline
Chestnut Hill capacitors	Online (as much as possible without causing high voltages)	Offline
Fitzwilliam transformer taps	Fitzwilliam 115 kV voltage at [redacted] pre-contingency	Fitzwilliam 115 kV voltage at [redacted] pre-contingency
Q371 project voltage schedule	Controlling 115 kV bus to [redacted] kV	Controlling 115 kV bus to [redacted] kV

As the complete results are too large to show in the body of the report, they are given in Appendix D.5. However, Table 7-2 below, provides an example of the local voltages and the Project’s impact, which in some cases alleviates the high voltages.

Table 7-2. Shoulder Load, Post-NEEWS, East to West Flows

[redacted]

The voltage sensitivity results are shown in Table 7-3 and Table 7-4 for the same buses and contingencies shown in the previous voltage analysis (Table 5-11 and Table 5-12).

The results in Table 7-3 show that with the WTG reactive power limits set to +/- 0.3 Mvar the voltages at G2 WTG terminal are less than 1.08 per unit.

[redacted]

No adverse voltage impact caused by the Project with the reduced reactive power limits was found.

Table 7-3. Low Voltage Case, Project WTG 12.0 kV Terminal Post-Contingency Voltages

[redacted]

The results in Table 7-4 show that with the WTG reactive power limits set to +/- 0.3 Mvar, the voltages at G3 WTG terminal are higher than 0.95 per unit.

No adverse voltage impact caused by the Project with the reduced reactive power limits was found.

Table 7-4. High Voltage Case, Project WTG 12.0 kV Terminal Post-Contingency Voltages

[redacted]

Section

8

Line-Out Analysis (N-1-1)

The impact of the Project was tested under N-1-1 conditions for three different initial contingencies. The Project will not be required to upgrade the system to operate to its full capacity under these conditions; the intent of this analysis is only to document the restrictions to which the Project may be subjected under various line-out scenarios.

For each line-out case the complete set of N-1 contingencies were analyzed with the same study methodology described in Section 3.

All thermal and voltage N-1-1 results can be found in Appendix D.6.

Shoulder Load

As the N-1 analysis results shown, the shoulder load with East to West flow conditions was the most limiting case. As such the pre and post NEEEWS shoulder load conditions with East to West flows was studied with the following line out conditions:

- 381 345 kV line (Northfield-Vernon)
- 301/302 345 kV line (Ludlow-Carpenter Hill-Millbury)

For each shoulder load case the 115 kV Greggs series reactor is in-service

Minimum Load

Pre and post-NEEWS conditions were studied for the I135N (Fitzwilliam-Monadnock-Bellows Falls) line-out case.

8.1 N-1-1 Thermal Results

8.1.1 381 (Northfield-Vernon) Line-Out

Pre-NEEWS

No base case thermal violations were found above the normal line ratings.

Table 8-1 below shows several thermal overloads occurred on the Scobie to Lawrence Rd and the Lawrence Rd to Sandy Pond 345 kV lines (section 326) above the LTE ratings for [redacted] The 326 line has an SPS that trips Newington G1 generation, however this unit is offline. By turning all

Granite Ridge and Schiller generation units offline following the first contingency the overload can be mitigated in the event of the second contingency occurring.

The thermal overload on the Pemigewasset to Webster 115 kV line (section A-111) for [redacted] can be mitigated by backing down generation at prior queued wind project "Q345" by [redacted] following the first contingency.

For all thermal overloads described above the Project has minimal impact.

Table 8-1. N-1-1 Thermal Results – Shoulder Load, Pre-NEEWS, East to West Flows, 381 Line-Out

[redacted]

Post-NEEWS

No base case thermal violations were found above the normal line ratings.

Table 8-2 below shows thermal overloads occur on the Q345 POI to Ashland 115 kV line (E-115 South) and the Pemigewasset to Webster 115 kV line (section A-111) for [redacted] Both thermal overloads can be resolved by backing down generation at prior queued wind project "Q345" by [redacted] following the first contingency.

[redacted]

For all thermal overloads described above the Project has minimal impact.

Table 8-2. N-1-1 Thermal Results – Shoulder Load, Post-NEEWS, East to West Flows, 381 Line-Out

[redacted]

8.1.2 301/302 (Ludlow-Carpenter Hill-Millbury) Line-Out Case

Pre-NEEWS

No base case thermal violations were found above the normal line ratings.

Table 8-3 below shows thermal overloads occur on the Keene to Monadnock 115 kV line (T-198) and the Keene to the Project POI 115 kV line (L-163 South) for [redacted] The first thermal overload can be resolved by backing down generation at Bellows falls by [redacted] following the first contingency and the second thermal overload by turning all Project WTG's offline following the first contingency.

Table 8-3. N-1-1 Thermal Results – Shoulder Load, Pre-NEEWS, East to West Flows, 301 Line-Out

[redacted]

[redacted]

Post-NEEWS

No base case thermal violations were found above the normal line ratings.

Table 8-4 below shows a thermal overload occurs on the Keene to the Project POI 115 kV line (L-163 South) for [redacted] The thermal overload can be resolved by turning all Project WTG's offline following the first contingency.

Table 8-4. N-1-1 Thermal Results – Shoulder Load, Post-NEEWS, East to West Flows, 301 Line-Out

[redacted]

[redacted]

[redacted]

8.1.3 I135N (Fitzwilliam-Monadnock-Bellows Falls) Line-Out Case

No thermal violations were found with or without NEEWS.

8.2 N-1-1 Voltage Results

Similarly as previously described in Section 5.3 some voltage violations are shown in the results, however they are considered pre-existing, [redacted]

No adverse voltage impact caused by the Project was found with or without NEEWS for any of the line-out scenarios studied.

Section

9

Transfer Limit Analysis

Queue Position 371 Transfer Limit Analysis

Executive Summary

As part of the steady-state System Impact Study for Queue Position 371 ("the Project") (interconnecting to the 115 kV PSNH L163 line between Jackman and Keene, New Hampshire), an analysis of transfer limit impacts was conducted. The intent of this analysis is to determine whether the Project degrades transfer capability across the New England East-West Interface. The analysis determined that the Project does degrade transfer capability across the interface in the pre-NEEWS/Pittsfield-Greenfield system, but has no impact after NEEWS and the Pittsfield-Greenfield project are in service. As a result, the project would be required to upgrade the "L163S" line, between its Point of Interconnection (POI) and Keene. This upgrade is not required, however, because this impact is addressed by the Pittsfield-Greenfield project. In the event that the Project wishes to connect before the Pittsfield-Greenfield project is energized, without upgrading the L163S line, the Project may be subject to additional operational restrictions to address this overload on a day-to-day basis, as described in the ISO New England Transmission, Markets, and Services Tariff, section II, schedule 22, article 5.9.

Introduction

According to ISO New England Planning Procedure 5-6 and Schedule 22 of Section II of the ISO New England Transmission, Markets, and Services Tariff, a new generator must "… interconnect in a manner that avoids any significant adverse effect on the reliability, stability, and operability of the New England Transmission System, including protecting against the degradation of transfer capability for interfaces affected by the Generating Facility." The analysis contained in this section of the report is intended to evaluate Queue Position 371's impact on transfer capability across affected interfaces.

The Project has proposed to interconnect to Public Service of New Hampshire (PSNH)'s L163 line, between Jackman and Keene, New Hampshire. This line is one of the components of both the New England East-West and New England West-East Interfaces.

The steady-state contingency analysis, as described in earlier sections of the System Impact Study, examined both East-West and West-East transfer conditions. However, as seen in the results of that analysis, East-West transfers at shoulder load conditions tended to be the only conditions under which constraints relevant to the project's interconnection were identified. As a result, only East-West transfer conditions, at shoulder load conditions, were analyzed in this transfer limit analysis.

Transfer Limit Analysis Procedure

Comparison of Pre- and Post-Project Transfer Capability

The goal of this analysis was to examine the effects of the Project on East-West transfer limits. As such, under a number of different system conditions (as described below), East-West power flows were increased in a pre-Project case until flows are limited by a transmission line or transformer rating. Typically, the limit was due to a post-contingency flow exceeding a transmission element's Long-Term Emergency (LTE) rating. However, it is also possible that a pre-contingency flow could exceed an element's Normal rating.

This analysis was then repeated in a post-Project case. Comparison of the pre-Project and post-Project transfer limits indicated whether the Project degrades transfer capability across the East-West interface. As with the steady-state contingency analysis, under East-West transfer conditions, the Project was dispatched against the Merrimack G1 unit, which is the existing generator with the greatest impact on east-west flows on the L163 line.

The transfer limit analysis performed here only examines thermal conditions; [redacted] All analysis was performed in PSS® MUST, version 10.1. Please note that, for the purposes of this analysis, the Project was assumed to be on the eastern side of the East-West interface; in other words, the L163S line was assumed to be part of the interface, and not the L163N.

Cases Analyzed

The cases analyzed were taken directly from the steady-state analysis, as described earlier in the System Impact Study. As with the steady-state thermal contingency analysis, cases were analyzed both with and without two major projects which will impact flows in southwestern New Hampshire and across the East-West interface: the New England East-West Solution (NEEWS), and the Pittsfield-Greenfield Project in western Massachusetts.

The full list of contingencies analyzed in the steady-state analysis was used to test post-contingency flows. A number of contingencies outside of New Hampshire, which tend to impact flows across the East-West interface, were also added to the list. These additional contingencies can be found in Table 1 below.

Table 1: Additional Contingencies Tested in Transfer Limit Analysis

[redacted]

[redacted]

Transfer Conditions Examined

Because the East-West interface is a very large interface, including electrically distant transmission lines across the entire New England region, three different transfer conditions were tested. While each transfer condition increased New England East-West power flows, they did so in different ways, by stressing different parts of the East-West interface.

The first transfer condition tested, the "Northern" condition, increased generation in southeastern New Hampshire (with high levels of flow from Maine into New Hampshire) and northeastern Massachusetts. On the receiving end of the transfer, generation on the other side of the East-West interface, in western Massachusetts, was decreased. A "Southern" condition was also tested, with generation in southeastern Massachusetts increased, and generation in Connecticut decreased. Finally, a transfer was tested with a "Distributed" mix of generation on each side of the interface, mixing the "Northern" and "Southern" generation sets roughly equally.

Utilization of the Greggs Series Reactor

At the Greggs substation, a series reactor can be manually switched into service or bypassed by system operators. This reactor increases the impedance, and thus decreases power flows, on the 115 kV transmission path between Greggs and Keene. The L163 line, onto which the Project has proposed to connect, is a part of this path. [redacted]

Transfer Limit Analysis Results

Pre-NEEWS/Pittsfield-Greenfield Transfer Limit Analysis Results

The results of the transfer limit analysis for the pre-NEEWS/Pittsfield-Greenfield cases can be found in Table 2.

Table 2: Pre-NEEWS/Pittsfield-Greenfield Transfer Limit Analysis Results

[redacted]

In the "Northern" East-West transfer condition, the pre-NEEWS/Pittsfield-Greenfield transfer analysis shows that the Project degrades transfer capability by approximately [redacted]

[redacted]

The “Southern” and “Distributed” transfer conditions do not show the L163 line as a limiting element, in cases either with or without the Project in service. With the reactor bypassed, a reduction in transfer capability is caused by the addition of the Project. [redacted]

Because a degradation in transfer capability was seen in the pre-NEEWS/Pittsfield-Greenfield case, the Project will be responsible for an upgrade of the L163S line between the Point of Interconnection and Keene if it interconnects before the in-service-date of NEEWS and the Pittsfield/Greenfield project. Currently, the LTE rating of this line is [redacted] The transfer analysis showed that, for the “Northern” transfer, East-West transfers have approximately a [redacted] transfer distribution factor onto the L163S line; in other words, [redacted] of every additional megawatt transferred across the East-West interface will flow on the L163S line. Knowing this, the required rating of the upgraded line can be found by multiplying the required increase in transfer limits ([redacted] the difference between the pre- and post-project transfer limits) by the transfer distribution factor ([redacted]) to obtain a [redacted] required increase in line ratings. Thus, the upgraded L163S line must have an LTE rating of at least [redacted]

Post-NEEWS/Pittsfield-Greenfield Transfer Limit Analysis Results

The results of the transfer limit analysis for the pre-NEEWS/Pittsfield-Greenfield cases can be found in Table 3.

Table 3: Post-NEEWS/Pittsfield-Greenfield Transfer Limit Analysis Results

[redacted]

In the post-NEEWS/Pittsfield-Greenfield system, the Project does not degrade transfer capability, regardless of the transfer condition studied. The only impact to the interface concerns the use of the Greggs series reactor. [redacted] As a result, if the project only interconnects to the post-NEEWS/Pittsfield-Greenfield system, it will not be required to upgrade the L163S line.

[redacted]

Conclusion

The analysis contained in this section was performed to determine whether the Queue Position 371 project degrades transfer capability on the New England East-West interface. Both pre-NEEWS/Pittsfield-Greenfield and post-NEEWS/Pittsfield-Greenfield cases were tested, and transfer limits were evaluated both with the Greggs series reactor bypassed and inserted.

In the pre-NEEWS/Pittsfield-Greenfield system, the Project does degrade transfer capability on the East-West interface by approximately [redacted] This degradation does not appear in the post-NEEWS/Pittsfield Greenfield system, where pre- and post-project transfer limits are essentially equal. [redacted]

As a result of this analysis, the Project will have two options to meet the Minimum Interconnection Standard under Schedule 22 of Section II of the ISO New England Transmission, Markets, and Services Tariff. The first is to upgrade the L163S line, between the Project's Point of Interconnection and Keene, to an LTE rating of at least [redacted] This upgrade is not required, however, because this impact is addressed by the Pittsfield-Greenfield project. In the event that the Project wishes to connect before the Pittsfield-Greenfield project is energized, without upgrading the L163S line, the Project may be subject to additional operational restrictions to address this overload on a day-to-day basis, as described in the ISO New England Transmission, Markets, and Services Tariff, section II, schedule 22, article 5.9. By connecting only to the post-NEEWS/Pittsfield-Greenfield system, the Project would not degrade transfer capability on the East-West interface.

[redacted]

Short Circuit Analysis

The short circuit analysis was performed by PSNH, the Transmission Owner. The short circuit report is provided below.

Northeast Utilities System

NU Transmission Group

Project Queue 371
Short Circuit & PSNH Circuit Breaker Duty Study

Introduction

Short circuit studies and Breaker Ratings studies were performed to determine the effect of the 33MW wind powered facility ISO-NE Queue #371, on the PSNH transmission system. The short circuit levels and adequacy of the existing PSNH circuit breakers were examined as part of the study. The program used for the analysis was ASPEN OneLiner short circuit program.

Summary

The addition of the 33MW wind powered facility will not cause any PSNH Transmission breakers to become overdutied or exceed 80% of their current rating. For all breaker rating studies, a pre-fault voltage of 1.05pu is used.

Study Models

The following ASPEN OneLiner cases were used for this study:

Pre-Queue 371.olr: This base case represents the present transmission system along with the following proposed generation and projects:

- South Southern Loop (aka Coolidge Connector) Project
- Western Massachusetts Transmission Reinforcements (NEEWS)
- Long Island Replacement Cable
- Norwalk-Glenbrook Cables
- Haddam 345/115-kV autotransformer
- Barbour Hill 345/115-kV autotransformer
- Killingly 345/115-kV autotransformer
- Northern Reliability Interconnect Project (NRI)
- Heywood Road – ME
- Maguire Road – ME
- Y138 Closing – ME
- Rumford-Woodstock-Kimball Road – ME
- Rumford Falls Hydro Interconnection – ME
- Hancock County & Downeast – ME
- Keene Road Autotransformer – ME
- Monadnock Project
- Bethel-Norwalk Project
- Middletown-Norwalk Transmission Project

Post-Queue 371.olr: This case includes everything from the Pre-Queue 371 case as well as the 33MW wind powered facility, ISO-NE Queue 371 connected to the L163 line between Keene S/S and Jackman S/S.

Study Results

1. PSNH Base Case Breaker Duty (Pre-Queue 371)

[redacted]

Flags:
W1 – BREAKER INTERRUPTING DUTY EXCEEDS 80% OF RATING
W2 – BREAKER MOMENTARY (CLOSE-AND-LATCH) CURRENT DUTY EXCEEDS 80% OF RATING

[redacted]

2. PSNH Post - Queue 371 Breaker Duty

After introducing the 33MW wind powered facility on the L163 line, no additional PSNH breakers become overdutied or exceed 80% of their current rating.

[redacted]

[redacted]

W1 – BREAKER INTERRUPTING DUTY EXCEEDS 80% OF RATING
W2 – BREAKER MOMENTARY (CLOSE-AND-LATCH) CURRENT DUTY EXCEEDS 80% OF RATING

3. Fault Current Level Changes with Addition of Queue 371

[redacted]

Substations that experienced an increase in fault current of more than 10% can be seen below in red.

[redacted]

Section

11

Conclusion

Thermal and voltage analyses were performed to determine the thermal and voltage impacts of the Project on the performance of the power system. Peak, shoulder and minimum load scenarios were evaluated with and without the Project. The minimum load scenario was included to identify any overvoltage condition caused by the Project.

The Study results are summarized below:

11.1 N-0 Results

No thermal or voltage violations caused by the Project were found during pre-contingency conditions.

11.2 N-1 Thermal Results

N-1 thermal analysis was performed for peak and shoulder load conditions. The thermal results are summarized below:

Peak Load – Pre-NEEWS Conditions – East to West Flows

- The Q345 POI to Ashland 115 kV section of the E-115 line overloads for the [redacted] The Project causes a loading of [redacted] As part of prior queued project "Q345", this portion of the E-115 line will be upgraded to an LTE rating of [redacted] Therefore the Q371 Project is not required to upgrade this line. The E115 line upgrade's in-service date is December 2013, while the in-service date of the Q345 project is October 2012; the Q345 project's output may be limited under certain scenarios until this line upgrade is complete.

Shoulder Load – Pre-NEEWS and Post-NEEWS Conditions – East to West Flows

- Q371 POI to Keene 115 kV section of the L-163 line overloads for several contingencies with the highest loading caused by [redacted] The Project causes a loading of [redacted] the fact that an overload was found indicated the need for a transfer limit analysis to be performed. The results of this analysis can be found in the "Transfer Limit Analysis" section.

[redacted]

11.3 Greggs Series Reactor Sensitivity

Switching the Greggs 115 kV series reactor in service was studied to ensure that the addition of the Project did not adversely impact the system in this state.

For this study the Greggs 115 kV by-pass switch is opened forcing the current to flow through the series reactor. Both pre-NEEWS and post-NEEWS shoulder load conditions with East to West flows were tested for N-1 contingencies and monitored for any thermal and voltage impacts.

The results show that the Project does not adversely impact system operation; no thermal overloads occur, and no voltage violations were found.

11.4 N-1 Voltage Results

No adverse voltage impact caused by the Project on the New England bulk power system was found.

However, for all conditions studied, post-contingency high voltages up to [redacted] were seen in simulation at the Project's WTG 12.0 kV terminals and within the 34.5 kV collector system and [redacted] ow voltages occur below [redacted] within the Project. This is due to the WTG's reaching their reactive power limits of +/-1.2 Mvar trying to maintain the scheduled voltage at the POI, for contingencies that cause either low or high voltages on the 115 kV system.

In reality the reactive power output limits reduce for voltages above or below the 0.95 – 1.05 per unit range, thereby limiting such extreme voltages.

11.5 Voltage Sensitivity Analysis

This sensitivity test was performed to ensure that, with terminal voltages outside of their 0.95-1.05 per unit range, the turbines could still provide sufficient reactive power to avoid any voltage violations on the transmission system. Therefore, for this sensitivity analysis, reactive power limits of +/- 0.3 Mvar (considered conservative) were set for each WTG.

The results shown that with limited reactive power limits, no voltage violations on the New England bulk power system occur. However, the Project may not be able to hold its voltage schedule with the reactive power limits reduced.

11.6 N-1-1 Thermal Results

Shoulder Load East to West Flows

For the pre-NEEEWS conditions with the 381 (Northfield-Vernon) line-out, area generation reduction following the line-out situation will prevent any thermal overloads occurring following a possible second contingency. For the post-NEEWS conditions less area generation reduction is required.

[redacted]

For the pre-NEEEWS conditions with the 301/302 (Ludlow-Carpenter Hill-Millbury) line-out, area generation reduction following the line-out situation will prevent any thermal overloads occurring following a possible second contingency. For the post-NEEWS conditions less area generation is required.

Minimum Load

No thermal overloads were found for the I135N (Fitzwilliam-Monadnock-Bellows Falls) line-out case.

11.7 N-1-1 Voltage Results

For all N-1-1 line-out scenario's studied the reduced reactive power output of +/- 0.3 Mvar (considered conservative) were set for each WTG.

No adverse voltage impact caused by the Project was found with or without NEEWS for any of the line-out scenarios studied.

11.8 Transfer Limit Analysis

The analysis was performed to determine whether the Project degrades transfer capability on the New England East-West interface. Both pre-NEEWS and post-NEEWS cases were tested, and transfer limits were evaluated both with the Greggs series reactor bypassed and inserted.

In the pre-NEEWS/Pittsfield-Greenfield system, the Project does degrade transfer capability on the East-West interface by approximately [redacted] This degradation does not appear in the post-NEEWS/Pittsfield-Greenfield system, where pre- and post-Project transfer limits are essentially equal. [redacted]

11.9 Short Circuit

The addition of the 33MW wind powered facility will not cause any PSNH Transmission breakers to become overdutied or exceed 80% of their current rating.

11.10 Final Conclusions

For pre-NEEWS/Pittsfield-Greenfield conditions, due to the thermal overload on the portion of the L163 line between the Point of Interconnection and Keene and the impact to the East-West transfer limits, this portion of the L163 115 kV line will need to be upgraded to a minimum LTE rating of [redacted] This upgrade is not required, however, because this impact is addressed by the Pittsfield-Greenfield project. In the event that the Project wishes to connect before the Pittsfield-Greenfield project is energized, without upgrading the L163S line, the Project may be subject to additional operational restrictions to address this overload on a day-to-day basis, as described in the ISO New England Transmission, Markets, and Services Tariff, section II, schedule 22, article 5.9.

[redacted]

The estimated in-service date for the Project is December 2013; if the Project does not elect to upgrade the Line L163 and elects to rely on the Pittsfield-Greenfield Project to mitigate the overload of Line L163 and impacts to thermal limits on transfers across the East-West Interface, then the project can interconnect in 2013 as planned. However, until the Pittsfield-Greenfield Project is constructed, the Project may be restricted in real-time operations to mitigate the potential overload of Line L163 and impacts to thermal transfer limits. If for reasons beyond NU's control (e.g. siting and regulatory approval) the Pittsfield-Greenfield Project is cancelled, the Project will be held responsible to upgrade the section of Line L163 from the Project's Point of Interconnection to the Keene substation.

The steady state and short circuit analyses performed show that the Project, along with the proposed thermal solutions, will not have a steady state adverse impact on the reliability or operating characteristics of the power system.

11.11 Interconnection Cost Estimate

NU's non-binding good faith estimate to interconnect Antrim Wind to the Public Service of New Hampshire (PSNH) system in the Town of Antrim, NH ranges between -50% $6.34 million to 200% $38 million. This estimate is based on constructing a [redacted] configuration, looping into the L163 line about 6.5 miles southwards of the Jackman 115-kV Substation.

NU's non-binding good faith estimate to uprate the L163 line for the Q371 interconnect is in the order of magnitude -50% $6.6 million to +200% $40 million.

The section of line between the POI and Keene substation requires uprate, this is approximately 19 miles in length. The scope of work will allow the line to be operated at a summer LTE temperature of 140C, resulting in a new summer LTE rating of [redacted] The uprate does not affect the impedance of the 115 kV conductors.

[redacted]

Appendix

A

Power Flow Summaries

Appendix

B

Power Flow One-Line Diagrams

[redacted]

Appendix

C

Contingency List

[redacted]

[redacted]

Appendix D

Results

D.1 N-1 Thermal Results

[redacted]

D.2 N-1 Voltage Results

[redacted]

D.3 N-1 Thermal - Greggs Series Reactor Results

D.4 N-1 Voltage - Greggs Series Reactor Results

D.5 N-1 Voltage – Sensitivity Results

D.6 N-1-1 Thermal & Voltage Results

Appendix

E

Project IDEV

[redacted]

[redacted]

[redacted]

Siemens Industry, Inc.
Siemens Power Technologies International
400 State Street • P.O. Box 1058
Schenectady, New York 12301-1058 USA
Tel: +1 (518) 395-5000 • Fax: +1 (518) 346-2777

EXHIBIT
AWE - 10B

R110-11

Stability Study Report for Q371 Wind Project Interconnecting to Line L-163 near Jackman 115 kV Substation in New Hampshire

Prepared for

ISO-NE

Submitted by:
Baldwin P.Lam, Senior Manager
Octavio Gutierrez, Senior Staff Consultant
David Lovelady, Senior Consultant

August 31, 2012
September 17, 2012 – Revision 1
November 30, 2012 – Revision 2

Siemens PTI Project Number: P/21-113619

Siemens Industry, Inc.
Siemens Power Technologies International
400 State Street • P.O. Box 1058
Schenectady, New York 12301-1058 US
Tel: 518-395-5000 • Fax: 518-346-2777
www.siemens.com/power-technologies

SIEMENS

Revision History

Date	Rev.	Description
August 31, 2012	0	Initial draft
September 17, 2012	1	Changes to address comments received from ISO-NE 9/7/2012 and Northeast Utilities 9/14/2012
November 30, 2012	2	Corrected a typo in the report title

Contents

[redacted]

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[redacted]

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[redacted]

Executive Summary

Siemens Industry, Inc., Siemens Power Technologies International (Siemens PTI), conducted a Stability Study ("Study") of Project Q371 ("the Project") under the ISO New England (ISO-NE) Open Access Transmission Tariff ("Tariff") Schedule 22-Standard Large Generator Interconnection Procedures ("LGIP") and Network Capability Interconnection Standard ("NCIS"), PP5-6 on behalf of ISO-NE.

Project Description

The Project can be described as follows:

- 11 Acciona 3.0 MW wind turbine generators (WTG's) with a maximum aggregated output of 33 MW. The Project's net output at the point of interconnection (POI) is, approximately, 32 MW.

- Each WTG will be connected to the 34.5 kV underground collector system via its own 12.0/34.5 kV generator step-up transformer (GSU).

- A single 34.5 kV overhead line will carry the power from an underground wind turbine string to the Project's Collector Substation where a 24 MVA 34.5/115 kV transformer will step up the voltage and connect directly to the Point of Interconnection (POI) at a new 115 kV [redacted] Switching Station tapping the L-163 line between Keene and Jackman 115 kV Substations at about 6.5 miles southwards of Jackman 115 kV Substation.

- The Project will operate in field bus voltage control mode, using a centralized voltage regulator maintaining a scheduled voltage at the POI.

- The proposed commercial operation date for this Project is December of 2013.

Stability Study

- For the Stability Study the Project is modeled as an equivalent model, that is with a single equivalent WTG (33 MW) that connects to an equivalent GSU 12.0/34.5 kV transformer. A single equivalent 34.5 kV underground collector cable connected to the 34.5 kV overhead line that carries the power to the Projects 34.5 kV Collector Substation. The 34.5/115 kV transformer and interconnection to the 115 kV L-163 are modeled explicitly.

- Normal, extreme and Bulk Power System (BPS) contingencies were simulated for light and peak load conditions with high West to East and high East to West interface flows.

- The New England East West Solution & Pittsfield/Greenfield projects were assumed in-service. Sensitivity testing was performed without these projects.

- Testing with Delayed Auto-Reclosing (DAR) schemes on the L163S and L163N lines and with the Greggs series reactor in-service was performed.

Stability Results

- BPS testing was performed [redacted] The total loss of source was less than 1,200 MW in each of the BPS contingencies simulated. Therefore, none of the buses tested needs to be classified as a BPS facility due to the interconnection of the Project.

- Normal contingencies tested in the local area surrounding the Project shown no generating units were tripped. Also, for the post-NEEWS case (not tested for pre-NEEWS conditions), no generating units were tripped for the Delayed Auto-Reclosing schemes on the L163S and L163N lines and with Greggs series reactor in-service.

- No units were tripped following simulation of the EC contingencies.

Final Conclusions

- The Study determined the Project operating with field bus control (centralized voltage regulator) controlling the project's 115 kV Point of Interconnection voltage, nominal tap settings (ratio of 1.0) for the 34.5/115 kV main transformer and 12/34.5 kV Wind Turbine GSU and without any system upgrades, will not have an adverse impact on the stability of the power system.

[redacted]

Section

1

Introduction

Siemens Industry, Inc., Siemens Power Technologies International (Siemens PTI), conducted a Stability Study ("Study") of Project Q371 ("the Project") under the ISO New England (ISO-NE) Open Access Transmission Tariff ("Tariff") Schedule 22-Standard Large Generator Interconnection Procedures ("LGIP") and Network Capability Interconnection Standard ("NCIS"), PP5-6 on behalf of ISO-NE.

This document presents the Stability Study Report.

The Project consists of eleven (11) Acciona 3.0 MW (AW3000) wind turbine generators (WTG's) and the associated collector system. The maximum aggregated output of the WTG's will be 33 MW. The Project's net output at the point of interconnection (POI) is, approximately, 32 MW, once the losses in the collector system have been subtracted. The Project service load is negligible.

The proposed commercial operation date for this Project is December of 2013.

The Project will interconnect to the Public Service of New Hampshire (PSNH) system in New Hampshire at a new 115 kV Switching Station [redacted] tapping the L-163 line about 6.5 miles southwards of the Jackman 115 kV Substation.

The Study included N-1 stability testing for normal conditions with all lines in-service and BPS testing. Peak and light load conditions were considered in the study. Both load conditions were studied with high West to East and East to West New England interface flows, each case was also studied with NEEWS (New England East West Solution) & Pittsfield/Greenfield projects modeled, to be known hereafter as "post-NEEWS".

A sensitivity study was carried out to test the worst fault conditions on the cases without NEEWS (New England East West Solution) & Pittsfield/Greenfield projects.

It was determined that stability simulations of N-1-1 line-out conditions were not required to be studied for this Project. Under line-out conditions, operational restrictions on the Project may be necessary on a case-by-case basis to maintain system reliability

Section

2

Project Description

2.1 Project Description and Interconnection Plan

The Project consists of 11 Acciona 3.0 MW wind turbine generators (WTG's) with a maximum aggregated output of 33 MW. The Project's net output at the point of interconnection (POI) is, approximately, 32 MW, once the losses in the collector system have been subtracted. The service load is negligible. Each WTG will be connected to the 34.5 kV underground collector system via its own 12.0/34.5 kV generator step-up transformer (GSU). A single 34.5 kV overhead line will carry the power from an underground wind turbine string to the Project's Collector Substation where a 24 MVA 34.5/115 kV transformer will step up the voltage and connect directly to the Point of Interconnection (POI) at a new 115 kV [redacted] Switching Station on the L-163 line between Keene and Jackman 115 kV Substations.

The Developer provided a detailed layout showing the individual wind turbine generators and feeders. For this study an equivalent model was used that consists of a single equivalent WTG (33 MW) that connects to an equivalent GSU 12.0/34.5 kV transformer. A single equivalent 34.5 kV underground collector cable connected to the 34.5 kV overhead line that carries the power to the Projects 34.5 kV Collector Substation. The 34.5/115 kV transformer and interconnection to the 115 kV L-163 are modeled explicitly. The equivalent model was derived following the methodology documented in the NREL wind equivalent conference paper [1], using the Project data provided by the Developer.

Figure 2-1 shows a one-line diagram of the equivalent Project model and adjacent substations in the area.

[1] E.Muljadi, C.P.Butterfield (January 2006). *Equivalencing the Collector System of a Large Wind Power Plant*. NREL: Conference Paper NREL/CP-500-38940.

[redacted]

[redacted]

Figure 2-1. Project Interconnection and buses nearby the Project

Figure 2-2 below illustrates the approximate geographical location of the Project and the transmission lines in the area of interest.

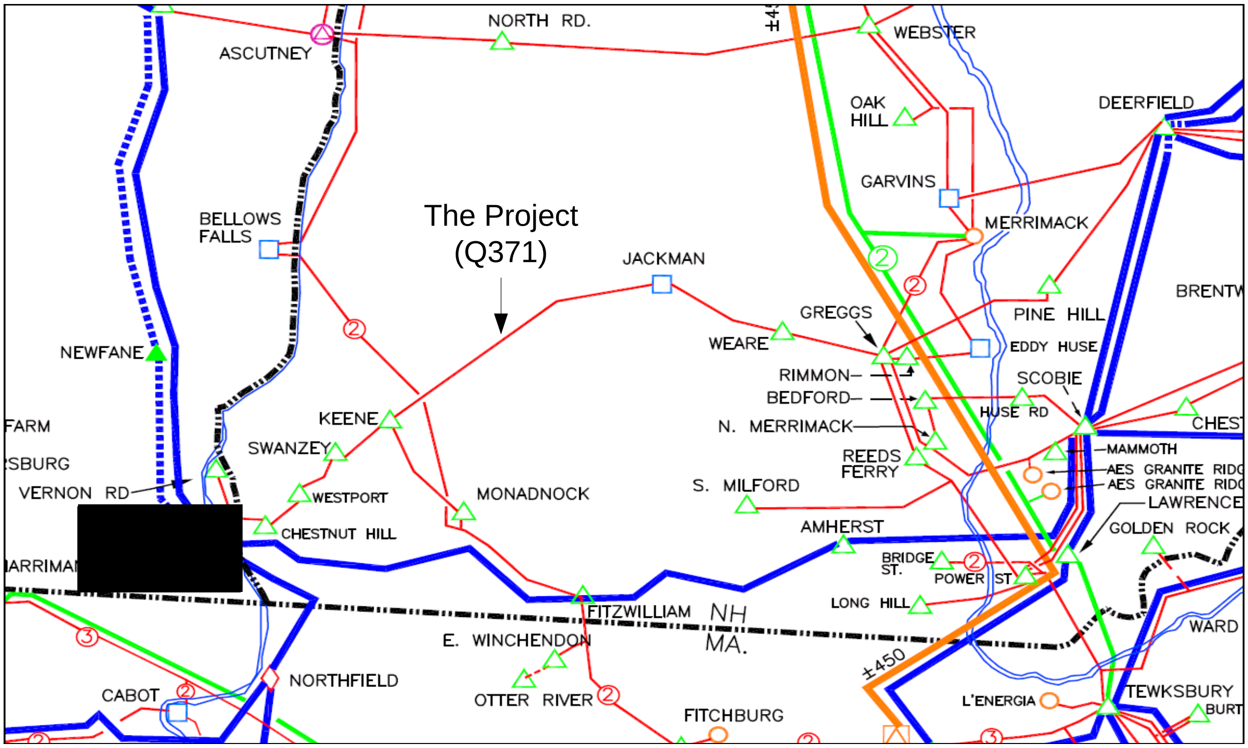


Figure 2-2. Approximate Geographical Location of the Project

2.2 Project Data

The Project data for each WTG and the corresponding GSU transformer are shown below in Table 2-1 and Table 2-2, respectively.

Table 2-1. Wind Turbine Generator (WTG) Data

Ratings of each Wind Turbine Generator	3.23 MVA, 12,000 V
Gross Output of each wind generator	3.0 MW
Exporting Reactive Power Limit at 3.0 MW output [2]	1.2 Mvar (0.928 power factor)
Importing Reactive Power Limit at 3.0 MW output [3]	-1.2 Mvar (0.928 power factor)
Station Service Load	When the WTG's are online, the service load is negligible[4].

[2] For terminal voltages between 0.95 – 1.05 V per unit for each wind turbine, measured at 12 kV terminals.
[3] For terminal voltages between 0.95 – 1.05 V per unit for each wind turbine, measured at 12 kV terminals.
[4] Service load is 0.165MW and 0.044MVAr for the entire wind farm when all WTG's are offline.

Table 2-2. Wind Unit GSU Transformer Data

Nameplate ratings (self cooled/maximum)	3.4/3.4 MVA
Voltage ratio, generator side/system side	12.0/34.5 kV
Winding connections, low voltage/high voltage	Wye grounded/Delta
Available Tap positions	5 steps, each +/- 2.5% of nominal
Tap position for the Study	1.0 (nominal)
Impedance, Z_1 (on self cooled MVA rating)	6.0%, X/R = 8.0
Impedance, Z_0 (on self cooled MVA rating)	6.0%, X/R = 8.0

Figure 2-3 and Figure 2-4 below show the Acciona WTG reactive power output for varying conditions. Both figures were obtained from Acciona documentation [5] provided by the Developer.

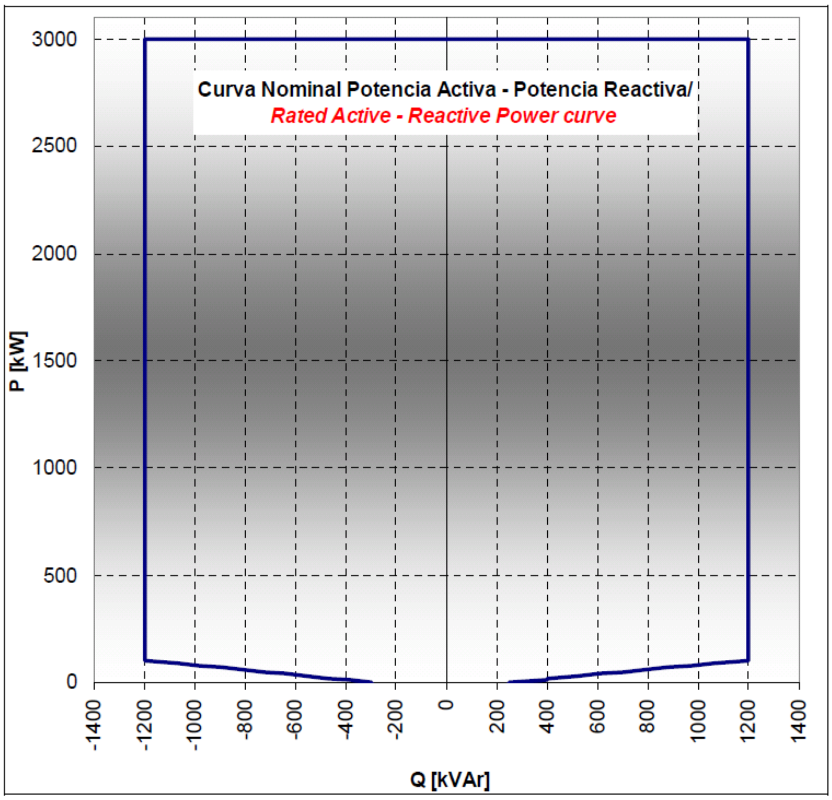


Figure 2-3. WTG Rated Active (P) vs Reactive Power (Q) Curve [6]

Figure 2-4 below, shows the reactive power output limits of each turbine are reduced significantly for terminal voltages outside of the 0.95 – 1.05 V per unit range. This reactive power limit curve is simulated by the Acciona dynamic model (described below in section 2.4) i.e. if the WTG terminal voltage falls outside the 0.95-1.05 per unit range, the dynamic model automatically limits reactive power output as required.

[5] Acciona (Approved 04-28-2011). *AW3000 Electric Grid Data.* Document: DG200032, REF: F
[6] For WTG terminal voltage between 0.95 and 1.05 per unit

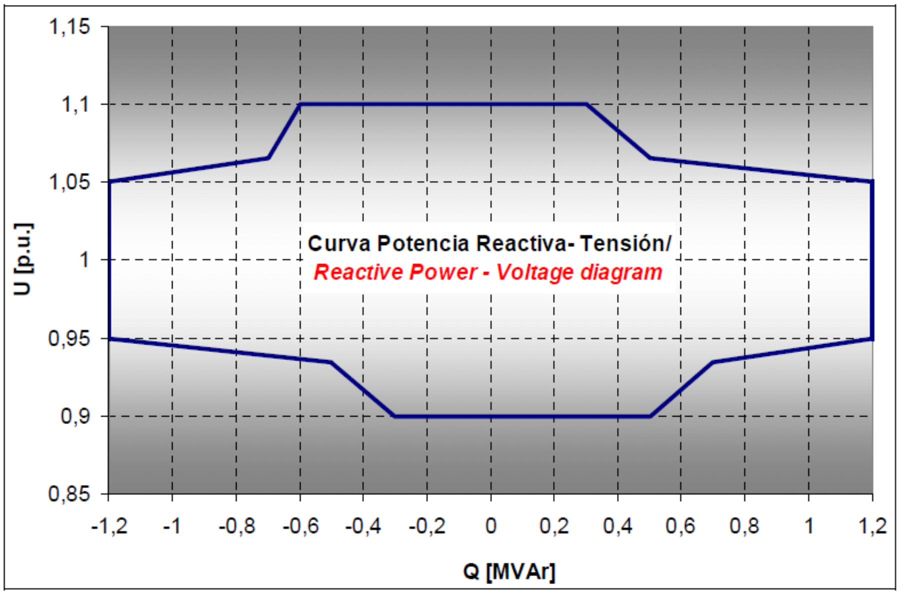


Figure 2-4. WTG Reactive Power (Q) vs Terminal Voltage (U) at Full Rated Active Power Output

The parameters of the main transformer are shown in Table 2-3 below.

Table 2-3. Main Transformer at Collector station

Nameplate ratings (self cooled/maximum)	30/50 MVA
Voltages, High/Low voltage/Tertiary	115/34.5/13.2 kV
Winding connections, High/Low/Tertiary	Wye grounded/Wye grounded/Delta
Available Tap positions	5 steps, each +/- 2.5% of nominal
Tap position for the Study	1.0 (nominal)
Impedance Z_1 (% on self cooled MVA rating)	9.0 %, X/R = 26
Impedance Z_0 (% on self cooled MVA rating)	9.0 %, X/R = 26

Table 2-4 below, shows the parameters of the 34.5 kV overhead line that will connect the WTG strings to the 34.5 kV Project Collector Substation, based on values calculated by the Project Developer.

Table 2-4. 34.5kV Overhead Line Feeder Data

Length (feet)	Positive Sequence – Ohms			Zero Sequence –Ohms	
	R	Xl	Xc (MOhms)	R	Xl
4,500	0.1185	0.5185	0.16548	0.2765	1.356

2.3 Power Flow Model

As stated in the Project Description section, an equivalent power flow model of the Project was used. Table 2-5 and Table 2-6 provide the equivalent WTG and the corresponding GSU transformer data.

Table 2-5. Equivalent Wind Turbine Generator (WTG) Data

Equivalent Rating	35.53 MVA, 12,000 V
Equivalent Gross Output	33.0 MW
Equivalent Exporting Reactive Power Limit at 33.0 MW output [7]	13.2 Mvar (0.928 power factor)
Equivalent Importing Reactive Power Limit at 33.0 MW output [8]	-13.2 Mvar (0.928 power factor)

The actual equivalent WTG reactive power limits are set specifically for each power flow case to ensure the initial conditions fall within the reactive power vs terminal voltage bounded area as shown in Figure 2-4 above, that is, if the reactive power output from the equivalent WTG fell outside of the bounded area, then the reactive power limits were reduced in the power flow case to ensure the initial conditions were within the physical capabilities of the WTG.

Table 2-6. Equivalent Wind Unit GSU Transformer Data

Nameplate ratings (self cooled/maximum)	37.4/37.4 MVA
Voltage ratio, generator side/system side	12.0/34.5 kV
Winding connections, low voltage/high voltage	Wye grounded/Delta
Available Tap positions	5 steps, each +/- 2.5% of nominal
Tap position for the Study	1.0 (nominal)
Impedance, Z_1 (on self cooled equivalent MVA rating)	6.0%, X/R = 8.0
Impedance, Z_0 (on self cooled equivalent MVA rating)	6.0%, X/R = 8.0

Table 2-7 below, shows the equivalent 34.5 kV collector cable data.

Table 2-7. Equivalent 34.5 kV Collector Cable Data

Positive Sequence – Per Unit (on 34.5 kV 100 MVA base)		
R	**Xl**	**B**
0.04782	0.04437	0.0007

[7] For terminal voltages between 0.95 – 1.05 V per unit for each wind turbine, measured at 12 kV terminals.
[8] For terminal voltages between 0.95 – 1.05 V per unit for each wind turbine, measured at 12 kV terminals.

2.3.1 Voltage Control and Transformer Tap Settings

The reactive power exchanged with the power system can be controlled in real time by means of the power converter within the limits defined above. This control may be either local or remote for constant reactive power or power factor operation. The remote control allows the implementation at plant-wide level of different reactive controls. The most commonly used control modes are listed below:

- Field bus voltage control, to balance the field bus voltage and therefore the machine voltages. The voltage at the POI would be controlled according to a set point. This voltage is periodically sampled to determine whether the POI voltage is different from the set point, and if so, command signals are sent to the turbines via SCADA to adjust their reactive power.

- Remote voltage control. In this mode, the reactive power set point to be generated by the wind farm comes directly from remote controls of system operators.

- Scheduled power factor. The power factor of the turbines is changed periodically during the day according a scheduled program usually established by the electric grid operator.

Field bus voltage control, modeled as a centralized voltage regulator (described further in Section 2.4) was selected by the Developer and as such was modeled for this Study.

Currently there is no specific voltage schedule at the POI as it is a new Switching Station on the L-163 line. To ensure that the Project is capable of operating at a range of voltage set points, without voltage violations on transmission buses and without turbine trips due to under- or over-voltage, the Project was set to maintain a scheduled voltage of [redacted] for light load conditions and [redacted] for peak load conditions.

The equivalent wind turbine GSU transformer and the main 34.5/115 kV transformer are both set at the nominal tap position (ratio of 1.0).

Figure 2-5 below shows the equivalent Project one line diagram with the impedance data.

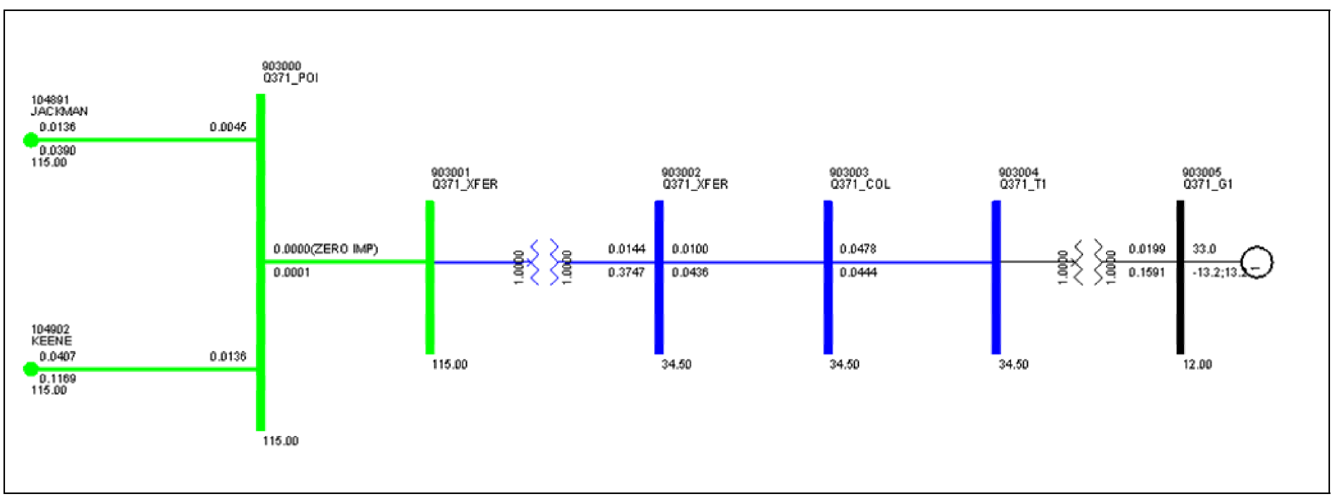


Figure 2-5. Equivalent Project Impedance One Line Diagram

The IDV file to incorporate the Project to the PSS®E Version 30.3.3 CVF, power flow database is included in Appendix C.

2.4 Stability Models

The electrical generation is based on a doubly fed induction generator that is electronically controlled. The rated stator line voltage is 12 kV while the generation power (active and reactive) is controlled through the rotor currents. Those currents are produced by means of a hard switching electronic power converter based on IGBTs.

The PSS®E dynamic modeling package includes the module of the wind turbine unit employing the DFIG machine and the module of the centralized voltage regulator (field bus control). The wind turbine dynamic simulation model includes the rotor aerodynamics, a two-mass mechanical drive train, the blade pitch control system and the electrical generator and power electronic converter. The dynamic models provided by the Developer and used for this Study are:

- awt1530_p303cvf_v700_Tf1.lib
- AWT1530MODULE_V501.OBJ
- AWTVRG_V501.OBJ

Available set points of over- and under frequency protection implemented within the turbine model are shown in Table 2-8 below. The set points used for the Study are based on data provided by the Developer.

Table 2-8. Frequency Protection Settings

Description	Min	Set Point for Study	Max
Over-frequency Trip point (Per Unit)	0 (60 Hz)	0.05	0.05 (63 Hz)
Under-frequency Trip Point (Per Unit)	-0.05 (57 Hz)	-0.05	0 (60 Hz)
Over-frequency delay (seconds)	0	5	5
Under-frequency delay (seconds)	0	5	5

The standard normal operation voltage range is 90% to 110% of rated voltage (12 kV line-to-line). Outside these limits the turbine control changes its operational mode from Normal to Fault mode and tries to get the voltage back to normal range through reactive current injection. Figure 2-6 below, shows the voltage protection curve that represents the set points implemented in the model. Should the terminal voltage remain outside of the grey area for a sustained period of time the WTG will trip offline.

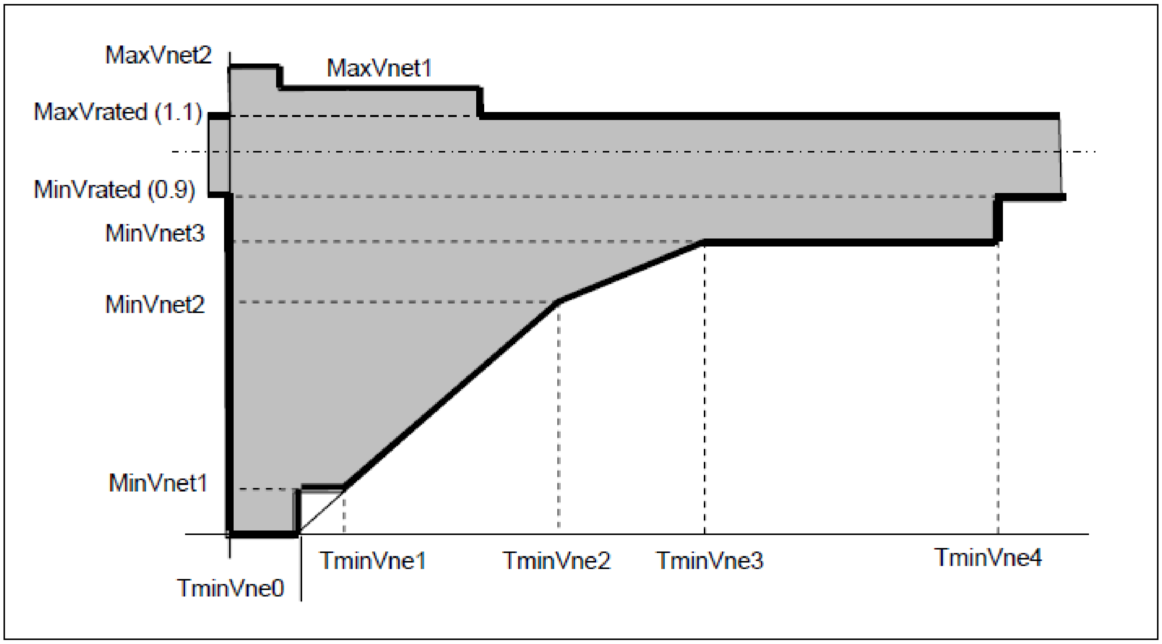


Figure 2-6. Voltage Protection Curves

Available set points of over and under voltage protection implemented within the turbine model are shown in Table 2-9 below. The set points used for the Study are based on data provided by the Developer.

Table 2-9. Voltage Protection Settings

Description	Name	Min	Set Value	Max
Overvoltage limit 1 (pu)	MaxVnet1	>1.1	1.15	1.18
Overvoltage limit 2 (pu)	MaxVnet2	>MaxVnet1	1.2	1.3
Maximum time for overvoltage limit 1 (seconds)	TmaxVnet1	0	5	5
Maximum time for overvoltage limit 2 (seconds)	TmaxVnet2	0	0.1	5
Undervoltage #1 (pu)	MinVnet1	0.1	0.1	1.0
Undervoltage #2 (pu)	MinVnet2	0.75	0.9	1.0
Undervoltage #3 (pu)	MinVnet3	0.85	0.9	1.0
Undervoltage #0 Delay (seconds)	TminVne0	0	0.5	0.5
Undervoltage #1 Delay (seconds)	TminVne1	>TminVne0	1.0	1.0

Description	Name	Min	Set Value	Max
Undervoltage #2 Delay (seconds)	TminVne2	>TminVne1	2.0	5.0
Undervoltage #3 Delay (seconds)	TminVne3	>TminVne2	15.0	20.0
Undervoltage #4 Delay (seconds)	TminVne4	>TminVne3	210.0	250.0

Table 2-10 and Table 2-11 below, show the complete list of parameters and values set for the dynamic modeling of the Acciona WTG for this Project.

Table 2-10. WTG Model Parameters for this Study

Constant	Description	Name	Set Value
CON(J)	Rated Wind Speed (m/s)	Vv_nom	15
CON(J+1)	Over-frequency Trip point (Per Unit)	MaxFnet	0.05 (63 Hz)
CON(J+2)	Under-frequency Trip Point (Per Unit)	MinFnet	-0.05 (57 Hz)
CON(J+3)	Over-frequency delay (s)	TmaxFnet	5
CON(J+4)	Under-frequency delay (s)	TminFnet	5
CON(J+5)	Overvoltage limit 1 (pu)	MaxVnet1	1.15
CON(J+6)	Overvoltage limit 2 (pu)	MaxVnet2	1.2
CON(J+7)	Maximum time for overvoltage limit 1 (s)	TmaxVnet1	1.5
CON(J+8)	Maximum time for overvoltage limit 2 (s)	TmaxVnet2	0.2
CON(J+9)	Undervoltage #1 (pu)	MinVnet1	0
CON(J+10)	Undervoltage #2 (pu)	MinVnet2	0.8
CON(J+11)	Undervoltage #3 (pu)	MinVnet3	0.85
CON(J+12)	Undervoltage #0 Delay (s)	TminVne0	1.6
CON(J+13)	Undervoltage #1 Delay (s)	TminVne1	1.6
CON(J+14)	Undervoltage #2 Delay (s)	TminVne2	3.5
CON(J+15)	Undervoltage #3 Delay (s)	TminVne3	15
CON(J+16)	Undervoltage #4 Delay (s)	TminVne4	210
CON(J+17)	Undervoltage for MaxIc (pu)	V_MaxIc	0.5
CON(J+18)	Maximum reactive current (Voltage dips) (pu)	MaxIc	1
CON(J+19)	Minimum reactive current (Voltage dips) (pu)	MinIc	0.2
CON(J+20)	Maximum reactive current (Overvoltage) (pu)	MaxIi	1
CON(J+21)	Minimum reactive current at MaxVrated	MinIi1	0.2

Constant	Description	Name	Set Value
CON(J+22)	Minimum reactive current at MaxVnet1	MinIi2	1
CON(J+23)	Minimum reactive current at MaxVnet2	MinIi3	1
CON(J+24)	External Reactive Power Control Flag (1 = enable, 0 = disable)	DYN_Q	1
CON(J+25)	Grid side power converter reactive power contribution - activation Flag (1 = enable, 0 = disable)*.	PC_Q_ON	1
CON(J+26)	Time for reactive power priority during voltage dips (s)	TimeQ_VD	3
CON(J+27)	Time for reactive power priority during over-voltage (s)	TimeQ_SW	3
CON(J+28)	Rotor current control – Proportional factor (ohm)	Kp	25
CON(J+29)	Rotor current control – Integral factor (ohm/s)	Ki	500
CON(J+30)	Active power ramp (kW/s) (steady state)	P_ramp	6000
CON(J+31)	Reactive power ramp (kVA/s) (steady state)	Q_ramp	6000
CON(J+32)	Duration of the post-fault Q ramping	T_POST_ PRIOR_Q	20
CON(J+33)	Rate of the post-fault Q ramping	Q_RAMP_ POST	40

Table 2-11. Centralized Voltage Regulator Model Parameters for this Study

Constant	Description	Name	Set Value
CON(J)	Proportional Gain, p.u.	Kp	3
CON(J+1)	Integral Gain, p.u./sec.	Ki	1.8
CON(J+2)	Transducer Time Constant, sec.	VTtau	0.01
CON(J+3)	SCADA Cycle Time, sec.	SCDEL	0.1
CON(J+4)	Maximum Reactive Power, p.u. on SBASE	MaxQ	1.2
CON(J+5)	Minimum Reactive Power, p.u. on SBASE	MinQ	-1.2
CON(J+6)	Lower limit of normal voltage range	Min_Vsub	0.85
CON(J+7)	Upper limit of normal voltage range	Max_Vsub	1.15
CON(J+8)	Duration of anti-wind-up after fault is detected	Tmax_AWU	4

2.4.1 Acciona Dynamic Model TF Parameter

During the initial stability contingency analysis for several contingencies, some sustained oscillations were observed from the Projects reactive power output, in particular for the peak load cases as shown below in Figure 2-7and Figure 2-8.

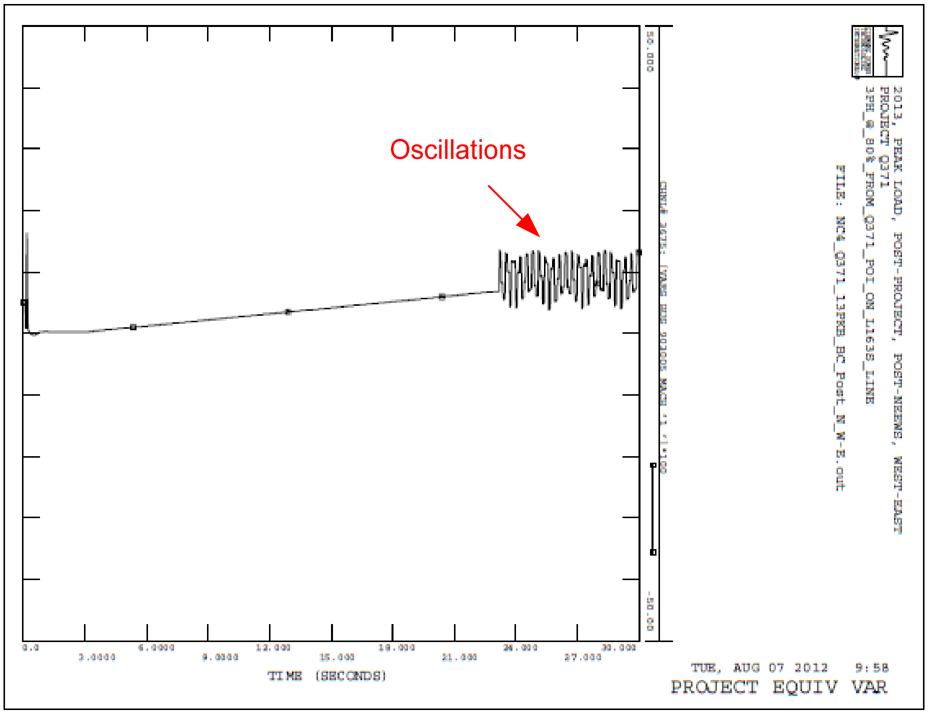


Figure 2-7. Project Q output for PK E-W Post NEEWS case for contingency NC4

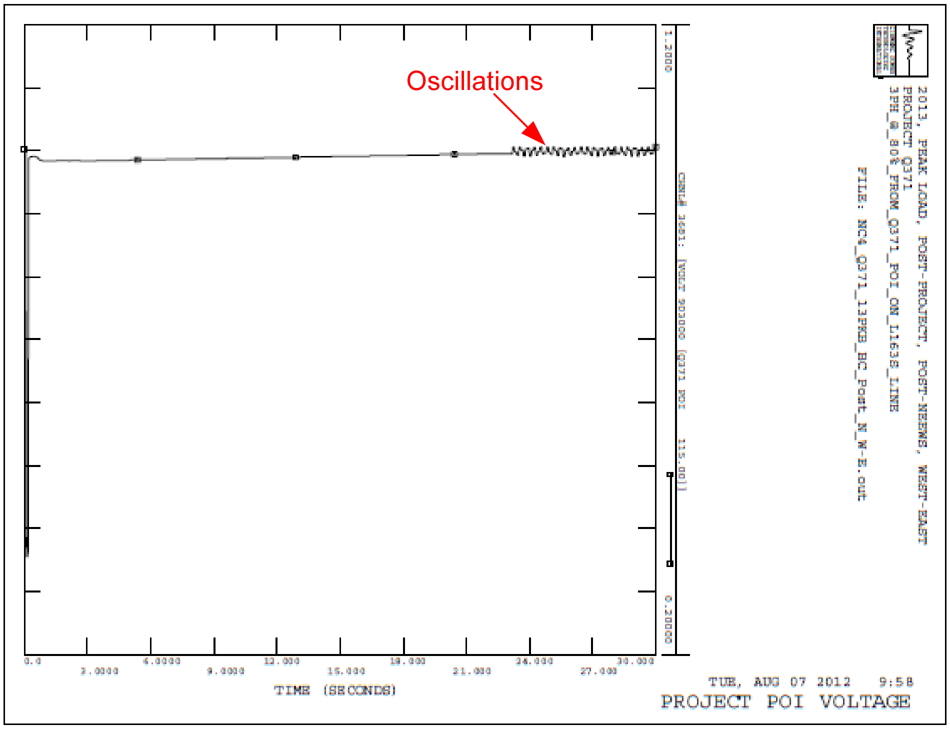


Figure 2-8. POI Voltage for PK E-W Post NEEWS case for contingency NC4

Following a discussion with the Developer and Acciona, it was determined an internal model parameter change to a gain function "TF" should be set to equal 1 (TF=1). With this change, as reflected in the model "awt1530_p303cvf_v700_Tf1.lib", the oscillation problem was resolved as shown in the latest results below in Figure 2-9 and Figure 2-10. When the Project is constructed, the Acciona turbines must be set to reflect this choice of Tf = 1 second

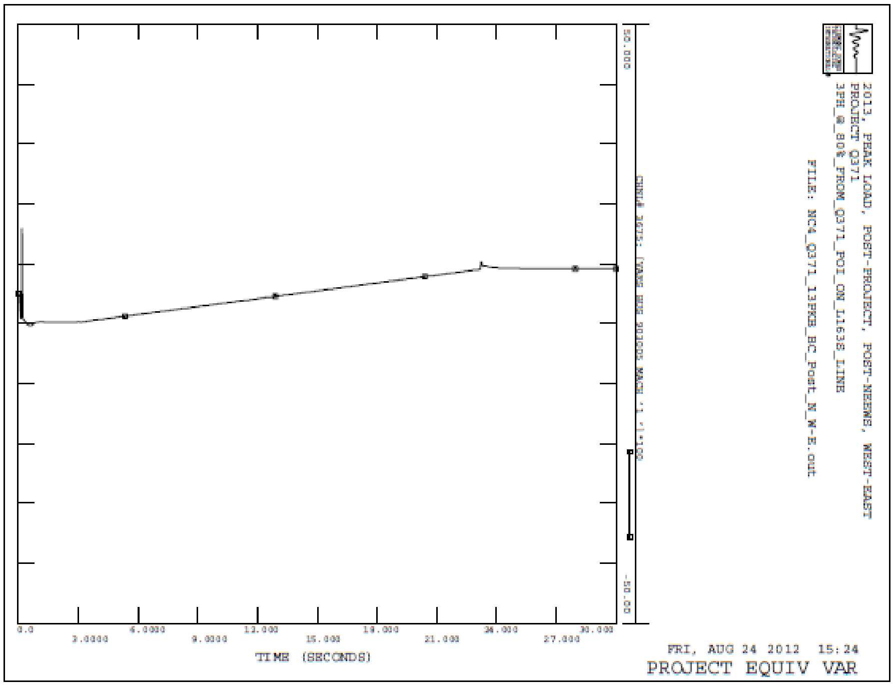


Figure 2-9. Project Q output for PK E-W Post NEEWS case for NC4 with TF=1

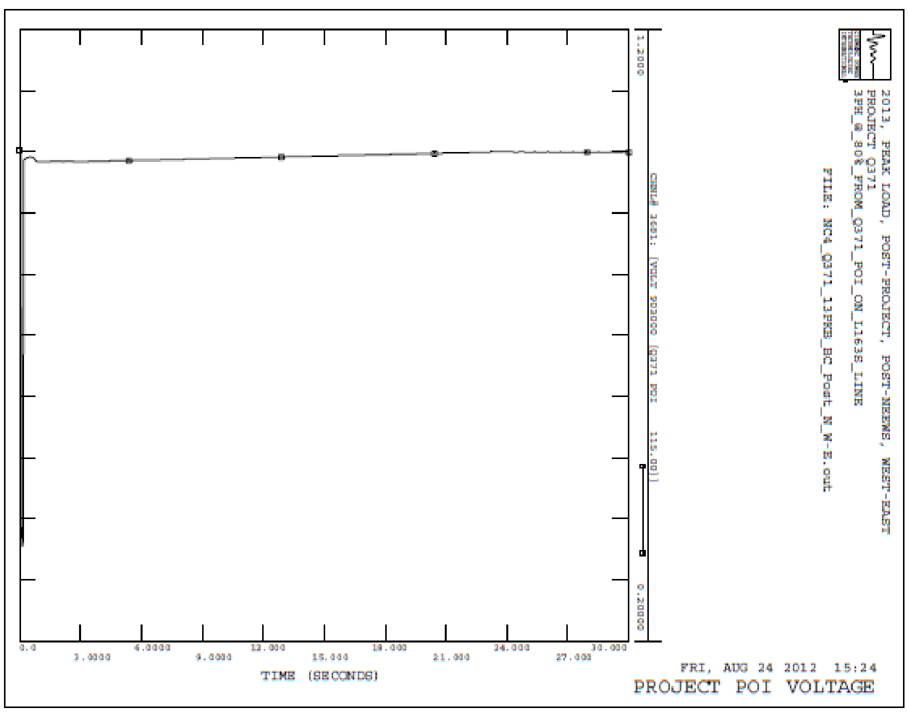


Figure 2-10. POI Voltage for PK E-W Post NEEWS case for NC4 with TF=1

Appendix C includes the DYR file with the stability parameters for the WTG including the protection settings and the centralized voltage regulator used for this Study.

Section

3

Study Methodology

3.1 Introduction

The Study was performed under the ISO New England (ISO-NE) Open Access Transmission Tariff ("Tariff") Schedule 22-Standard Large Generator Interconnection Procedures ("LGIP"), and in accordance with:

- Northeast Power Coordinating Council (NPCC) Document A-2 "Basic Criteria for Design and Operation of Interconnected Power Systems".
- Interconnection Procedures contained in Schedule 22 of the Tariff.
- ISO-NE Planning Procedure No. 3, "Reliability Standards for the New England Area Bulk Power System" (October 2006).
- ISO-NE Planning Procedure No. 5-3, "Guidelines for Conducting and Evaluating Proposed Plan Application Analyses".
- ISO-NE Planning Procedure 5-6, "Scope of Study for System Impact Studies under the Network Capability Interconnection Standard (NCIS)".
- ISO-NE Operating Documents.
- Transmission Reliability Standards for Northeast Utilities (May 2008).

3.2 Criteria and Methodology

The study was performed using the ISO-NE stability criteria in the ISO-NE Reliability Standards dated February 2005, and in accordance with the "Transmission Planning Guideline for Northeast Utilities", dated May 2008. The criteria are included in Appendix D.

- Stability testing was performed for normal conditions with all lines in-service (N-1 analysis) with the Project modeled in-service.
- BPS testing was performed as per NPCC's Document A-10 of December 01, 2009.

Siemens PTI software PSS®E Version 30.3.3 CVF was used in the stability analysis.

Section

4

Base Cases and Generation Dispatch

ISO-NE provided 6-digit power flow base cases representing 2013 peak and light load conditions. The New England loads represented in the cases match the CELT 2011 forecast load levels. Additionally, generating units in New England were represented with the most updated maximum power outputs at 0°F.

4.1 Local Area Voltage Setup

To ensure the Project can operate under different local 115 kV area voltage levels, low area voltages were simulated for the peak load conditions and conversely high area voltages for the light load conditions.

To achieve the high area voltage conditions, local switched shunt capacitors modeled at Jackman 115 kV and Chestnut Hill 115 kV were locked at the highest dispatch possible, whilst ensuring the local voltages were below the N-0 steady state criteria of 1.05 per unit. In addition the Fitzwilliam Auto transformer was set to regulate a voltage of [redacted]

To achieve the low area voltage conditions, local switched shunt capacitors modeled at Jackman 115 kV and Chestnut Hill 115 kV were locked to the lowest dispatch possible (i.e. offline), whilst ensuring the local voltages were above the N-0 steady state criteria of 0.95 per unit. In addition the Fitzwilliam Auto transformer was set to regulate a voltage of [redacted]

As previously described in Section 2.3, to be consistent with local pre-Project voltages and typical system operating levels, the reactive power output of the Project WTG's adjust to maintain a scheduled voltage at the POI of [redacted] for light load conditions and [redacted] for peak load conditions.

4.2 Development of Base Cases

Power flow cases representing 2013 peak and light load conditions were used in the Study. The peak load represents, approximately, the 2013 summer peak 90/10 load of the CELT 2011 forecast and the light load is calculated as the 45% of the summer 50/50 peak load.

Table 4-1 below, shows the New England (NE) loads and the transmission losses in the peak and light load post-Project base cases that were considered in the Study.

Table 4-1. NE Load and Losses for 2013 (MW)

	Load	Losses	Total
Peak	30,150	890	31,040
Light	13,692	512	14,204

The following approved projects and their associated upgrades were assumed in service and were modeled in all base cases:

- Closing of the Y138 line from White Lake 115 kV Substation to Saco Valley 115 kV Substation.
- 115 kV capacitors at Beebe and White Lake substations.
- Monadnock transmission project.
- Q166 Granite Wind project (99 MW) interconnecting on the W179 line. The following upgrades are related to this Project: closing of 1J95 Switch at Littleton 115kV Substation; W179 line (Paris-Pontook-Berlin 115 kV) uprated to [redacted] O154 line (Paris-Lost Nation 115kV) uprated to [redacted] D142 (Lost Nation-Whitefield 115 kV) uprated to [redacted] added 4x4.8 MVAR capacitor bank and 4 MVAR DVAR at the project 34.5 kV collector bus.
- Q172 wind project (40 MW) interconnecting in Vermont on the St. Johnsbury-Irasburg line.
- Q197 wind project (50 MW), named Record Hill in the power flow cases, interconnecting in Maine to the Rumford 115 kV Substation.
- Southern Loop transmission project.
- Q251 Laidlaw Berlin Biomass project (65.9 MW) plus associated line rating upgrades of the following 115 kV lines caused by the project: O154 line (Paris-Lost Nation 115 kV) upgraded to [redacted] D142 line (Lost Nation to Whitefield 115 kV) upgraded to [redacted] and S136 line (Whitefield to Berlin 115 kV) upgraded to [redacted] for all ratings.
- Q290 wind project (18 MW), interconnecting in Maine to the Woodstock 115 kV Substation.
- Q291 Merrimack G2 up-rate to the following ratings: gross output 354 MW, gross over-excited [redacted] gross under-excited [redacted] with a service station load of [redacted]
- Q311 Wind project interconnecting in the 46.0 kV distribution system in VT.

[redacted]

- Q323 wind project up-rate of former project Q290 to 20 MW (increase of 2 MW) in Maine.
- Lyndonville reliability project, that adds a [redacted] Substation, a 115/34.5 kV transformer and two 12.5 MVAr capacitors. The project taps the St Johnsbury to Sheffield 115 kV line in Vermont.
- Q345 Wind Project (24 MW) interconnecting between Beebe River and Ashland Tap on the E-115 115 kV line in New Hampshire.
- Wind project Q368 interconnecting at Monadnock Substation to the 34.5 kV bus in New Hampshire at an output of 16.1 MW.

The following changes were made to the **light load** cases originally provided by ISO-NE:

- Two, 4 MVAr statcom devices required as upgrades for project Q345 were added and modeled as a single 8 MVAr device, connected to the 34.5 kV collector bus via a 34.5/0.5 kV transformer. The reactive power output is set close to zero MVAr output pre-contingency.
- Bearswamp and Northfield pumped storage units were set to maximum power output in pumping mode.
- Millstone 2 units were turned online.
- Phase II HVDC was to set to a total of [redacted] into New England.
- Blissville and Sandbar PAR's set to [redacted] transfer.
- Interfaces of interests were stressed to recommended levels.
- The power output from generating units in NH and VT were set to maximum power output according data provided by ISO-NE.
- The local area to the Project was configured to simulate high area voltages by switching local capacitors online were possible, thereby forcing the Project to import reactive power (within the capable limits of the WTG's).
- VT Yankee generating unit turned offline in all East-West stressed cases only, to stress the system by eliminating one of the major sources of reactive support in that area.

The following changes were made to the **peak load** cases originally provided by ISO-NE:

- Errors in several zone numbers were resolved using an IDEV file provided by ISO-NE.
- Two, 4 MVAr statcom devices required as upgrades for project Q345 were added and modeled as a single 8 MVAr device, connected to the 34.5 kV collector bus via a 34.5/0.5 kV transformer. The reactive power output is set close to zero MVAr output pre-contingency.

- The power output from generating units in NH and VT were set to maximum power output according data provided by ISO-NE.
- The local area to the Project was configured to simulate low area voltages by switching local capacitors offline were possible, thereby forcing the Project to export reactive power (within the capable limits of the WTG's).
- VT Yankee generating unit turned offline in all East-West stressed cases only, to stress the system by eliminating one of the major sources of reactive support in that area

4.3 Generation Dispatch

The generation dispatch in ISO-NE can be found in Table 4-2 below for all cases studied along with several New England interface flows. "OOS" refers to a generating unit being "Out Of Service".

Complete power flow case summaries and one line diagrams can be found in Appendix A and Appendix B, respectively.

For the light load West to East cases, the ME and NH interface flows were significantly reduced to enable high West to East flows due to the light load conditions and only minimal MA and RI generation already online.

Table 4-2. Generation Dispatch (MW) and Interface Flows (MW) for the Post-Project Cases

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Section

5

Stability Contingencies

The list of contingencies tested in the Study is shown in Table 5-1, along with the clearing times at each terminal.

The list includes Normal Contingencies (NC), Extreme Contingencies (EC), and Bulk Power System (BPS) contingencies. The contingencies were tested for the peak and light load scenarios documented in Section 4.

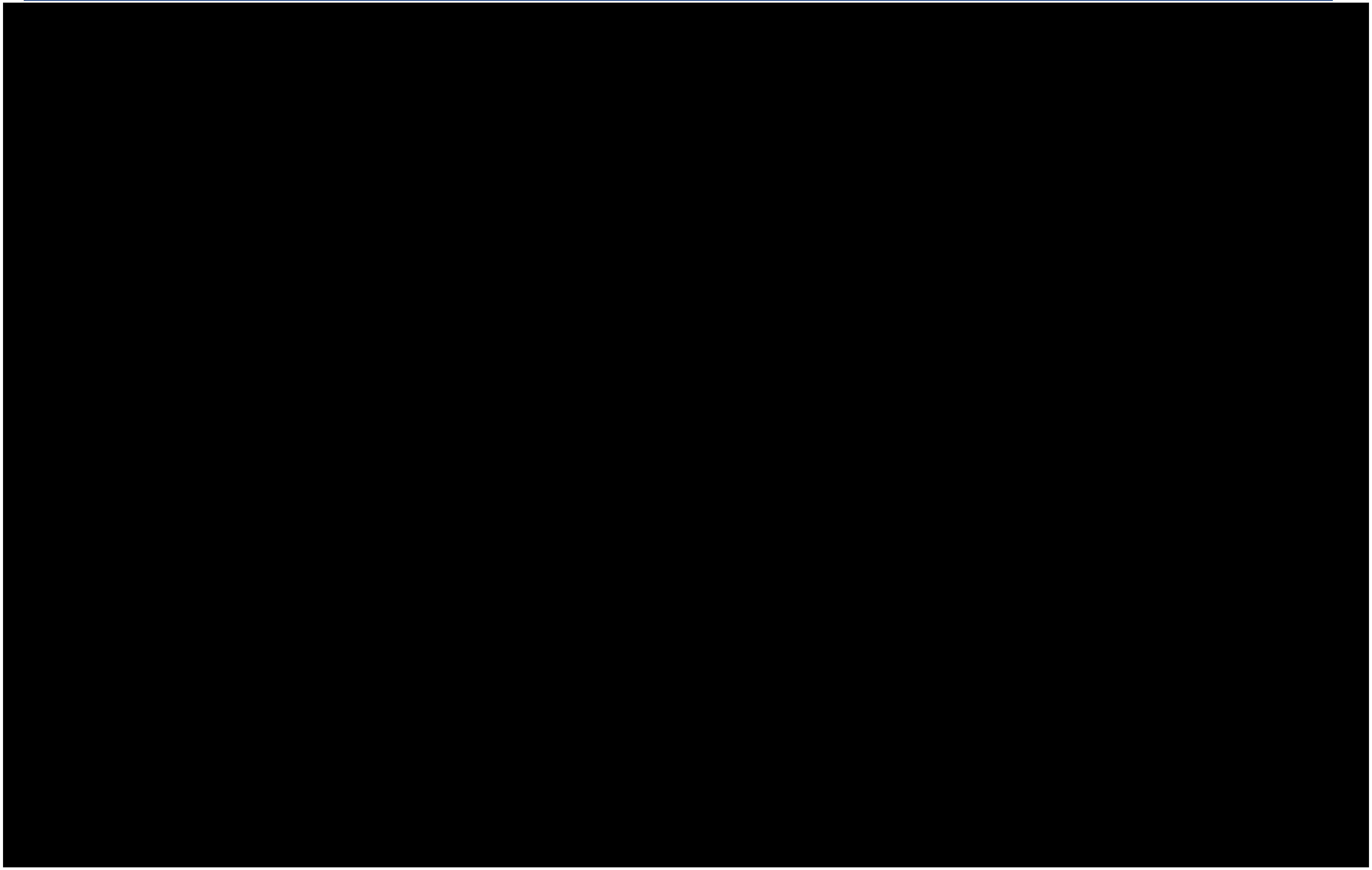
Each NC 115kV line contingency was simulated twice a) with a three-phase line fault adjacent to the bus (zone 1 local clearing) and b) with a three-phase fault 80% along the line from the same bus (zone 2 clearing).

Delayed Auto-Reclosing (DAR) schemes [redacted] were simulated with one shot [redacted] after the initial fault with reclose by the circuit breaker closest to the fault and the remote terminal remaining open (synchronized closing).

Contingencies NC1–NC3 and NC6-NC8 were re-tested with the Greggs series reactor in-service i.e. bypass switch in the open position (current flowing through the series reactor).

Table 5-1. List of Stability Contingencies

[redacted]



[redacted]

Section

6

Stability Results

Dynamic simulations of the contingencies described in Section 5 were performed for the post-NEEWS peak and light load scenarios described in Section 4. The analysis was performed as per the applicable reliability standards.

The stability results are described below and shown in Table 6-1. Simulation plots are provided in Appendix E.

6.1 BPS Testing

Peak Load Results

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Light Load Results

[redacted]

[redacted]

The BPS testing results show that the total loss of source was less than 1,200 MW in each of the BPS contingencies simulated; therefore none of the buses tested needs to be classified as a BPS facility due to the Project.

6.2 NC Testing

These results are for both the light and peak load conditions with both East to West and West to East flows.

Results for normal contingencies NC1 through NC16 show no loss of source occurs, including contingencies re-tested with DAR (Delayed Auto Reclose) and with the Greggs 115 kV series reactor bypass switch in the open position (current flowing through the series reactor).

6.3 EC Testing

These results are for both the light and peak load conditions with both East to West and West to East flows.

[redacted]

Results for contingencies EC19 to EC21, show no loss of source occurs.

As no units were tripped following simulation of the EC contingencies, re-testing these contingencies as single-line-to-ground faults was not required.

[redacted]

6.4 POI Voltage Recovery

For several contingencies: [redacted] the reactive power output limit of the turbines was reached due to the terminal voltage limitation shown previously in Figure 2-4 and again below in Figure 6-1 for reference.

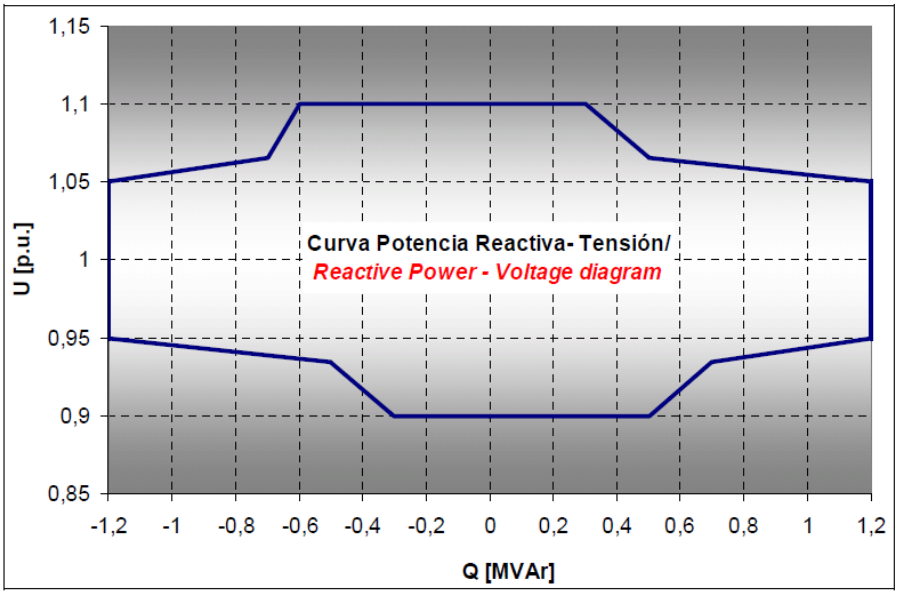


Figure 6-1. WTG Reactive Power (Q) vs Terminal Voltage (U) at Full Rated Active Power Output

For these contingencies the scheduled POI voltage is not maintained. The results show the highest voltage occurred for the light load case with East to West flows for contingency NC11 with [redacted] at the POI, as shown below in Figure 6-2 and Figure 6-3 below.

[redacted]

Figure 6-2. Project Q output for LL E-W Post NEEWS case for contingency NC11

[redacted]

Figure 6-3. POI Voltage for LL E-W Post NEEWS case for contingency NC11

As the light load case is stressed for high area voltages with local switchable shunt capacitors at Jackman 115 kV and Chestnut Hill 115 kV locked at maximum dispatch [redacted] this high voltage will only last a short duration until these capacitors are redispatched. Following a steady state power flow solution of this

[redacted]

contingency, allowing the capacitors to redispatch, the scheduled voltage of [redacted] at the POI was reached. For the peak load case the lowest voltage of [redacted] was found at the POI for contingency NC6.

The Project is not required to make any system upgrades to maintain a voltage schedule at the POI.

Table 6-1. Post-NEEWS Peak and Light Load Stability Results

[redacted]

[redacted]

[redacted]

[redacted]

Section

7

Sensitivity Stability Results

Dynamic simulations of the contingencies described in Section 5 were performed for the pre-NEEWS peak and light load scenarios described in Section 4. The Delayed Auto-Reclosing (DAR) schemes [redacted] and Greggs series reactor in-service conditions were not simulated for pre-NEEEWS conditions. The analysis was performed as per the applicable reliability standards.

The stability results are described below and shown in Table 7-1. Simulation plots are provided in Appendix E.

The results shown the generating units that tripped offline due to each contingency, matched exactly the results found for the post-NEEWS conditions described in Section 6 above. As such a detailed description of the results is not provided.

[redacted]

Table 7-1. Pre-NEEWS Peak and Light Load Stability Results

[redacted]

[redacted]

[redacted]

Section
8

Conclusions

The stability study results are summarized as follows:

8.1 BPS Testing

BPS testing was performed [redacted] The total loss of source was less than 1,200 MW in each of the BPS contingencies simulated. Therefore, none of the buses tested needs to be classified as a BPS facility due to the interconnection of the Project.

8.2 Normal Contingencies (NC) Testing

Normal contingencies tested in the local area surrounding the Project shown no generating units were tripped. Also, for the post-NEEWS case (not tested for pre-NEEWS conditions), no generating units were tripped for the Delayed Auto-Reclosing schemes [redacted] and with Greggs series reactor in-service.

8.3 Extreme Contingencies (EC) Testing

No units were tripped following simulation of the EC contingencies.

8.4 Final Conclusions

The Study determined the Project operating with field bus control (centralized voltage regulator) controlling the project's 115 kV Point of Interconnection voltage, nominal tap settings (ratio of 1.0) for the 34.5/115 kV main transformer and 12/34.5 kV Wind Turbine GSU and without needing any upgrades, will not have an adverse impact on the stability of the power system.

Appendix

A

Power flow Summaries

[redacted]

Appendix

B

Power Flow One-Line Diagrams

Appendix
C

Project IDEV and DYR Files

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Appendix

D

ISO-NE Stability Criteria

D.1 BPS Testing Criteria

- System instability is a significant adverse impact outside the local area.
- An oscillatory or negatively damped system response is a significant adverse impact outside the local area.
- If a discrete bounded sub-area of the system that is susceptible to voltage collapse or separation from the rest of the system cannot be determined then the system response is considered to have a significant adverse impact outside the local area.
- If analysis results in isolation of a sub-area, the net load and/or generation in that sub-area must be quantified. If the sub-area is supplying more than 1,200 MW to the rest of the system, or if it is absorbing more than 1,200 MW of power it has a significant adverse impact outside the local area.
- If the sub-area is supplying < 1,200 MW or absorbing < 1,200 MW, the result may be classified as not having a significant adverse impact outside the local area, and the bus may not be part of the bulk power system. However, net source or load served by an area may not necessarily be the only determining factor in deciding if a significant adverse impact outside the local area has occurred. Gross load, gross generation, number of buses, or the geographic area of impact, etc., may also discretionarily be used to determine if a significant adverse impact outside the local area has occurred. This is covered with the next bullet.
- Islanding of any control Area is a significant adverse impact outside the local area. [redacted]
- If a discrete bounded sub-area of the system that is susceptible to voltage collapse included portions of another control Area, or if the facilities of another control Area exceed their STE ratings, then the results will be coordinated with that control Area to determine if a significant adverse impact outside the local area has occurred.

D.2 Normal Contingency Criteria

[redacted]

The guideline defining acceptable transient stability performance of the transmission system for **normal contingencies** (3-phase faults cleared by the slower of the two fastest protection groups or 1-phase faults with backup clearing) are as follows:

- All units should be transiently stable with positive damping
- A 53% reduction in the magnitude of system oscillations must be observed over four periods of the oscillation
- A loss of source greater than 1,200 MW is not acceptable

D.3 Extreme Contingency Criteria

The guideline defining acceptable transient stability performance of the transmission system for these 3-phase faults with delayed clearing extreme contingencies are as follows:

- A loss of source greater than 1,400 MW is not immediately acceptable
- A loss of source between 1,400 MW and 2,200 MW may be acceptable depending upon a limited likelihood of occurrence and other factors
- A loss of source greater than 2,200 MW is not acceptable
- A 53% reduction in the magnitude of system oscillations must be observed over four periods of the oscillation
- Transiently stable with positive damping

D.4 ISO-NE VOLTAGE SAG Guidelines

The minimum post-fault positive sequence voltage sag must remain above 70% of nominal voltage and must not exceed 250 milliseconds below 80% of nominal voltage within 10 seconds following a fault.

These limits are supported by the typical sag tolerances shown in IEEE Standard 1346-1998.

[redacted]

Appendix

E

Stability Plots

E.1 Post NEEWS Peak Load East to West

E.2 Post NEEWS Peak Load West to East

[redacted]

E.3 Post NEEWS Light Load East to West

E.4 Post NEEWS Light Load West to East

[redacted]

E.5 Pre NEEWS Peak Load East to West

E.6 Pre NEEWS Peak Load West to East

[redacted]

E.7 Pre NEEWS Light Load East to West

E.8 Pre NEEWS Light Load West to East

[redacted]

Siemens Industry, Inc.
Siemens Power Technologies International
400 State Street • P.O. Box 1058
Schenectady, New York 12301-1058 US
Tel: 518-395-5000 • Fax: 518-346-2777

www.siemens.com/power-technologies