System Impact Study

Redington Mountain Wind Farm

90 MW Capacity

Final Report

Central Maine Power
System Planning

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Table of Contents

Figures & Tables

Executive Summary

Endless Energy has proposed a 90 MW wind farm, consisting of multiple Vestas V90 3 MW wind turbine-generators located on the Black Nubble and Redington Mountain Ranges in Redington, Maine. This location is in the mountains of northwest Maine, near the CMP 115 kV transmission system emanating from the upper Kennebec River generation, and distant from the Maine 345 kV system (see Figure 1 for the location of this generation project relative to the Maine transmission system). The 90 MW generation project is known as Redington Mountain Wind Farm. The in-service date for this project is now anticipated to be early 2007.

For the steady state portion of this study Redington Mountain Wind Farm is dispatched against the Wyman and Harris hydroelectric generation on the upper Kennebec River. To provide reasonably stressed system conditions for this study, system conditions were modeled and area generation was maximized so that either 115 kV Section 63, Section 66, or Section 83 is loaded to its rating, either its normal rating in the base case, or its Short-Term Emergency (STE) rating following the loss of any other line section. A total of twelve steady state base cases that reflected different reasonably stressed system conditions were developed. The initial Redington 90 MW project base cases show bus voltages at Wyman Hydro 1.5% lower in the light load cases and 2% to 3.5% lower in the peak load cases, compared to the pre-project base cases. Each of these twelve base cases was tested with a total of 50 contingencies. Test results indicate that there were several contingencies that resulted in unacceptably low voltages, all located in the Waterville-Winslow-Skowhegan area, and in Guilford. With a total of 45 MVAR of capacitor additions at Winslow, Lakewood, Guilford and Sturtevant (23 MVAR is CMP's responsibility, and 22 MVAR is Redington's responsibility), all 50 contingencies for all base system conditions resulted in acceptable performance with the Redington Mountain Wind Farm, with and without the NRI and Y138 projects.

The transient cases represent a stressed Northwestern area export, specifically around Wyman Hydro. In the pre-Redington project cases, Wyman Hydro, Harris, Williams and Stratton Energy Associate (SEA) generators are on at full output. In the post-Redington project cases, Redington generation is dispatched against Harris and Wyman Hydro. With most other Maine generation ON, AEI Livermore Falls and two out of the three Androscoggin Energy Center (AEC) units were turned off in order to achieve maximum interface flows. These conditions were used for all faults with the exception of a three-phase normally closed fault at Buxton on Section 385, and a three-phase stuck-breaker fault at West Medway on Section 357. Both of these contingencies resulted in an unstable system response with the Maine–New Hampshire interface at 1,700 MW. This is consistent with the results obtained in the "Y138 Closing Study." CMP and ISO New England are separately investigating ME-NH interface limits with W. F. Wyman unit #4 on-line. The interface was reduced to approximately 1,400 MW to enable an acceptable system response. Discussions with ISO-New England validated the 1,400 MW ME-NH interface transfer as acceptably stressed under these conditions.

In addition, two sensitivity cases were analyzed for transient stability. Analysis with both the NRI and Y138 Closing Project in service, showed there were no adverse effects on the interconnection of the 90 MW wind farm, nor does the wind farm have any adverse effect on the system performance with these projects.

The Light Western Maine Dispatch sensitivity was conducted to evaluate the Low Voltage Ride Through (LVRT) capabilities of the Vestas V90 turbine generators when there was less generation in the area to sustain local voltages. Although for the three-phase fault cases, the post-fault voltage dipped lower than cases with more generation dispatched in the immediate area, the ride-through capability of the generator met the LVRT criteria.

Protection analysis revealed that in order for the Section 215 line rating to increase to the 212°F limit of approximately 135 MVA, the relaying must changed from overcurrent to step distance/directional ground overcurrent. To provide high speed and dedicated fault clearing for Section 215, the backup overcurrent protection on the K63-1 breaker must be removed and Section 215 connected to the Wyman Hydro bus through a new 115 KV breaker. The existing transfer trip carrier that trips the Stratton Energy plant for K215-1 opening must be modified to include a trip of the Redington Wind Farm generation and a 115 KV breaker added at Bigelow Substation to connect the Redington Wind Farm site. The Redington 115/34.5 KV transformer should be provided with CMP's standard protection package for a transformer of this size and voltage, which is primary transformer differential and backup high-side overcurrent.

Interconnection Requirements and Cost Estimate

The study resulted in the following interconnection requirements for Redington Mountain Wind Farm with the corresponding estimated cost:

Endless Energy Responsibility - *$3,200,000*

- ***Bigelow Substation:*** Expand yard, add a 115 KV bus, breaker, and control house - $1,510,000
- ***Wyman Substation:*** Separate Section 215 from 63, terminate with a breaker **-** $660,000 *
- ***Section 215 Transmission Line:*** Re- rate to 212^{o} F - $300,000
- ***Lakewood Substation:*** Add a new 10.8 MVAR capacitor bank **-** $370,000
- ***Guilford Substation:*** Expand the existing 5.4 MVAR capacitor bank to 10.8 MVAR **-** $140,000
- ***Sturtevant Substation:*** Add a new 5.4 MVAR capacitor bank. **-** $220,000

* This amount includes a credit of $50,000, the cost to replace the existing over-dutied circuit switcher K215-1.

CMP Responsibility

- **Winslow Substation:** Expand the existing capacitor bank from 9 MVAR to 16.2 MVAR
- **Winslow Substation:** Add a new second 16.2 MVAR capacitor bank
- **Wyman Substation:** subject to further review with accurate Harris & Wyman Hydro generator models, replace breaker K63-1

Note that the Section 215 future normal summer 212° F rating of 135 MVA may limit Redington (90 MW) and SEA (47 MW) with a very light load at Bigelow Substation.

With these interconnection requirements, the Redington Mountain Wind Farm meets the ISO New England Reliability Standards and the Minimum Interconnection Standard; and. the interconnection causes no significant adverse impact to the NEPOOL bulk power system. There are no relevant queued resources ahead of Redington Mountain Wind Farm.

1. Introduction

Endless Energy has proposed a 90 MW wind farm, consisting of multiple Vestas V90 3 MW wind turbine-generators located on the Black Nubble and Redington Mountain Ranges in Redington Maine. This location is in the mountains of northwest Maine, near the CMP 115 kV transmission system emanating from the upper Kennebec River generation, and distant from the Maine 345 kV system (see Figure 1 for the location of this generation project relative to the Maine transmission system). The 90 MW generation project is known as Redington Mountain Wind Farm. A System Impact Study for the Redington Mountain Wind Farm 'Phase I' project, with a proposed 30 MW total capacity was completed in November 2003.

Utilizing the Vestas V90 turbine, Redington Mountain Wind Farm will connect to the Central Maine Power (CMP) transmission system under the ISO New England Minimum Interconnection Standard. The in-service date for this project is now anticipated to be early 2007.

2. Interconnection of Redington Wind Farm

A new Endless Energy Electric Harvest (a.k.a. Nash Stream) Substation will be constructed and connected to Central Maine Power's Bigelow Substation by an 8.2-mile 115 kV transmission line. The new substation will include two parallel step-up 34.5/115 kV Delta-Wye 37.5/50/62.5 MVA transformers (Z = 8.5% on transformer base). Two 34.5 kV generator lead circuits will extend 1.0 mile and 2.1 miles to the Black Nubble and Redington Pond Range turbine regions, respectively. The 34.5 kV circuits then will extend between the turbines through underground cabling for 2.0 miles, and 1.5 miles with a half-mile spur, respectively. Several figures provide maps and diagrams to indicate how the Redington Wind Farm project interconnects with the Maine transmission system:

- Figure 1 geographically illustrates the location and interconnection of the proposed Redington Mountain Wind Farm in the Maine transmission system.

- Figure 2 geographically illustrates the location and interconnection of the proposed Redington Mountain Wind Farm in local detail, showing the substation and individual turbine-generator locations.

- Figure 3 is a one-line diagram that illustrates the proposed generation in relation to the northwestern CMP 115 kV transmission system. Note that the area in which the Redington Mountain Wind Farm is located is a generation-rich exporting area, and boundaries for the "Wyman Hydro Export" and "Northwestern Maine Export" areas are shown on the one-line diagram.

- Figure 4 is a one-line diagram that illustrates the proposed generation in relation to the local CMP 115 kV transmission system around Wyman Hydro, with both current and proposed breaker configurations. Section 215 must connect directly to the Wyman Hydro 115 kV bus with a circuit breaker to provide adequate system protection.

3. Generator Information

Two turbine site locations are planned for the Redington Mountain Wind Farm. The Vestas Model V90 wind turbine-generators were modeled by using two equivalent aggregate generators at the two collector sites along the Black Nubble & Redington Pond Range turbine regions.

3.1 Vestas Model V90

The Vestas V90 is a 3.0 MW unit that utilizes a variable-speed wound-rotor induction generator, rated at 1000V line-to-line. The V90 has a microprocessor control unit that adjusts the current in the rotor circuit of the generator, which gives precise control of the reactive power. The reactive power capability is between 96% inductive and 98% capacitive at full output. The V90 has an "OptiTip" microprocessor pitch control system, which continuously positions the blades' pitch angle. This study models the Vestas V90 units as two aggregate 45 MW generators, each with a reactive range of –13 to 9.1 MVAR, controlling the generator terminal bus voltage to 105%.

The Vestas V90 Electrical Characteristics document with control system description is in Appendix A of this System Impact Study report.

4. Steady State Criteria

Impacts due to Redington will be noted by the normal pre-contingency and post-contingency performance criteria that are defined by the following:

Pre-Contingency

- Acceptable branch loadings are less than 100% of the Normal summer rating,
- Acceptable bus voltages are in the range, 0.95 <= Vpu <= 1.05.

Post-Contingency

- No branch loadings can exceed 100% of the Short-Term Emergency (STE) summer ratings,
- Branch loadings greater than the Long-Term Emergency rating (LTE) and less than STE must be reduced to LTE in 15 minutes,
- Acceptable bus voltages are in the range, 0.95<= Vpu <= 1.05.

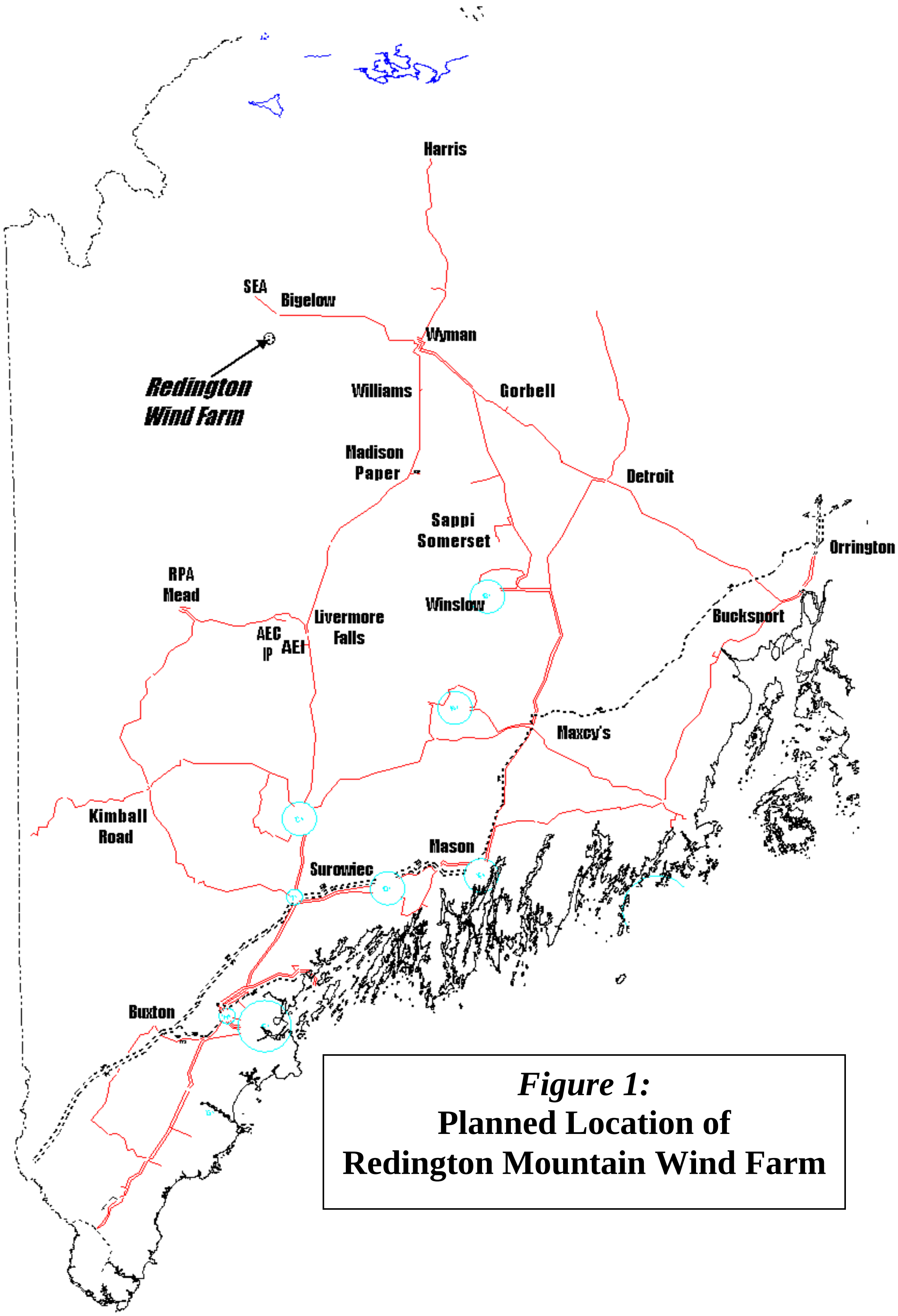
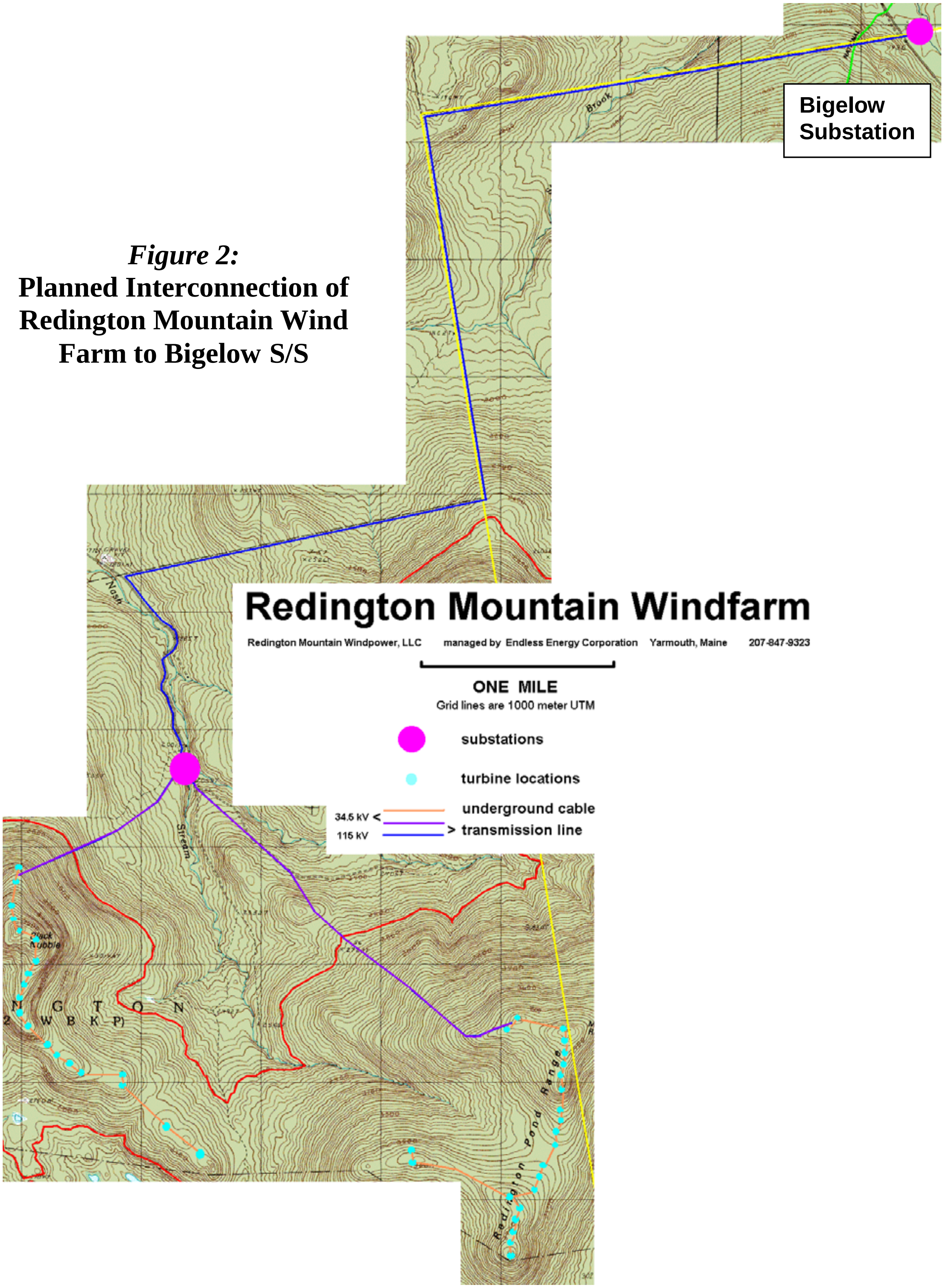
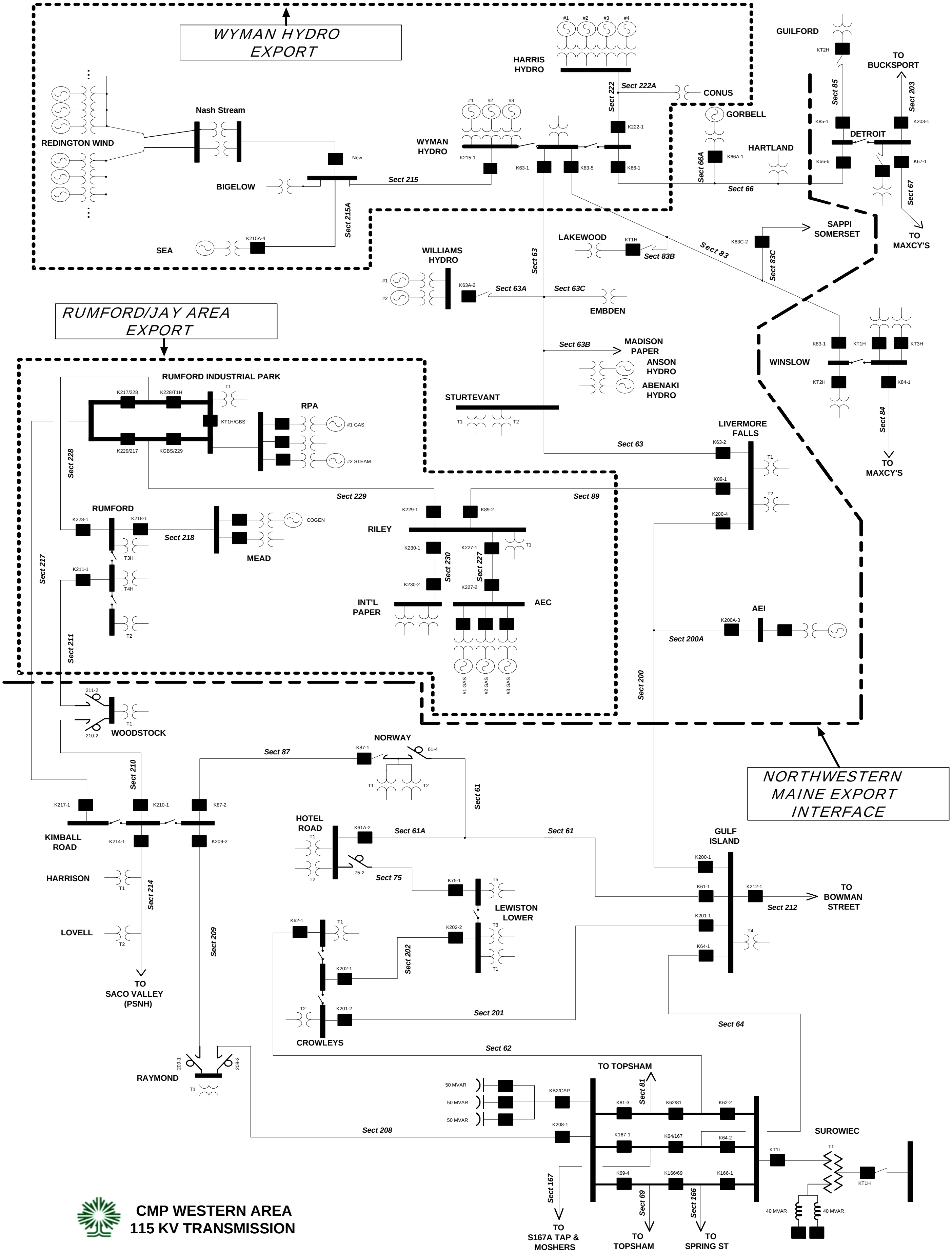


Figure 1:
Planned Location of Redington Mountain Wind Farm

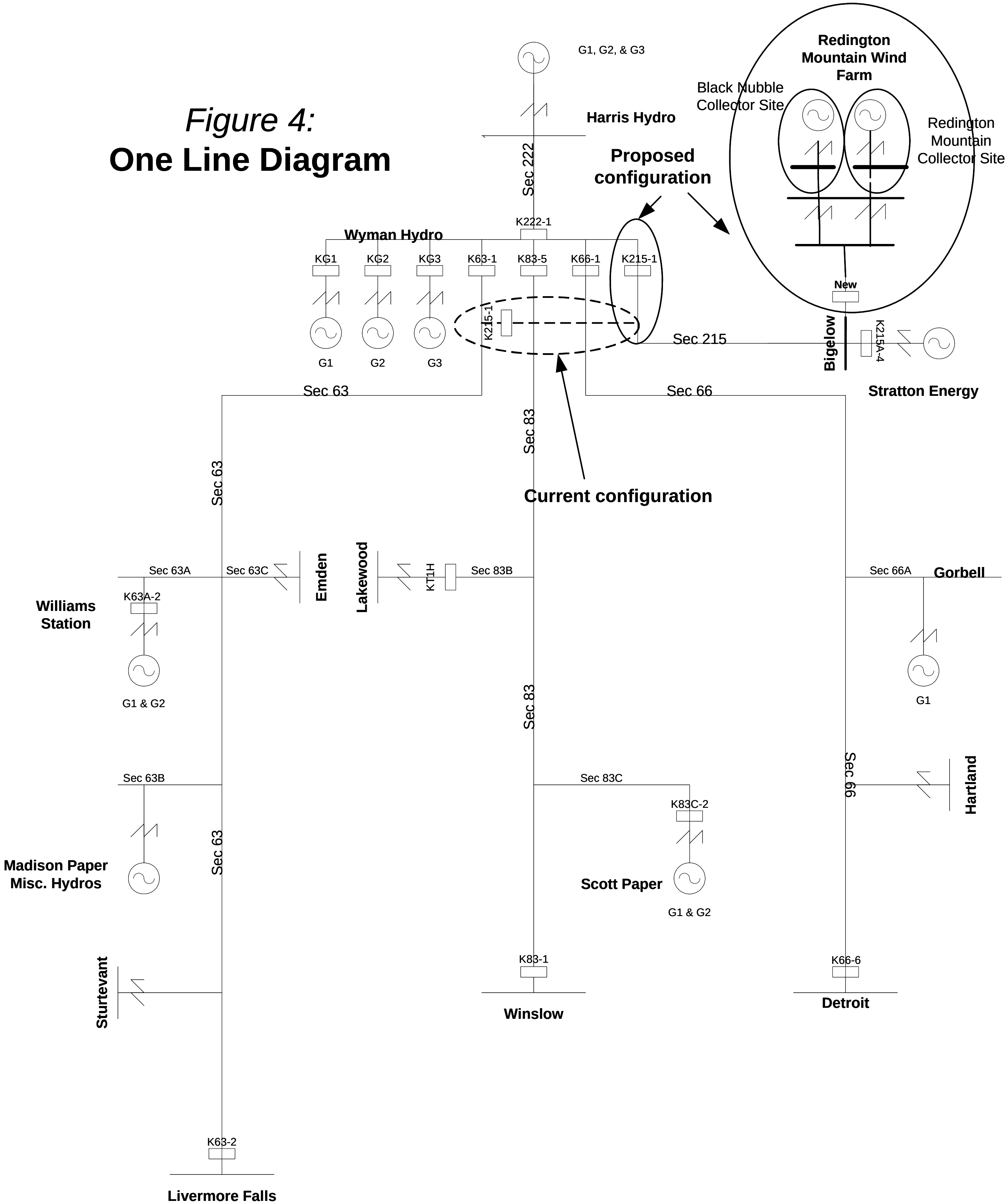
Figure 2:
Planned Interconnection of Redington Mountain Wind Farm to Bigelow S/S




WYMAN HYDRO EXPORT
HARRIS HYDRO
Sect 222
Sect 222A
CONUS
GUILFORD
TO BUCKSPORT
Sect 85
Sect 203
Nash Stream
REDINGTON WIND
New
BIGELOW
Sect 215
WYMAN HYDRO
GORBELL
DETROIT
HARTLAND
Sect 66A
Sect 66
Sect 67
Sect 215A
SEA
LAKEWOOD
Sect 83B
Sect 83
SAPPI SOMERSET
Sect 83C
TO MAXCY'S
WILLIAMS HYDRO
Sect 63
Sect 63A
Sect 63C
EMBDEN
RUMFORD/JAY AREA EXPORT
Sect 63B
MADISON PAPER
ANSON HYDRO
ABENAKI HYDRO
WINSLOW
RUMFORD INDUSTRIAL PARK
RPA
#1 GAS
#2 STEAM
STURTEVANT
Sect 84
TO MAXCY'S
LIVERMORE FALLS
Sect 63
Sect 228
Sect 229
Sect 89
RUMFORD
COGEN
RILEY
Sect 218
MEAD
Sect 217
Sect 230
Sect 227
INT'L PAPER
AEC
AEI
Sect 200A
Sect 211
#1 GAS
#2 GAS
#3 GAS
Sect 200
WOODSTOCK
NORWAY
Sect 87
NORTHWESTERN MAINE EXPORT INTERFACE
Sect 210
Sect 61
KIMBALL ROAD
HOTEL ROAD
Sect 61A
Sect 61
GULF ISLAND
HARRISON
Sect 214
Sect 75
LEWISTON LOWER
TO BOWMAN STREET
Sect 212
LOVELL
Sect 209
Sect 202
TO SACO VALLEY (PSNH)
Sect 201
CROWLEYS
Sect 64
Sect 62
RAYMOND
TO TOPSHAM
Sect 81
50 MVAR
50 MVAR
50 MVAR
SUROWIEC
Sect 208
40 MVAR
40 MVAR
Sect 167
Sect 69
Sect 166
CMP WESTERN AREA
115 KV TRANSMISSION
TO S167A TAP & MOSHERS
TO TOPSHAM
TO SPRING ST

Redington Mountain Wind Farm

Figure 4:
One Line Diagram



5. Base Case Development

Base cases were developed starting with the year 2007 ‘T1R’ peak load and ‘T1LTR’ light load cases used in the ‘Seabrook Uprate’ System Impact Study. These cases included the addition of the following future system enhancements:

a. Mystic 8 & 9 generation
b. AES Londonderry generation
c. Kendall 4 generation
d. Chestnut Hill caps
e. New Scobie autotransformer and 115 kV bus reconfiguration
f. Cross Sound DC link
g. Section G146 upgrade
h. New Merrimack 230/115 kV transformer
i. Series reactors on the S Agawam-N Bloomfield lines
j. Central Mass. Upgrades including Wachusetts 345 kV Substation
k. Third PAR at Waltham
l. Line rating changes, series reactors, etc. in Boston area
m. New Capacitors at Northboro Road and Millbury
n. Shunt reactors at Scobie (for light load case)
o. NH Seacoast changes including caps, addition of substations at Portsmouth, Brentwood, and Great Bay, second transformer at Rochester and load estimates for 2007 peak
p. Crowley’s 50 MVAR capacitor bank

Additional updates to the base cases:

q. Capacitor banks at Bridgton (modeled at Kimball Road), Lovell and Woodstock, which will be in service in 2005.
r. Turned off the Gorbell generator (interconnected to Section 66, Wyman-Detroit), which was retired and dismantled in 2004.
s. Western Maine peak loads were revised to conform to the 2004 NPCC library update, which resulted in higher area loads in the peak load cases.

Minor revised line ratings and impedance changes for the new Redington Mountain Wind Farm project were modeled. These impedance changes were made to accommodate a wind turbine placement study for Endless Energy. Based on the recommendations of the Redington Mountain Wind Farm Phase I System Impact Study, the line rating of Section 215 (Wyman Hydro – Bigelow) was increased to its 477 KCM ACSR conductor ampacity of 135 MVA, from today’s 56 MVA summer normal rating. With these updates, the base cases are compliant with today’s OP-17 requirements.

Interface definitions as found in the Interface Transfer Summaries do not include flows created by the NRI or Y138 project unless specifically noted in this report. The interfaces today are defined as follows:

New Brunswick – Maine	Section 396
Maine - New Hampshire	Section 391
	Section 197
	Section 250
	Section 385

Sensitivities with the Y138 Closing Project in service will add flow to the Maine-New Hampshire interface from Saco Valley to the White Lake Phase Angle Regulator. Sensitivities with the NRI project in service will add flow from Point Lepreau to Orrington, Section 3016.

5.1 Steady State Base Case

Three variations of the peak and light load base cases were created, to individually stress each of the three 115 kV lines (Sections 63, 66, and 83) emanating from Wyman Hydro. Flows on these lines are influenced not only by the generation (Redington, SEA, Harris, Wyman) at the top of the "tree" in the north (reference Figure 4), but also by generation and industrial load on or downstream of these lines, such as Madison Paper, Scott Paper (SAPPI SD Warren-Somerset), and Rumford/Jay area load and generation. Because of the influence of all of these factors, three separate dispatches were created to stress the flow on each line. Sections 63, 66, and 83 are limited as follows:

- **Section 63 (Wyman Hydro – Section 63A&C tap – Section 63B tap – Sturtevant – Livermore Falls):**

Limiting Element	Normal (MVA)	LTE (MVA)	STE (MVA)
160° F limited Coot 795 36/1 conductor	162.4	162.4	171.8
Breakers	175.3	188.0	266.1

- **Section 66 (Wyman Hydro – Section 66A tap – Hartland – Detroit):**

Limiting Element	Normal (MVA)	LTE (MVA)	STE (MVA)
Disconnect switches	143.4	164.9	193.6
160° F limited Coot 795 36/1 ACSR conductor	162.4	162.4	171.8

- **Section 83 (Wyman Hydro – Section 83B tap – Section 83C tap – Winslow)**:

Limiting Element	Normal (MVA)	LTE (MVA)	STE (MVA)
180° F limited conductor Pelican 477 18/1 ACSR	135.3	138.9	142.8
AB switches	143.4	164.9	193.6
Wave Traps	167.3	192.8	251.8
Breaker	175.3	188.0	266.1

Note that none of these 115 kV line sections is limited by its conductor ampacity (the thermal current-carrying capacity of the wire itself). Rather, the ratings are limited by either sag clearances at lower conductor temperatures or by terminal equipment. However, if sag clearances were increased or terminal equipment were replaced, additional reinforcements may be needed; due to increased flows and/or lower voltages.

For the pre-project (Redington Phase I @ 30 MW) initial base case, each of the three dispatch scenarios was initially set up to maintain a high flow up to 100 % of the Normal rating of the 115 kV line section being stressed. The three sets of base cases are labeled:

- Peak Load: 'Peak 63,' 'Peak 66,' and 'Peak 83' for maximum loading on the labeled line section at peak system loads
- Light Load: 'Light 63,' 'Light 66,' and 'Light 83' for maximum loading on the labeled line section at light system loads

An initial contingency analysis was performed to confirm a secure dispatch under reasonably stressed system conditions for the initial base condition described above. Several loading and voltage issues were identified following this initial contingency analysis on the initial base cases. In order to obtain secure system conditions, the following dispatch changes were made:

- The Rumford Power Associates (RPA) and Mead Cogeneration output was reduced in the 'Light 66' and 'Light 83' cases, to avoid an overload of Sections 208 and 209 (Kimball Road-Raymond-Surowiec), following a stuck breaker contingency at Gulf Island Substation.
- A single Wyman Hydro G1 generator was reduced or switched off in the 'Peak 66' and 'Peak 83' cases, to avoid an overload of Section 83 (Wyman-Lakewood tap), following a Section 66 outage or stuck breaker contingencies at Detroit and Gulf Island Substations.
- Androscoggin Energy Center G1, G2 & G3 output was reduced in the 'Peak 66' and 'Peak 83', and 'Light 66' and 'Light 83' base cases to avoid an overload on Section 89 (Riley-Livermore Falls), under all-line-in conditions.

Because the Redington pre-project (Phase I) base cases had northwestern Maine generation restricted to respect reliability criteria, it was determined that the Redington post-project base cases would have to be dispatched versus generation north of the "Wyman Export" interface shown in Figure 3. Since the Section 215 rating must be increased, and will avoid a dispatch tradeoff with Stratton Energy Associates (SEA) generation, Wyman Hydro and Harris were chosen as the plants to dispatch against Redington.

It can be observed that the northwestern CMP 115 kV voltage profile is reduced with Redington Mountain Wind Farm generation replacing Wyman and Harris hydroelectric generation. By dispatching Wyman Hydro and/or Harris generation off-line with generation at Redington, this area loses some reactive support for which Redington, with its limited generator reactive capability at a more remote location, is not able to compensate. When comparing the pre-project base cases to the Redington 90 MW project cases, the bus voltages at Wyman Hydro are 1.5% lower in the light load cases and 2% to 3.5% lower in the peak load cases, as indicated in the one-line diagrams found in Appendix B.

It is possible but not probable for dispatch restrictions to occur without Redington in service, and these restrictions are not significant. With the Redington 90 MW project however, the potential congestion in the Upper Kennebec area is more significant.

Table 5-1: *Summary of Steady State Base Cases* summarizes base cases developed for the steady state portion of this study. Case summaries for these cases are included in Appendix C.

Table 5-1: Summary of Steady State Base Cases

	Description (All units in MW)	Section 63 Stressed				Section 66 Stressed				Section 83 Stressed			
		red2_lt630 V8030 Light Load / Redington 30 MW	red2_lt63_V9030 Light Load / Redington 90 MW	red2_pk63_V8030 Peak Load / Redington 30 MW	red2_pk63_V9030 Peak Load / Redington 90 MW	red2_lt66_V8030 Light Load / Redington 30 MW	red2_lt66_V9090 Light Load / Redington 90 MW	red2_pk66_V8030 Peak Load / Redington 30 MW	red2_pk66_V9090 Peak Load / Redington 90 MW	red2_lt83_V8030 Light Load / Redington 30 MW	red2_lt83_V9090 Light Load / Redington 90 MW	red2_pk83_V8030 Peak Load / Redington 30 MW	red2_pk83_V9090 Peak Load / Redington 90 MW
	Modeled NEPOOL Load/Losses	12128	12134	27863	27868	12006	12011	27676	27682	12024	12031	27676	27669
Interfaces	NB-ME	695	695	695	695	696	696	695	695	696	696	696	696
	Orrington-South	1096	1096	987	987	580	580	348	348	745	744	988	988
	Wyman Hydro Export	178	171	223	217	157	151	191	185	180	173	174	167
	Rumford / Jay Export	21	21	263	263	384	384	421	421	378	378	427	427
	Northwestern Maine Export	126	119	373	366	485	479	536	529	468	460	491	483
	Surowiec-South	1067	1060	740	734	938	932	265	258	1079	1072	825	833
	ME-NH	1318	1311	1620	1613	1191	1185	1151	1144	1330	1322	1090	1099
	NNE-Scobie+394	2393	2387	2900	3085	2280	2274	2679	2673	2401	2395	2579	2632
	North-South	2862	2857	3022	3023	2748	2742	2630	2624	2871	2864	2579	2586
	Boston Import	1839	1839	3342	3342	1834	1834	3322	3322	1839	1839	3320	3320
	SEMA/RI Export	1667	1667	2353	2354	1667	1667	2355	2355	1667	1667	2355	2355
	NE East-West	1628	1621	2812	2627	1512	1506	2396	2389	1638	1632	2340	2348
	New York-New England	155	161	-1157	-1152	271	277	-770	-764	143	150	-716	-724
	Phase II Import	0	0	2000	2000	0	0	2000	2000	0	0	2000	2000
Area Generation / Industrial Load	Redington	30	90	30	90	30	90	30	90	30	90	30	90
	Wyman Hydro	25	0	82	57	5	0	50	25	60	35	65	40
	Harris Hydro	85	50	86	51	85	30	86	51	52	17	52	17
	Sub-Total	140	140	198	198	120	120	166	166	142	142	147	147
	Stratton Energy (SEA)	45	45	45	45	45	45	45	45	45	45	45	45
	Williams Hydro	15	15	15	15	15	15	15	15	14	14	14	14
	Madison Paper Net Load	35	35	35	35	35	35	35	35	35	35	35	35
	Lakewood	7	7	9	9	7	7	9	9	7	7	9	9
	SAPPI Somerset Net Load	20	20	20	20	20	20	20	20	55	55	54	54
	Winslow	11	11	11	11	11	11	11	11	0	0	0	0
	Gorbell	0	0	0	0	0	0	0	0	0	0	0	0
	Guilford 70157	20	20	15	15	0	0	0	0	20	20	15	15
	Maine Independence 1-3	523	523	523	523	0	0	0	0	166	166	523	523
	Champion G3	65	65	65	65	65	65	65	65	65	65	65	65
	Bucksport Energy G4	0	0	115	115	0	0	0	0	0	0	115	115
	AEI	0	0	0	0	16	16	39	39	19	19	39	36
	AEC 1-3	50	50	50	50	120	120	120	120	120	120	120	120
	International Paper Net Load	47	47	47	47	7	7	9	9	13	13	2	2
	RPA 1-2	0	0	0	0	235	235	266	266	235	235	266	266
	Mead Paper Net Gen	30	26	25	25	44	44	75	75	44	44	75	75
	Gulf Island	34	34	34	34	34	34	34	34	34	34	34	34
	Lewiston Lower	47	47	47	47	47	47	47	47	46	46	47	47
	W. F. Wyman 1-3	0	0	239	239	0	0	239	239	0	0	239	239
	W. F. Wyman 4	0	0	622	620	0	0	622	622	0	0	0	0
	Westbrook 1-3	438	344	531	531	344	344	531	531	344	344	531	531
	Seabrook	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209
	Schiller 4-6	0	0	145	145	0	0	145	145	0	0	145	145
	Newington	0	0	411	411	0	0	411	411	0	0	411	411
	Con Ed Newington	338	338	533	533	338	338	533	533	338	338	533	533

5.2 Transient Base Case

The base case for all transient analysis was created from the Seabrook Phase 1 System Impact Study, spring light load case representing the 2007 transmission system. That case has a NEPOOL system load of 11,980 MW, and is derived from the 2000 New England Loadflow library. This base case was modified to include the steady state interconnection requirements for the 90 MW Redington Mountain Wind Farm. A total of 45 MVAR of capacitor additions at Winslow, Lakewood, and Guilford Substations' 34.5 kV busses are required to obtain acceptable performance for all system conditions which were tested. These reinforcements are reflected in the modified cases as follows:

- expand the existing capacitor bank from 9 MVAR to 16.2 MVAR at Winslow Substation
- a second 16.2 MVAR capacitor bank at Winslow Substation
- a 10.8 MVAR capacitor bank at Lakewood Substation
- expand the existing 5.4 MVAR capacitor bank to 10.8 MVAR at Guilford Substation
- a 5.4 MVAR capacitor bank at Sturtevant Substation.

5.3 Transient Dispatch Conditions

The cases represent a stressed Northwestern area export, specifically around Wyman Hydro. Pre - project, Wyman Hydro, Harris, Williams and Stratton Energy Associate (SEA) generators are on at full output, disregarding the thermal constraints discussed in Section 5.1 above. Post-project, the 90 MW of generation is dispatched against Harris and Wyman Hydro. For both pre- and post-project cases, the W. F. Wyman 4 generator is dispatched at full output, in lieu of the Westbrook generator. With most other Maine generation ON, AEI Livermore Falls and two out of the three Androscoggin Energy Center (AEC) units were turned off, in order to achieve maximum interface flows as seen in Table 5-2: *Interface Transfer Summary*. The resulting dispatch is listed in Table 5-3, *Major Generator Conditions with ME-NH Interface at 1700 MW.*
These conditions were used for all faults with the exception of a three-phase normally-cleared fault at Buxton on Section 385, and a three-phase-stuck breaker extreme contingency fault at Medway on Section 357. Both of these contingencies resulted in an unstable system response with the Maine–New Hampshire interface at 1,700 MW. This is consistent with the results obtained in the "Y138 Closing Study." For these two faults, the interface was reduced to approximately 1,400 MW; which was the maximum the transfer for the Section 385 fault to result in a stable system response. The dispatch to obtain this transfer is listed in Table 5-4: *Major Generator Conditions with ME-NH Interface at 1,400 MW.* Discussions with ISO-New England validated the 1,400 MW ME-NH interface transfer as acceptably stressed under these conditions.

Detailed transient case summaries: load, generation and transfers are attached in Appendix E.
One-line diagrams of the transient and sensitivity base cases are in Appendix H.

Table 5-2: Interface Transfer Summary

Interfaces	Transfer Limit (MW)	Redington Generation OFF (MW)	Redington Generation ON (MW)
New Brunswick - Maine	700	699	699
Orrington - South	*1200	1162	1162
Surowiec-South		1180	1173
Maine – New Hampshire	**1700	1689	1682
Seabrook-South		1141	1141
Northern New England – Scobie + 394		2504	2499
North-South	3000-3400	3033	3031
East-West		2325	2319

Section 86 is within normal limits
** With Wyman unit # 4 ON

Table 5-3 Major Generator Conditions with ME-NH Interface at 1,700 MW

Generators	Gross Capability (MW)	Redington Generation OFF (MW)	Redington Generation ON (MW)
Redington	90	0	90
Wyman 1-3	80	80	27
Harris 1-3	90	88	52
Williams	15	14	14
SEA - Stratton	47	43	43
AEI - Livermore	39	0	0
Mead Hydros	39	18	18
Mead Cogen	110	65	65
MIS	549	549	549
Bucksport	191	191	191
RPA	273	273	273
AEC	161	54	54
WF Wyman 1-3	239	182	182
WF Wyman 4	636	636	636
Westbrook	579	0	0

Table 5-4 Major Generator Conditions with ME-NH Interface at 1,400 MW

Generators	Gross Capability (MW)	Redington Generation OFF (MW)	Redington Generation ON (MW)
Redington	90	0	90
Wyman 1-3	80	80	27
Harris 1-3	90	88	52
Williams	15	14	14
SEA - Stratton	47	43	43
AEI - Livermore	39	0	0
Mead Hydros	39	18	18
Mead Cogen	110	65	65
MIS	549	549	549
Bucksport	191	0	0
RPA	273	273	273
AEC	161	54	54
WF Wyman 1-3	239	57	57
WF Wyman 4	636	636	636
Westbrook	579	0	0

5.4 Transient Sensitivity Analysis

A sensitivity analysis was performed to establish the transient effect that Redington Mountain Wind Farm has on the system with both the Y-138 Project and Northeast Reliability Interconnect (NRI, also known as the 2nd New Brunswick Tie) Project operational. In addition, a Light Western Generation sensitivity was performed to ensure that Redington Mountain Wind Farm meets the Low Voltage Ride Through (LVRT) requirements under these conditions. These sensitivity analyses were done using the same 2007 light load (11,980 MW) case.

Y138 & NRI Sensitivity Case Modifications

The Y138 Closing Project is based on a model developed by Northeast Utilities and E/PRO Consulting, with the following facilities, which are referred to as the Y138 Line Closing Project:

- Addition of +20/- 60° phase angle regulator on the Y138 Line at Saco Valley
- Re-tension all 28 miles of Section 214 (Kimball Road to Saco Valley) to obtain the 212° F ratings of the existing 795 kCM ACSR conductor, 185/226/241 MVA (summer) and 246/275/293 MVA (winter)
- Upgrade the Beebe Substation B112 terminal equipment (circuit breaker, disconnect switches, bus work and secondary equipment) to reach or exceed the conductor rating of the B112 transmission line, 129/138/160 MVA (summer) and 153/160/178 MVA (winter)
- Addition of two 115 kV breakers at Saco Valley on Y138 and K1214 Lines
- A total of 60 MVARs of 115 kV capacitors at Kimball Road
- At total of 22 MVARs of 115 kV capacitors at White Lake
- Increase to 40 MVARs of 115 kV capacitors at Beebe

The phase shifter was set to the allow the maximum flow on Section 214 so its flow reaches its 212°F conductor rating (185 MVA summer normal rating) by adjusting the Phase Angle Regulator (PAR) based on generation patterns between Maine and New Hampshire.

The Northeast Reliability Interconnect (NRI) was modeled by simulating a new 345 kV single-circuit transmission line from Point Lepreau generation station in New Brunswick to the Orrington Substation in Maine. A 30 MVAR shunt capacitor bank was added on the 115 kV bus at Gulf Island Substation (the Kimball Road 30 MVAR capacitor is included in the Y138 project listing above). Series compensation on Section 388 from Orrington to Maxcys, equal to 50% of the impedance of Section 388 and 392, was simulated. The NRI project increases New Brunswick-Maine transfer capability from 700 MW to 1,000 MW. Therefore, generation in New Brunswick was increased by 300 MW, and one Maine Independence Station generator was dispatched off; in order to maintain Orrington-south interface transfers near the 1,200 MW limit.

These modifications were made to the base cases with a Maine-New Hampshire interface of approximately 1,700 MW. Case Summaries for this sensitivity can be found in Appendix E.

In the table below, additional flows have been added to account for the NRI and Y138 Closing Project.

Table 5-5: Interface Transfer Summary with NRI & Y138 & Redington Projects In-Service

Interfaces	Limit (MW)	NRI, Y138 & Redington (MW)
New Brunswick - Maine	*1000	1041
Orrington - South	1200	1239
Surowiec-South		1105
Maine – New Hampshire	1700	**1758
Seabrook-South		1135
NNE-Scobie+394		2466
North-South	3000-3400	3078
East-West		2376

* Valid with NRI in service.

** The transfer summary in the appendix does not reflect additional flows to account for the Y138 Closing Project in service. The total ME-NH interface is the amount shown in the summary, 1616 MW, with an additional 142 MW to account for the closing of PSNH Line Y138.

Table 5-6: Major Generator Conditions with NRI, Y138 & Redington Projects In-Service

Generators	Gross Capability (MW)	NRI, Y138 & Redington (MW)
Redington	90	90
Wyman 1-3	80	27
Harris 1-3	90	52
Williams	15	14
SEA	47	43
AEI	39	0
Mead Hydros	39	18
Mead Cogen	110	65
MIS	549	274
Bucksport	191	191
RPA	273	273
AEC	161	54
WF Wyman 1-3	239	182
WF Wyman 4	636	636
Westbrook	579	0

Light Western Maine Generation Sensitivity

Using the transient base case with Redington Mountain Wind Farm 90 MW project in service, and a Maine-New Hampshire interface flow of approximately 1,700 MW, generation in the upper Kennebec River area was reduced. The generation dispatch was based on actual conditions of June 12 to 14 of 2005. Table 5-7: *Light Western Maine Generation Summary* compares the generation in the upper Kennebec River.

A complete case summary for this sensitivity can be found in Appendix E.

Table 5-7: Light Western Maine Generation Summary

Generators	Gross Capability (MW)	Base Case (MW)	Light Generation (MW)
Redington	90	90	90
Wyman 1-3	80	27	14
Harris 1-3	90	52	1.5
Williams	15	14	14
SEA	47	43	0

This sensitivity case was developed to ensure that the wind turbine-generators are able to sustain the local voltage in the absence of other significant generation in the same area, and not mask any low voltage ride-through issues that could occur with the wind farm.

6. Steady State Contingencies

Contingency analysis was performed to confirm a secure dispatch under reasonably stressed system conditions for the pre-project base condition and determine system behavior with the Redington Mountain Wind Farm 90 MW project, and determine any additional interconnection requirements for the 90 MW project. Redington Mountain Wind Farm 90 MW interconnection results must satisfy **ISO New England Planning Procedure PP-5-6**, ***Scope of Study for System Impact Studies Under the Minimum Interconnection Standard and Enhanced Interconnection***. All power flow analysis was performed using General Electric's PSLF power flow simulation software. The same contingencies were analyzed as for the Redington Mountain Wind Farm Phase I System Impact Study, and are listed below.

Table 6-1: 115 kV Line Contingencies

Type	#	Name	Description
Line	1	Sect 89	Riley – Livermore Falls
Line	2	Sect 229	Riley – Rumford I.P.
Line	3	Sect 228	Rumford I.P. – Rumford
Line	4	Sect 211	Rumford – Woodstock
Line	5	Sect 210	Woodstock – Kimball Rd
Line	6	Sect 210 & 211	Rumford – Woodstock – Kimball Rd
Line	7	Sect 217	Rumford I.P. – Kimball Rd
Line	8	Sect 87	Kimball Rd – Norway
Line	9	Sect 209	Kimball Rd – Raymond
Line	10	Sect 208	Raymond – Surowiec
Line	11	Sect 208 & 209	Surowiec – Raymond– Kimball Rd
Line	12	Sect 61 /61A	Norway – S61A Tap – Gulf Island / S61A Tap – Hotel Rd
Line	13	Sect 75	Hotel Rd – Lewiston Lower
Line	14	Sect 202	Lewiston Lower – Crowley's
Line	15	Sect 201	Crowley's – Gulf Island
Line	16	Sect 212	Gulf Island – Bowman St
Line	17	Sect 200	Livermore Falls – S200A Tap - Gulf Island / S200A Tap – AEI
Line	18	Sect 64	Gulf Island – Surowiec
Line	19	Sect 62	Crowley's – Surowiec
Line	20	Sect 63 /63A/63B	Livermore Falls – Sturtevant – S 63B Tap – Williams – Wyman Hydro / S 63B Tap – Madison Paper
Line	21	Sect 81	Mason – Topsham – Surowiec
Line	22	Sect 69	Bath – Topsham – Surowiec
Line	23	Sect 166	Surowiec – Spring St
Line	24	Sect 167	Surowiec – S167A Tap – Moshers / S167A Tap – Prides Corner
Line	25	Sect 203	Bucksport – Detroit
Line	26	Sect 67 /67A	Maxcy's – S 67A Tap – Detroit / S 67A Tap – Rice Rips
Line	27	Sect 84	Maxcy's – Winslow
Line	28	Sect 66	Wyman Hydro – Gorbell – Hartland – Detroit
Line	29	Sect 83	Wyman Hydro – S 83 B Tap – S 83 C Tap – Winslow / S 83 B Tap – Skowhegan / S 83 C Tap – SAPPI Somerset

Table 6-2: Autotransformer Contingencies

Type	#	Name	Description
Auto	1	Surowiec T1	Loss of Surowiec Autotransformer T1
Auto	2	Maxcy's T1	Loss of Maxcy's Autotransformer T3
Auto	3	Mason T1	Loss of Mason Autotransformer T9

Table 6-3: 115 kV Stuck Breaker Contingencies

Type	#	Name	Description
StkB	1	Detroit Any SB	Loss of Sections 66, 85, 67, 203, Detroit load
StkB	2	Winslow Any SB	Loss of Sections 84, 83, Winslow load
StkB	3	Livermore Falls Any SB	Loss of Sections 89, 63, 200, Livermore Falls load
StkB	4	Gulf Island Any SB	Loss of Sections 61, 64, 201, 212, 200, AEI gen
StkB	5	Maxcy's KT3L-1 SB	Loss of Sections 60, 80, 67, Maxcy's load, Auto T3, caps
StkB	6	Maxcy's KT3L-2 SB	Loss of Sections 88, 68, 84, Auto T3
StkB	7	Bucksport KBS1/2 SB	Loss of Sections 203, 205, 86, 65, Champion Paper, Bucksport Energy gen, Bucksport load

Table 6-4: 345 kV Line Contingencies

Type	#	Name	Description
345L	1	Section 375	Maine Yankee – Buxton
345L	2	Section 377	Maine Yankee – Surowiec
345L	3	Section 374	Surowiec – Buxton
345L	4	Section 385	Buxton – Deerfield
345L	5	Section 391	Buxton – Scobie

Table 6-5: 345 kV Stuck Breaker Contingencies

Type	#	Name	Description
345B	1	Surowiec Any SB	Loss of Sections 374, 377, autotransformer T1
345B	2	Scobie 9126	Loss of Sections 391, 326
345B	3	Deerfield 785	Loss of Sections 385, 307
345B	4	Deerfield 851	Loss of Sect 385, Deerfield autotransformer
345B	5	Deerfield 72	Loss of Sections 307, 373

Table 6-6: 345 kV Double Circuit Tower Contingency

Type	#	Name	Description
345D	1	DCT Sect 375/377	Loss of Sections 375, 377, Maine Independence Station and Bucksport Energy generation

Contingencies involving 345/115 KV autotransformers maintained the 115 KV capacitors on-line, if they were not removed by fault protection or their automatic controls.

6.1 Line Outage (N-2) Steady State Testing

N-2 steady-state testing was not a part of this study, as the 90 MW of generation proposed in this project is not likely to cause greater than 1,200 MW loss-of-source under line outage conditions. Prior Maine generation System Impact Studies have shown less than 1,200 MW loss-of-source in their N-2 steady-state analysis.

6.2 Relevant Special Protection Systems (SPSs)

Saco Valley Undervoltage SPS

CMP today supplies the Conway area of New Hampshire radially by its interconnection of Section 214 (Kimball Road to Harrison to Lovell to Saco Valley) with Public Service Company of New Hampshire. If the Saco Valley 115 kV voltage falls below 94% for 4 seconds, then all feeder loads at PSNH Saco Valley and Intervale Substations are tripped.

Winslow-SD Warren Undervoltage SPS

If the Winslow 115 kV voltage on Section 83 falls below 96%, then SAPPI SD Warren-Somerset load is shed, such that the net flow into the mill is reduced to below 40 MW from above 40 MW. If Section 83C flow is less than 40 MW into the mill, no load is shed.

Load is shed in multiple blocks, by opening feeder breakers. Each stage is cumulative, if additional load is still required to be shed:

a) always first stage, approximately 4 MW
b) either 10 – 15 MW, or 20 – 25 MW, depending on order schedule
c) the 'other' load from either of the two blocks in (b) above
d) last stage, 28 – 32 MW, effectively shuts down all paper machines

The total duration of the four blocks of load shedding in this SPS can take up to 10 minutes. CMP is pursuing an automated scheme to speed operation of this SPS.

7. Steady State Analysis Results

7.1 Pre-Project (Phase I at 30 MW) Results

The northern part of Section 86 from Bucksport to Belfast in the ‘Peak 63’ base case is slightly overloaded with a pre-contingency flow of 1% above its normal rating. This loading indicates that the Orrington-South interface is at its transfer limit. In the same ‘Peak 63’ case, Section 250 is as much as 19% above its STE rating and Section 197 is 1% above its STE rating following the 345 Deerfield 851 stuck breaker contingency. Section 250 reaches its STE rating following the 345 Scobie stuck breaker contingency in the same ‘Peak 63” case. These loadings indicate that the Maine-New Hampshire transmission interface is stressed beyond its transfer limit.

Bus voltages in the light load cases and the ‘Peak 63’ and ‘Peak 66’ cases are acceptable at or above 95% - however several contingencies require SPS operation to achieve a 95% or greater voltage. The exception to this occurs in the ‘Peak 83’ case with stuck breaker contingencies, KT3L-1 or KT3L-2 at Maxcy’s Substation or Section 84 out of service. Due to the split 115 kV bus arrangement at Maxcy’s Substation, both stuck breaker contingencies will remove the Maxcy’s autotransformer. Maxcy’s KT3L-1 stuck breaker contingency will remove 115 kV Section 60 (Maxcys – Bowman Street), Section 67 (Maxcys – Detroit), and Section 80 (Maxcys – Highland). Maxcy’s KT3L-2 stuck breaker contingency will remove 115 kV Section 68 (Maxcys to Mason), Section 88 (Augusta East Side to Maxcys), and Section 84 (Winslow to Maxcys). Note that ISO New England does not consider these stuck-breaker outages in system operations, per **ISO New England Operating Procedure OP-19, *Transmission Operations***. Therefore, the low voltages involving these stuck breaker contingencies are treated as a pre-existing condition, and for these contingencies post-project voltages cannot be any worse than pre-project (Phase I) voltages. An outage of Section 84 by itself will produce voltages in the Winslow – Waterville area almost as low as the Maxcy’s KT3L-2 stuck breaker. For this reason a new 16.2 MVAR capacitor bank must be installed at the Winslow 34.5 kV bus by CMP (in addition to the existing 9 MVAR capacitor bank). When these capacitors are in place, voltages for all three of these contingencies, once the Winslow – SD Warren SPS Undervoltage is operated, are equal to or greater than 95%. (See Appendix D: Exception Reports for Contongencies)

One-line diagrams of all contingencies with the final pre-project secure dispatch with reasonably stressed system conditions can be found in Appendix B.

7.2 Initial 90 MW Redington Mountain Wind Farm post-project results

The Redington Mountain Wind Farm was modeled as described in report Sections 2 and 3. The same base cases and contingencies were used as in the pre-project final base cases, adjusted to obtain stressed system conditions with a secure dispatch as described above; with the additional generation at Redington is dispatched against Wyman Hydro and Harris Hydro.

From the initial base cases, it can be observed that the northwestern CMP 115 kV voltage profile is reduced with Redington generation replacing Wyman and Harris hydroelectric generation, which have more local voltage control due to their location and greater reactive power capacity. By dispatching of Wyman and/or Harris generation off-line against the increase in generation at Redington, this area loses some reactive support for which Redington, with its limited generator reactive capability at a more remote location, is not able to compensate. When comparing the pre-project cases to the post-project cases, the initial base cases show bus voltages at Wyman Hydro 1.4% lower in the light load cases and as much as 2.2% lower in the peak load cases as indicated in the one lines found in Appendix B.

Because Redington is only separated from Wyman and Harris generation by a radial transmission line, and because there is a MW-for-MW tradeoff of generation between these locations, no problems occurred with transmission line loading for any contingencies. In the post-project ‘Peak 63’ case, as in the same pre-project case, Section 86 from Bucksport to Belfast is slightly overloaded at 1% greater than its normal rating, indicating that the Orrington-south interface is at its transfer limit. The post-project ‘Peak 63’ case also illustrates the Maine-New Hampshire transmission interface is at its limit; with Section 250 from Louden to Maguire Road overloaded as much as 18% with the 345 Deerfield stuck breaker contingency. This is consistent with the corresponding pre-project case.

The reduction in reactive support along with certain outages cause low bus voltages to appear in the post-project peak load cases. All post-contingent voltages are adequate in the light load cases. Bus voltages for the Maxcy’s stuck breaker KT3L-1 contingency are between 1% and 6% lower for the post-project case as compared to the pre-project case as illustrated below in Table 7-1.

Other contingencies which result in voltages below 95% in the peak load cases, have low voltages occur in the same Waterville-Winslow-Skowhegan area, and in Guilford.

Table 7-1:

Comparison of Voltage Performance
Peak 83 Case with Maxcy’s 115 kV Stuck Breaker KT3L-1 Outage

	Pre-project			Post-project without reinforcements			Post-project with reinforcements			Pre- vs. Post-project	
Bus Name	base case	outage case	After SPS	base case	outage case	After SPS	base case	outage case	After SPS	Post-SPS w/out rein-forcements Delta	Post-SPS with rein-forcements Delta
LAKEWOOD	100%	95%	96%	95%	89%	90%	101%	95%	96%	-6%	0%
SDW SOMS	100%	94%	96%	95%	88%	90%	100%	94%	96%	-6%	0%
WINSLOW	101%	96%	96%	97%	89%	91%	101%	95%	96%	-5%	0%
GUILF GN	98%	96%	97%	97%	93%	93%	98%	96%	97%	-4%	0%
NORT AUG	102%	95%	95%	105%	93%	94%	101%	95%	95%	-1%	0%
PUDDLDK	102%	95%	95%	100%	93%	94%	101%	95%	95%	-1%	0%
AUG E S	102%	95%	96%	105%	93%	94%	101%	95%	96%	-2%	0%
BOWMAN	102%	96%	96%	101%	94%	95%	102%	96%	96%	-1%	0%

7.3 Final 90 MW Redington Mountain Wind Farm post-project results, with Reactive Reinforcements

There were no loading issues for any of the base cases with the Redington Mountain Wind Farm dispatched against Wyman and Harris hydroelectric generation.

Low voltage issues occurred in all three of the peak cases. In each case, for several contingencies, the low voltages occurred in the same Waterville-Winslow-Skowhegan area, and also at Guilford (see Appendix D: Exception Reports). To alleviate these low voltages, additional reactive support needs to be added to compensate for the loss of reactive support from the displaced hydro units. An additional 7.2 MVAR of capacitors are required at Winslow Substation to expand one existing 9 MVAR bank to 16.2 MVAR for a total of 32.4 MVAR at Winslow Substation. (Subsequent sensitivity analysis discussed in section 8.3 of this report has determined this additional capacitance is CMP's responsibility.) At Lakewood Substation a new 10.8 MVAR of capacitor bank is required, and Guilford Substation requires an additional 5.4 MVAR for its existing capacitor bank. All 50 contingencies listed in Section 7 were simulated with and without these reinforcements in the three peak cases. Without these reinforcements, voltages in that area fell below 95% for several contingencies. With these reinforcements, no voltage fell below 95% with any contingency. As shown in Table 7-1, low voltages for the Maxcy's KT3L-1 stuck breaker contingency in the post-project 'Peak 83' case are now between 95% and 97%, which are within the acceptable limits.

One-line diagrams of all contingencies with the final post-project dispatch, with reinforcement requirements to obtain adequate post-contingency voltages, are in Appendix B.

7.4 Kennebec River 345 kV Double Circuit Tower Contingency

The Kennebec River double circuit tower contingency was simulated for all cases. This contingency removes Section 375 between Maine Yankee and Buxton and Section 377 between Maine Yankee and Surowiec, from service.

All voltages for both the peak and light load cases were above 95% with the exception of two cases. The 'Light 66' case shows the voltage at the Surowiec 345 kV bus to be at 94% for both the pre-project and post-project corresponding cases. The 'Light 83' case shows the voltage at the Surowiec 345 kV bus at 93% for the 30 MW case and 94.5% for the post-project case.

There were no loading issues for any of the peak load cases. The increased Maine load in these peak cases is utilizing the area generation so that 115 kV underlying flows are reduced and, there are not any overloads. The light cases consistently showed overloading on Section 81 from Mason to Topsham to Surowiec and on Section 207 from Mason to Maine Yankee to Bath - as expected. The 'Light 66' case showed the greatest overloads on Section 81 at 60% above its STE rating for the 30 MW case. Sections 81 and 207 overloads for the post-project cases are 1% to 2% lower than the pre-project cases, as shown in Appendix B.

The voltage and loading results from this contingency show that there is no significant difference in the pre-project and the post-project cases and therefore Redington Mountain Wind Farm does not have an adverse effect with regard to this contingency. This contingency has received an exclusion from both NEPOOL and NPCC, per the ISO New England "Reliability Standards" and the NPCC "Basic Criteria."

8. Steady State Sensitivity Analysis Results

8.1 Northeast Reliability Interconnect (NRI) Project

A Northeast Reliability Interconnect (NRI, also known as the 2nd New Brunswick Tie Project) sensitivity analysis was performed to demonstrate the steady state voltage and thermal effect on the system with the Redington Mountain Wind Farm project.

Dispatch

Redington was modeled with the Vestas V90 at 90 MW and the recommended capacitive reinforcements installed. The Peak 83 case was modified to obtain a New Brunswick – Maine interface transfer of 1,000 MW and an Orrington–South interface transfer of 1,200 MW with the NRI project in service. This was achieved by reducing generation in Maine while increasing generation in New Brunswick as shown in Table 8-1 and in Appendix C.

Table 8-1: NRI Generation Dispatch Comparison

Generator	P Max (MW)	Peak 83 Case (MW)	NRI Peak 83 Case
Bucksport G4	191	191	OFF
Coleson Cove G3 (New Brunswick)	352	OFF	335
Great Falls GL (New Brunswick)	61	30.6	OFF
MLT G1-2 (New Brunswick)	3.6	3.6	OFF
Total		**225.2**	**335**

Results

Both the Section 84 outage and the Maxcy's KTL3-2 stuck breaker contingencies were used with the redispatched 'Peak 83' case with the above modifications. These contingencies were chosen since they were the most severe contingencies along the MEPCO corridor where the NRI project interconnects; and they produced the lowest voltages with the 'Peak 83' case. A voltage comparison between the NRI base case and the outages can be seen below. There are no loading or voltage violations for either contingency. Results show that Redington Mountain Wind Farm interconnection has no significant impact on the proposed NRI project.

NRI Voltage Results
1000 MW New Brunswick–Maine Transfer
Peak 83 Case,
Vestas V90 at 90 MW with Reinforcements

Table 8-2:

	Base (%)	Sec 84 OOS (%)	SB Maxcys KT3L-2 (%)
SD Warren	99	96	96
Sect. 83C Tap	102	96	96
Winslow	100	96	96
Prides Corner	98	98	98
Guilford	98	99	99
Wyman	100	99	97

8.2 Line Y138 Closing Project

A sensitivity analysis was performed which demonstrates the steady state voltage and thermal effect on the system with the Y138 Closing Project and Redington Mountain Wind Farm operational.

Dispatch

Redington was modeled with the Vestas V90 at 90 MW and the recommended capacitive reinforcements installed. The 'Peak 63' case was modified to stress Western Maine and Northern Hydro generation and transfers as much as possible with the Y138 project in service. This was achieved by maximizing the generation north of the Surowiec-South transmission interface as shown in Table 8-3 below, while keeping the Maine-New Hampshire transmission interface below its thermal limit (See Appendix C). In addition W. F. Wyman units 1 and 3 (57 MW and 125 MW respectively) were switched off to maintain Maine-New Hampshire transfers.

Table 8-3: Steady State Western Maine Generation

Generator	P Max (MW)	Peak 63 Case (MW)	Stressed Western Maine Pak 63 Case
AEC G1	57.7	37	56
AEC G2	57.7	37	56
AEC G3	57.7	OFF	56
Sub - Total		**74**	**168**
RPA CG1	179	176	176
RPA SG293.5	94	90	90
Sub - Total		**266**	**266**
AEI	39	OFF	**39**
Mead CoGen	110	**93**	**110**
Total		**433**	**583**

Results

The re-dispatched Peak 63 case with the above modifications was simulated with the full set of contingencies. Results showed there were no overloads or voltage violations. (See Appendix B: One-Line Diagrams).

Results of other contingencies in the Maine-New Hampshire transmission interface 345 kV corridor indicate local overloads in New Hampshire only.

Based on these results the Y138 Line Closing Project has no adverse impact on the Redington Mountain Wind Farm Project.

8.3 Upper Kennebec Dispatch

The generation in the Upper Kennebec area of the 30 MW 'Peak 63' Case was re-dispatched to correspond to that of the post-project 'Peak 83' case. This illustrates whether the contributing factor to the low voltages is the dispatch used for the Redington cases or the additional Redington generation. The Wyman and Harris dispatch from the post-project case provide more severe results for the pre-project case, than the stressed dispatch to obtain maximum transfers. See Table 8-4: *Upper Kennebec Generation Sensitivity*.

Table 8-4*: Upper Kennebec Generation Sensitivity*

Generator	90 MW	Pre-project	Re-dispatched Pre-project
Harris 1	16.8	16.8	16.8
Harris 2	OFF	35.0	OFF
Harris 3	OFF	OFF	OFF
Wyman 1	20.0	20.0	20.0
Wyman 2	20.0	20.0	20.0
Wyman 3	OFF	25.0	OFF
Redington	90.0	30.0	30.0

Line Section 84 was taken out of service on the re-dispatched case and the results were compared with the original pre-project and post-project cases with the Section 84 contingency. The results can be seen in the first three data columns of Table 8-5: *Upper Kennebec Dispatch Voltages*.

Table 8-5: Upper Kennebec Dispatch Voltages (%)

	Original Pre-project	Original Post-project	Pre-project – New Dispatch	Pre-project w/added capacitors New Dispatch
Winslow	96	96	93	96
SD Warren	96	96	94	96
83 C Tap	96	96	94	96
Lakewood	97	97	94	97
83 B Tap	97	97	95	97
Guilf. Gen	98	99	98	98
Wyman	100	100	100	100

The re-dispatched case shows voltages below 95%. In addition to the 16.2 MVAR capacitor bank discussed in Section 7.1, by adding an additional 7.2 MVAR of capacitance at Winslow (upgrading the present 9 MVAR to 16.2 MVAR for a total of 32.4 MVAR) the voltages are raised to acceptable limits in the redispatched pre-project case, as illustrated in the 4th data column of Table 8-5: *Upper Kennebec Dispatch Voltages*.

The results indicate that the reduced transfers from the redispatch did not unstress the northern CMP 115 kV system enough to compensate for the reduction in MVAR capabilities. With additional reactive compensation, by expanding the existing Winslow Substation capacitor bank from 9 MVAR to 16.2 MVAR for a total of 32.4 MVAR, the results are acceptable. Therefore, this becomes CMP's requirement rather than a Redington project requirement.

8.4 Livermore Falls Stuck Breaker Sensitivity

A second contingency was performed which isolates only the Livermore Falls Substation 115 kV bus. The original model simulates the lack of bus differential protection at Livermore Falls for a bus fault, by opening remote breakers through zone 2 protection. However, since breaker failure protection exists at Livermore Falls Substation, a contingency was simulated on the post-project 'Peak 63' case to represent a stuck breaker at Livermore Falls other than the Section 63 breaker. As seen in Table 8-6:*Livermore Falls Stuck Breaker Sensitivity – Voltages (%)*, voltages are low for the post-project case as compared to the pre-project case and the voltage at Sturtevant falls below acceptable levels. The third column, "pre-project Case – New Dispatch" has the Livermore Bus isolated under post-project generation dispatch, i.e. Wyman and Harris generators are modeled as they are in the post-project case (see Section 8.3: Upper Kennebec Generation). Even with this dispatch the voltages are at acceptable levels “pre- Redington”. A 5.4 MVAR capacitor bank was modeled at Sturtevant, which provided acceptable voltages in the area.

Table 8-6: Livermore Falls Stuck Breaker Sensitivity – Voltages (%)

	Post-project w/ Reinforcements	Pre-project Original Dispatch	Pre-project New Dispatch	Post-project w/Reinforcements & Sturtevant Capacitor
Sturtevant	94	96	95	96
Prides Corner	98	98	98	98
Williams	98	100	100	99
Guilford	99	98	98	99
Rice Rips	99	99	99	99

9. Transient Performance Criteria

9.1 Contingencies

Stability results were analyzed using the criteria in the *Reliability Standards for New England Power Pool, (Planning Procedure 3), January 2004.* Low voltage ride through criteria was based on the third draft of the *Generator Low Voltage Ride Through Criteria* by the NEPOOL Stability Task Force dated August 3, 2005.

<u>Normal Contingencies</u>
The following normal contingencies, as defined by Reliability Standards of the New England Power Pool (Planning Procedure #3), were considered for this analysis.

a. Permanent 3-phase fault on any generator, transmission circuit, transformer or bus section, with normal fault clearing.
b. Simultaneous permanent phase-to-ground faults on different phases of each of two adjacent transmission circuits on a multiple-circuit transmission tower, with normal fault clearing. If multiple circuit towers are used only for station entrance and exit purposes, and if they do not exceed five towers at each station, then this condition and other similar situations can be excluded on the basis of acceptable risk, provided that NEPOOL specifically approves each request for exclusion. The NPCC Reliability Coordinating Committee must grant similar approval.
c. Permanent phase-to-ground fault on any transmission circuit, transformer, or bus section with delayed fault clearing.
d. Loss of any element without a fault.
e. Permanent phase-to-ground fault in a circuit breaker with normal fault clearing.
f. Simultaneous permanent loss of both poles of a direct current bipolar facility without an ac fault.
g. Failure of any Special Protection System (SPS) which is not functionally redundant following the contingencies listed in “a” through “f” above.
h. The failure of a circuit breaker associated with an SPS following: loss of any element without a fault; or a permanent phase to ground fault, with normal fault clearing, on any transmission circuit, transformer, or bus section.

The following criteria define stable transmission system performance for normal contingencies.

- All units transiently stable except for units tripped for fault clearing.
- A 50% reduction in the magnitude of system oscillations must be observed over the last four periods of the oscillation.
- Loss of source not greater than 1,200 MW.
- No entry of the Keswick GCX apparent impedance relay characteristic on Section 396/3001 line from Keswick to Orrington at Keswick S/S.

<u>Extreme Contingencies</u>
The Reliability Standards also address extreme contingencies that are considered more severe than a normal contingency but have a lower probability of occurrence. The transmission bulk power system performance in response to an extreme contingency is intended to be a gauge of the system’s robustness or a measure of the extent of the disturbance.

The following extreme contingencies, as defined by Reliability Standards will be considered for this analysis:

a. Loss of the entire capability of a generating station.

b. Loss of all lines emanating from a generating station, switching station or substation.
c. Loss of all transmission circuits on a common right-of-way.
d. Permanent three-phase fault on any generator, transmission circuit, transformer or bus section, with delayed fault clearing and with due regard to reclosing. This delayed fault clearing could be due to a circuit breaker, relay system or signal channel malfunction.
e. Sudden dropping of a large load or major load center.
f. The effect of severe power swings rising from disturbances outside New England
g. Operation or partial operation of Special Protection for and event or condition for which it was not intended to operate.

Of the seven types of extreme contingencies which were considered, the NEPOOL Stability Task Force (STF) typically focuses on permanent three-phase stuck breaker faults with delayed clearing, detailed in bullet d) above. The STF has indicated measures that should be used to determine acceptable and unacceptable system performance resulting from this type of fault.

The following responses are considered acceptable:

- A 50% reduction in the magnitude of system oscillations observed over four periods of the oscillation.
- Loss of source up to 1,400 MW.
- 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 the likelihood of occurrence and other factors.

The following responses are considered unacceptable:

- Transiently unstable with wide spread system collapse.
- Transiently stable with undamped or sustained system oscillations.
- Loss of source greater than 2,200 MW.

<u>Oscillatory Response</u>
All design contingencies, both normal and extreme, shall meet the “ISO New England Damping Criteria” which states; “Acceptable damping with time domain analysis requires running a transient stability simulation for sufficient time (up to 30 seconds) that only a single mode of oscillation remains. A 50% reduction in the magnitude of the oscillation must then be observed over four periods of the oscillation. A sufficient number of system quantities including rotor angle, voltage, and interface transfers should be analyzed to ensure that adequate system damping is observed.” [NEPOOL Stability Task Force submittal, August 18, 1999].

<u>Low Voltage Ride Through Criteria</u>
The basic criterion for generator low voltage ride through capability is that for all design contingencies, for which the clearing of the disturbance does not require disconnecting the generator, the generator must stay connected to the transmission system and not cause a significant adverse effect to the transmission system. Design contingencies are described in the ISO New England Planning Procedures (reference PP 5-3, etc.). Specifically, the low voltage ride through requirements vary depending on where the fault is located on the transmission system as follows:

a. For design contingencies on the BPS, the unit must stay synchronized when the simulation is based on fault clearing initiated by the “system A” protection group, and also shall be maintained when the simulation is based on fault clearing initiated by the “system B” protection group.
b. For design contingencies on the non-BPS, the unit must stay synchronized when the simulation is based on either fault clearing initiated by the “system A” protection group, OR when the simulation is based on fault clearing initiated by the “system B” protection group. This ride through capability may be attained either by enhanced capability in the generator or faster clearing times, or both.

9.2 Bulk Power System Testing

Given the remote site location and the relatively small amount of generation that has been proposed for the Redington Mountain Wind Farm site, no Bulk Power System Testing is required for this study.

9.3 Short Circuit Analysis

The short circuit analysis modeled the wind turbine generators as variable-speed wound-rotor induction machines capable of contributing rated short circuit current to the low voltage (1000 kV) windings of the generator step-up transformers. Step-up transformation was modeled with the manufacturer's specified impedance.

10. Transient Analysis Study Methodology

The dynamic stability analysis was performed using General Electric's PSLF software package, Version 15. The Vestas V90, 90 MW wind turbine was modeled according to the "Advanced Grid Option 2, V90 VCRS – 3.0 MW" preliminary documentation dated October 4, 2004, and documentation regarding Low Voltage Ride Through (LVRT) for the Vestas V90, dated October 26, 2005, which was provided by Vestas, the turbine manufacturer (see Appendix F). Additional modeling details, specific to PSLF, were provided by EnerNex Corporation via a memorandum, "Modeling the Vestas V90 Wind Turbine in GE PSLF – Version 1", from Bob Zavidil (EnerNex Corporation) to Steve Saylors (Vestas) dated July 18, 2005. (See Appendix G) This model was tested by CMP to determine whether the model would provide a reasonable machine response to a severe local contingency. It did. CMP cannot verify model accuracy for the manufacturer's equipment. The purpose of the analysis is to determine the effect, if any, that interconnecting 90 MW at the Nash Stream Substation has on the transient and dynamic performance of the CMP and New England System in response to a number of different disturbances.

10.1 Fault Contingency Descriptions

Table 10-1: *Transient Fault Contingency Summary – Three-phase Faults,* and Table 10-2: *Transient Fault Contingency Summary - Single Line-to-Ground Faults,* provide a description of the faults which were used to analyze the impact of the Redington Mountain Wind Farm Project on local and system wide stability performance.

Table 10-1: Transient Fault Contingency Summary – Three-phase Faults

Type	ID	Sect #	Fault Location	Fault Type	Stuck Breaker	Faulted Element	Tripped Element	Clearing Time (cycles)
NC	3P66S	66	Wyman Hydro 115 kV	Three-phase	None	Wyman Hydro–Detroit	Wyman Hydro K66-1 Detroit K66-6	7 6
NC	3P83	83	Wyman Hydro 115 kV	Three-phase	None	Wyman Hydro–Winslow	Wyman Hydro K83-5 Winslow K83-1	5 8
NC	3P63	63	Wyman Hydro 115 kV	Three-phase	None	Wyman Hydro–Livermore Falls	Wyman Hydro K63-1 Livermore Falls K63-2	7 9
NC	3P396	396	Keswick 345 kV	Three-phase	None	Keswick-Orrington	Orrington K396-1, K396/388 Keswick: K3-6, K3-5	4 4
NC	3P385	385	Buxton 345 kV	Three-phase	None	Buxton-Deerfield	Buxton K385-1 Buxton K385/374 Deerfield 851 Deerfield 785	4 4 5 5
EC	3P357	357	West Medway 345 kV	Three-phase, with a Stuck Breaker	W. Medway 105 (IPT)	W. Medway to Milbury	W. Medway 104 Milbury 4357 Milbury 302 W. Medway 106 Bridgewater 1680 Bridgewater 1690	4 4 4 10.25 10.25 10.25

Table 10-2: Transient Fault Contingency Summary - Single Line-to-Ground Faults

Type	ID	Sect #	Fault Location	Fault Type	Stuck Breaker	Faulted Element	Tripped Element	Clearing Time (cycles)
NC	1P203 S	203	Detroit 115 kV	Single Line–to-Ground stuck breaker	Detroit K203-1	Detroit – Bucksport	Bucksport K203-2 Maxcy's K67-4 Wyman Hydro K66-1	6 62 62
NC	1P63a	63	Wyman Hydro 115 kV	Single Line- to-Ground Stuck Breaker	Wyman Hydro K63-1	Wyman Hydro – Livermore Falls	Livermore Falls K63 –2 Wyman Hydro K83-5 Wyman Hydro K66-1 Wyman Hydro K222-1 Wyman Hydro KG1, KG2, & KG3	9 20 20 20 21
NC	1P200	200	Livermore Falls 115 kV	Single Line–to-Ground stuck breaker	Livermore Falls K200-4	Livermore Falls – Gulf Island	Gulf Island K200-12 AEI K200A-3 Livermore Falls K63-2, Livermore Falls K89-1	6 9 19 19
NC	1P66	66	Wyman Hydro 115 kV	Single Line- to-Ground Stuck Breaker	Wyman Hydro K66-1	Wyman Hydro– Detroit	Detroit K66-6 Wyman Hydro K83-5 Wyman Hydro K63-1 Wyman Hydro K222-1 Wyman Hydro KG1, KG2, KG3	5 20 20 20 21
NC	1P84	84	Winslow 115 kV	Single Line–to-Ground stuck breaker	Winslow K84-1	Winslow-Maxcy's	Maxcy's K84-2 Winslow K83-1	8 21
NC	1P83	83	Wyman Hydro 115 kV	Single Line- to-Ground Stuck Breaker	Wyman Hydro K83-5	Wyman Hydro – Winslow	Winslow K83-1 Wyman Hydro K66-1 Wyman Hydro K222-1 Wyman Hydro K63-1 Wyman Hydro KG1, KG2, KG3	5 20 20 20 21

11. Transient Analysis Results

The comparison discussion of the fault results is limited to the Redington generator busses and the Bigelow 115 kV (point of interconnection) for voltage. The angle observations are limited to SEA, Wyman Hydro and Harris. The result of the transient analysis is that the interconnection of Redington Mountain Wind Farm at 90 MW has no adverse effect on the system.

Voltage and angle plots can be found in Appendix H.
For voltage plots, Redington OFF and ON must be identified by the color of the graph: Redington OFF in BLUE and Redington ON in GREEN. Note that the color in the plot legend is correct, but the tick marks are **not** correct.
For the machine angle plots, Redington OFF and ON can be identified by the tick marks: Redington OFF tick marks are noted by an "a", Redington ON tick marks are noted by a "b", in the legend.

11.1 Transient Three-phase Fault Results

Table 11-1: *Transient Three-phase Fault Result Summary* provides a description of the system performance resulting from fault simulations as described in Table 10-1*: Transient Fault Contingency Summary – Three-phase Faults.* As seen from the Fault Result Summary, all faults were stable with the 90 MW contribution from Redington Mountain Wind Farm, with the exception of the three-phase stuck-breaker extreme contingency fault on Section 357.

The three-phase faults on Section 63, Section 66, and Section 83 were applied at the Wyman Hydro bus, electrically the same location for each fault, but each with a different post-fault system configuration. For the Section 83 fault, the damping appears the same with Redington ON or OFF. As seen from the plot results, the Section 66 fault system response appears to be unstable with Redington OFF, but stable with Redington ON. This has been observed in other studies. This is attributed to the modeling of the Harris generators (Harris units 2 & 3 have no excitation system model). With all three generators on, G1 remains on line while G2 and G3 lose synchronism. Unfortunately this modeling issue cannot be corrected until additional generator data is obtained for the Harris Hydro units. With Redington ON, this fault on Section 66 is stable since Redington is dispatched against one of the three Harris generators. With Redington ON, the results of this fault are quite similar to those of Section 83.

As seen in Table 10-1: *Transient Fault Contingency Summary – Three-phase Faults,* clearing times for a three-phase fault on Section 63 are 7 cycles for Wyman Hydro breaker K63-1 and 9 cycles for Livermore Falls breaker K63-2. With Wyman Hydro K63-1 breaker clearing time modeled at 7 cycles, this fault results in all three Harris Hydro generator units losing synchronism, with Redington OFF. The fault was modeled again substituting 6-cycles for the-7 cycle clearing time at the Wyman Hydro end of Section 63. With this shorter clearing time, the fault results are stable and the damping is the same with both Redington OFF and ON. Therefore, a breaker with a faster clearing time may be required at the Wyman Hydro end of Section 63, pending further investigation of this fault with accurate excitation system models for all of the Harris generators. If required, a faster breaker would be CMP’s responsibility.

Table 11-1: Transient Three-phase Fault Result Summary

Type		Redington OFF	Redington ON	Comments
NC	3P66S	Harris Unstable	Stable	All other generators are stable when Redington is dispatched against one of the three Harris generators. See three-phase fault results.
NC	3P83	Stable	Stable	Damping is the same with Redington ON and OFF
NC	3P63	Stable	Stable	Both ON and OFF conditions require a maximum 6 cycle clearing time at Wyman K63-1 breaker.
NC	3P396	Stable	Stable	Damping is the same with Redington ON and OFF
NC	3P385	Stable	Stable	Damping is the same with Redington ON and OFF. Both ON and OFF conditions require a maximum 1,400 MW ME-NH interface.
EC	3P357	Unstable	Unstable	Damping slightly better with Redington ON. Both ON and OFF conditions require a maximum 1,400 MW ME-NH interface.

The three-phase fault on Section 396 shows damping to be the same with Redington OFF or ON. A three-phase normally-cleared fault at Buxton on Section 385, and a three-phase stuck-breaker fault at West Medway on Section 357, required the interface flow between Maine and New Hampshire to be reduced from 1,700 MW to 1,400 MW with Redington ON or OFF. This is consistent with the results obtained in the "Y138 Closing Study." The interface was reduced to approximately 1,400 MW to enable an acceptable system response. Discussions with ISO-New England validated the 1,400 MW ME-NH interface transfer as acceptably stressed under these conditions. With this new dispatch, with a three-phase fault on Section 385, damping is slightly better with Redington ON.

For a three-phase stuck-breaker extreme contingency fault at West Medway on Section 357, the system is unstable. Under the base conditions, the system separates about 1.7 seconds after the fault between northern Maine and southern Maine, near Bangor, along the Orrington-south interface (345 KV Section 388 and 396, and 115 KV Sections 86 and 203 trip) for this extreme contingency. Details of this fault are approximately the same with Redington OFF or ON, as seen in Table 11-2: *Section 357, Three-phase Stuck-breaker Fault Summary*. The one line diagrams for this contingency are found in Appendix H. Redington Mountain Wind Farm does not have any significant adverse impact to the system for this extreme contingency.

Table 11-2: Section 357 Three-phase Stuck-breaker Fault Summary

Redington OFF t = seconds	Redington ON t = seconds	Occurrence
0.1	0.1	Fault Applied
1.483	1.475	Opened Section 86 and Section 203 (Bucksport Overcurrent SPS operation)
1.741	1.754	Opened Section 388 (step distance)
1.817	1.808	Opened Section 396 (step distance)

11.2 Single Line-To-Ground Fault Results

Table 11-3: *Single Line-to-Ground Fault Result Summary*, provides a description of the system performance resulting from fault simulation as described in and *Table* 10-2: *Transient Fault Contingency Summary - Single Line-to Ground Faults*. Voltage and angle plots can be found in Appendix H.

Table 11-3: Transient Single Line-to-Ground Fault Result Summary

Type		Redington OFF	Redington ON	Comments
NC	1P63a	Stable	Stable	Island formation: Sect. 222/82 with Harris over-speed protection Sect. 63/215 with SEA and Redington SEA over-speed unknown, otherwise transfer trip
NC	1P66P	Stable	Stable	
NC	1P83	Stable	Stable	
NC	1P84	Stable	Stable	
NC	1P200	Stable	Stable	
NC	1P203S	Stable	Stable	Better damped with Redington ON

<u>Voltages</u>

When a single line-to-ground fault was applied to Section 63, Section 66, or Section 83, with a stuck breaker on the Wyman Hydro end, the results were almost identical with or without Redington interconnected to the system. For the remaining single line-to-ground faults, because the fault location is electrically far away from the Redington site, the voltage sags at the generator terminal are barely noticeable. For all these faults on Section 84, Section 200 and Section 203, the transient voltage sag on the Bigelow 115 KV bus is less than 20% of nominal voltage. The worst transient voltage sag of these faults occurs on Section 203.

<u>Angles</u>

Although mild in both amplitude and duration for all single line-to-ground stuck-breaker faults, the angle oscillations are slightly more pronounced in the 1P203S fault. As seen in *Table* 10-2: *Transient Fault Contingency Summary - Single Line-to Ground Faults*, 1P203S has a fault duration approximately three times greater than the other faults while the electrical proximity to the Redington site is comparable. None of the faults come close to causing a trip of the Redington generators either at the generator terminals or the point of interconnection.

12. Transient Sensitivity Analysis

12.1 Northeast Reliability Interconnect (NRI) and Line Y138 Closing Project

This study was based on the generation dispatch described in Section 5.4. All faults were run on cases with Redington Mountain Wind Farm in service.

Table 12-1: Transient Fault Contingency Summary – NRI & Y138 Sensitivity

Type	ID	Base Case Redington ON	With NRI and Y138 projects Redington ON	Comments
NC	3P63	Stable	Stable	No significant difference
NC	3P66_S	Stable	Stable	No significant difference
NC	3P83	Stable	Stable	No significant difference
NC	3P385b	Stable	Stable	The base case required a maximum 1,400 MW ME-NH transfer. With NRI & Y138 in service, the interface was modeled above 1,700 MW with a stable result.
NC	3P396	Stable	Stable	Damping improves slightly with NRI & Y138 projects in service.
EC	3P357	Unstable	Unstable	With NRI &Y138 in service, the system breaks apart at the ME-NH interface instead of the Orrington-South interface.
NC	1P63a	Stable	Stable	No significant difference.
NC	1P66P	Stable	Stable	No significant difference.
NC	1P83	Stable	Stable	Slightly less damping with NRI & Y138 in service.
NC	1P84	Stable	Stable	No significant difference.
NC	1P200_LF	Stable	Stable	No significant difference.
NC	1P203S	Stable	Stable	No significant difference.

All base cases have a 1700 MW ME/NH interface except 3P357 and 3P385b which have a ME/NH interface of 1400 MW.

With the NRI and the Y138 Closing Project in service, the interface was modeled at over 1,700 MW, consistent with the Y138 Closing Project Study. For a three-phase fault on Section 385 with Redington Mountain Wind Farm in service, the Maine-New Hampshire interface can not be grater than 1,400 MW. With these projects in place, the initial fault recovery time is slightly better; however the damping recovery is slightly worse with the 300 MW of additional ME-NH transfer.

For a three-phase stuck-breaker extreme contingency fault at West Medway on Section 357, the system is unstable:

- Under the base conditions, the system separates about 1.7 seconds after the fault between northern Maine and southern Maine, near Bangor, along the Orrington-south interface (345 KV Section 388 and 396, and 115 KV Sections 86 and 203 trip) for this extreme contingency. The equivalent loss-of-source to the eastern interconnected systems for this contingency is 970 MW.
- Under the sensitivity condition with the NRI and Y138 projects in service, the system breaks apart about 1.9 seconds after the fault in southern Maine, along the Maine-New Hampshire interface (345 KV Section 385 and 391, and 115 KV Sections 224, and 250 and Y138 trip) for this extreme contingency. The equivalent loss-of-source to the eastern interconnected systems for this contingency is 1820 MW.

The equivalent loss-of-source to the eastern interconnected systems was determined by summing the measured pre-contingency flows on the lines which tripped to cause system separation.

The three-phase fault on Section 396 was modeled with the "Section 396 SPS" in service, designed to trip the Maine Independence Station generators when the Keswick-Chester-Orrington 345 KV line (Section 396) is opened. Damping improves slightly with the NRI and Y138 Closing Project in service.

In conclusion, this sensitivity shows that the NRI and Y138 projects have no adverse effect on the interconnection of the 90 MW wind farm, nor does the wind farm have any adverse effect on the projects. The most significant results of this study show that with the projects in service, 1) the system can withstand a three-phase fault on Section 385 with the Maine–New Hampshire Interface greater than 1,700 MW and 2) with a three-phase fault on Section 357, the system will separate at the ME-NH interface instead of the Orrington-South interface, with an increased loss-of-source to the eastern interconnected systems.

12.2 Light Western Dispatch

This sensitivity was based on the generation dispatch described in Section 5.4. All faults were run on cases with Redington Mountain Wind Farm in service. These sensitivities were conduced to evaluate the Low Voltage Ride-Through (LVRT) capabilities of the V90 turbine-generators when there is less generation in the local area to sustain the voltage. Although for the three-phase fault cases the post-fault voltage dipped lower than cases with more generation dispatched in the immediate area, the ride-through capability of the generator met the LVRT criteria.

Table 12-2: Transient Fault Contingency Summary – Light Western Maine Dispatch Sensitivity

Type	Fault ID	Base Case	Light Western Generation	Comments
NC	3P63	Stable	Stable	Fault voltage drops lower with light generation.
NC	3P66_S	Stable	Stable	Fault voltage drops lower with light generation.
NC	3P83	Stable	Stable	Fault voltage drops lower with light generation. Damping improves slightly.
NC	1P84	Stable	Stable	No significant difference.
NC	1P200	Stable	Stable	No significant difference.
NC	1P203S	Stable	Stable	No significant difference.

13. Short Circuit Protection

The short circuit analysis modeled the wind turbine generators as variable-speed wound-rotor induction machines capable of contributing rated short circuit current to the low voltage (1000 kV) windings of the generator step-up transformers. Step-up transformation was modeled with the manufacturer's specified impedance. Table 13-1: *Short Circuit Fault Study* illustrates that the short circuit duties were found to be within the ratings of the existing 34.5 KV and 115 KV system equipment. No adverse short circuit impact was found as a result of interconnecting Redington Mountain Wind Farm.

Table 13-1: Short Circuit Fault Study

Substation		Base System		With Redington		Rated	Comment
	kV	3LG kA	1LG kA	3LG kA	1LG kA	kA	
Redington	115			3.96	1.67		
Bigelow	115	3.30	1.87	4.59	2.09	10	
Stratton Energy	115	3.03	1.60	3.89	1.73	10	
Wyman Hydro	115	8.09	7.70	8.68	8.05	6	K215-1 Overdutied in Base System & with Redington *
Embden	115	6.31	5.20	6.54	5.30	10	
Williams Hydro	115	6.00	4.95	6.21	5.04	17	
Madison Paper	115	5.62	3.63	5.71	3.65	7	
Sturtevant	115	6.02	4.03	6.05	4.04	10	
Moscow	115	4.48	3.70	4.63	3.77	7	
Harris Hydro	115	3.06	3.40	3.10	3.43	17	
Hartland	115	5.36	3.53	5.43	3.55	10	
Detroit	115	6.13	3.91	6.18	3.92	7	
Lakewood	115	4.63	2.76	4.68	2.77	40	
Redington	34.5			12.55	14.33		
Bigelow	34.5	2.15	2.35	2.26	2.44	8	
Stratton	34.5	1.42	1.24	1.47	1.26	10	

Basis: 1. Bus fault duty kA rms symmetrical
2. Interrupting rated kA rms symmetrical
3. Aspen case jul05.olr

* The cost to replace the existing over-dutied circuit switcher, K215-1, with a one having adequate capacity, has been credited to Endless Energy against the Wyman Substation portion of this project.

13.1 Protection Analysis

The following information summarizes the protection requirements for the connection of 90 MW of generation onto Section 215 at Bigelow Substation:

<u>Protection Summary</u>

1. 115 KV Section 215 is tapped onto Section 63 at Wyman Hydro Substation through a circuit switcher K215-1. Section 215 supplies a fused transformer at Bigelow Substation and connects to Section 215A, which provides a connection to the Stratton Energy plant.

2. The existing Section 215 primary protection at Wyman Hydro consists of electro-mechanical non-directional overcurrent relays and a single distance relay that are supplied from a set of in-line current transformers on the Section 215 tap. The primary relaying trips circuit switcher K215-1.

3. The Section 215 backup protection is provided by slow-clearing non-directional overcurrent relays on the K63-1 breaker. The backup relaying trips breaker K63-1.

4. There is an existing transfer trip carrier that trips the Stratton Energy plant on a K215-1 "b" contact or relay operation.

<u>Protection Recommendations</u>

1. In order for the Section 215 line rating to increase to the 212°F limit of approximately 135 MVA, the relaying should be changed from overcurrent to step distance/directional ground overcurrent. This should be designed to CMP’s current 115 KV protection standards, which would require primary and backup digital protection relays supplied from separate current transformers.

2. The existing Section 215 primary overcurrent relays could misoperate for a close-in Section 63 fault because of infeed from the Section 215 generation. This should be corrected as listed in (1) above.

3. In order to provide high speed and dedicated fault clearing for Section 215, the backup overcurrent protection on the K63-1 breaker should be removed and Section 215 should be connected to the Wyman Hydro bus through a new 115 KV breaker. The K63-1 breaker should not be required to operate for Section 215 faults.

4. The existing transfer trip carrier that trips the Stratton Energy plant for K215-1 opening should be modified to include a trip of the Redington Wind Farm generation. This will minimize the chance for wind farm generation to be islanded with CMP Bigelow customers on a Section 215 fault. This new breaker will replace the current K215-1 circuit switcher, see Figure 4. Since the current K215-1 is currently overdutied in the base case, it is CMP’s responsibility to replace this circuit switcher. With the interconnection of Redington Mountain Wind Farm, Endless Energy will be credited the amount of a new circuit switcher towards the required new breaker.

5. A 115 KV breaker should be added at Bigelow Substation to connect the Redington Wind Farm site. This breaker should be provided with CMP’s standard 115KV primary and backup digital relaying to limit the effect on CMP’s customers for a fault on the new Redington 115 KV transmission line.

6. The Redington 115/34.5 KV transformer should be provided with CMP’s standard protection package for a transformer of this size and voltage, which is primary transformer differential and backup high-side overcurrent.

14. Conclusions & Recommendations

Based on the steady state analysis described in report Sections 7 and 8, a total of 40 MVAR of capacitor additions at Winslow, Lakewood, and Guilford Substations' 34.5 KV busses, are required to obtain acceptable performance for all system conditions which were tested. The following are the interconnection requirements and cost estimates to interconnect the Redington Mountain Wind Farm 90 MW project, and avoid any significant adverse impact to the CMP and NEPOOL systems:

Endless Energy Responsibility - $3,200,000

- **Bigelow Substation**: Expand yard, add a 115 KV bus, breaker, and control house - $1,510,000
- **Wyman Substation**: Separate Section 215 from 63, terminate with a breaker - $660,000*
- **Section 215 Transmission Line**: Re- rate to 212o F - $300,000
- **Lakewood Substation**: Add a new 10.8 MVAR capacitor bank - $370,000
- **Guilford Substation**: Expand the existing 5.4 MVAR capacitor bank to 10.8 MVAR - $140,000
- **Sturtevant Substation**: Add a new 5.4 MVAR capacitor bank. - $220,000

* The $50,000 cost to replace the existing over-dutied circuit switcher K215-1, with a one having adequate capacity, has been credited to Endless Energy against the Wyman Substation portion of this project.

CMP Responsibility

- **Winslow Substation:** Expand the existing capacitor bank from 9 MVAR to 16.2 MVAR
- **Winslow Substation:** Add a new second 16.2 MVAR capacitor bank
- **Wyman Substation:** subject to further review with accurate Harris & Wyman Hydro generator models, replace breaker K63-1

The application of these capacitors at 34.5 kV both reduces the cost of reactive compensation and increases its effectiveness by also reducing the local 115/34.5 kV transformer reactive power losses.

No upgrades are required to address impacts due to transient stability performance.

With the interconnection reinforcement requirements, there is a reduced likelihood of operation of the Winslow SPS. This is demonstrated in Appendix D.

With these interconnection requirements, the Redington Mountain Wind Farm 90 MW project meets the ISO New England Reliability Standards and the Minimum Interconnection Standard.

There are no relevant queued resources ahead of Redington Mountain Wind Farm.