Entergy Nuclear Northeast
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October 28, 2003
BVY 03-95

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Subject: **Vermont Yankee Nuclear Power Station**
License No. DPR-28 (Docket No. 50-271)
Technical Specification Proposed Change No. 263 - Supplement No. 2
Extended Power Uprate – Grid Impact Study

By letter dated September 10, 2003[1] and supplemented by letter dated October 1, 2003[2], Vermont Yankee[3] (VY) proposed to amend Facility Operating License, DPR-28, for the Vermont Yankee Nuclear Power Station (VYNPS) to increase the maximum authorized power level from 1593 megawatts thermal (MWt) to 1912 MWt. The request for license amendment acknowledged that an analysis of the effects of the extended power uprate on plant and transmission grid stability was being prepared and would be transmitted at a later date. That analysis is provided herewith.

VY is providing as Attachment 1 a determination[4] by the transmission grid operator, ISO New England, that the extended power uprate of VYNPS will not have a significant adverse effect on the reliability or operating characteristics of VYNPS or on the offsite electrical system, based upon satisfaction of certain conditions. VY plans to satisfy the intent of each of the conditions enumerated in Attachment 1 prior to achieving full power uprate. The modifications described in Attachment 1 will ensure that adequate grid protection will be maintained, and that VYNPS' design will continue to meet the intent of General Design Criterion 17 at the EPU condition[5].

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[1] Vermont Yankee letter to U.S. Nuclear Regulatory Commission, "Extended Power Uprate," Proposed Change No. 263, BVY 03-80, September 10, 2003.
[2] Vermont Yankee letter to U.S. Nuclear Regulatory Commission, "Extended Power Uprate – Technical Review Guidance," Proposed Change No. 263, Supplement No. 1, BVY 03-90, October 1, 2003.
[3] Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. are the licensees of the Vermont Yankee Nuclear Power Station.
[4] ISO New England, Inc. letter to Entergy Nuclear Vermont Yankee, LLC, "Entergy-03-G01 and Entergy-03-T01," October 8, 2003.
[5] VYNPS was licensed in accordance with draft design criteria issued by the U.S. Atomic Energy Commission (AEC) in 1967, and VYNPS was designed in accordance with the proposed AEC GDC 24 and 39 which have been found to collectively meet the intent of the finally-adopted GDC-17.

A001

Attachment 2 is the grid impact study[6] that provided the basis for the determination reached in Attachment 1. It should be noted that a significant plant operating response (i.e., a rapid, large power reduction) is discussed in Section 3.6 of Attachment 2 for certain electrical grid contingency events. VY believes that a rapid, large power reduction could increase the potential for inducing a plant transient, and other compensatory measures may be more appropriate under the circumstances postulated in Section 3.6 of Attachment 2. For these reasons, VY is pursuing alternative operating strategies with the grid operator to address the postulated condition.

Attachment 2 contains certain embedded links or references to spreadsheets, figures, etc. that support the conclusions reached in the study. Based on discussions with NRC staff, we do not believe that inclusion of the referenced spreadsheets, etc. is necessary for NRC review of the study. Therefore, those references are not included herewith. However, if the NRC staff should require additional information that is contained in any supporting reference, VY will provide the relevant information upon request.

If you have any questions with this submittal, please contact Mr. Len Gucwa at (802) 258-4225.

Sincerely,

Jay K. Thayer
Site Vice President

STATE OF VERMONT)
)ss
WINDHAM COUNTY)

Then personally appeared before me, Jay K. Thayer, who, being duly sworn, did state that he is Site Vice President of the Vermont Yankee Nuclear Power Station, that he is duly authorized to execute and file the foregoing document, and that the statements therein are true to the best of his knowledge and belief.

Sally A. Sandstrum, Notary Public
My Commission Expires February 10, 2007

SALLY A. SANDSTRUM NOTARY PUBLIC WINDHAM COUNTY, VERMONT

Attachments (2)
cc: (with attachments)

USNRC Region 1 Administrator
USNRC Resident Inspector – VYNPS
USNRC Project Manager – VYNPS (two copies)
Vermont Department of Public Service

[6] "Final Report to: ISO-New England for Vermont Yankee Uprate System Impact Study," prepared by General Electric International, Inc., October 7, 2003.

Docket No. 50-271
BVY 03-95

Attachment 1

Vermont Yankee Nuclear Power Station

Technical Specification Proposed Change No. 263

Supplement No. 2

Extended Power Uprate – Grid Impact Study

ISO-New England Letter of October 8, 2003

Stephen G. Whitley
Senior Vice President & Chief Operating Officer

October 8, 2003

Mr. Craig Nichols
Mr. George Thomas
Entergy Nuclear Vermont Yankee, LLC
Vermont Yankee Nuclear Power Station
P.O. Box 250
Governor Hunt Road
Vernon, VT 05354

Subject: ENTERGY-03-G01 and ENTERGY-03-T01

Gentlemen:

ISO New England has determined pursuant to Section 18.4 that implementation of the Participant plans identified in the following applications will not have a significant adverse effect on the reliability or operating characteristics of the Participant that submitted the applications or upon the system of any other Participant, subject to satisfaction of any conditions identified below with respect thereto:

The Entergy Nuclear Vermont Yankee, LLC (ENTERGY) Subordinate Generation 18.4 Application ENTERGY-03-G01 for increasing the gross electrical megawatt output of the Vermont Yankee Nuclear Power Station generator, located in Vernon, Vermont (the "Project"), by 104 MW (563 MW to 667 MW), effective in two uprate stages commencing in the third quarter of 2004 (624 MW) and completed in the fourth quarter of 2005 (667 MW), as detailed in Messrs. Craig Nichols' and George Thomas' September 29, 2003 transmittal to Mr. Stephen Rourke, Chairman - NEPOOL Reliability Committee, subject to the following conditions:

1. The Project having the net ratings of 641.5 MW at 20 °F and 50 °F and 634.5 MW at 90 °F; a gross maximum plant rating of 667 MW; and a gross reactive capability, under full output conditions, of 100 MVAr leading and 150 MVAr lagging.

2. Increasing the pre-contingency MVA rating on the Vermont Yankee -Northfield 345 kV Line (Section 381) from the current rating of 869 MVA to a minimum rating of 1075 MVA by replacing the limiting line relay equipment.

3. Increasing the post-contingency MVA rating on the Ascutney – Coolidge 115 kV Line from the current LTE rating of 205 MVA to 240 MVA by replacing approximately 25 feet of the limiting riser conductor.

4. Adding one bank of 30 MVAr switched capacitors and two banks of 15 MVAr switched capacitors at the Vermont Yankee 115 kV switchyard. The 30 MVAr bank should be connected such that it trips with the autotransformer. The 15 MVAr banks should be connected to the 115 kV bus such that they are available with the autotransformer out of service.

5. Providing a second primary protection scheme on Vermont Yankee north bus to achieve acceptable performance in response to a normal contingency fault.

6. Adding a second primary protection scheme on the Vermont Yankee GSU to achieve acceptable performance in response to a normal contingency fault.

7. Upgrading the Vermont Yankee 381 Breaker to an IPT breaker.

8. Addition of out-of-step protection on the Vermont Yankee generator to ensure acceptable performance in response to several extreme contingencies.

9. Completion of any additional transmission modifications required for the Project that may result from the development of any or all of the Relevant Queued Resources to the extent required under the Subordinate 18.4 Application Policy. These relevant Queued Resources include:

   Berwick Energy Center
   UAE Tewksbury
   Neptune Phase 3 Boston Import
   Neptune Phase 7 Wyman Export
   Mystic 4,5,6 Conversion
   Millstone Unit No. 3 Power Uprate projects

10. The approval, under Section 18.4 of the Restated NEPOOL Agreement, of the modified excitation system model parameters for the Millstone Point Unit 3 generator that were included in the stability analysis for the Project or the installation of any additional transmission modifications that may be required as the result of those parameters being further modified to attain such approval.

And the Entergy Nuclear Vermont Yankee, LLC (ENTERGY) 18.4 Transmission Facilities 18.4 Application ENTERGY-03-T01, associated with Generation 18.4 Application ENTERGY-03-G01, for the installation of three (3) 115 kV switched, shunt capacitor banks comprised of two (2) 15 MVAr (nominal) capacitor banks and one (1) 30 MVAr (nominal) capacitor bank located at the Vermont Yankee 115 kV Substation in Vernon, Vermont, designed to provide a coincident trip of the 30 MVAr capacitor bank given a loss of the Vermont Yankee Autotransformer, with an in service date scheduled during the third quarter 2004, as detailed in Messrs. Craig Nichols' and George Thomas' September 29, 2003 transmittal to Mr. Stephen Rourke, Chairman - NEPOOL Reliability Committee.

The above plans are hereby approved for implementation.

Sincerely,

Stephen G. Whitley
Senior Vice President and Chief Operating Officer

cc: 18.4 Application

Docket No. 50-271
BVY 03-95

Attachment 2

Vermont Yankee Nuclear Power Station

Technical Specification Proposed Change No. 263

Supplement No. 2

Extended Power Uprate – Grid Impact Study

Final Report to: ISO-New England for Vermont Yankee Uprate System Impact Study

GE Power Systems

Final Report to:

ISO-New England

for

Vermont Yankee Uprate System Impact Study

Prepared by:

Kara Clark
Ming Wu

October 7, 2003

Foreword

This document was prepared by General Electric International, Inc. through its Power Systems Energy Consulting (PSEC) in Schenectady, NY. It is submitted to ISO-New England. Technical and commercial questions and any correspondence concerning this document should be referred to:

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Executive Summary

Entergy is requesting approval for an uprate of the Vermont Yankee nuclear plant. The Vermont Yankee Extended Power Uprate Project will increase the output of the unit in two steps. During the refueling outage scheduled for spring of 2004, numerous modifications will be implemented, including replacement of the high pressure turbine steam path and rewind of the main generator to increase the nameplate rating to 684MVA. Following receipt of Nuclear Regulatory Commission (NRC) approval of the Extended Power Uprate license amendment application during the third quarter of 2004, Vermont Yankee will increase its power output to as high as 624 MW gross and 150 MVAR. After the refueling outage scheduled for the fourth quarter of 2005, Vermont Yankee will further increase its power output to 667 MW gross and 150 MVAR.

The purpose of this study was to analyze the impact of this uprate on the interconnected New England system in accordance with the "NEPOOL Reliability Standards" and the NEPOOL "Minimum Interconnection Standard", and to identify any necessary facility upgrades to meet these standards under the NEPOOL Subordinate 18.4 Application Policy. Relevant queued resources for this project include the Berwick Energy Center, UAE Tewksbury, Neptune Phase 3 Boston Import, Neptune Phase 7 Wyman Export, Mystic 4,5, 6 conversion, and Millstone #3 uprate projects. Vermont Yankee is subordinate to all of these.

For this study, the existing Vermont Yankee unit was represented with a rating of 626MVA, a power output rating of 563MW, and a gross reactive power output rating of 150MVAr at rated power output.

The final Vermont Yankee uprate configuration, with a power output of 667 MW gross, was evaluated rather than the intermediate uprate, with a power output of 624 MW gross. An analysis of system performance with the final uprate and its associated reinforcements ensures that system performance with the intermediate uprate and the same reinforcements would be acceptable. Therefore, the proposed uprate project was represented with a rating of 684MVA, a final power output rating of 667MW, and a gross reactive power output rating of 150MVAr at rated power output. There is no expected change to the station service or cooling tower loads, which are 25.5MW, 13.5MVar and 8.5MW, 5.7MVAr, respectively. Therefore, the net rating of the uprate, as evaluated in this study with all station service and cooling loads in service under peak load conditions, was 633MW.

For the stability analysis, the Vermont Yankee exciter was modeled, both pre- and post-uprate, with an *exac3a* model representing an IEEE type AC3A excitation system. This is the manufacturer recommended model and replaced the *ieeet1* model used in prior studies. Therefore, this study also supports the exciter model change.

This study used a relative performance approach to determine the impact of the proposed Vermont Yankee nuclear plant uprate on the New England (NE) power system. First, system performance without the proposed uprate was determined in order to establish the benchmark. Then system performance with the proposed uprate was determined and compared to the benchmark. This relative approach removed any ambiguities as to the actual impact of the proposed project since existing criteria violations, if any, were identified.

Power flow and stability analyses were performed, including a voltage and thermal N-1 contingency analysis, a thermal N-2 contingency analysis, a transient stability analysis, and a ΔP analysis.

No short circuit analysis was performed because there was no significant change to the generator impedances, as described in Section 5.

The power flow analysis indicated that the following upgrades will be required as part of the Vermont Yankee uprate project:

1. Increase the pre-contingency MVA rating on the Vermont Yankee-Northfield 345kV line (Section 381) from the current rating of 896MVA to a minimum rating of 1075MVA by replacing the limiting line relay equipment.

2. Increase the post-contingency MVA rating on the Ascutney-Coolidge 115kV line from the current LTE rating of 205MVA to 240MVA by replacing approximately 25 feet of the limiting riser conductor.

3. Ensure that the Vermont Yankee 345kV pre-contingency bus voltage is not degraded as a result of the uprate project by the addition of 60MVAr of shunt capacitors at the Vermont Yankee 115kV bus (Section 3.2). One bank of 30MVAr and two banks of 15MVAr are proposed. The 30MVAr bank should be connected such that is trips with the autotransformer. The 15MVAr banks should be connected to the 115kV bus such that they are available with the autotransformer out of service.

The study identified the Vermont Yankee-Northfield 345kV line relay replacement as a reliability upgrade required to mitigate preexisting conditions. It was not prompted by the Vermont Yankee uprate, however it is required for the uprate. The Ascutney-Coolidge 115kV line upgrade and Vermont Yankee 115kV shunt capacitors are upgrades associated with the uprate project itself. The Vermont Yankee area voltage performance was significantly better with the uprate and its associated capacitor banks than with the existing system. In addition, Entergy has verified that there is sufficient room for the capacitor banks and any associated equipment.

Overloads were also observed, both with and without the uprate, on the Wallingford Tap-Mt Holly-Ludlow 46kV line segment under peak load conditions in response to the Ascutney-Coolidge 115kV line outage. This is a pre-existing problem that is adversely impacted by the uprate. Currently, there is no proposed mitigation for this problem. The uprate is not responsible for any additional mitigation.

The N-2 power flow analysis, as described in Section 3.6, showed the need for no additional system reinforcements due to the uprate. The Vermont Yankee plant will be required to reduce power output at the rate of approximately 13MW/min in order to reduce output from 667MW to 275MW in 30 minutes. Entergy has confirmed that this ramp rate can be safely achieved.

The results of the stability analysis are described in Section 4 and show that the following upgrades will be required as part of the Vermont Yankee uprate project:

1. Modification to provide a second primary protection scheme on the Vermont Yankee north bus to achieve acceptable performance in response to the normal contingency fault NC14.
2. Addition to provide a second primary protection scheme on the Vermont Yankee GSU to achieve acceptable performance in response to the normal contingency fault NC15.
3. Independent pole tripping on the Vermont Yankee 381 breaker is required to achieve acceptable performance in response to the extreme contingency fault EC8.
4. Addition of out of step protection on the Vermont Yankee generator to ensure acceptable performance in response to several extreme contingencies.

The study identified the second primary protection schemes as reliability upgrades required to mitigate preexisting conditions. It was not prompted by the Vermont Yankee uprate, however it is required for the uprate. The IPT breaker operation and the out of step protection are upgrades associated with the uprate project itself. Whether breaker 381 upgrade or replacement is required to achieve IPT capability will be determined by the facilities study.

ΔP is the sudden change in generator power output resulting from line switching; it is measured in per unit of the machine MVA rating. ΔP levels that could be imposed on the Vermont Yankee generator were calculated under relatively stressed transmission system loading conditions that would result in relatively high ΔP values. The highest level observed for the uprate with all lines in service was 0.36pu in response to reclosing Section 381 (Vermont Yankee-Northfield 345kV). The highest ΔP observed for the uprate with a line out of service was 0.39pu in response to reclosing Section 381 (Vermont Yankee-Northfield 345kV) with Section 394 (Seabrook-Tewksbury 345kV) out. The Vermont Yankee project has the option to mitigate the ΔP levels if it deems such action necessary.

After the uprate, the Vermont Yankee plant operators will continue to be required to reduce plant output to 275MW within 30 minutes of being instructed to do so by the System Operator immediately following the occurrence of certain single line outages. This requirement enables the System Operator to return the system to a secure operating state within 30 minutes of a continuous outage of a single transmission line or facility in accordance with established operating criteria.

1. Introduction

Entergy is requesting approval for an uprate of the Vermont Yankee nuclear plant. The Vermont Yankee Extended Power Uprate Project will increase the output of the unit in two steps. During the refueling outage scheduled for spring of 2004, numerous modifications will be implemented, including replacement of the high pressure turbine steam path and rewind of the main generator to increase the nameplate rating to 684MVA. Following receipt of Nuclear Regulatory Commission (NRC) approval of the Extended Power Uprate license amendment application during the third quarter of 2004, Vermont Yankee will increase its power output to as high as 624 MW gross and 150 MVAR. After the refueling outage scheduled for the fourth quarter of 2005, Vermont Yankee will further increase its power output to 667 MW gross and 150 MVAR.

The purpose of this study was to analyze the impact of this uprate on the interconnected New England system in accordance with the "NEPOOL Reliability Standards" and the NEPOOL "Minimum Interconnection Standard", and to identify any necessary facility upgrades to meet these standards under the NEPOOL Subordinate 18.4 Application Policy. Relevant queued resources for this project include the Berwick Energy Center, UAE Tewksbury, Neptune Phase 3 Boston Import, Neptune Phase 7 Wyman Export, Mystic 4,5, 6 conversion, and Millstone #3 uprate projects. Vermont Yankee is subordinate to all of these.

The capabilities of the existing Vermont Yankee plant as well as the proposed uprate are shown in *Table 1-1*. For this study, the existing Vermont Yankee unit was represented with a rating of 626MVA, a power output rating of 563MW, and a gross reactive power output rating of 150MVAr at rated power output. The final Vermont Yankee uprate configuration, with a power output of 667 MW gross, was evaluated rather than the intermediate uprate, with a power output of 624 MW gross. An analysis of system performance with the final uprate and its associated reinforcements ensures that system performance with the intermediate uprate and the same reinforcements would be acceptable. Therefore, the proposed uprate project was represented with a rating of 684MVA, a final power output rating of 667MW, and a gross reactive power output rating of 150MVAr at rated power output.

A one-line diagram of the Vermont Yankee plant and substation is shown in *Figure 1-1*. The station service load is connected to the generator terminal bus, and the cooling tower load is connected to the 115kV bus. Station service load is in-service for all system conditions. The cooling tower load is in-service for all study conditions except for the light load cases, because it is not needed during lower ambient temperatures.

The study approach is described in Section 2. Power flow, transient stability and short circuit analyses were performed. The results of the power flow analysis are described in Section 3, the stability analysis results are described in Section 4 and the short circuit analysis results are described in Section 5. Conclusions and recommendations are presented in Section 6.

Table 1-1. Capability of Existing and Uprated Vermont Yankee Plant.

Generator (gross)	Present	Uprate
MVA rating Pmax Pmin Qmax Qmin	626 MVA 563 MW 0 MW 150 MVAr -100 MVAr	684 MVA 667 MW 0 MW 150 MVAr -100 MVAr
Station Service Load		
P Q	25.5 MW 13.5 MVAr	25.5 MW 13.5 MVAr
Cooling Tower Load		
P Q	8.5 MW 5.7 MVAr	8.5 MW 5.7 MVAr

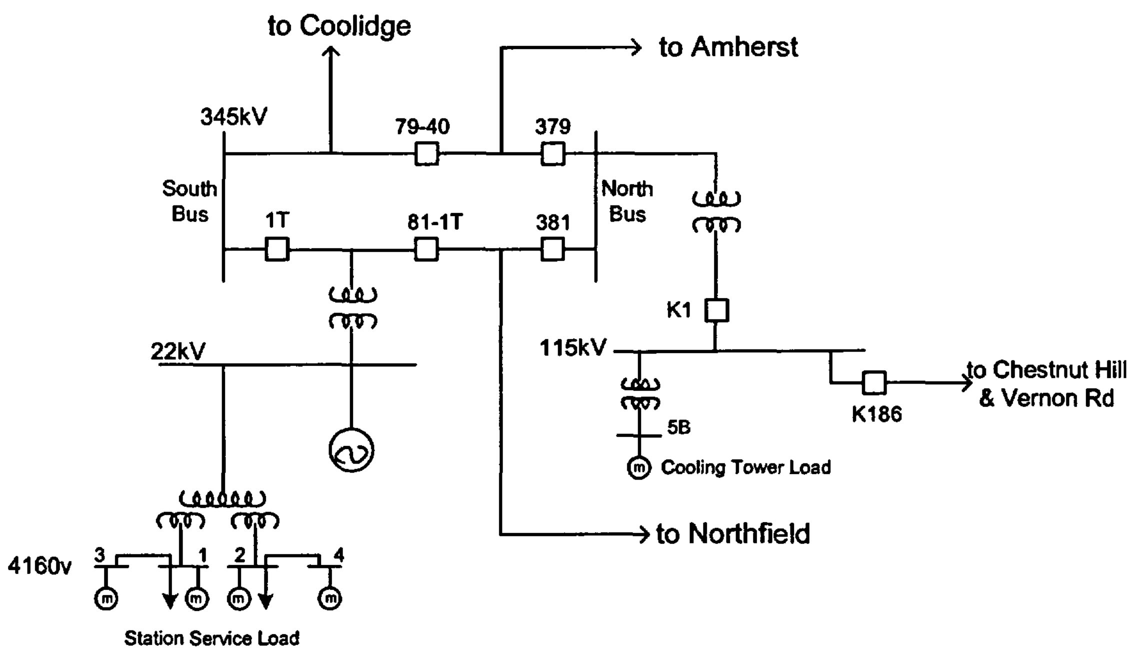


Figure 1-1. Existing Vermont Yankee Plant and Substation One-Line Diagram.

2. Study Approach

This study used a relative performance approach to determine the impact of the proposed Vermont Yankee nuclear plant uprate on the New England (NE) power system. First, system performance without the proposed uprate was determined in order to establish the benchmark. Then system performance with the proposed uprate was determined and compared to the benchmark. This relative approach removed any ambiguities as to the actual impact of the proposed project since existing criteria violations, if any, were identified. The following Sections describe the benchmark system conditions, uprate project study scenarios, as well as the performance criteria and contingency list.

The analysis was performed using PSEC's Positive Sequence Load Flow (PSLF) software package. PSLF is a large-scale database and network solution program for power flow analysis. It also includes the Symmetrical Component Short-Circuit (SCSC) program for fault current calculations and the Positive Sequence Dynamic Simulation (PSDS) program for transient stability analyses.

2.1 Power Flow Study

2.1.1 Benchmark System

The study was based on the "2000 New England Library" summer peak and light load conditions for 2006. The study cases were developed from databases used in a previous study. Mutually agreed upon modifications were made to these databases before the study began. Such modifications included the addition of new generating units, transmission system reinforcements, and load increases to better reflect expected 2006 load levels.

The generation unit additions were as follows:

- AES Londonderry 721MW combined cycle plant connected to the 230kV lines between Tewksbury and Comerford
- UAE Lowell, two 46MW units connected near the Tewksbury 115kV bus
- UAE Tewksbury, three 200MW gas turbines connected to the Tewksbury 345kV bus
- Mystic 8 800MW combined cycle plant connected to the Mystic 345kV bus
- Mystic 9 800MW combined cycle plant connected to the Mystic 115kV bus
- Fore River 800MW combined cycle plant connected to the Edgar 115kV bus

The transmission system modifications were as follows:

- Add Vermont 46kV system from Bennington to Vernon Rd
- Modify CVPS 46kV loads, increase Wallingford Tap-Mt. Holly-Ludlow 46kV line rating from 17MVA to 17.9MVA
- Add two 13.1MVAr, one 26.2MVAr capacitor banks at Chestnut Hill 115kV bus
- Add 350MVA, +/-60 degree PAR at Sand Bar 115kV bus

- Add 24.75MVAr 115kV capacitor bank at Georgia 115kV bus
- Add 26.4MVAr capacitor bank at each of the two 115kV Ocean Road buses
- Add two 25.4MVAr, one 12.6MVAr capacitor banks at Three Rivers 115kV bus
- Add two 25.4MVAr capacitor banks at Madbury 115kV bus
- Add 104.8MVAr capacitor bank at Frostbridge 115kV bus
- Add 157.2MVAr capacitor bank at Southington 115kV bus
- Add 63MVAr capacitor bank at Millbury 115kV bus
- Add 54MVAr capacitor bank at NBORO Road 115kV bus
- Add 20MVAr capacitor bank at Beebe 115kV bus
- Add 50MVAr capacitor bank at Crowleys 115kV bus
- Add 72MVAr capacitor bank at Merrimack 115kV bus
- Add a second Scobie 345/115kV autotransformer, identical to the existing autotransformer
- Upgrade Merrimack 230/115kV transformer rating from 230/245/305 MVA to 230/300/305 MVA
- Upgrade Deerfield-Garvins 115kV (Section G146) transmission line rating from 160/170/200 MVA to 300/380/430 MVA
- Upgrade Dover-Three River 115kV line rating from 165/180/210 MVA to 165/240/240 MVA
- Upgrade Maxcys-Bowman 115kV (Section 60) rating from 185.1/226.1/241.4 MVA to 190.1/232.5/251.5 MVA
- Maxcys-Augusta East Side 115kV (Section 88) line rating from 72.2/72.2/79.1 MVA to 126.8/126.8/135.1 MVA
- Upgrade Scobie-Lawrence 345kV line rating from 1220/1405/1430 MVA to 1220/1430/1430 MVA
- Upgrade Dunbarton-Merrimack 230kV line rating from 230/245/305 MVA to 230/300/305 MVA
- Add a third PAR at Waltham, identical to the two existing PARs
- Add 2.75ohm series reactor to Mystic-Woburn 115kV line
- Add North Cambridge-Brighton A 115kV series reactor
- Add North Cambridge-Brighton B 115kV series reactor
- Add Great Bay 115kV substation, 115/34.5kV transformer, and 27.1MW, 3.9MVAr load

The proposed VELCO 115kV Northern Loop project, with an expected in service date of December 2004, and the proposed VELCO Northwest Vermont Reliability Project (NRP), with expected in service dates ranging from May 2004 to December 2007, were not included. These projects were not represented for two reasons. First, because of uncertainties regarding in service dates and whether or not the VELCO projects would be completed before the uprate. Second, because the uprate would not adversely impact system performance with these projects due to its electrical distance from the projects and the intent of the VELCO projects is to maintain rather than increase the transfer capability of the transmission system external to Vermont.

A detailed model of the Vermont Yankee plant, down to the 4.16kV buses, was added to the system model. This load model includes transformers, individual motors and lumped equivalent induction motors. The 4160v plant buses are shown in all one-line diagrams of the Vermont system.

The Essex STATCOM was represented as a synchronous condenser in the power flows with a reactive power capability of +/-75MVAr. Two 5 MVAr capacitor banks were modeled on the STATCOM 3.2kV terminal bus. In addition, a total of 148.5MVAr of shunt capacitor banks were represented on the Essex 115kV bus. Two banks (24.75MVAr each) are always in service. The remaining four banks are in service as needed to support the Essex 115kV bus voltage.

The Highgate HVDC link is included in all cases, but with power transfer levels that vary with system load condition. The shunt capacitor banks at the Highgate 115kV bus are represented by a synchronous generator with a reactive power capability from 0 to 140MVAr.

For the power flow analysis, three peak load cases, representing the 2006 summer 90/10 peak load condition as published in the 2003 CELT report (New England total load and losses of approximately 28029 MW) were developed. One light load case, representing the 2006 light load condition (45% of 50/50 peak load, or approximately 11831 MW), was developed. One shoulder load case, representing the 2006 75% of 50/50 summer peak load condition (approximately 19715 MW), was developed. A second light load sensitivity case was also developed. The databases used in the power flow analysis represented each generation unit's maximum power output at its 50°F operating capability. Station service load is in-service for all system conditions. Cooling tower load is in-service for all conditions except for the light load cases, because it is not needed during lower ambient temperatures.

A brief summary of each benchmark case, including significant interface flows and major New England real and reactive power generation output, is shown in *Tables 2-1* and *2-2*. *Table 2-1* shows the real power output of major New England generating plants and selected NE interface flows. *Table 2-2* shows the reactive power output of major New England generating plants and selected reactive device output. A detailed summary for each case of the generation dispatch across New England, as well as additional interface flows and other information, is included in *Appendix A*. One line diagrams of the Vermont and NE 345kV transmission system for each case are also included in this appendix.

2.1.2 Vermont Yankee Uprate System

The proposed Vermont Yankee nuclear plant uprate increases the unit rating from 626MVA to 684MVA and the maximum power generation from 563MW to 667MW.

The maximum reactive power output remains at 150MVAr. There is also no expected change in the station service or cooling tower loads.

Six power flow cases with the proposed Vermont Yankee uprate were developed from the six benchmark cases described above. The Vermont Yankee uprate was redispatched against Merrimack G1 for all cases.

A brief summary of each uprate case, including significant interface flows and major New England real and reactive power generation output, is also shown in *Tables 2-1* and *2-2* with the corresponding benchmark cases. *Table 2-1* shows the real power output of major New England generating plants and selected NE interface flows. *Table 2-2* shows the reactive power output of major New England generating plants and selected reactive device output. A detailed summary for each case of the generation dispatch across New England, as well as additional interface flows and other information, is included in *Appendix B*. One line diagrams of the Vermont and NE 345kV transmission system for each case are also included in this appendix.

Table 2-1. Real Power Summary for Major New England Generating Plants and Selected Interface Flows.

	Light Load, TLT1		Light Load, TLT2		Peak Load, TPK1		Peak Load, TPK2		Peak Load, TPK3		Shoulder Load, TSH1		
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Pmax[3]**
NE Load (+ Losses)[1]	11944	11941	11942	11939	28049	28049	28007	28008	28043	28042	19781	19782	
NE Load (+ Losses) Goal	11831	11831	11831	11831	28029	28029	28029	28029	28029	28029	19715	19715	
Generation													
VT Yankee	563	667	563	667	536	667	536	667	536	667	536	667	563/667
Other Vermont	89	89	89	89	109	109	109	109	109	109	109	109	214
MIS	523	523	523	523	523	523	523	523	523	523	523	523	523
Bucksport	0	0	0	0	130	130	130	130	130	130	100	100	174
RPA	0	0	0	0	266	266	266	266	266	266	0	0	266
AEC	0	0	0	0	173	173	173	173	173	173	115	115	173
Other Western Maine[2]	67	67	67	67	233	233	185	185	233	233	198	198	247
WF Wyman 1,2,3	0	0	0	0	57	57	0	0	57	57	57	57	239
WF Wyman 4	0	0	0	0	0	0	0	0	0	0	0	0	636
Westbrook	0	0	0	0	531	531	531	531	531	531	531	531	531
Schiller 4,5,6	0	0	0	0	145	145	48	48	145	145	48	48	145
Merrimack 1,2	113	0	0	0	433	320	433	320	433	320	113	0	433
Newington 1	0	0	0	0	411	411	411	411	411	411	0	0	411
Con Ed Newington	267	267	533	436	533	533	533	533	533	533	533	533	533
Canal 1,2	0	0	0	0	966	966	966	966	966	966	498	498	1142
Brayton Point 1,2,3,4	0	0	0	0	1501	1501	1260	1260	1501	1501	425	425	1501
AES Londonderry	721	721	721	721	721	721	721	721	721	721	721	721	810
UAE Tewksbury	0	0	0	0	0	0	0	0	0	0	0	0	591
Mystic 7	565	565	565	565	565	565	565	565	565	565	0	0	565
Mystic 8	0	0	0	0	824	824	824	824	824	824	700	700	824
Mystic 9	700	700	700	700	824	824	824	824	824	824	700	700	824
Edgar/Fore River	702	702	702	702	824	824	824	824	824	824	702	702	824
Seabrook	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209
Northfield/Bear Swamp	-1560	-1560	-1560	-1560	1640	1640	1640	1640	1640	1640	1640	1640	1640
Comerford/Moore	0	0	0	0	0	0	0	0	0	0	0	0	356
Salem Harbor	0	0	0	0	79	79	79	79	79	79	79	79	702
Millstone 2,3	2008	2008	2008	2008	1146	1146	1146	1146	1146	1146	1146	1146	2008
Total	**3959**	**3950**	**4112**	**4119**	**13233**	**13251**	**12790**	**12808**	**13233**	**13251**	**9537**	**9555**	

Table 2-1. Real Power Summary for Major New England Generating Plants and Selected Interface Flows (continued).

	Light Load, TLT1		Light Load, TLT2		Peak Load, TPK1		Peak Load, TPK2		Peak Load, TPK3		Shoulder Load, TSH1	
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**
Interfaces												
NB/NE	696	696	696	696	696	696	696	696	696	696	696	696
Orrington-South	1095	1095	1095	1095	989	989	989	989	989	989	1083	1083
Surowiec-South	1082	1082	1048	1048	936	936	895	895	937	937	1043	1043
ME/NH	971	971	937	937	1031	1030	932	932	1032	1032	1332	1332
Seabrook South	1195	1189	1333	1278	1625	1619	1606	1600	1617	1612	1416	1410
NNE-Scobie+394 (variable limit)	2112 (2385)	2083 (2385)	2282 (2545)	2192 (2545)	2626 (2800)	2595 (2800)	2502 (2800)	2471 (2800)	2627 (2800)	2596 (2800)	2529 (2725)	2498 (2725)
North-South	2934	2929	3006	3012	2518	2536	2371	2388	2483	2502	2760	2777
East-West	712	605	726	633	1967	1858	1239	1130	2235	2126	1949	1839
CT Import	-714	-714	-605	-606	2289	2289	2273	2273	2121	2121	1367	1366
PV 20 Import	143	145	141	141	144	144	144	145	143	144	141	142
NEMA/Boston Import	1171	1169	1157	1155	3814	3813	3790	3789	3774	3777	2799	2798
Boston Import	1053	1050	1043	1039	3242	3240	3214	3212	3254	3253	2361	2359
SEMA/RI Export	-464	-463	-495	-495	1829	1829	1260	1260	2061	2061	556	556
NY/NE	-5	1	2	-8	18	-1	721	704	-692	-711	-1211	-1229
Northwest Vermont	-11	-10	-11	-10	297	298	299	300	295	296	129	130
Central Vermont	-93	-85	-71	-69	190	198	218	225	170	178	20	28
Highgate HVDC	220	220	220	220	215	215	215	215	215	215	215	215
Phase II HVDC	0	0	0	0	2000	2000	2000	2000	2000	2000	2000	2000

Notes:
1. Does not include 95MW of motor load (modeled as generators)
2. Includes Wyman, Williams, Harris, SEA, Gorbell
3. Maximum power is the generator output in the power flow. For most machines it represents a net value. Station service load is modeled only at Vermont Yankee, Seabrook, Mystic 8, Mystic 9, and Fore River. At those plants, the maximum power therefore represents a gross value.

Table 2-2. Reactive Power Summary for Major New England Generating Plants and Selected Interface Flows.

	Light Load, TLT1		Light Load, TLT2		Peak Load, TPK1		Peak Load, TPK2		Peak Load, TPK3		Shoulder Load, TSH1		
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Qmax**
NE Load (+ Losses)[1]	11944	11941	11942	11939	28049	28049	28007	28008	28043	28042	19781	19782	
NE Load (+ Losses) Goal	11831	11831	11831	11831	28029	28029	28029	28029	28029	28029	19715	19715	
Reactive Generation													
VT Yankee	150	150	150	150	150	150	150	150	150	150	150	150	150
Other Vermont	-9	-8	-10	-10	11	12	12	13	11	13	-6	-5	205
MIS	75	73	85	85	160	160	152	152	160	160	132	132	324
Bucksport	0	0	0	0	58	58	56	56	58	58	44	44	120
RPA	0	0	0	0	72	72	70	70	72	72	0	0	190
AEC	0	0	0	0	59	59	57	57	59	59	23	23	123
Other Western Maine[2]	3	3	3	3	45	45	35	35	45	45	12	12	103
WF Wyman 1,2,3	0	0	0	0	14	14	0	0	14	14	14	14	83
WF Wyman 4	0	0	0	0	0	0	0	0	0	0	0	0	242
Westbrook	0	0	0	0	103	104	107	108	104	105	114	115	330
Schiller 4,5,6	0	0	0	0	29	30	25	25	29	31	25	25	75
Merrimack 1,2	-10	0	0	0	54	56	49	51	57	58	-10	0	203
Newington 1	0	0	0	0	38	39	35	36	39	39	0	0	180
Con Ed Newington	0	0	38	27	113	116	105	108	116	118	108	110	330
Canal 1,2	0	0	0	0	359	359	359	359	359	359	120	120	359
Brayton Point 1,2,3,4	0	0	0	0	339	341	358	360	301	299	163	163	752
AES Londonderry	101	94	114	111	232	232	228	229	235	234	95	95	441
UAE Tewksbury	0	0	0	0	0	0	0	0	0	0	0	0	300
Mystic 7	-150	-150	-150	-150	204	207	221	234	184	191	0	0	335
Mystic 8	0	0	0	0	230	230	230	230	230	230	34	34	515
Mystic 9	50	42	45	43	328	328	331	336	325	325	134	133	515
Edgar/Fore River	0	-2	10	10	30	30	39	39	-7	-8	29	29	515
Seabrook	75	75	106	92	394	398	381	385	394	396	269	270	560
Northfield/Bear Swamp	341	346	351	366	514	515	536	538	516	517	502	501	610
Comerford/Moore	0	0	0	0	0	0	0	0	0	0	0	0	119
Salem Harbor	0	0	0	0	32	32	32	32	32	32	32	32	386
Millstone 2,3	0	0	0	0	459	463	364	367	489	493	165	169	940
Total	**626**	**623**	**742**	**727**	**3568**	**3587**	**3568**	**3603**	**3483**	**3497**	**1984**	**1997**	

Notes:
1. Does not include 95MW of motor load (modeled as generators)
2. Includes Wyman, Williams, Harris, SEA, Gorbell

Table 2-2. Reactive Power Summary for Major New England Generating Plants and Selected Interface Flows (continued).

	Light Load, TLT1		Light Load, TLT2		Peak Load, TPK1		Peak Load, TPK2		Peak Load, TPK3		Shoulder Load, TSH1		
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Qmax**
Reactive Devices													
Chester SVC	30	30	30	30	30	30	30	30	30	30	30	30	30
Orrington 345kV	201	201	201	201	201	201	201	201	21	201	201	201	201
Σ of Maxcys, Mason, Surowiec, South Gorham	300	300	250	250	350	350	350	350	350	350	300	300	300
Crowleys 115kV	50	50	50	50	50	50	50	50	50	50	50	50	50
Sanford 115kV	31	31	31	31	31	31	31	31	31	31	31	31	31
Beebe 115kV	20	20	20	20	20	20	20	20	20	20	20	20	20
3 Rivers 115kV	63	63	63	63	63	63	63	63	63	63	63	63	63
Ocean 115kV	53	53	53	53	53	53	53	53	53	53	53	53	53
Merrimack 230kV	72	72	72	72	72	72	72	72	72	72	72	72	72
Madbury 115kV	51	51	51	51	51	51	51	51	51	51	51	51	51
Chestnut Hill 115kV	52	52	52	52	52	52	52	52	52	52	52	52	52
Highgate 115kV	112	113	112	111	104	105	105	106	15	105	107	107	112
Highgate 46kV	0	0	0	0	0	0	0	0	0	0	0	0	0
Georgia 115kV	25	25	25	25	25	25	25	25	25	25	25	25	25
Sand Bar 115kV	0	0	0	0	25	25	25	25	25	25	25	25	0
Berlin 115kV	25	25	25	25	25	25	25	25	25	25	25	25	25
Barre 34.5kV	11	11	11	11	16	16	16	16	16	16	16	16	11
Essex Caps 115kV	109	109	109	109	119	119	119	119	124	124	119	119	109
Essex STATCOM	-6	-6	-8	-8	-1	-1	-1	0	-1	0	-8	-8	-6
Williston 115kV	0	0	0	0	25	25	25	25	25	25	0	0	0
Middlebury 115kV	0	0	0	0	23	23	23	23	23	23	0	0	0
Rutland 115kV	0	0	0	0	24	24	24	24	24	24	0	0	0
Coolidge 115kV	50	50	50	50	50	50	50	50	50	50	50	50	50
Ascutney 46kV	16	16	16	16	16	16	16	16	16	16	16	16	16

2.1.3 Performance Criteria

For the power flow analysis, different thermal, or branch loading, performance criteria were used for normal operation and for contingency operation. Similarly, different criteria were used to determine acceptable pre- and post-contingency bus voltages.

The thermal criteria required branch loading to be less than 100% of normal rating (Rate 1) for pre-contingency conditions, and to be less than the long term emergency (LTE) rating (Rate 2) for post-contingency conditions. The voltage criteria are summarized in *Table 2-3*.

Table 2-3. Voltage Performance Criteria for Power Flow Analysis.

Region	kV	Pre-contingency Voltage Criteria	Post-contingency Voltage Criteria
Vermont Yankee	345kV	0.985 pu < Vbus < 1.05 pu	0.985 pu < Vbus < 1.05 pu
Vermont Yankee	115kV	1.00 pu < Vbus < 1.05 pu	1.00 pu < Vbus < 1.05 pu (auto in) 0.95 pu < Vbus < 1.05 pu (auto out)
Vermont Yankee	4160v	0.90 pu < Vbus < 1.05 pu	0.90 pu < Vbus < 1.05 pu
Vermont	115kV 345kV	0.95 pu < Vbus < 1.05 pu	0.92 pu < Vbus < 1.05 pu
Chester	345kV	0.97 pu < Vbus < 1.042 pu	0.97 pu < Vbus < 1.042 pu
Seabrook	345kV	1.00 pu < Vbus < 1.05 pu	1.00 pu < Vbus < 1.05 pu
BHE	115kV	0.90 pu < Vbus < 1.05 pu	0.90 pu < Vbus < 1.05 pu
CMP, NSTAR, PSNH	115kV 345kV	0.95 pu < Vbus < 1.05 pu	0.95 pu < Vbus < 1.05 pu
Other NE	115kV	0.95 pu < Vbus < 1.05 pu	0.90 pu < Vbus < 1.05 pu
	345kV	0.95 pu < Vbus < 1.05 pu	0.95 pu < Vbus < 1.05 pu
NY Pleasant Valley 74344	345kV	0.994 pu < Vbus < 1.05 pu	0.951 pu < Vbus < 1.10 pu
NY Oakdale 75405	345kV	0.977 pu < Vbus < 1.05 pu	0.942 pu < Vbus < 1.10 pu
NY Oakdale 75415	230kV	0.943 pu < Vbus < 1.05 pu	0.900 pu < Vbus < 1.05 pu
NY Watercure 75418	230kV	0.935 pu < Vbus < 1.05 pu	0.900 pu < Vbus < 1.05 pu
NY Edic 78450	345kV	1.010 pu < Vbus < 1.05 pu	0.951 pu < Vbus < 1.05 pu
NY Leeds 78701	345kV	1.000 pu < Vbus < 1.05 pu	0.951 pu < Vbus < 1.08 pu
NY New Scotland 77	345kV	1.010 pu < Vbus < 1.05 pu	0.951 pu < Vbus < 1.05 pu
NY New Scotland 79	345kV	1.010 pu < Vbus < 1.05 pu	0.951 pu < Vbus < 1.05 pu
NY Marcy	345kV	1.010 pu < Vbus < 1.05 pu	0.951 pu < Vbus < 1.10 pu

Presently, Vermont Yankee requires that the voltage on both the 345kV and 115kV buses be maintained at 1.0 pu or above, under pre- and post-contingency conditions, whether the autotransformer is in service or not. The proposed changes, noted in the *Table 2-3*, will need to be reflected in the appropriate operations documents, such as MS#1, before they can go into effect.

The monitored region consisted of area 701 (NE), and selected buses in 702 (NY).

The power flow analysis was performed with pre-contingency solution parameters that allowed SVDs, PARs, and LTCs to move. The post-contingency solution parameters allowed SVDs and LTCs only to move for area 701 (NE), except for zones 41 (VELCO-

VT) and 42 (VELCO-NC). In these Vermont zones, no control action was allowed post-contingency.

2.1.4 Contingency List

The power flow contingency list consisted of single line contingencies, as well as multiple element outages reflecting the results of stuck breaker faults. These outages focused on the 345kV and 115kV transmission system near Vermont Yankee. The full contingency list is shown in *Table 2-4*.

Table 2-4. Power Flow Contingency List.

#	Description
1	Loss of Section 379 (Scobie-Amherst-Vermont Yankee 345kV)
2	Loss of Section 394 (Seabrook-Ward Hill-Tewksbury 345kV), Ward Hill 345/115kV autotransformer, and Pelham-G192 Tap 115kV line (SPS #31)
3	Loss of Section 326 (Scobie-Lawrence-Sandy Pd 345kV), Lawrence 345/34.5kV autotransformer
4	Loss of Section 312 (Northfield-Many-Alps-Berkshire 345kV), Berkshire 345/115kV autotransformer
5	Loss of Section 354 (Northfield-Ludlow 345kV)
6a	Loss of Highgate HVDC, St. ALB-T-Highgate 115kV line
6b	Loss of Highgate HVDC, St. ALB-T-Highgate 115kV line, insert Sandbar series reactor
7	Loss of PV-20, Plattsburgh-Grand-S. Hero-Sandbar 115kV line, run back Highgate to 150 MW
8	Loss of Section K-30 (West Rutland-Florence-Middlebury 115kV), Florence 115/46kV transformer
9	Loss of Section K-35 (Coolidge-Cold River 115kV)
10	Loss of Section K-31 (Coolidge-Ascutney 115kV)
11	Loss of Section K-149/W-149S (Ascutney-Slayton Hill-Bellows Falls 115kV)
12	Loss of Section W-149N (Wilde-Slayton Hill-Mt. Support 115kV)
13	Loss of Section K-174 (Ascutney-North Road 115kV)
14	Loss of Section M-127 (North Road-Webster 115kV)
15	Loss of Section K-186 (Vermont Yankee-Vernon Road-Chestnut Hill 115kV), and loads
16	Loss of Section N-186 (Chestnut Hill-Westport-Swanzey-Keene 115kV), including Chestnut Hill 115kV capacitor banks
17	Loss of Section L-163 (Keene-Jackman 115kV)
18	Loss of Section F-162 (Jackman-Greggs 115kV)
19	Loss of Section T-198 (Keene-Monadnock 115kV)
20	Loss of Section I-135N (Bellows Falls-Monadnock Tap-Flagg Pond- East Winchendon-Ashburnham 115kV)
21	Loss of Section I-135S (Flagg Pond-Pratts Junction 115kV)
22	Loss of Section I-136N (Bellows Falls-East Winchendon-Ashburnham-Flagg Pond 115kV), Ashburnham 115/13.8kV transformer
23	Loss of Section J136S (Flagg Pond-Litchfield Street-Pratts Junction 115kV)

Table 2-4. Power Flow Contingency List (continued).

#	Description
24	Granite K52 breaker failure, Loss of Section K-26 (Barre-Wilder 115kV), Chelsea 115/46kV transformer, and Hartford 115/46kV transformer
25	Loss of Section F-206 (Comerford-Granite 230kV), Granite transformer
26	Loss of Section 340 (Vermont Yankee-Coolidge 345kV)
27	Loss of Section 350 (Coolidge-West Rutland 345kV)
29	Loss of Section 381 (Vermont Yankee-Northfield 345kV)
30	Loss of Vermont Yankee 345/115kV autotransformer
31	Loss of Coolidge 345/115 autotransformer
32	Coolidge 40-50 breaker failure, Loss of Sections 350 (Coolidge-West Rutland 345kV) and 340 (Vermont Yankee-Coolidge 345kV)
33	Vermont Yankee 79-40 breaker failure, Loss of Sections 379 (Scobie-Amherst-Vermont Yankee 345kV) and 340 (Vermont Yankee-Coolidge 345kV)
34	Vermont Yankee 379 breaker failure, Loss of Section 379 (Scobie-Amherst-Vermont Yankee 345kV) and Vermont Yankee autotransformer
35	Vermont Yankee 381 breaker failure, Loss of Section 381 (Vermont Yankee-Northfield 345kV line) and Vermont Yankee autotransformer
36	Vermont Yankee 1T breaker failure, Loss of Section 340 (Vermont Yankee-Coolidge 345kV) and Vermont Yankee GSU and generator
37	Loss of Granite-Wilder 115kV, Chelsea and Hartford 115/46kV transformers.
38	Loss of Granite-Chelsea 115kV
39	Granite K52 breaker failure, loss of K26-Barre-Chelsea 115kV

2.2 Transient Stability Study

2.2.1 Benchmark System

A light load power flow case, slt1, was developed to represent a New England 2005 light load condition with a high level of Maine generation, and with the modifications described in *Section 2.1.1.* As noted in that Section, the proposed VELCO 115kV Northern Loop project, with an expected in service date of December 2004, and the proposed VELCO Northwest Vermont Reliability Project (NRP), with expected in service dates ranging from May 2004 to December 2007, were not included. However, the Amherst project, represented as a 345kV four circuit breaker ring bus at the Amherst Substation, was included in the stability analysis.

Modifications were also made to each generating unit's output such that each in-service unit was generating at its 0^{o} rated output. The overall generation dispatch was also modified to stress the transmission interfaces up to their stability limits, disregarding thermal limitations as needed. A second light load power flow case, slt2, was developed from the above slt1 case with the Newington units replacing some of the Maine generation. A peak load power flow case, spk1, representing a New England 2006 peak load condition was also developed. Finally, two peak power flow sensitivity cases with high levels of East-West interface flow were developed. One case includes all Northfield units, spk4, and one cases includes no Northfield units, spk5.

A brief summary of each benchmark case, including significant interface flows and major New England real and reactive power generation output, is shown in *Tables 2-5* and *2-6. Table 2-5* shows the real power output of major New England generating plants and selected NE interface flows. *Table 2-6* shows the reactive power output of major New England generating plants and selected reactive device output. A detailed summary for each case of the generation dispatch across New England, as well as additional interface flows and other information, is included in *Appendix C.* One line diagrams of the Vermont and NE 345kV transmission system for each case are also included in this appendix.

The Vermont Yankee plant was represented using the following models:

- GENROU - Solid rotor generator represented by equal mutual inductance rotor modeling
- EXAC3A - IEEE type AC3A excitation system
- No governor model
- MOTOR1 - a one-cage induction machine for the station service motor loads
- OOSLEN – a three zone out of step relay model with a low voltage threshold

For the stability analysis, the Vermont Yankee exciter was modeled, both pre- and post-uprate, with an *exac3a* model representing an IEEE type AC3A excitation system. This is the manufacturer recommended model and replaced the *ieeet1* model used in prior studies.

Appendix D contains block diagrams and corresponding data for the dynamic models used to represent the existing Vermont Yankee plant in this study.

The Vermont Yankee KLF relay is a loss-of-field relay currently used for out of step protection. The relay operates when all of the following criteria are met for 15 cycles:

- The apparent impedance as seen from the generator is within the impedance circle
- The apparent impedance as seen from the generator is below the reactance characteristic of the directional unit
- The generator terminal voltage is below 0.8pu (17.6kV)

The relay operation characteristic, as provided by Vermont Yankee, is shown in *Appendix F*, as well as the parameters of the *ooslen* model.

The Vermont Yankee 4160v buses are equipped with undervoltage relays that both alarm and trip. If the relay indicates a low bus voltage (less than 0.90pu for more than 10 sec), an alarm is generated. The control room tries to determine the cause of the alarm and contacts the grid dispatcher. If corrective actions are in progress and the alarm will clear quickly, then the plant will stay on line. Otherwise, the operators will take the plant off line. These relays are represented in the motor load models using the voltage and time thresholds that initiate motor tripping.

In addition, there is undervoltage, overvoltage and underfrequency protection on the motor-generator (MG) sets on the reactor protection system (RPS) buses. The voltage protection is only in-service when the MG set voltage regulators are out of service. Hence, that protection was not represented in the stability study. The underfrequency protection was represented. This relay monitors the output of the RPS MG sets and trips when that frequency falls below approximately 57.8Hz. This corresponds to a slightly higher system frequency, due to the slip of the MG drive motor, so actual system frequency corresponding to this trip threshold would be about 58.6Hz. A time delay of 0.15 seconds was assumed for the underfrequency trip. If the underfrequency trips are actuated for both MG sets, the reactor will trip.

Table 2-5. Real Power Summary for Major New England Generating Plants and Selected Interface Flows.

Description	Light Load, SLT1 Existing	Light Load, SLT1 Uprate	Light Load, SLT2 Existing	Light Load, SLT2 Uprate	Peak Load, SPK1 Existing	Peak Load, SPK1 Uprate	Peak Load, SPK4 Existing	Peak Load, SPK4 Uprate	Peak Load, SPK5 Existing	Peak Load, SPK5 Uprate	Pmax[3]
NE Load (+ Losses)[1]	11732	11719	11691	11678	28103	28115	28181	28193	28124	28135	
NE Load (+ Losses) Goal	11831	11831	11831	11831	28029	28029	28029	28029	28029	28029	
Generation											
VT Yankee	563	667	563	667	563	667	563	667	563	667	563/667
Other Vermont	190	87	190	87	109	9	109	8	109	8	232
MIS	358	358	0	0	550	550	550	550	550	550	550
Bucksport	191	191	191	191	191	191	191	191	191	191	191
RPA	0	0	0	0	273	273	273	273	273	273	273
AEC	0	0	161	161	108	108	108	108	108	108	161
Other Western Maine[2]	153	153	153	153	175	175	175	175	175	175	247
WF Wyman 1,2,3	0	0	0	0	239	239	239	239	239	239	239
WF Wyman 4	0	0	0	0	0	0	0	0	0	0	636
Westbrook	579	579	0	0	579	579	579	579	579	579	579
Schiller 4,5,6	0	0	0	0	146	146	146	146	146	146	145
Merrimack 1,2	440	440	440	440	440	440	440	440	440	440	440
Newington 1	0	0	422	422	422	422	422	422	422	422	422
Con Ed Newington	0	0	561	561	561	561	561	561	561	561	561
Canal 1,2	0	0	0	0	1142	1142	1142	1142	1142	1142	1142
Brayton Point 1,2,3,4	482	482	482	482	1320	1320	1320	1320	1320	1320	1561
AES Londonderry	0	0	0	0	811	811	811	811	811	811	810
UAE Tewksbury	0	0	0	0	0	0	0	0	0	0	591
Mystic 7	565	565	565	565	0	0	565	565	565	565	565
Mystic 8	866	866	866	866	866	866	866	866	866	866	866
Mystic 9	866	866	866	866	866	866	866	866	866	866	866
Edgar/Fore River	0	0	0	0	865	865	865	865	865	865	866
Seabrook	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209
Northfield/Bear Swamp	-1310	-1310	-1310	-1310	1666	1666	1080	1080	293	293	1666
Comerford/Moore	356	356	356	356	96	96	96	96	96	96	356
Salem Harbor	400	400	231	231	230	230	745	745	745	745	662
Millstone 2,3	1146	1146	1146	1146	2008	2008	2008	2008	2008	2008	2008
Total	**5908**	**5909**	**5946**	**5947**	**13427**	**13431**	**15929**	**15932**	**15142**	**15145**	

Table 2-5. Real Power Summary for Major New England Generating Plants and Selected Interface Flows (continued).

	Light Load, SLT1		Light Load, SLT2		Peak Load, SPK1		Peak Load, SPK4		Peak Load, SPK5	
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**
Interfaces										
NB/NE	699	699	699	699	696	696	696	696	696	696
Orrington-South	1078	1078	723	723	1059	1059	1059	1059	1059	1059
Surowiec-South	885	885	708	708	909	909	909	909	909	909
ME/NH	1220	1220	484	484	1197	1197	1196	1196	1196	1196
Seabrook South	1017	1018	1478	1479	1704	1705	1636	1637	1625	1626
NNE-Scobie+394 (variable limit)	2121 (2445)	2114 (2445)	2408 (2520)	2402 (2520)	2833 (2800)	2824 (2800)	2826 (2800)	2817 (2800)	2828 (2800)	2819 (2800)
North-South	2961	2985	3214	3238	2990	2991	2895	2892	2957	2957
East-West	2123	2108	2199	2184	2130	2109	3129	3107	3163	3141
CT Import	937	937	728	727	2359	2358	1826	1826	1818	1818
PV 20 Import	103	110	101	109	108	109	102	100	102	102
NEMA/Boston Import	-276	-276	-105	-105	4228	4227	3184	3185	3161	3161
Boston Import	-259	-260	-89	-89	3604	3605	2673	2674	2641	2641
SEMA/RI Export	-246	-246	-246	-246	1957	1957	1947	1947	1952	1952
NY/NE	-271	-285	-262	-275	8	17	-714	-704	16	24
Northwest Vermont	-90	-17	-91	-17	281	364	278	361	278	361
Central Vermont	-171	-142	-168	-139	150	191	92	135	115	158
Highgate HVDC	221	221	221	221	215	215	215	215	215	215
Phase II HVDC	0	0	0	0	2000	2000	2000	2000	2000	2000

Notes:
1. Does not include 95MW of motor load (modeled as generators)
2. Includes Wyman, Williams, Harris, SEA, Gorbell
3. Maximum power is the generator output in the power flow. For most machines it represents a net value. Station service load is modeled only at Vermont Yankee, Seabrook, Mystic 8, Mystic 9, and Fore River. At those plants, the maximum power therefore represents a gross value.

Table 2-6. Reactive Power Summary for Major New England Generating Plants and Selected Interface Flows.

	Light Load, SLT1		Light Load, SLT2		Peak Load, SPK1		Peak Load, SPK4		Peak Load, SPK5		
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Qmax**
NE Load (+ Losses)[1]	11732	11719	11691	11678	28103	28115	28181	28193	28124	28135	
NE Load (+ Losses) Goal	11831	11831	11831	11831	28029	28029	28029	28029	28029	28029	
Reactive Generation											
VT Yankee	150	150	150	150	150	150	150	150	150	150	150
Other Vermont	-30	-48	-31	-47	15	53	-15	19	-16	18	205
MIS	105	105	0	0	169	169	173	173	173	173	324
Bucksport	58	57	57	57	66	67	68	68	68	68	120
RPA	0	0	0	0	68	68	69	69	69	69	190
AEC	0	0	44	44	50	50	52	52	52	52	123
Other Western Maine[2]	12	12	7	7	34	34	36	36	36	36	103
WF Wyman 1,2,3	0	0	0	0	44	44	47	48	47	48	83
WF Wyman 4	0	0	0	0	0	0	0	0	0	0	242
Westbrook	66	65	0	0	91	92	99	99	99	99	330
Schiller 4,5,6	0	0	0	0	21	23	31	32	31	32	75
Merrimack 1,2	13	5	1	-7	33	46	59	67	57	66	203
Newington 1	0	0	-45	-45	42	43	51	52	52	52	180
Con Ed Newington	0	0	121	119	125	128	154	157	155	157	330
Canal 1,2	0	0	0	0	359	359	359	359	359	359	359
Brayton Point 1,2,3,4	20	19	19	18	400	404	534	539	462	466	752
AES Londonderry	0	0	0	0	231	246	256	276	247	265	441
UAE Tewksbury	0	0	0	0	0	0	0	0	0	0	300
Mystic 7	-150	-150	-150	-150	0	0	251	260	185	193	335
Mystic 8	149	147	142	140	311	314	235	235	235	235	515
Mystic 9	-16	-19	-33	-37	413	416	355	356	343	344	515
Edgar/Fore River	0	0	0	0	30	31	57	58	42	43	515
Seabrook	125	120	133	128	489	501	469	478	455	462	560
Northfield/Bear Swamp	247	256	252	261	537	541	320	320	145	145	610
Comerford/Moore	-25	-38	-27	-42	5	15	14	25	14	25	119
Salem Harbor	-104	-106	-60	-60	79	79	161	161	157	158	386
Millstone 2,3	183	184	154	155	579	584	773	785	598	605	940
Total	**620**	**575**	**580**	**536**	**3762**	**3873**	**4758**	**4874**	**4215**	**4320**	

Table 2-6. Reactive Power Summary for Major New England Generating Plants and Selected Interface Flows (continued).

	Light Load, SLT1		Light Load, SLT2		Peak Load, SPK1		Peak Load, SPK4		Peak Load, SPK5		
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Qmax**
Reactive Devices											
Chester SVC	30	30	30	30	30	30	30	30	30	30	450
Orrington	201	201	201	201	201	201	201	201	201	201	201
Σ of Maxcys, Mason, Surowiec, South Gorham	200	200	50	50	450	450	450	450	450	450	450
Crowleys	50	50	50	50	50	50	50	50	50	50	50
Sanford	31	31	31	31	31	31	31	31	31	31	31
Beebe	20	20	20	20	20	20	20	20	20	20	20
3 Rivers	63	63	63	63	63	63	63	63	63	63	63
Ocean	53	53	53	53	53	53	53	53	53	53	53
Merrimack	72	72	72	72	72	72	72	72	72	72	72
Madbury	51	51	51	51	51	51	51	51	51	51	51
Chestnut Hill	52	52	52	52	52	52	52	52	52	52	52
Highgate	114	112	114	112	107	108	96	97	96	97	140
Highgate 46kV	0	0	0	0	0	0	6	6	6	6	6
Georgia	25	25	25	25	25	25	25	25	25	25	25
Sand Bar	0	0	0	0	0	0	25	25	25	25	25
Berlin	25	25	25	25	25	25	25	25	25	25	25
Barre 34.5kV	0	0	0	0	16	16	16	16	16	16	16
Essex Caps	124	124	124	124	149	149	149	149	149	149	150
Essex STATCOM	-32	-53	-34	-52	3	53	-28	18	-28	17	75
Williston	0	0	0	0	0	0	25	25	25	25	25
Middlebury	23	23	23	23	23	23	23	23	23	23	23
Rutland	0	0	0	0	24	24	24	24	24	24	24
Coolidge	50	50	50	50	50	50	50	50	50	50	50
Ascutney 46kV	16	16	16	16	16	16	16	16	16	16	16

Notes:

1. Does not include 95MW of motor load (modeled as generators)
2. Includes Wyman, Williams, Harris, SEA, Gorbell

2.2.2 Vermont Yankee Uprate System

The proposed Vermont Yankee nuclear plant uprate increases the unit rating from 626MVA to 684MVA and the maximum power generation from 563MW to 667MW. The maximum reactive power output remains at 150MVAr. There is also no expected change in the station service or cooling tower loads.

Power flow cases with the proposed Vermont Yankee uprate were developed from the benchmark cases described above. The Vermont Yankee uprate was redispatched against Vermont units.

A brief summary of each uprate case, including significant interface flows and major New England real and reactive power generation output, is also shown in *Tables 2-5* and *2-6* with the corresponding benchmark cases. *Table 2-5* shows the real power output of major New England generating plants and selected NE interface flows. *Table 2-6* shows the reactive power output of major New England generating plants and selected reactive device output. A detailed summary for each case of the generation dispatch across New England, as well as additional interface flows and other information, is included in *Appendix E.* One line diagrams of the Vermont and NE 345kV transmission system for each case are also included in this appendix.

The Vermont Yankee plant was represented using the following models:

- GENROU - Solid rotor generator represented by equal mutual inductance rotor modeling
- EXAC3A - IEEE type AC3A excitation system
- No governor model
- MOTOR1 - a one-cage induction machine for the station service motor loads
- OOSLEN – a three zone out of step relay model with a low voltage threshold

The parameters associated with the generator model are the only differences between the representation of the existing unit and the uprated unit. The excitation system was unchanged as well as the station service motor load. The same protection functions as described in Section 2.2.1 were also used in the uprate analysis. *Appendix F* contains block diagrams and corresponding data for the dynamic models used to represent the uprated Vermont Yankee plant in this study.

The Vermont Yankee KLF relay settings will be modified as part of the uprate. The relay operates when all of the following criteria are met for 15 cycles:

- The apparent impedance as seen from the generator is within the impedance circle
- The apparent impedance as seen from the generator is below the reactance characteristic of the directional unit
- The generator terminal voltage is below 0.8pu (17.6kV)

The new relay operation characteristic, as recalculated by Stone & Webster and provided by Vermont Yankee, is shown in *Appendix F*, as well as the parameters of the *ooslen* model.

2.2.3 Performance Criteria

The criteria defining stable transmission system performance 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 must be transiently stable except for units tripped for fault clearing
- A 50% reduction in the magnitude of system oscillations must be observed over four periods of the oscillation
- A loss of source greater than 1200MW is not acceptable
- Keswick GCX entry is not acceptable

The criteria defining stable transmission system performance for extreme contingencies (3-phase faults with breaker failure and backup clearing) are as follows:

- Transiently stable with positive damping
- A loss of source greater than 1400MW is not immediately acceptable
- A loss of source between 1400MW and 2200MW may be acceptable depending upon a limited likelihood of occurrence and other factors
- A loss of source above 2200MW is not acceptable
- A 50% reduction in the magnitude of system oscillations must be observed over four periods of the oscillation

Selected 345kV and 115kV bus voltages in Vermont and throughout NE were monitored. The generator angle, field voltage, terminal voltage, machine speed, real and reactive power output were also monitored for all units in Vermont, as well as units with a power output of at least 40MW in the rest of New England. In addition, the angular swings for selected generators in New York were monitored.

2.2.4 Fault Scenario List

A variety of 3-phase and 1-phase faults with both primary and backup clearing were evaluated for this study. *Tables 2-7* and *2-8* summarizes all the fault scenarios that were analyzed. The planned upgrade of the Amherst station to a full ring bus configuration was assumed for faults on Section 379.

Table 2-7. Normal Contingency List for Stability Analysis.

ID	Fault Location	Type	Impedance	Stuck Breaker	Near End Clearing	Far End Location	Clearing
nc1	Chestnut Hill 115kV	3ϕ	0.0+j0.0	none	6.0 cy	VY, Vernon Rd 115kV Vernon Rd 115/69kV TX Vernon Rd 115/46kV TX	35.0 cy 35.0 cy 35.0 cy
nc2	Vermont Yankee 345kV	3ϕ	0.0+j0.0	none	4.0 cy	Amherst 345kV	4.0 cy
nc3	Vermont Yankee 345kV	3ϕ	0.0+j0.0	none	4.0 cy	Northfield 345kV	4.0 cy
nc4	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203 (0-4cy) 0.0033+j0.037 (4-9.3cy)	81-1T	9.3 cy	Northfield 345kV VY Generator	4.0 cy 9.3 cy
nc5	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203 (0-4cy) 0.0033+j0.037 (4-10.3cy)	381	9.3 cy	Northfield 345kV VY 345/115kV Autotransformer	4.0 cy 10.3 cy
nc6	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	1T	9.3 cy	Coolidge 345kV VY Generator	4.0 cy 9.3 cy
nc7	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	79-40	9.3 cy	Coolidge 345kV Amherst 345kV	4.0 cy 10.3 cy
nc8	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	79-40	9.3 cy	Amherst 345kV Coolidge 345kV	4.0 cy 12.6 cy
nc9	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	379	9.3 cy	Amherst 345kV VY 345/115kV Autotransformer	4.0 cy 10.3 cy
nc10	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	381	10.3 cy	VY 345/115kV Autotransformer Northfield 345kV	5.5 cy 12.6 cy
nc11	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	379	10.3 cy	VY 345/115kV Autotransformer Amherst 345kV	5.5 cy 11.3 cy
nc12	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	81-1T	9.3 cy	Northfield 345kV VY Generator	11.55 cy 11.55 cy
nc13	Vermont Yankee 345kV	1ϕ	0.0025+j0.0203	1T	10.3 cy	Coolidge 345kV VY Generator	12.6 cy 12.6 cy
nc14	Vermont Yankee 345kV North Bus	3ϕ	0.0+j0.0	none	27.5 cy	Coolidge, Northfield, Amherst VY Generator VY 345/115kV Autotransformer Chestnut Hill, Vernon Rd 115kV Vernon Rd 115/69kV TX Vernon Rd 115/46kV TX	27.5 cy 27.5 cy 27.5 cy 5.0 sec 5.0 sec 5.0 sec
nc14x	Vermont Yankee 345kV North Bus	3ϕ	0.0+j0.0	none	4.0 cy	VY 379, 381 VY 345/115kV Autotransformer Chestnut Hill, Vernon Rd 115kV Vernon Rd 115/69kV TX Vernon Rd 115/46kV TX	4.0 cy 4.0 cy 5.0 sec 5.0 sec 5.0 sec

Table 2-7. Normal Contingency List for Stability Analysis (continued).

ID	Fault Location	Type	Impedance	Stuck Breaker	Near End Clearing	Far End Location	Clearing
nc15	Vermont Yankee 345/22kV GSU High Side	3ϕ	0.0+j0.0	none	27.5 cy	Coolidge, Northfield, Amherst VY Generator VY 345/115kV Autotransformer	27.5 cy 27.5 cy 27.5 cy
nc15x	Vermont Yankee 345/22kV GSU High Side	3ϕ	0.0+j0.0	none	4.0 cy	VY 81-1T, 1T VY Generator	4.0 cy 4.0 cy
nc16	Northfield 345kV	3ϕ	0.0+j0.0	none	4.0 cy	Alps 345kV Berkshire 345/115kV Autotransformer	4.0 cy 5.0 cy
nc17	Northfield 345kV	3ϕ	0.0+j0.0	none	4.0 cy	Ludlow 345kV	4.0 cy
nc18	Scobie 345kV	3ϕ	0.0+j0.0	none	4.0 cy	Sandy Pond 345kV Lawrence 345/34.5kV Autotransformer	4.0 cy 6.0 cy
nc19	Scobie 345kV	1ϕ	0.0053+j0.0280	7973	8.0 cy	Deerfield 345kV Amherst 345kV	4.0 cy 8.0 cy
nc396	Orrington 345kV	3ϕ	0.0+j0.0	none	4.0 cy	Keswick 345kV Chester SVC	4.0 cy 4.0 cy
nc312	Northfield 345kV	1ϕ	0.0022+j0.0201	3T	8.05 cy	Alps 345kV Berkshire 345/115kV Autotransformer VY 345kV	4.0 cy 5.0 cy 10.3 cy
ph2	Trip Phase II HVDC	NA	NA	none	NA	NA	NA
ny01	Edic 345kV	3ϕ	0.0+j0.0	none	3.5 cy	N.SCOT77 345kV N.SCOT77 re-close N.SCOT77 re-open	5.0 cy 41.0 cy 45.0 cy
ny02	Fraser 345kV	Two 1ϕ	0.0007838+j0.007716	none	3.5 cy	Marcy 345kV Coopers Corners 345kV Edic 345kV	4.5 cy 4.5 cy 5.5 cy
ny03	Marcy 345kV	3ϕ	0.0+j0.0	none	3.5 cy	Massena 345kV Chateauguay 345kV Massena 345kV	5.5 cy 9.5 cy 11.5 cy

Table 2-8. Extreme Contingency List for Stability Analysis.

ID	Fault Location	Type	Impedance	Stuck Breaker	Near End Clearing	Far End Location	Clearing
ec1	Vermont Yankee 115kV	3ϕ	0.0+j0.0	N186	19.3 cy	Chestnut Hill 115kV Vernon Rd 115kV Vernon Rd 115/69kV TX Vernon Rd 115/46kV TX	35.0 cy 35.0 cy 35.0 cy 35.0 cy
ec2	Vermont Yankee 345kV	3ϕ	0.0+j0.0	81-1T	9.3 cy	Northfield 345kV VY Generator	4.0 cy 9.3 cy
ec3	Vermont Yankee 345kV	3ϕ	0.0+j0.0	381	9.3 cy	Northfield 345kV VY 345/115kV Autotransformer	4.0 cy 10.3 cy
ec4	Vermont Yankee 345kV	3ϕ	0.0+j0.0	1T	9.3 cy	Coolidge 345kV VY Generator	4.0 cy 9.3 cy
ec5	Vermont Yankee 345kV	3ϕ	0.0+j0.0	79-40	9.3 cy	Coolidge 345kV Amherst 345kV	4.0 cy 10.3 cy
ec6	Vermont Yankee 345kV	3ϕ	0.0+j0.0	79-40	9.3 cy	Amherst 345kV Coolidge 345kV	4.0 cy 12.6 cy
ec7	Vermont Yankee 345kV	3ϕ	0.0+j0.0	379	9.3 cy	Amherst 345kV VY 345/115kV Autotransformer	4.0 cy 10.3 cy
ec8	Vermont Yankee 345kV	3ϕ	0.0+j0.0	381	10.3 cy	VY 345/115kV Autotransformer Open BKR 81-1T Northfield 345kV	5.5 cy 10.3 cy 12.6 cy
ec8x	Vermont Yankee 345kV	3ϕ	0.0+j0.0	381	9.5 cy	VY 345/115kV Autotransformer Open BKR 81-1T Northfield 345kV	5.5 cy 9.5 cy 10.5 cy
ec8ipt	Vermont Yankee 345kV	3ϕ/1ϕ	0.0025+j0.0203	381	10.3 cy	VY 345/115kV Autotransformer Open BKR 81-1T Northfield 345kV	5.5 cy 10.3 cy 12.6 cy
ec9	Vermont Yankee 345kV	3ϕ	0.0+j0.0	379	10.3 cy	VY 345/115kV Autotransformer Amherst 345kV	5.5 cy 11.3 cy
ec10	Vermont Yankee 345kV	3ϕ	0.0+j0.0	81-1T	11.55 cy	Northfield 345kV VY Generator	11.55 cy 11.55 cy
ec11	Vermont Yankee 345kV	3ϕ	0.0+j0.0	1T	10.3 cy	Coolidge 345kV VY Generator	12.6 cy 12.6 cy
ec19	Scobie 345kV	3ϕ	0.0+j0.0	7973	8.0 cy	Deerfield 345kV Amherst 345kV	4.0 cy 8.0 cy
ec312	Northfield 345kV	3ϕ/1ϕ	0.0022+j0.0201	3T	8.05 cy	Alps 345kV Berkshire 345/115kV Autotransformer VY 345kV	4.0 cy 5.0 cy 10.3 cy
ec326	Scobie 345kV	3ϕ/1ϕ	0.0053+j0.0280	9126	8.0 cy	Sandy Pond 345kV Lawrence 345/34.5kV Autotransformer Buxton 345kV	4.0 cy 6.0 cy 8.0 cy
ec328	Sherman Rd 345kV	3ϕ/1ϕ	0.0020+j0.0162	142	9.5 cy	West Farnum 345kV ANP 336 345kV	4.0 cy 10.5 cy

Table 2-8. Extreme Contingency List for Stability Analysis (continued).

ID	Fault Location	Type	Impedance	Stuck Breaker	Near End Clearing	Far End Location	Clearing
ec368	Card 345kV	3ϕ/1ϕ	0.0044+j0.0211	2T	10.5 cy	Manchester 345kV Millstone 345kV	4.0 cy 12.75 cy
ec394a	Seabrook 345kV	3ϕ/1ϕ	0.00081+j0.01351	294	8.0 cy	Tewksbury 345kV Ward Hill 345/115kV Autotransformer	4.0 cy 4.0 cy

2.2.5 Other Dynamic Modeling

Several protective functions and other special dynamic modeling are described below.

Vernon Road Undervoltage Protection

If an undervoltage condition is detected on the Vernon Rd 115kV bus, then circuit breakers on the low voltage sides of the transformers are opened. Specifically, for the 46kV and 69kV breakers to open, the 115kV voltage must be below 0.92pu for 0.5seconds.

Bear Swamp/Northfield Underfrequency Protection

There is underfrequency protection on the Bear Swamp and Northfield units when they are pumping. If the frequency falls below 59.65Hz, the units are tripped.

Sand Bar Overload Management System (OMS)

This function is designed to mitigate overloads on the PV20 tie. If the flow on the PV20 tie exceeds 254MW for 5 seconds, the Sand Bar series reactor is inserted to mitigate overloads on that tie.

Generic Out of Step Relay Function

A generic out of step relay function was used to trip units that appear to lose synchronism with the rest of the system. Throughout a simulation, unit machine angles are compared to their initial angles. If the difference exceeds 180 degrees, the unit is tripped.

Capacitor Switching Model

The shunt capacitors at five Maine 345kV substations (Orrington, Maxcys, Mason, South Gorham, and Surowiec) are allowed to switch during transient stability simulations.

In the power flow, these capacitor installations are modeled as static var devices (SVD) with the appropriate number of banks. Specifically, three 67MVAr banks are represented at Orrington, three 50MVAr banks at Surowiec, and two 50MVAr banks at each of the other three substations.

The control logic for dynamic simulations was provided by Central Maine Power Co. in a dynamic capacitor switching model, msc6.p, for the Maxcys, Mason, South Gorham, and Surowiec banks. A separate dynamic model, orrington.p, was also provided by CMP to represent the Orrington capacitor banks.

Chester SVC Low Voltage Blocking Function Model

The dynamic modeling of the Chester SVC consists of a voltage regulating SVC (vwscc), which regulates to the scheduled voltage from the power flow, a power oscillation damping control (pss2a) and a supervisory low voltage blocking function. This blocking function reduces the SVC output to 0MVAr when the Chester 345kV bus voltage is below 0.60pu. Voltage control is restored to the SVC when the 345kV bus voltage returns to 0.68pu or greater.

Load Model

Load was modeled as constant impedance P and constant impedance Q.

Millstone #3 Exciter Model

The Millstone 3 exciter model *exac3a* parameters were changed from the original data to more representative data. The block diagram and data for the Millstone 3 *exac3a* model are shown in *Appendix G*. This modeling change is subject to analysis and review as part of the Millstone #3 power uprate study, and its subsequent approval under Section 18.4 of the NEPOOL Agreement.

Appendix H documents the models that were out-of-service for in-service generators. These models include generator exciter, governor and power system stabilizer models. These models were removed in the initial database development to improve simulation initialization and prevent unstable model behavior.

2.2.6 Special Protection System Modeling

The Maine Special Protection Systems (SPS) were modeled for the stability analysis, as described below.

Maxcys Over-Current SPS (NPCC SPS #28)

The purpose of this SPS is to protect the underlying 115kV system for loss of Section 392 (Maxcys–Maine Yankee 345kV). The Maxcys over-current SPS trips the Maxcys 345/115kV autotransformer when current flow on the Maxcys-Mason 115kV line (Section 68) exceeds 960A (equivalent to 191MVA at 1.0pu voltage) for 0.2 seconds.

Bucksport Over-Current SPS (NPCC SPS #21)

The purpose is to protect the underlying 115kV system for loss of Sections 392 (Maxcys–Maine Yankee 345kV) and 388 (Orrington–Maxcys 345kV). The Bucksport over-current SPS trips the Bucksport-Detroit (Section 203) and Bucksport-Belfast (Section 86) 115kV lines as well as the Bucksport and Maine Independence Station generators when total flow on the Orrington-Bucksport (Section 65) and Betts Rd-Bucksport (Section 205) 115kV lines exceeds a threshold for a specified amount of time.

Specifically, this SPS begins timing if the current flow on Section 65 exceeds 678A (135MVA) and the current flow on Section 205 exceeds 693A (138MVA) simultaneously, or if the Section 65 current exceeds 960A (191MVA), or if the Section 205 current exceeds 960A (191MVA). When the timer reaches 0.2 seconds, Sections 203 and 86 and the Bucksport generator are tripped. In addition, a transfer trip is started and the Maine Independence Station is tripped after 15 cycles.

Bucksport Reverse Power SPS (NPCC SPS #22)

The purpose is to protect BHE from low voltages for loss of Section 388 (Orrington–Maxcys 345kV) or 392 (Maxcys–Maine Yankee 345kV) as well as Section 396 (Keswick-Orrington 345kV) with low internal generation. The Bucksport reverse power SPS trips the Bucksport-Orrington (Section 65) and Bucksport-Betts Road (Section 205) 115kV lines when the total south-to-north power flow on those lines exceeds 50MW for 0.3 seconds.

In addition, there is an under-voltage supervisory function which prevents operation of this SPS if the Bucksport 115kV bus voltage remains above 0.92pu and allows operation when the voltage has been below 0.92pu voltage for 0.2 seconds.

Saco Valley Under Voltage Load Shed

Although not an SPS, its purpose is to relieve local undervoltage problems in the vicinity of Saco Valley. This protection system trips the loads at the Saco Valley and Intervale 34.5kV buses when the Saco Valley 115kV bus voltage has been below 0.94pu for 4 seconds.

Maine Yankee Double Circuit Tower Outage SPS (NPCC SPS #141)

The purpose of the DCT SPS is to relieve overloads on the underlying 115kV system for loss of the two 345kV lines crossing the Kennebec River south of Maine Yankee (Sections 375 and 377) or the Maxcys-Maine Yankee and Maine Yankee–Buxton (Sections 392 and 375) 345kV lines. The Maine Yankee DCT SPS trips the Maine Independence Station for these two events.

Keswick Loss of 3001 SPS (NPCC SPS #5)

The purpose of the Loss of Line 3001 SPS is to detect islanding of the Maritimes due to trips of any one of the existing Maine 345kV connections to southern New England, i.e., Line 3001/Section 396 (Keswick-Orrington 345kV) or Sections 388 (Orrington – Maxcys 345kV) or 392 (Maxcys – Maine Yankee 345kV). This SPS rejects generation in New Brunswick and/or reduces import in response to a sudden drop in power flow on the Keswick-Orrington 345kV line simultaneous with an increase in frequency at the Keswick 345kV bus. This SPS is only armed when the initial power flow on Line 3001 is greater than 180MW.

The SPS begins when the power flow on Line 3001/Section 396 falls below 330MW and the first timer is started. If the power flow falls below 260MW before this first timer reaches 3 seconds, then a second timer is started. If the Keswick 345kV bus frequency exceeds 60.3Hz and the second timer has not reached 1.25seconds, then generation is tripped in New Brunswick. The amount of generation tripped approximates the initial flow on Section 3001 less 200MW.

The system operator selects sufficient generation and/or HVDC imports from the list shown in *Table 2-9* to trip about 200 MW less than the initial flow on Line 3001/Section 396.

Table 2-9. NB Power Generation Rejection Option List.

Facility	Operational Choices
Madawaska 350MW HVDC link	Runback to 175MW or block to zero
Eel River 350MW HVDC link	Runback to 270 ,200, 160, 120, 80 or 40MW
Mactaquac Hydro plant	Up to four of six 110 MW units can be tripped
Beechwood Hydro plant	All three 35MW units can be tripped
Coleson Cove Steam plant	One of three 350MW units can be tripped
Belledune	One 480MW unit can be tripped
Dalhousie	Unit 2 (200MW) can be tripped
Lingan Steam plant (NS)	One or two of four 160MW units can be tripped

Keswick GCX SPS (NPCC SPS #11)

The purpose of the Keswick GCX SPS is to provide overload protection for Line 3001/Section 396 (Keswick-Orrington 345kV) such that it does not trip for a large load loss in the Maritimes when it is near its maximum export (from NB) capability. The GCX SPS has frequency supervision so that it will not operate for a large source loss in New England. The characteristics of the Keswick GCX relay are shown in *Table 2-10,* where the distance and angle determine the center point and the reach defines the diameter of the impedance circle.

Table 2-10. Keswick Zone 1, Zone 2, and GCX Relay Characteristics.

Zone	Reach (pu)	Center Distance (pu)	Angle (deg)	Operating Time (sec)
1	0.0440	0.0220	75	0.0
2	0.0723	0.0672	75	0.3
3	0.1060	0.0530	60	If over-frequency conditions are satisfied.

Zone 1 and 2 and the line protection are always armed. When the apparent impedance of Line 3001/Section 396 (Keswick-Orrington 345kV) enters zone 1 or 2, it trips the line (instantaneously in zone 1 and after 0.3 seconds in zone 2). Loss of Line 3001/Section 396 (Keswick-Orrington 345kV) causes the Section 396 Type I SPS (NPCC SPS #140) to operate to trip the Maine Independence Station.

The zone 3 portion represents the GCX circle of the SPS, and is armed or blocked based upon the Keswick 345kV bus frequency. If the Keswick bus frequency exceeds 60.06Hz for more then 0.1 seconds with a rate of change in excess of 0.1Hz/sec, then the GCX relay is armed on the basis of over-frequency for 8 seconds. If the bus frequency falls below 59.94Hz for more then 0.1 seconds with a rate of change in excess of 0.1Hz/sec, then the GCX relay is blocked on the basis of under-frequency for 10 seconds.

If the apparent impedance enters the GCX circle (zone 3 of the model) and the overfrequency conditions are satisfied, the GCX sends a signal to reject some amount of pre-selected generation in New Brunswick according to the rules of the Loss of 3001 SPS as described above. A 6-cycle delay is allowed between generation rejection and the instant where both the overfrequency conditions are satisfied and GCX entry occurs.

Keswick Power Relay (NPCC SPS #12)

Another SPS called the Keswick Power Relay (KPR), is normally out-of-service and armed only when the Chester SVC is out of service and flows are high (i.e. > 550MW). This SPS causes runback of import from Eel River HVDC link, if the real power flow from Keswick to Orrington exceeds 650 MW and the reactive power flow exceeds 200MVAR. For the purposes of this study it was assumed that this SPS was out-of-service.

3. Power Flow Analysis Results

The power flow analysis was performed using GE's PSLF program. For pre-contingency solutions, transformer tap and phase shifting transformer angle movement as well as static var device switching were allowed. For post-contingency solutions, phase shifter angles remained fixed, while transformer tap and static var device switching were allowed for area 701 (NE), except for zones 41 (VELCO-VT) and 42 (VELCO-NC). In these Vermont zones, no control action was allowed post-contingency.

The bus voltage and branch loading performance was compared against appropriate criteria, as described in Section 2.1.3. The results of this analysis are described in the following subsections.

The results of both the base case and contingency analysis for the 10 study conditions (5 benchmark cases and 5 cases with the uprate) are shown in the linked Excel workbook. The voltage and thermal violations are presented in several tabbed worksheets and are discussed below.

Entries in the tables that are in violation of criteria are indicated in red type. Black type and zero entries indicate that the result is within criteria.

3.1 Guide to Power Flow Analysis Results Workbook

The first tab **(Outages)** of the workbook contains the contingency list. The second tab **(VT Qg)** documents the reactive power output from Vermont Yankee unit for all contingencies. The third tab **(Essex Statcom)** documents the reactive power output from the static compensator at Essex for all contingencies.

The fourth tab **(Pre-cont VVs)** documents all voltage violations for pre-contingency cases, grouped by bus. The fifth tab **(VV by Bus)** documents all voltage violations for post-contingency cases, also grouped by bus. The sixth tab **(VV by Outage)** documents the same post-contingency voltage violations, but grouped by contingency.

The seventh tab **(Uprate Impact on Low VVs)** is a subset of the fifth tab, reporting only significant bus voltage violations in New England and New York for post-contingency cases due to the Vermont Yankee uprate. A significant uprate impact was defined as a post-contingency bus voltage that was at least 1% lower with the uprate. Vermont Yankee bus voltage results are included even if the pre- and post-uprate results are not significantly different. The results were further screened such that only low voltage violations are shown. The results are grouped by bus.

The eighth tab of the workbook **(Pre-cont OLs)** documents all thermal violations in New England for pre-contingency cases, grouped by branch. The ninth tab of the workbook **(LTE OLs by Branch)** documents all long-term emergency (post-contingency) thermal violations in New England, also grouped by branch. The tenth tab of the workbook **(LTE OLs by Outage)** documents the same thermal violations, but grouped by contingency.

The eleventh tab of the workbook **(Uprate Impact on OLs)** is a subset of the ninth tab, reporting only significant branch overloads due to the Vermont Yankee uprate. A significant overload was defined as branch loading that was at least 3% higher with the uprate. The results are grouped by branch.

3.2 Pre-contingency Bus Voltage Results

There are several buses throughout New England that have minor pre-contingency high and low voltage violations, as shown in the fourth tab in the results workbook **(Pre-cont VVs)**. The high voltages are observed primarily in Maine and in the neighborhood of the Comerford/Moore hydro plants for the light load cases both pre- and post-uprate. The Comerford/Moore units are out of service for these cases. The low voltages are primarily observed on the Vermont 34.5kV and 46kV system. These voltage violations are largely unaffected by the uprate. Minor differences between the benchmark and corresponding uprate cases are due mostly to differences in unit commitment between the cases.

The pre-contingency voltages in the Vermont Yankee area for the ten primary power flow study cases are shown in *Table 3-1.* This table shows the Vermont Yankee generator reactive power output, 345kV scheduled voltage, 345kV actual voltage, 115kV actual voltage, 4160v station service bus voltage, the nominal reactive power from the Chestnut Hill capacitors, and the Chestnut Hill 115kV actual voltage.

An additional pk3 scenario, with approximately 700MW flowing from NE to NY, was developed with low levels of Vermont generation. This Vermont dispatch scenario maintained regional interfaces, such as NY-NE, East-West and North-South, constant. The pre-contingency Vermont Yankee voltages for these two cases are also shown in *Table 3-1.*

The Vermont Yankee 115kV and 345kV buses meet the minimum bus voltage criteria, 1.0pu and 0.985pu respectively, for all cases. The Vermont Yankee plant 4160v buses, for both the station service and cooling tower loads, also meet the minimum bus voltage criteria, 0.90pu, for all cases.

However, the voltage schedule at the Vermont Yankee 345kV bus is not met in any of the pre- or post-uprate cases. Since the existing system does not meet the voltage schedule under the study conditions, the uprate project will not be required to meet the voltage schedule. However, a comparison of the pre-uprate 345kV voltage with the post-uprate voltage shows a slight reduction due to the uprate. Therefore, the uprate project is required to maintain the 345kV voltage at pre-uprate levels. The worst case voltage reduction was observed for the pk3 sensitivity case with the Vermont dispatch. With the uprate, the Vermont Yankee 345kV bus voltage was reduced from 1.024pu to 1.016pu, a 0.008pu reduction. All other system conditions showed approximately 0.005pu voltage reduction due to the uprate. Therefore, Vermont dispatch scenario was the most limiting study condition in terms of voltage impact. Any mitigation that works under those conditions, will also work under the other study conditions.

Since the voltage requirements are on the Vermont Yankee 345kV bus, the local Vermont Yankee substation is the preferred location for the proposed capacitor banks. In addition, these shunt capacitor banks are better placed on the 115kV bus because it would be more cost effective than on the 345kV bus. Therefore, it is proposed that the additional voltage support be provided by 60MVAr of capacitor banks on the Vermont Yankee 115kV bus.

Entergy has confirmed that there is sufficient room in their 115kV switchyard for these capacitor banks and associated equipment.

The impact of the proposed 60MVAr shunt capacitors on pre-contingency voltages in the Vermont Yankee area is shown in *Table 3-2*. This table shows the same information as *Table 3-1* for the pk3 sensitivity case with and without the uprate. In addition, it shows the local Vermont Yankee conditions with the uprate and the proposed 60MVAr capacitor banks. *Table 3-2* shows that the proposed capacitors provide sufficient additional voltage support and ensure equivalent Vermont Yankee 345kV bus voltage performance under both pre- and post-uprate system conditions. This table also shows that it is feasible to operate, under pk3 peak load all-lines-in conditions, with the proposed capacitor banks on the Vermont Yankee 115kV bus and the existing capacitor banks on the Chestnut Hill 115kV bus. The 115kV bus voltages resulting with both the Vermont Yankee and Chestnut Hill banks in-service are below the specified maximum pre-contingency voltage criteria of 1.05pu.

3.2.1 Vermont Yankee 115kV Capacitor Switching Evaluation

Additional power flow analysis was performed to determine the number and size of each switchable bank of the proposed 60MVAr shunt capacitor at Vermont Yankee 115kV. This analysis focused on the expected change in voltage (ΔV) on the Vermont Yankee area buses with the insertion of the proposed Vermont Yankee 115kV capacitor banks under the Vermont dispatch scenario. Taking the Chestnut Hill capacitor banks as an example, the 60MVAr addition was split into one 30MVAr bank and two 15MVAr banks. Both 15MVAr and 30MVAr capacitor bank removals at the Vermont Yankee 115kV bus were performed with either all lines in service or with the Vermont Yankee autotransformer out of service. In addition, similar capacitor switching events were performed with the Chestnut Hill 13.1MVAr and 26.2MVAr capacitor banks as a comparison. No other SVD, LTC or PAR action was allowed in this analysis. The ΔV capacitor switching criteria was as follows:

- ΔV < 2.5% with all line in service
- ΔV < 5% with the Vermont Yankee autotransformer out of service

Complete results of this capacitor switching analysis as well as the contingency analysis described in Section 3.3.1 are shown in the linked spreadsheet, capanal.xls. The ΔV results with all lines in service are shown in *Table 3-3*. The ΔV analysis results with the autotransformer out of service are shown in *Table 3-4*.

The largest ΔV with all lines in service was -1.2% at the Vermont Yankee 115kV for a 30MVAr capacitor removal. This meets the criteria and indicates the feasibility of switching a 30MVAr bank under normal operating conditions.

The largest ΔV with the autotransformer out of service was –9.6% at the Vermont Yankee 115kV for a 30MVAr capacitor removal. Switching out a 15MVAr bank resulted in a –4.8% ΔV at the 115kV bus. The 30MVAr capacitor switching event does not meet criteria, however, the 15MVAr capacitor switching does result in acceptable ΔVs. Therefore, it is proposed that the 60MVAr shunt capacitor be split into three banks

– one 30MVAr bank and two 15MVAr banks. This will allow for capacitor switching both with and without the autotransformer in service.

The final step in sizing the capacitor banks considered the impact of these banks on local voltage performance in response to outages. This is discussed in the next section.

Table 3-1. Pre-Contingency Bus Voltages and Reactive Power Output in the Vermont Yankee Area.

	Light Load (vy-tlt1) NY-NE = 0MW		**Peak Load (vy-tpk1) NY-NE = 0MW**		**Peak Load (vy-tpk2) NY-NE = 700MW**		**Peak Load (vy-tpk3) NY-NE = -700MW**		**Low Vt Generation (vy-tpk3novt) NY-NE = -700MW**		**Shoulder Load (vy-tsh1) NY-NE = -1200MW**	
Description	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**	**Existing**	**Uprate**
VY G1 Reactive Power Output (MVAr)	150	150	150	150	150	150	150	150	150	150	150	150
VY 345kV Scheduled Voltage (pu)	1.026	1.026	1.043	1.043	1.043	1.043	1.043	1.043	1.043	1.043	1.043	1.043
VY 345kV Bus Voltage (pu)	1.024	1.024	1.030	1.025	1.034	1.030	1.025	1.021	1.024	1.016	1.025	1.020
VY 115kV Bus Voltage (pu)	1.022	1.021	1.028	1.023	1.030	1.027	1.023	1.019	1.023	1.015	1.018	1.014
VY 4160v Bus Voltage (pu)	0.949	0.946	0.955	0.947	0.959	0.951	0.951	0.943	0.950	0.938	0.951	0.942
Chestnut Hill Capacitors (MVAr)	0	0	51	51	51	51	51	51	51	51	0	0
Chestnut Hill 115kV Bus Voltage (pu)	1.020	1.021	1.028	1.024	1.029	1.027	1.023	1.019	1.023	1.015	1.015	1.011

Table 3-2. Vermont Yankee Area Conditions with Additional 60MVAr Capacitor Bank.

Description	Low Vt Generation (vy-tpk3novt) NY-NE = -700MW		
	Existing	Uprate	Uprate+ 60MVAr
VY G1 Reactive Power Output (MVAr)	150	150	150
VY 345kV Scheduled Voltage (pu)	1.043	1.043	1.043
VY 345kV Bus Voltage (pu)	1.024	1.016	1.024
VY 115kV Capacitors (MVAr)	0	0	60
VY 115kV Bus Voltage (pu)	1.023	1.015	1.035
VY 4160v Bus Voltage (pu)	0.950	0.938	0.946
Chestnut Hill Capacitors (MVAr)	51	51	51
Chestnut Hill 115kV Bus Voltage (pu)	1.023	1.015	1.034

Table 3-3. ΔV in Response to Capacitor Bank Insertions with All Lines In-Service.

Bus	Low Vt Generation (vy-tpk3novt) NY-NE = -700MW			
	Existing	Uprate+ 60MVAr	ΔVmax (pu)	Capacitor Switching Event
70490 VERNONRD 115	0.000	-0.011	0.025	Switch Out 30MVAr Vermont Yankee 115kV Caps
70490 VERNONRD 115	-0.010	-0.011	0.025	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
70506 V.RD.TAP 115	0.000	-0.011	0.025	Switch Out 30MVAr Vermont Yankee 115kV Caps
70506 V.RD.TAP 115	-0.010	-0.011	0.025	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
70523 VTYANKEE 115	0.000	-0.012	0.025	Switch Out 30MVAr Vermont Yankee 115kV Caps
72717 CHSNT HL 115	0.000	-0.011	0.025	Switch Out 30MVAr Vermont Yankee 115kV Caps
72717 CHSNT HL 115	-0.012	-0.013	0.025	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
72750 WESTPORT 115	-0.011	-0.012	0.025	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
73906 VYBUS 5B 4	0.000	-0.012	0.025	Switch Out 30MVAr Vermont Yankee 115kV Caps

Table 3-4. ΔV in Response to Capacitor Bank Insertions with Vermont Yankee Autotransformer Out of Service.

Bus	Low Vt Generation (vy-tpk3novt) NY-NE = -700MW			
	Existing	Uprate+ 60MVAr	ΔVmax (pu)	Capacitor Switching Event
70506 V.RD.TAP 115	NA	-0.047	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
70506 V.RD.TAP 115	NA	-0.093	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
70506 V.RD.TAP 115	-0.064	-0.079	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
70506 V.RD.TAP 115	-0.029	-0.039	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps
70490 VERNONRD 115	NA	-0.047	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
70490 VERNONRD 115	NA	-0.093	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
70490 VERNONRD 115	-0.063	-0.078	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
70490 VERNONRD 115	-0.028	-0.039	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps
70523 VTYANKEE 115	NA	-0.048	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
70523 VTYANKEE 115	NA	-0.096	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
70523 VTYANKEE 115	-0.064	-0.079	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
70523 VTYANKEE 115	-0.029	-0.040	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps
72717 CHSNT HL 115	NA	-0.045	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
72717 CHSNT HL 115	NA	-0.090	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
72717 CHSNT HL 115	-0.064	-0.078	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
72717 CHSNT HL 115	-0.029	-0.039	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps
72726 KEENE 115	NA	-0.026	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
72726 KEENE 115	NA	-0.052	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
72726 KEENE 115	-0.037	-0.045	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
72726 KEENE 115	-0.017	-0.022	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps
72747 SWANZEY 115	NA	-0.032	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
72747 SWANZEY 115	NA	-0.063	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
72747 SWANZEY 115	-0.045	-0.055	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
72747 SWANZEY 115	-0.020	-0.027	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps
72750 WESTPORT 115	NA	-0.040	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
72750 WESTPORT 115	NA	-0.079	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
72750 WESTPORT 115	-0.056	-0.069	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
72750 WESTPORT 115	-0.025	-0.034	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps
73906 VYBUS 5B 4	NA	-0.048	0.05	Switch Out 15MVAr Vermont Yankee 115kV Caps
73906 VYBUS 5B 4	NA	-0.096	0.05	Switch Out 30MVAr Vermont Yankee 115kV Caps
73906 VYBUS 5B 4	-0.064	-0.079	0.05	Switch Out 26.2MVAr Chestnut Hill 115kV Caps
73906 VYBUS 5B 4	-0.029	-0.040	0.05	Switch Out 13.1MVAr Chestnut Hill 115kV Caps

3.3 Post-Contingency Bus Voltage Results

There are several Vermont buses that have post-contingency low voltage violations, as shown in the seventh tab in the results workbook (**Uprate Impact on Low VVs**). This worksheet shows only the Vermont Yankee area voltages and low voltage violations that are significantly impacted by the uprate. Differences between pre- and post-uprate performance that are less than 1% are not included in this tab, but can be found in the fifth and sixth tabs (**VV by Bus** and **VV by Outage**). Bus violations impacted by the uprate, without the proposed capacitor banks, were observed for the following eight contingencies:

#2. Loss of Section 394 (Seabrook-Tewksbury 345kV)
#4. Loss of Section 312 (Northfield-Alps 345kV)
#24. Granite K52 Breaker Failure
#30. Loss of Vermont Yankee Autotransformer
#34. Vermont Yankee 379 Breaker Failure, Loss of Section 379 (Vermont Yankee-Scobie 345kV) and Autotransformer
#35. Vermont Yankee 381 Breaker Failure, Loss of Section 381 (Vermont Yankee-Northfield 345kV) and Autotransformer
#36. Vermont Yankee 1T Breaker Failure, Loss of Section 340 (Vermont Yankee-Coolidge 345kV) and Generator
#37. Loss of Granite-Wilder 115kV line, Chelsea & Hartford 115/46kV Transformers

The Granite K52 breaker failure outage (contingency 24) and the Granite-Wilder 115kV line outage (contingency 37) result in significant low voltages on the Vermont 46kV system, some as low as 0.60pu, both with and without the uprate. Some bus voltages are improved by the addition of the uprate and some are reduced. These violations are a pre-existing problem, and there is a plan to add breakers at Chelsea and/or Hartford station to reduce the number of elements lost for these two contingencies. The primary concern is branch loading, rather than bus voltages, so a sensitivity analysis was performed under pk2 peak load conditions with 700MW flowing from NY to NE to evaluate the impact of the planned additions on local branch loading. That analysis is described in Section 3.5.1.

Three of the Vermont Yankee contingencies listed above (contingencies 30, 34, and 35) show significant low voltages on the Vermont 46kV, 69kV and 115kV system, some as low as 0.83pu, both with and without the uprate. The Vermont Yankee 4160v bus with the cooling tower load is among those with low voltages. In general, the uprate improves these voltages. There are no known plans to address these low voltages. This is a pre-existing problem due to the loss of the Vermont Yankee autotransformer in each of these contingencies, and the uprate project will not be required to mitigate it.

The 345kV line outages (contingencies 2 and 4) result in slight voltage violations at the Vermont Yankee 115kV bus for both pre- and post-uprate system conditions. The lowest voltage observed pre-uprate was 0.995pu for the loss of Section 312 (Northfield-Alps 345kV) under peak load conditions with near zero flow on the NY/NE interface. The lowest voltage observed post-uprate was 0.988pu, also for the loss of Section 312 under peak load conditions with near zero flow on the NY/NE interface.

Contingency 36 (Vermont Yankee 1T stuck breaker) results in slight low voltages on both the Vermont Yankee 115kV bus both with and without the uprate. The 115kV bus voltage was low, both pre- and post-uprate, under system conditions with a high NE to NY transfer (peak load with 700MW NE/NY, and shoulder load with 1200MW NE/NY). The minimum voltage observed was 0.992pu, both pre- and post-uprate.

3.3.1 Vermont Yankee 115kV Capacitor Post-Contingency Evaluation

The low voltages observed on the Vermont Yankee buses with the uprate will be improved by the addition of the 60MVAr of shunt capacitors proposed in the previous section. An analysis of the impact of the banks on post-contingency performance was performed and is described in the following paragraphs. The peak load condition with the Vermont dispatch and approximately 700MW flowing from NE to NY was evaluated for all study contingencies as described in Section 2.1.4. Contingencies that include the loss of the Vermont Yankee autotransformer have the greatest impact on the local bus voltages. Therefore, coordination between the loss of that transformer and the proposed capacitor banks is important. To evaluate the impact of the proposed capacitor banks, several variations on existing contingencies 30, 34 and 35 were developed, as follows:

#30x. Loss of Vermont Yankee Autotransformer and 15MVAr of 115kV Capacitors
#30y. Loss of Vermont Yankee Autotransformer and 30MVAr of 115kV Capacitors
#34y. Vermont Yankee 379 Breaker Failure, Loss of Section 379 (Vermont Yankee-Scobie 345kV), Autotransformer, and 30MVAr of 115kV Capacitors
#35. Vermont Yankee 381 Breaker Failure, Loss of Section 381 (Vermont Yankee-Northfield 345kV), Autotransformer, and 30MVAr of 115kV Capacitors

Complete results of this contingency analysis as well as the capacitor switching analysis described in Section 3.2.1 are shown in the linked spreadsheet, capanal.xls.

While the analysis shows a number of voltage violations, the Vermont dispatch conditions were considered severe and only the Vermont Yankee area was deemed significant. The proposed VELCO projects are expected to address any other concerns. Therefore, a subset of significant results is shown in *Table 3-5*. The first column identifies the bus, while the second and third columns show the specified post-contingency bus voltages for the existing system and for the uprate system with the 60MVAr of shunt capacitors. The next to last column shows the minimum acceptable voltage at that bus, and the final column identifies the contingency. Bus voltages that violate the specified criteria are shown in red, a zero indicates that the bus voltage was within criteria.

Under these peak load conditions, there were no voltage violations, either with or without the uprate, on the Vermont Yankee 345kV bus. Hence, it does not appear in *Table 3-5*. There were low voltage violations on the Chestnut Hill 115kV bus without the uprate, but acceptable voltages with the uprate regardless of the coordination of capacitor tripping with the loss of the autotransformer.

Without the uprate and its associated capacitors, the Vermont Yankee 115kV and 4160v bus voltages were unacceptable for contingencies including the loss of the autotransformer. Bus voltages under these conditions were approximately 0.89pu, while the minimum voltage criteria for this bus is 1.00pu.

With the uprate and the capacitors, but without any capacitor tripping in conjunction with the loss of the autotransformer, the Vermont Yankee 115kV and 4160v bus voltages are 1.039pu to 1.055pu for the three contingencies. This indicates the potential for unacceptably high voltages (maximum acceptable voltage criteria is 1.05pu) after the loss of the autotransformer if all of the 60MVAr of capacitor banks are left in service.

Tripping 30MVAr of capacitors with the autotransformer reduces the post-contingency voltages at both the 115kV and 4160v buses. The 4160v bus voltages are acceptable and therefore are not shown in the table. The 115kV buses are approximately 0.94pu to 0.95pu post-contingency. This violates the minimum voltage criteria for the Vermont Yankee 115kV bus. These voltages are still, however, much higher than observed in the existing system. Currently, the NRC allows the Vermont Yankee plant to operate for one week with the autotransformer out of service and with the corresponding reduced voltage on the 115kV bus. That is not expected to change with the uprate. The VELCO 115kV post-contingency voltage limit is 0.92pu. Therefore, no upgrades are needed to meet VELCO voltage criteria. However, Entergy may wish to improve the 115kV bus voltage to meet their own needs.

One final evaluation of the coordination of capacitor bank tripping with the loss of the Vermont Yankee autotransformer was performed. This evaluation focused on the ΔV resulting from an outage that includes loss of the autotransformer as well as 30MVAr of capacitors. The ΔV criteria in response to contingencies was as follows:

- $\Delta V < 5\%$ on the 345kV system
- $\Delta V < 10\%$ on the 115kV system and below

The significant results are shown in *Table 3-6*. There are no violations of the contingency ΔV criteria at the Vermont Yankee 345kV bus either with or without the uprate. Without the uprate, there are ΔVs in excess of 10% at both the Vermont Yankee and Chestnut Hill 115kV buses. With the uprate and its associated capacitors, there are no ΔV violations for any of the contingencies including the loss of the autotransformer, regardless of any associated capacitor tripping.

As a result of the analysis described above, as well as in Section 3.2.1, it is proposed that the 60MVAr of capacitors be divided into one 30MVAr bank and two 15MVAr banks. In addition, the 30MVAr capacitor bank should be connected such that it will trip with the Vermont Yankee autotransformer and the two 15MVAr capacitor banks should be connected to the 115kV bus such that they will be available for post-contingency switching. A one-line diagram of such an arrangement is shown in *Figure 3-1*. The final design of the proposed capacitor banks and their associated equipment (e.g., circuit breakers) will require review and approval by VELCO.

Table 3-5. Post-Contingency Bus Voltages in the Vermont Yankee Area with Additional 60MVAr of Shunt Capacitor Banks.

	Low Vt Generation (vy-tpk3novt) NY-NE = -700MW			
Bus	**Existing**	**Uprate+ 60MVAr**	**Vmin (pu)**	**Outage Description**
70523 VTYANKEE 115	0.897	1.055	1.000	Loss of VY Autotransformer
70523 VTYANKEE 115	0.897	0.958	1.000	Loss of VY Autotransformer, 30MVAr VY Caps
70523 VTYANKEE 115	0.885	1.044	1.000	VY 379 BK Failure, trip 379 & VY Auto
70523 VTYANKEE 115	0.885	0.947	1.000	VY 379 BK Failure, trip 379 & VY Auto, 30MVAr cap
70523 VTYANKEE 115	0.887	1.039	1.000	VY 381 BK Failure, trip 381 & VY Auto
70523 VTYANKEE 115	0.887	0.942	1.000	VY 381 BK Failure, trip 381 & VY Auto, 30MVAr cap
72717 CHSNT HL 115	0.900	1.048	0.950	Loss of VY Autotransformer
72717 CHSNT HL 115	0.889	1.037	0.950	VY 379 BK Failure, trip 379 & VY Auto
72717 CHSNT HL 115	0.890	1.032	0.950	VY 381 BK Failure, trip 381 & VY Auto
73906 VYBUS 5B 4	0.897	1.055	0.900	Loss of VY Autotransformer
73906 VYBUS 5B 4	0.885	1.044	0.900	VY 379 BK Failure, trip 379 & VY Auto
73906 VYBUS 5B 4	0.887	1.039	0.900	VY 381 BK Failure, trip 381 & VY Auto

Table 3-6. Post-Contingency ΔV in the Vermont Yankee Area with Additional 60MVAr of Shunt Capacitor Banks.

Bus	Low Vt Generation (vy-tpk3novt) NY-NE = -700MW			
	Existing	**Uprate+ 60MVAr**	**ΔVmax (pu)**	**Outage Description**
70486 VTYNK345 345	0.015	0.000	0.05	VY 379 BK Failure, trip 379 & VY Auto
70486 VTYNK345 345	0.000	-0.019	0.05	VY 381 BK Failure, trip 381 & VY Auto
70486 VTYNK345 345	0.000	-0.022	0.05	VY 381 BK Failure, trip 381 & VY Auto, 30MVAr cap
70523 VTYANKEE 115	-0.125	-0.029	0.10	Loss of VY Autotransformer, 15MVAr VY Caps
70523 VTYANKEE 115	-0.125	-0.076	0.10	Loss of VY Autotransformer, 30MVAr VY Caps
70523 VTYANKEE 115	-0.125	0.021	0.10	Loss of VY Autotransformer
70523 VTYANKEE 115	-0.137	0.009	0.10	VY 379 BK Failure, trip 379 & VY Auto
70523 VTYANKEE 115	-0.137	-0.088	0.10	VY 379 BK Failure, trip 379 & VY Auto, 30MVAr cap
70523 VTYANKEE 115	-0.136	0.005	0.10	VY 381 BK Failure, trip 381 & VY Auto
70523 VTYANKEE 115	-0.136	-0.093	0.10	VY 381 BK Failure, trip 381 & VY Auto, 30MVAr cap
70523 VTYANKEE 115	-0.011	-0.005	0.10	VY 1T BK Failure, trip 340 & VY G1
72717 CHSNT HL 115	-0.123	-0.032	0.10	Loss of VY Autotransformer, 15MVAr VY Caps
72717 CHSNT HL 115	-0.123	-0.077	0.10	Loss of VY Autotransformer, 30MVAr VY Caps
72717 CHSNT HL 115	-0.123	0.015	0.10	Loss of VY Autotransformer
72717 CHSNT HL 115	-0.134	0.003	0.10	VY 379 BK Failure, trip 379 & VY Auto
72717 CHSNT HL 115	-0.134	-0.088	0.10	VY 379 BK Failure, trip 379 & VY Auto, 30MVAr cap
72717 CHSNT HL 115	-0.133	-0.001	0.10	VY 381 BK Failure, trip 381 & VY Auto
72717 CHSNT HL 115	-0.133	-0.093	0.10	VY 381 BK Failure, trip 381 & VY Auto, 30MVAr cap
72717 CHSNT HL 115	-0.013	-0.008	0.10	VY 1T BK Failure, trip 340 & VY G1

Note: 0 indicates acceptable performance

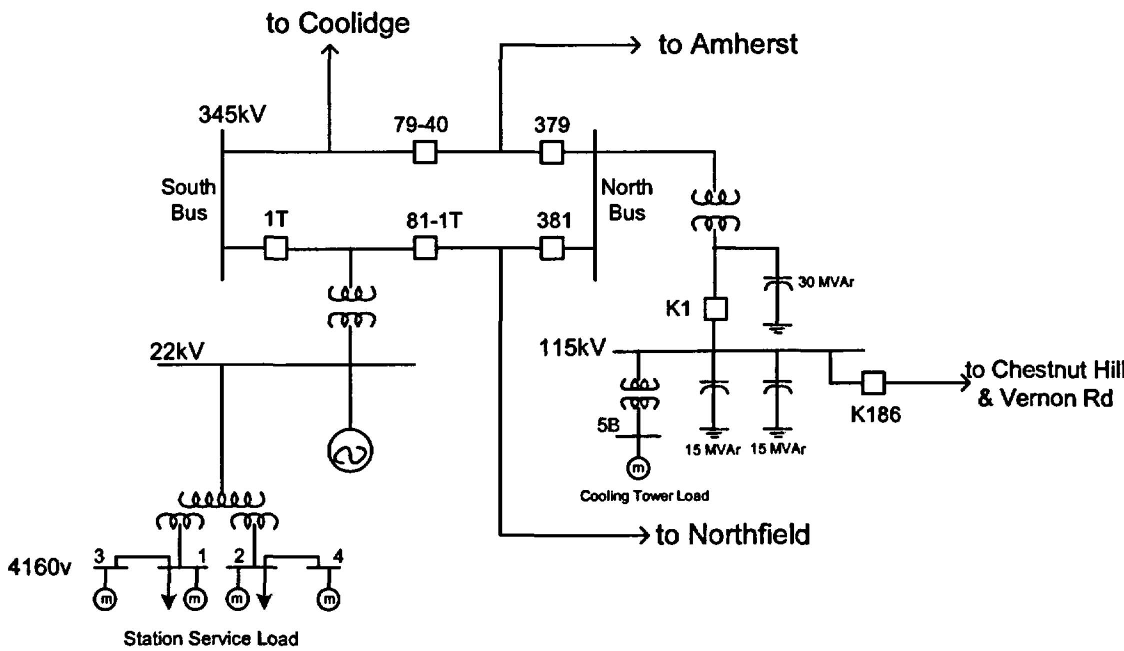


Figure 3-1. Uprated Vermont Yankee Plant and Substation One-Line Diagram with 60MVar of Shunt Capacitors.

3.4 Pre-Contingency Branch Loading Results

There are several branches throughout the region that have minor thermal violations, as shown in the eighth tab in the results workbook (**Pre-cont OLs**). The violations outside of the Vermont Yankee region are largely unaffected by the addition of the Vermont Yankee uprate project. The minor differences between the benchmark cases and corresponding uprate cases are mostly due to differences in unit commitment between the cases.

The 345kV line from Vermont Yankee to Northfield is currently rated at 896MVA. Under light load conditions the flow on this line is 0.96pu pre-uprate and 1.0pu post-uprate. The redispatch of the uprate was taken against the smaller of the two Merrimack units in this case. The Merrimack unit is connected to the 115kV system, while other possible redispatch choices, such as the ConEd Newington plant, are connected to the 345kV system. Therefore, a second series of light load cases (tlt2r and tlt2u) was developed to test the sensitivity of the Vermont Yankee-Northfield 345kV line flow to the uprate redispatch scenario under pre-contingency conditions only. For the sensitivity case without the uprate, the Vermont Yankee-Northfield 345kV line flow was approximately 0.98pu. With the uprate, the sensitivity case showed a Vermont Yankee-Northfield 345kV line flow of approximately 1.02pu. This indicates a relative lack of sensitivity to redispatch choices on the east side of the NE East-West interface.

The relatively low 345kV line rating, 896MVA, is due to the limited rating of line relay equipment at the Vermont Yankee substation. The rating on this line should be increased by replacing the limiting equipment.

A detailed summary of the generation dispatch across New England, as well as additional interface flows and other information, for the light load sensitivity cases is included in *Appendices A* and *B*. One line diagrams of the Vermont and NE 345kV transmission system for each sensitivity case are also included in these appendices. Pre-uprate information is shown in *Appendix A* and post-uprate information is shown in *Appendix B*.

3.5 Post-Contingency Branch Loading Results

There are several Vermont branches that have post-contingency overloads, as shown in the eleventh tab in the results workbook (**Uprate Impact on OLs**). This worksheet shows only the branch overloads that are significantly impacted by the uprate. Differences between pre- and post-uprate performance that are less than 3% are not included in this tab, but can be found in the ninth and tenth tabs (**LTE OLs by Branch** and **LTE OLs by Outage**). In addition, the post-contingency overloads for the Vermont Yankee-Northfield 345kV line are shown in the **Uprate Impact on OLs** tab.

The maximum overload observed on Vermont Yankee-Northfield 345kV line was 1.20pu, which indicates that the rating of the Vermont Yankee-Northfield 345kV line must be increased to a minimum of 1075MVA.

Additional branch overloads were observed for the following contingencies:

> #10. Loss of Coolidge-Ascutney 115kV (Section K31)
> #24. Granite K52 Breaker Failure
> #35. Vermont Yankee 381 Breaker Failure, Loss of Section 381 (Vermont Yankee-Northfield 345kV) and Autotransformer
> #37. Loss of Granite-Wilder 115kV line, Chelsea & Hartford 115/46kV Transformers

Overloads were observed, both with and without the uprate, on the W Rutland-Blissville-Whitehall 115kV line under light load conditions (near zero NE/NY flow) and shoulder load conditions (1200MW NE/NY flow) for contingency 35. The largest pre-uprate overload was 1.04pu of LTE rating on the W Rutland-Blissville section under shoulder load conditions. The largest post-uprate overload was 1.09pu on the same section under the same load conditions. This is a pre-existing problem and it is expected that the proposed PAR on the Whitehall-Blissville line will mitigate these overloads. No additional mitigation will by required of the uprate project.

Overloads were also observed, both with and without the uprate, on the Wallingford Tap-Mt Holly-Ludlow 46kV line segment under peak load conditions in response to the Ascutney-Coolidge 115kV line outage. The maximum pre-uprate loading was 1.23pu with a NY/NE interface flow of 700MW on the Wallingford Tap-Mt Holly segment. The maximum post-uprate loading was 1.30pu under the same conditions. A sensitivity was performed with the Ascutney Jet unit in service. For the pre-uprate sensitivity, an overload of 1.11pu was observed. For the post-uprate sensitivity, an overload of 1.18pu was observed. This indicates that the Ascutney Jet is effective in reducing flow on the 46kV system. This is a pre-existing problem that is adversely impacted by the uprate. Currently, there is no proposed mitigation for this problem. The uprate is not responsible for any additional mitigation.

Overloads on the Ascutney-Coolidge 115kV line were observed for the uprate cases, under all peak load conditions in response to the Vermont Yankee 381 breaker failure outage (contingency 35). This overload can be attributed to the uprate project, and mitigation will be required. The limiting item is approximately 25 feet of riser conductor. Replacing that will increase the Ascutney-Coolidge 115kV line rating to 240MVA which would result in acceptable performance. The Vermont Yankee uprate project is responsible for replacing the limiting riser conductor.

Overloads were observed, both with and without the uprate, on a few 46kV line segments in response to the Granite K52 breaker failure outage (contingency 24) and the Granite-Wilder 115kV line outage (contingency 37) under all peak load conditions. There are current plans for additional circuit breakers at Chelsea and/or Hartford 115kV stations, which would mitigate these overloads. A sensitivity analysis, focused on Granite area outages, was performed and is discussed in the following section.

3.5.1 Impact of Additional Breakers at Chelsea and Hartford 115kV

The Granite area sensitivity analysis evaluated performance of the peak load case, pk2, with a NY/NE flow of 700MW. This system condition was selected because it showed the largest impact due to the uprate. The original Granite area contingencies were as follows:

#24. Granite K52 Breaker Failure, Loss of Barre-Granite and Granite-Wilder 115kV lines, Chelsea & Hartford 115/46kV Transformers
#37. Loss of Granite-Wilder 115kV line, Chelsea & Hartford 115/46kV Transformers

Five more contingencies were evaluated,

#38. Loss of Granite-Chelsea 115kV line
#39. Granite K52 Breaker Failure, Loss of Barre-Granite and Granite-Chelsea 115kV lines
#40. Loss of Granite-Hartford 115kV line, Chelsea 115/46kV Transformer
#41. Loss of Hartford-Wilder 115kV
#42. Loss of Chelsea-Wilder 115kV line, Hartford 115/46kV Transformer

Contingencies 38, 39 and 42 assumed new breakers at the Chelsea 115kV substation. Contingencies 40 and 41 assumed new breakers at the Hartford 115kV substation. The primary analysis discussed in the previous section included all contingencies through 39. Contingencies 40 through 42 were only evaluated for this sensitivity analysis. Complete branch loading results for this Granite area analysis are shown in the linked spreadsheet, granite.xls.

In response to contingency 24 (Granite K52 stuck breaker without new breakers), an increase in flow due to the uprate was observed on the ASCUT-HIBR and WNDSR V4-TAFTS 46-QUECHE T-NORWICH 46kV lines, and the Windsor 115/46kV transformer. The maximum increase due to the uprate was about 11%. Several of these line segments were overloaded without the uprate.

Contingency 39 is the equivalent Granite K52 stuck breaker contingency with the proposed new breakers at Chelsea 115kV substation. The number of overloads was reduced to only those branches that had pre-contingency overloads. The post-contingency overloads were somewhat larger than the pre-contingency overloads, and there was no significant impact due to the uprate.

Contingency 37 (Granite-Chelsea-Hartford-Wilder 115kV line outage without new breakers) shows about a 3% increase in flow on the Windsor transformer and about a 5%

increase in flow on the TAFTS-QUECHE 46kV line due to the uprate. Both branches were overloaded without the uprate for this outage.

Contingency 38 is the above Granite-Wilder outage modified with additional breakers at Chelsea. There were overloads on the Blissville and N Rutland transformers that are a bit higher than already observed under pre-contingency conditions. There was no significant impact due to the uprate.

Contingency 40 is the above Granite-Wilder outage modified with additional breakers at Hartford instead of Chelsea. There were overloads on the Blissville and N Rutland transformers again that are a bit higher than under pre-contingency conditions. There was no significant impact due to the uprate.

Contingency 41 (Loss of Hartford-Wilder 115kV) shows no post-contingency overloads. Contingency 42 (Loss of Chelsea-Wilder 115kV line and Hartford 115/46kV transformer) shows no increase in the pre-contingency overloads.

This indicates that the proposed breakers at Chelsea and/or Hartford will eliminate the overloads observed on the local 46kV system for the existing Granite-Wilder 115kV line and Granite stuck breaker outages. In addition, there was no adverse impact due to the uprate once those breakers were added.

3.6 N-2 Contingency Analysis Results

The first step in the N-2 contingency analysis was to develop power flow cases representing the appropriate N-1 system conditions. The peak load condition with 700MW of flow from NE to NY (pk3 series) was selected. Power flow cases representing two N-1 conditions were then created. One case represented a system with Section 379 (Vermont Yankee-Amherst 345kV line) out of service, and the other represented a system with Section 381 (Vermont Yankee-Northfield 345kV line) out of service. All controlled devices (SVDs, LTCs, PARs) were allowed to act. This approximates the actions required to accommodate a contingency. These power flow cases represented both the existing system and the system with the Vermont Yankee uprate.

Several pre-contingency overloads observed in the primary pk3 cases, were also observed in the N-1 power flow cases. No modifications were made to address these overloads.

Next, approximately a 1200MW redispatch was performed on each case. This represents the maximum redispatch allowed after one contingency in order to ensure acceptable system performance in response to a second contingency. This redispatch is illustrated in *Table 3-7*. Note that system conditions with and without the uprate are identical after the redispatch because the Vermont Yankee output was limited to 275MW. Therefore, one case represents both the pre- and post-uprate system conditions, for each of the N-1 outages.

Table 3-7. Redispatch After N-1 Outage and Before N-2 Outage.

	Existing System			Uprated System		
Unit	**Pre-Redispatch**	**Post-Redispatch**	**ΔP**	**Pre-Redispatch**	**Post-Redispatch**	**ΔP**
Vermont Yankee	563MW	275MW	288MW	667MW	275MW	392MW
Merrimack #1	120MW	0MW	120MW	0MW	0MW	0MW
ConEd Newington	533MW	125MWW	408MW	533MW	125MW	408MW
Newington #1	411MW	0MW	411MW	411MW	0MW	411MW
Total Redispatch			**1227MW**			**1211MW**

A detailed summary for each case of the generation dispatch across New England, as well as additional interface flows and other information, are included in *Appendix I*. One line diagrams of the Vermont and NE 345kV transmission system for each case are also included in this appendix.

All contingencies, as shown in Section 2.1.4, were then applied to the N-1 power flow cases. In addition, three variations on existing contingencies were created to include insertion of the Greggs series reactor. The new contingencies are 30G (Loss of Vermont Yankee autotransformer and Greggs series reactor insertion), 34G (Vermont Yankee 379 breaker failure and Greggs series reactor insertion), and 35G (Vermont Yankee 381 breaker failure and Greggs series reactor insertion). The resulting N-2 contingency performance was evaluated against LTE ratings. Results are shown in the linked spreadsheet, n-2.xls.

A combination of N-1 and N-2 outages that leaves the Vermont Yankee generator connected only to the autotransformer and the Vermont Yankee-Vernon Road 115kV line is of particular interest. Such a combination is the Section 381 N-1 outage with the stuck breaker 79-40 loss of both Sections 379 and 340 (Contingency 33). No overloads were observed on Vermont Yankee-Vernon Road 115kV line.

The majority of overloads shown in the N-2 spreadsheet were observed in the primary power flow analysis. In that analysis, no significant difference was observed between the pre- and post-uprate cases for these overloads. Therefore, these overloads were ascribed to the system conditions represented in the study cases (generation dispatch, load level, etc), rather than the Vermont Yankee uprate. These overloads include the following:

- WDFRD 115/46kV transformers #1 and #2
- SANDB115-SB RCTOR 115kV line segment
- GRAND IS-S HERO 115kV line segment
- GRAND IS-PLAT T#3 115kV line segment
- SB PAR-S HERO 115kV line segment
- COLD RV 115/46kV transformer
- ASCUT 115/46kV transformer
- BLISS 115/46kV transformer
- BURL34-MCNEIL T 34.5kV line segment

- WILL#2-ESSEX 34.5kV line segment
- PRATTS J-LITCHTP 115kV line segment
- PELHAM51-G192 TAP 115kV line segment
- GH TP 45-WKFLDJ45 115kV line segment
- GH TP 46-WKFLDJ46 115kV line segment
- GLDNRKTP-W METHUN 115kV line segment
- DRACUT J-E DRCT51 115kV line segment
- DRACUT J-W METHUN 115kV line segment
- E DRCT51-TWKSJ51 115kV line segment

Several other overloads identified in the primary contingency analysis were also observed in the N-2 analysis, as follows:

- WALL TAP-MT HOLLY-LUDLOW 46kV line segment
- TAFTS 46-QUECHE T 46kV line segment
- WNDSR V4 115/46kV transformer

These overloads are discussed in Sections 3.5 and 3.5.1.

The SBRAT TP-NBRAT TP 69kV line segment became slightly overloaded with the Section 379 N-1 outage, but before the 1200MW redispatch. After the 1200MW redispatch and the N-2 loss of Section 312 (Northfield-Alps 345kV), a slight overload was observed.

Minor overloads were observed on the GREGGS-GREGG RX 115kV line segment in response to Contingencies 1 and 29. The overloads observed for Contingencies 30, 34 and 35 disappear for Contingencies 30G, 34G, and 35G which include the series reactor insertion.

The FLAGG PD-PRATTSJ and FLAGG PD-LITCHTP 115kV lines show minor overloads for outages that include the Greggs reactor insertion. Overloads were also observed for local outages (Contingencies 21 and 23). These overloads are due primarily to the N-1 outage. For example, the FLAGG PD- PRATTS J 115kV line flow increased by about 10% between the benchmark peak load case, tpk3, and the N-1 peak load cases with Section 379 out of service. These line segments pick up significant flow because they connect to Vermont, effectively underlying the 345kV lines that constitute the N-1 outages for this analysis.

A final overload was observed on the HUDSON-SCOBIE1 115kV line segment in response to the loss of Section 326. This 115kV line is part of underlying system parallel to the Scobie-Sandy Pond 345kV line (Section 326). This overload would be alleviated by operation of the Y-151 SPS. This SPS measures line current at Hudson, and opens Section Y-151 (Hudson-Dracut Jcn-W Methuen-Tewksbury 115kV) if the line rating is exceeded for more than 5 seconds. This SPS was designed to operate for the loss of either Section 326 or 394 with high levels of North-South interface flow.

None of the overloads discussed above are attributable to the uprate. Therefore, no additional system reinforcements are required by the N-2 analysis. The Vermont Yankee plant will be required to reduce power output at the rate of approximately 13MW/min in order to reduce output from 667MW to 275MW in 30 minutes.

4. Transient Stability Analysis

A transient stability analysis was performed under the assumptions described in Section 2. The results for the light load case with high levels of Maine generation, slt1, are summarized in the Excel file slt1stabresults5.xls. The results for the light load case with high levels of Newington generation, slt2, are summarized in the Excel file slt2stabresults4.xls. And, results for the peak case, spk1, are summarized in the Excel file spk1stabresults4.xls. A description of the format of the results shown in the Excel files is provided in Section 4.1. Sections 4.2, 4.3, and 4.4 describe the primary stability simulation results under each of the studied system conditions. The order of the discussion corresponds to fault type groups in the spreadsheet summaries.

As shown in Section 5, there are no significant differences between the pre- and post-uprate generator impedances. In addition, the difference between the existing turbine generator inertia (3.89 MW-sec/MVA) and the uprated inertia (3.875 MW-sec/MVA) is small. As a result, there was no need to reevaluate the line out stability limits.

4.1 Guide to Stability Simulation Results

At the top of each Excel file, and above the major column groupings, is a summary of the initial conditions. The Pre-fault Caps shows the total on-line MVArs for all Maine 345kV shunt capacitor bank, Essex shunt capacitor bank and Essex Statcom. WF Wyman #4 shows the initial power output of this unit. Interface Flows shows eleven key interface flows in the following order: NBNE (New Brunswick–New England), OrSo (Orrington South), SuSo (Surowiec South), MENH (Maine–New Hampshire), NNE (Northern New England-Scobie + 394), NS (North–South), EW (East–West), NYNE (New York–New England), SEMARI Export (Southeast Massachusetts and Rhode Island), NWVT (Northwest Vermont), and CVT (Central Vermont).

NB Gen max is the total New Brunswick generation that might be rejected by the GCX Zone 3 or Loss of 3001 SPSs. When NB load rejection occurs, this value is used in calculation of loss of service (LOS), even when the actual amount tripped, as shown in NB Gen Rej, is less. Phase II is the initial power transfer on the Phase II HVDC tie. The output of key generators (MIS, Bucksport, Seabrook, Westbrook, Pt. Lepreau) is also shown.

The summary tables list the faults in the first set of columns, the results of the benchmark system analysis in the second set, and the results of the uprate system in the third and final set. The individual columns in each set of results represent the details of the simulation.

For the existing system set of columns, column 1 indicates system response in terms of transient stability. Simulations are either stable (S) or unstable (U). Cases which result in a system separation note the location of the split. Column 2 shows the damping of the least damped mode of oscillation in this system (0.25 Hz). It is calculated as the real part of the 0.25Hz component of a measured signal. The 0.25Hz component is derived from an FFT frequency decomposition of the Seabrook machine angle signal. The third column indicates the total MW of generation tripped by a generic out-of-step tripping function during the simulation. The individual machines tripped are identified in the comment box. Columns 4 through 10 show the time of a specific SPS operation. The final column shows the total loss of source (LOS) in the simulation. It is the sum of the unstable units tripped (column 3), the units tripped by SPS operation (e.g., Maine Independence Station in response to Bucksport OC SPS operation), any NB generation rejection, and any generation tripped as part of the fault.

The set of results for the Vermont uprate presents the same information in the first 10 columns, and the final column again shows the total loss of source.

A hyperlink is provided in the Fault ID column to plots of each simulation. In all plots, the solid line represents the existing system and the dotted line represents the uprate system. The plots show selected interface real and reactive power flows on the first two pages, and SPS variables on pages 3 and 4. Vermont Yankee generator variables are shown on page 5. The machine angles for selected NE machines are shown on pages 6 and 7, the real power output for the same units are shown on pages 8 and 9, and the reactive power output are shown on pages 10 and 11. Selected 345kV voltages across NE are shown on pages 12 and 13, selected 115kV voltages in Vermont are shown on page 14, and selected 345kV bus frequencies are shown on page 15. Variables associated with significant Vermont devices, such as the Highgate HVDC link and the Essex STATCOM, are shown on page 16. PV20 flow is also shown on this page. The apparent impedance seen by the Keswick GCX relay is shown on page 17, as well as the zone 1, 2 and 3 impedance circles. The apparent impedance seen by the Vermont Yankee KLF relay is shown on page 18, as well as the impedance circles and directional line for both the existing relay (upper circle) and the modified relay associated with the uprate (lower circle).

Entry of the apparent impedance into the zones shown on either page 17 or 18 may indicate relay operation. However, there are additional timers associated with both relays and a voltage threshold associated with the Vermont Yankee KLF relay. The Keswick GCX relay is represented by a detailed dynamic model that incorporates all of the relevant functions and its operation is noted in the Excel summary sheets. The KLF relay was represented by a detailed dynamic model for selected simulations only. In general, its operation was inferred from entry of the apparent impedance into the zone 1 circle and operation of the generic out of step relay function.

4.2 2006 Light Load Case with High Maine Generation (sltl)

This section discusses the simulation results for the faults under 2006 light load conditions with a high level of Maine generation (sltl). Section 4.2.1 discusses the simulation results for normally cleared 1-phase or 3-phase faults and Section 4.2.2 discusses the simulation results for 3-phase stuck breaker faults.

4.2.1 Normally Cleared Faults

The normally cleared 1-phase and 3-phase fault simulation results are described in this Section. A brief summary of each fault is shown in *Table 4-1*, which also provides hyperlinks to the plotted results.

All normal contingencies, both with and without the uprate, were stable and met LOS and damping criteria except for the NC14 and NC15 fault scenarios. NC14 and NC15 consist of bolted 3-phase faults at the Vermont Yankee 345kV bus with one primary protection system out of service, resulting in a fault duration of 27.5 cycles. System performance in response to these faults is unstable either with or without the uprate. This indicates the need for a second primary protection system, such that the loss of one system would not significantly increase fault clearing times.

Additional fault scenarios, NC14X and NC15X with 4 cycle fault clearing, were created to illustrate the performance improvement due to the addition of a second primary protection scheme. Simulation results were stable and met LOS and damping criteria for the NC14X and NC15X fault scenarios, both with and without the uprate.

In addition, no operation of the Vernon Rd 115kV undervoltage protection, Vermont Yankee RPS MG set underfrequency protection, Bear Swamp and Northfield underfrequency protection, or the Sand Bar OMS was observed for any of the stable simulations.

Table 4-1. Normally Cleared Fault Results for Light Load Condition SLT1.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc1	Chestnut Hill 115kV	3φ	none	VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc2	Vermont Yankee 345kV	3φ	none	VY-Amherst 345kV
nc3	Vermont Yankee 345kV	3φ	none	VY-Northfield 345kV
nc4	Vermont Yankee 345kV	1φ	81-1T	VY-Northfield 345kV VY Generator, GSU
nc5	Vermont Yankee 345kV	1φ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
nc6	Vermont Yankee 345kV	1φ	1T	VY-Coolidge 345kV VY Generator, GSU
nc7	Vermont Yankee 345kV	1φ	79-40	VY-Coolidge 345kV VY-Amherst 345kV
nc8	Vermont Yankee 345kV	1φ	79-40	VY-Amherst 345kV VY-Coolidge 345kV
nc9	Vermont Yankee 345kV	1φ	379	VY-Amherst 345kV VY 345/115kV Autotransformer
nc10	Vermont Yankee 345kV	1φ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
nc11	Vermont Yankee 345kV	1φ	379	VY 345/115kV Autotransformer VY-Amherst 345kV
nc12	Vermont Yankee 345kV	1φ	81-1T	VY-Northfield 345kV VY Generator, GSU
nc13	Vermont Yankee 345kV	1φ	1T	VY-Coolidge 345kV VY Generator, GSU
nc14	Vermont Yankee 345kV North Bus	3φ	none	VY-Coolidge 345kV VY-Northfield 345kV VY-Amherst 345kV VY Generator, GSU VY 345/115kV Autotransformer VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc14x	Vermont Yankee 345kV North Bus	3φ	none	VY 345/115kV Autotransformer VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer

Table 4-1. Normally Cleared Fault Results for Light Load Condition SLT1 (continued).

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc15	Vermont Yankee 345/22kV GSU High Side	3ϕ	none	VY-Coolidge 345kV VY-Northfield 345kV VY-Amherst 345kV VY Generator, GSU VY 345/115kV Autotransformer
nc15x	Vermont Yankee 345/22kV GSU High side	3ϕ	none	VY Generator, GSU
nc16	Northfield 345kV	3ϕ	none	Northfield-Alps 345kV Berkshire 345/115kV Autotransformer
nc17	Northfield 345kV	3ϕ	none	Northfield-Ludlow 345kV
nc18	Scobie 345kV	3ϕ	none	Scobie-Sandy Pond 345kV Lawrence 345/34.5kV Autotransformer
nc19	Scobie 345kV	1ϕ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV
nc396	Orrington 345kV	3ϕ	none	Orrington-Keswick 345kV Chester SVC
nc312	Northfield 345kV	1ϕ	3T	Northfield-Alps 345kV Berkshire 345/115kV Autotransformer VY-Northfield 345kV
ny01	Edic 345kV	3ϕ	none	Edic-New Scotland 345kV New Scotland re-close New Scotland re-open
ny02	Fraser 345kV	Two 1ϕ	none	Fraser-Edic 345kV Coopers Corners-Marcy 345kV
ny03	Marcy 345kV	3ϕ	none	Marcy-Massena 345kV Chateauguay-Massena 345kV

4.2.2 Three-Phase Stuck Breaker Faults

The three phase stuck breaker fault simulation results are described in this Section. A brief summary of each fault is shown in *Table 4-2*, which also provides hyperlinks to the plotted results.

All extreme contingencies, both with and without the uprate, were stable and met LOS and damping criteria except for the EC8 (3-phase fault on autotransformer, 381 stuck breaker at Vermont Yankee) fault with the uprate. System response, both with and without the uprate, to the equivalent single phase, stuck breaker faults (NC10) was stable with an acceptable LOS.

An additional fault scenario, EC8X, with faster backup fault clearing, was created to illustrate the performance improvement possible with faster relay operation. The simulation results were stable and met LOS criteria for the EC8X fault with the uprate.

Another variation on the EC8 fault scenario, EC8IPT, with independent pole tripping (IPT) on the Vermont Yankee 381 breaker was evaluated with the original fault clearing times. The simulation results were stable and met LOS criteria with the uprate.

The Vermont Yankee uprate loses synchronism in response to faults EC5 (3-phase fault on Coolidge line, 79-40 stuck breaker at Vermont Yankee), EC6 (3-phase fault on Amherst line, 79-40 stuck breaker at Vermont Yankee), EC7 (3-phase fault on Amherst line, 379 stuck breaker at Vermont Yankee), and EC9 (3-phase fault on autotransformer, 379 stuck breaker at Vermont Yankee). A comparison of the apparent impedance seen by the generator with the modified KLF relay circle (lower circle) indicates that the unit will not be tripped by the KLF relay. Therefore, out of step protection will be required with the uprate.

In addition, no operation of the Vermont Yankee RPS MG set underfrequency protection, Bear Swamp and Northfield underfrequency protection, or the Sand Bar OMS was observed for any of the stable simulations.

The Vernon Rd 115kV undervoltage protection would operate for fault scenarios EC3, EC4, EC5, EC6, EC8, EC8X, EC9, EC11, EC19, EC326, and EC394A both with and without the uprate.

Table 4-2. 3-Phase Stuck Breaker Fault Results for Light Load Condition SLT1.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
ec1	Vermont Yankee 115kV	3ϕ	N186	VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
ec2	Vermont Yankee 345kV	3ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU
ec3	Vermont Yankee 345kV	3ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
ec4	Vermont Yankee 345kV	3ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
ec5	Vermont Yankee 345kV	3ϕ	79-40	VY-Coolidge 345kV VY-Amherst 345kV
ec6	Vermont Yankee 345kV	3ϕ	79-40	VY-Amherst 345kV VY-Coolidge 345kV
ec7	Vermont Yankee 345kV	3ϕ	379	VY-Amherst 345kV VY 345/115kV Autotransformer
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec8x	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec8ipt	Vermont Yankee 345kV	3ϕ/1ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Autotransformer VY-Northfield 345kV
ec10	Vermont Yankee 345kV	3ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU
ec11	Vermont Yankee 345kV	3ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
ec19	Scobie 345kV	3ϕ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV
ec312	Northfield 345kV	3ϕ/1ϕ	3T	Northfield-Berkshire 345kV Berkshire 345/115kV Autotransformer VY-Northfield 345kV
ec326	Scobie 345kV	3ϕ/1ϕ	9126	Scobie-Sandy Pond 345kV Lawrence 345/34.5kV Autotransformer Scobie-Buxton 345kV
ec328	Sherman Rd 345kV	3ϕ/1ϕ	142	Sherman Rd-West Farnum 345kV Sherman Rd-ANP 336 345kV
ec368	Card 345kV	3ϕ/1ϕ	2T	Card-Manchester 345kV Card-Millstone 345kV
ec394a	Seabrook 345kV	3ϕ/1ϕ	294	Seabrook-Tewksbury 345kV Ward Hill 345/115kV Autotransformer

4.3 2006 Light Load Case with High Newington Generation (slt2)

This section discusses the simulation results for the faults under 2006 light load conditions with a high level of Newington generation (slt2). Section 4.3.1 discusses the simulation results for normally cleared 1-phase or 3-phase faults and Section 4.3.2 discusses the simulation results for 3-phase stuck breaker faults.

4.3.1 Normally Cleared Faults

The normally cleared 1-phase and 3-phase fault simulation results are described in this Section. A brief summary of each fault is shown in *Table 4-3*, which also provides hyperlinks to the plotted results.

All normal contingencies, both with and without the uprate, were stable and met LOS and damping criteria except for the NC14 and NC15 fault scenarios. NC14 and NC15 consist of bolted 3-phase faults at the Vermont Yankee 345kV bus with one primary protection system out of service, resulting in a fault duration of 27.5 cycles. System performance in response to these faults is unstable either with or without the uprate. As noted in Section 4.2, this indicates the need for a second primary protection system, such that the loss of one system would not significantly increase fault clearing times.

Additional fault scenarios, NC14X and NC15X with 4 cycle fault clearing, were created to illustrate the performance improvement due to the addition of a second primary protection scheme. Simulation results were stable and met LOS and damping criteria for the NC14X and NC15X fault scenarios, both with and without the uprate.

In addition, no operation of the Vernon Rd 115kV undervoltage protection, Vermont Yankee RPS MG set underfrequency protection, Bear Swamp and Northfield underfrequency protection, or the Sand Bar OMS was observed for any of the stable simulations.

Table 4-3. Normally Cleared Fault Results for Light Load Condition SLT2.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc1	Chestnut Hill 115kV	3ϕ	none	Chestnut Hill-VY-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc2	Vermont Yankee 345kV	3ϕ	none	VY-Amherst 345kV
nc3	Vermont Yankee 345kV	3ϕ	none	VY-Northfield 345kV
nc4	Vermont Yankee 345kV	1ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU
nc5	Vermont Yankee 345kV	1ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
nc6	Vermont Yankee 345kV	1ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
nc7	Vermont Yankee 345kV	1ϕ	79-40	VY-Coolidge 345kV VY-Amherst 345kV
nc8	Vermont Yankee 345kV	1ϕ	79-40	VY-Amherst 345kV VY-Coolidge 345kV
nc9	Vermont Yankee 345kV	1ϕ	379	VY-Amherst 345kV VY 345/115kV Autotransformer
nc10	Vermont Yankee 345kV	1ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
nc11	Vermont Yankee 345kV	1ϕ	379	VY 345/115kV Autotransformer VY-Amherst 345kV

Table 4-3. Normally Cleared Fault Results for Light Load Condition SLT2 (continued).

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc12	Vermont Yankee 345kV	1ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU
nc13	Vermont Yankee 345kV	1ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
nc14	Vermont Yankee 345kV North Bus	3ϕ	none	VY-Coolidge 345kV VY-Northfield 345kV VY-Amherst 345kV VY Generator, GSU VY 345/115kV Autotransformer VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc14x	Vermont Yankee 345kV North Bus	3ϕ	none	VY 345/115kV Autotransformer VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc15	Vermont Yankee 345/22kV GSU High Side	3ϕ	none	VY-Coolidge 345kV VY-Northfield 345kV VY-Amherst 345kV VY Generator, GSU VY 345/115kV Autotransformer
nc15x	Vermont Yankee 345/22kV GSU High Side	3ϕ	none	VY Generator, GSU
nc16	Northfield 345kV	3ϕ	none	Northfield-Alps 345kV Berkshire 345/115kV Autotransformer
nc17	Northfield 345kV	3ϕ	none	Northfield-Ludlow 345kV
nc18	Scobie 345kV	3ϕ	none	Scobie-Sandy Pond 345kV Lawrence 345/34.5kV Autotransformer
nc19	Scobie 345kV	1ϕ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV
nc396	Orrington 345kV	3ϕ	none	Orrington-Keswick 345kV Chester SVC
nc312	Northfield 345kV	1ϕ	3T	Northfield-Alps 345kV Berkshire 345/115kV Autotransformer VY-Northfield 345kV
ny01	Edic 345kV	3ϕ	none	Edic-New Scotland 345kV New Scotland re-close New Scotland re-open
ny02	Fraser 345kV	Two 1ϕ	none	Fraser-Edic 345kV Coopers Corners-Marcy 345kV
ny03	Marcy 345kV	3ϕ	none	Marcy-Massena 345kV Chateauguay-Massena 345kV

4.3.2 Three-Phase Stuck Breaker Faults

The three phase stuck breaker fault simulation results are described in this Section. A brief summary of each fault is shown in *Table 4-4*, which also provides hyperlinks to the plotted results.

All extreme contingencies, both with and without the uprate, were stable and met LOS and damping criteria except for the EC8 (3-phase, 381 stuck breaker fault at Vermont Yankee) fault with the uprate. System response, both with and without the uprate, to the equivalent single phase, stuck breaker faults (NC10) is stable with an acceptable LOS.

An additional fault scenario, EC8X with faster backup fault clearing, was created to illustrate the performance improvement possible with faster relay operation. The simulation results were stable and met LOS and damping criteria for the EC8X fault with the uprate.

The Vermont Yankee uprate loses synchronism in response to faults EC5 (3-phase fault on Coolidge line, 79-40 stuck breaker at Vermont Yankee), EC6 (3-phase fault on Amherst line, 79-40 stuck breaker at Vermont Yankee), EC7 (3-phase fault on Amherst line, 379 stuck breaker at Vermont Yankee), and EC9 (3-phase fault on autotransformer, 379 stuck breaker at Vermont Yankee). A comparison of the apparent impedance seen by the generator with the modified KLF relay circle (lower circle) indicates that the unit will not be tripped by the KLF relay. Therefore, out of step protection will be required with the uprate.

In addition, no operation of the Vermont Yankee RPS MG set underfrequency protection, Bear Swamp and Northfield underfrequency protection, or the Sand Bar OMS was observed for any of the stable simulations. The Vernon Rd 115kV undervoltage protection would operate for fault scenarios EC3, EC4, EC5, EC6, EC8, EC8X, EC9, EC11, EC19, EC326, and EC394A both with and without the uprate.

Table 4-4. 3-Phase Stuck Breaker Fault Results for Light Load Condition SLT2.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
ec1	Vermont Yankee 115kV	3φ	N186	VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
ec2	Vermont Yankee 345kV	3φ	81-1T	VY-Northfield 345kV VY Generator, GSU
ec3	Vermont Yankee 345kV	3φ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
ec4	Vermont Yankee 345kV	3φ	1T	VY-Coolidge 345kV VY Generator, GSU
ec5	Vermont Yankee 345kV	3φ	79-40	VY-Coolidge 345kV VY-Amherst 345kV
ec6	Vermont Yankee 345kV	3φ	79-40	VY-Amherst 345kV VY-Coolidge 345kV
ec7	Vermont Yankee 345kV	3φ	379	VY-Amherst 345kV VY 345/115kV Autotransformer
ec8	Vermont Yankee 345kV	3φ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec8x	Vermont Yankee 345kV	3φ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec9	Vermont Yankee 345kV	3φ	379	VY 345/115kV Auto VY-Amherst 345kV
ec10	Vermont Yankee 345kV	3φ	81-1T	VY-Northfield 345kV VY Generator, GSU
ec11	Vermont Yankee 345kV	3φ	1T	VY-Coolidge 345kV VY Generator, GSU
ec19	Scobie 345kV	3φ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV
ec312	Northfield 345kV	3φ/1φ	3T	Northfield-Alps 345kV Berkshire 345/115kV Autotransformer VY-Northfield 345kV
ec326	Scobie 345kV	3φ/1φ	9126	Scobie-Sandy Pond 345kV Lawrence Auto 34.5kV Scobie-Buxton 345kV

Table 4-4. 3-Phase Stuck Breaker Fault Results for Light Load Condition SLT2 (continued).

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
ec328	Sherman Rd 345kV	3ϕ/1ϕ	142	Sherman Rd-West Farnum 345kV Sherman Rd-ANP 336 345kV
ec368	Card 345kV	3ϕ/1ϕ	2T	Card-Manchester 345kV Card-Millstone 345kV
ec394a	Seabrook 345kV	3ϕ/1ϕ	294	Seabrook-Tewksbury 345kV Ward Hill 345/115kV Autotransformer

4.4 2006 Summer Peak Load Case (spk1)

This section discusses the simulation results for the faults under 2006 summer peak load condition. Section 4.4.1 discusses the simulation results for normally cleared 1-phase or 3-phase faults and Section 4.4.2 discusses the simulation results for 3-phase stuck breaker faults.

4.4.1 Normally Cleared Faults

The normally cleared 1-phase and 3-phase fault simulation results are described in this Section. A brief summary of each fault is shown in *Table 4-5*, which also provides hyperlinks to the plotted results.

All normal contingencies, both with and without the uprate, were stable and met LOS and damping criteria except for the NC14 and NC15 fault scenarios. NC14 and NC15 consist of bolted 3-phase faults at the Vermont Yankee 345kV bus with one primary protection system out of service, resulting in a fault duration of 27.5 cycles. System performance in response to these faults is unstable either with or without the uprate. As before, this indicates the need for a second primary protection system, such that the loss of one system would not significantly increase fault clearing times.

Additional fault scenarios, NC14X and NC15X with 4 cycle fault clearing, were created to illustrate the performance improvement due to the addition of a second primary protection scheme. Simulation results were stable and met LOS and damping criteria for the NC14X and NC15X fault scenarios, both with and without the uprate.

In addition, no operation of the Vermont Yankee RPS MG set underfrequency protection, Bear Swamp and Northfield underfrequency protection, or the Sand Bar OMS was observed for any of the stable simulations.

The Vernon Rd 115kV undervoltage protection would operate for fault scenarios NC5, NC9, NC10, NC11, and NC14X both with and without the uprate.

Table 4-5. Normally Cleared Fault Results for Peak Load Condition SPK1.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc1	Chestnut Hill 115kV	3ϕ	none	Chestnut Hill-VY-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc2	Vermont Yankee 345kV	3ϕ	none	VY-Amherst 345kV
nc3	Vermont Yankee 345kV	3ϕ	none	VY-Northfield 345kV
nc4	Vermont Yankee 345kV	1ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU

Table 4-5. Normally Cleared Fault Results for Peak Load Condition SPK1 (continued).

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc5	Vermont Yankee 345kV	1ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
nc6	Vermont Yankee 345kV	1ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
nc7	Vermont Yankee 345kV	1ϕ	79-40	VY-Coolidge 345kV VY-Amherst 345kV
nc8	Vermont Yankee 345kV	1ϕ	79-40	VY-Amherst 345kV VY-Coolidge 345kV
nc9	Vermont Yankee 345kV	1ϕ	379	VY-Amherst 345kV VY 345/115kV Autotransformer
nc10	Vermont Yankee 345kV	1ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
nc11	Vermont Yankee 345kV	1ϕ	379	VY 345/115kV Autotransformer VY-Amherst 345kV
nc12	Vermont Yankee 345kV	1ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU
nc13	Vermont Yankee 345kV	1ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
nc14	Vermont Yankee 345kV North Bus	3ϕ	none	VY-Coolidge 345kV VY-Northfield 345kV VY-Amherst 345kV VY Generator, GSU VY 345/115kV Autotransformer VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc14x	Vermont Yankee 345kV North Bus	3ϕ	none	VY 345/115kV Autotransformer VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
nc15	Vermont Yankee 345/22kV GSU High Side	3ϕ	none	VY-Coolidge 345kV VY-Northfield 345kV VY-Amherst 345kV VY Generator VY 345/115kV Autotransformer
nc15x	Vermont Yankee 345/22kV GSU High Side	3ϕ	none	VY Generator, GSU
nc16	Northfield 345kV	3ϕ	none	Northfield-Alps 345kV Berkshire 345/115kV Autotransformer
nc17	Northfield 345kV	3ϕ	none	Northfield-Ludlow 345kV
nc18	Scobie 345kV	3ϕ	none	Scobie-Sandy Pond 345kV Lawrence 345/34.5kV Autotransformer
nc19	Scobie 345kV	1ϕ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV
nc396	Orrington 345kV	3ϕ	none	Orrington-Keswick345kV Chester SVC
nc312	Northfield 345kV	1ϕ	3T	Northfield-Alps 345kV Berkshire 345/115kV Autotransformer VY-Northfield 345kV
ph2	Trip Phase II HVDC	NA	none	NA
ny01	Edic 345kV	3ϕ	none	Edic-New Scotland 345kV New Scotland re-close New Scotland re-open
ny02	Fraser 345kV	Two 1ϕ	none	Fraser-Edic 345kV Coopers Corners-Marcy 345kV
ny03	Marcy 345kV	3ϕ	none	Marcy-Massena 345kV Chateauguay-Massena 345kV

4.4.2 Three-Phase Stuck Breaker Faults

The three phase stuck breaker fault simulation results are described in this Section. A brief summary of each fault is shown in *Table 4-6*, which also provides hyperlinks to the plotted results.

All extreme contingencies, both with and without the uprate, were stable and met LOS and damping criteria. In addition, no operation of the Vermont Yankee RPS MG set underfrequency protection, Bear Swamp and Northfield underfrequency protection, or the Sand Bar OMS was observed for any of the simulations.

The Vermont Yankee uprate loses synchronism in response to faults EC8 (3-phase fault on autotransformer, 381 stuck breaker at Vermont Yankee) and EC9 (3-phase fault on autotransformer, 379 stuck breaker at Vermont Yankee). A comparison of the apparent impedance seen by the generator with the modified KLF relay circle (lower circle) indicates that the unit will not be tripped by the KLF relay. Therefore, out of step protection will be required with the uprate.

The Vernon Rd 115kV undervoltage protection would operate for fault scenarios EC3, EC5, EC6, EC7, EC8, and EC9 both with and without the uprate.

Table 4-6. 3-Phase Stuck Breaker Fault Results for Peak Load Condition SPK1.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
ec1	Vermont Yankee 115kV	3ϕ	N186	VY-Chestnut Hill-Vernon Rd 115kV Vernon Rd 115/69kV Transformer Vernon Rd 115/46kV Transformer
ec2	Vermont Yankee 345kV	3ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU
ec3	Vermont Yankee 345kV	3ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
ec4	Vermont Yankee 345kV	3ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
ec5	Vermont Yankee 345kV	3ϕ	79-40	VY-Coolidge 345kV VY-Amherst 345kV
ec6	Vermont Yankee 345kV	3ϕ	79-40	VY-Amherst 345kV VY-Coolidge 345kV
ec7	Vermont Yankee 345kV	3ϕ	379	VY-Amherst 345kV VY 345/115kV Autotransformer
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Autotransformer VY-Northfield 345kV
ec10	Vermont Yankee 345kV	3ϕ	81-1T	VY-Northfield 345kV VY Generator, GSU
ec11	Vermont Yankee 345kV	3ϕ	1T	VY-Coolidge 345kV VY Generator, GSU
ec19	Scobie 345kV	3ϕ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV
ec312	Northfield 345kV	3ϕ/1ϕ	3T	Northfield-Berkshire 345kV Berkshire 345/115kV Autotransformer VY-Alps 345kV
ec326	Scobie 345kV	3ϕ/1ϕ	9126	Scobie-Sandy Pond 345kV Lawrence 345/34.5kV Autotransformer Scobie-Buxton 345kV
ec328	Sherman Rd 345kV	3ϕ/1ϕ	142	Sherman Rd-West Farnum 345kV Sherman Rd-ANP 336 345kV

Table 4-6. 3-Phase Stuck Breaker Fault Results for Peak Load Condition SPK1 (continued).

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
ec368	Card 345kV	3ϕ/1ϕ	2T	Card-Manchester 345kV Card-Millstone 345kV
ec394a	Seabrook 345kV	3ϕ/1ϕ	294	Seabrook-Tewksbury 345kV Ward Hill 345/115kV Autotransformer

4.5 2006 Summer Peak Load Sensitivity Analysis (spk4, spk5)

A sensitivity analysis was performed to test system performance, both with and without the uprate, at high levels of New England East-West interface flow. The impact of Northfield generation levels was also tested. Results for the peak case with all Northfield units in service and a high East-West interface flow, spk4, are summarized in the Excel file spk4stabresults4.xls. Results for the peak case with all Northfield units out of service and a high East-West flow, spk5, are summarized in the Excel file spk5stabresults4.xls.

A brief summary of each fault for the all Northfield in case, spk4, is shown in *Table 4-7*, which also provides hyperlinks to the plotted results. Similarly, a brief summary of each fault for the all Northfield out case, spk5, is shown in *Table 4-8*, which also provides hyperlinks to the plotted results.

All contingencies, both with and without the uprate, were stable and met LOS and damping criteria. The Vermont Yankee unit loses synchronism, under both peak sensitivity uprate conditions, in response to the two extreme contingencies evaluated.

In particular, the Vermont Yankee uprate loses synchronism in response to faults EC8 (3-phase fault on autotransformer, 381 stuck breaker at Vermont Yankee) and EC9 (3-phase fault on autotransformer, 379 stuck breaker at Vermont Yankee). A comparison of the apparent impedance seen by the generator with the modified KLF relay circle (lower circle) indicates that the unit will not be tripped by the KLF relay. Therefore, out of step protection will be required with the uprate.

In addition, no operation of the Vermont Yankee RPS MG set underfrequency protection, Bear Swamp and Northfield underfrequency protection, or the Sand Bar OMS was observed for any of the simulations.

The Vernon Rd 115kV undervoltage protection would operate for fault scenarios NC10, EC8 and EC9, both with and without the uprate.

Table 4-7. Sensitivity Results for Peak Load Condition SPK4.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc10	Vermont Yankee 345kV	1ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Autotransformer VY-Northfield 345kV

Table 4-8. Sensitivity Results for Peak Load Condition SPK5.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc10	Vermont Yankee 345kV	1ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Autotransformer VY-Northfield 345kV

4.6 ΔP Analysis Results

ΔP is the sudden change in generator power output resulting from line switching; it is measured in per unit of the machine MVA rating. A ΔP analysis was performed on the light load case with high levels of Newington generation, because the highest levels of line flow near the Vermont Yankee plant were observed under this condition. The intent was to calculate the highest ΔP under relatively stressed conditions, but within the existing transfer capability of the system. Stability simulations of line trip and reclose events were performed for each of the 345kV lines connected to Vermont Yankee. None of the lines are equipped with automatic high speed reclosing, so the reclose event occurred 10 seconds after the trip. No faults were associated with any of the line trip and reclose events.

The ΔPs observed on the Vermont Yankee unit with all lines in service, both with and without the uprate, are shown in *Table 4-9*. Values are shown in both MW and pu of machine MVA base.

Table 4-9. ΔP for Light Load Conditions (slt2) with All Lines In-Service.

	Existing		Uprate	
ΔP Cause	**MW**	**pu** (on 626MVA)	**MW**	**pu** (on 684MVA)
Trip Section 340 (Vermont Yankee-Coolidge 345kV)	9	0.014	5	0.007
Reclose Section 340 (Vermont Yankee-Coolidge 345kV)	-11	-0.018	-6	-0.009
Trip Section 379 (Vermont Yankee-Amherst 345kV)	83	0.13	79	0.12
Reclose Section 379 (Vermont Yankee-Amherst 345kV)	-113	-0.18	-109	-0.16
Trip Section 381 (Vermont Yankee-Northfield 345kV)	-220	-0.35	-220	-0.32
Reclose Section 381 (Vermont Yankee-Northfield 345kV)	259	0.41	249	0.36

An additional ΔP analysis under line out conditions was also performed. Power flows were developed with either Section 394 (Seabrook-Tewksbury 345kV) or Section 302 (Millbury-Ludlow 345kV) out of service for the light load study conditions. The line-out power flows were solved with all SVDs, LTCs, and PARs active. No system redispatch was implemented, because all line flows were less than the LTE rating. The sole exception was the Vermont Yankee-Northfield 345kV line, which is almost always overloaded because of the relay limited 896MVA rating.

With Section 302 out of service and no system redispatch, the trip of Section 381 caused Vermont Yankee to lose synchronism with the system, both with and without the uprate. Therefore, a redispatch of the system was performed for only this combination of events.

Two Northfield pumping units were removed, as well as a corresponding amount of generation at Brayton Point. This left one Northfield unit on.

The changes in power observed on the Vermont Yankee unit with either Section 394 or 302 out of service, both with and without the uprate, are shown in *Table 4-10.* Values are shown in both MW and pu of machine MVA base.

Table 4-10. ΔP for Light Load Conditions (slt2) with One Line Out of Service.

	Existing		Uprate	
ΔP Cause	**MW**	**pu (on 626MVA)**	**MW**	**pu (on 684MVA)**
Section 394 Out:				
Trip Section 379 (Vermont Yankee-Amherst 345kV)	98	0.16	93	0.14
Reclose Section 379 (Vermont Yankee-Amherst 345kV)	-135	-0.22	-131	-0.19
Trip Section 381 (Vermont Yankee-Northfield 345kV)	-239	-0.38	-239	-0.35
Reclose Section 381 (Vermont Yankee-Northfield 345kV)	284	0.45	267	0.39
Section 302 Out:				
Trip Section 379 (Vermont Yankee-Amherst 345kV)	112	0.18	107	0.16
Reclose Section 379 (Vermont Yankee-Amherst 345kV)	-173	-0.28	-168	-0.25
Trip Section 381 (Vermont Yankee-Northfield 345kV)*	-228	-0.36	-227	-0.33
Reclose Section 381 (Vermont Yankee-Northfield 345kV)*	275	0.44	261	0.38

* Redispatched after 302 outage

The highest ΔP observed for the uprate with all lines in service was 0.36pu in response to reclosing Section 381 (Vermont Yankee-Northfield 345kV). The highest ΔP observed for the uprate with a line out of service was 0.39pu in response to reclosing Section 381 (Vermont Yankee-Northfield 345kV) with Section 394 (Seabrook-Tewksbury 345kV) out.

4.7 Vermont Yankee Exciter Modeling

Historically, the Vermont Yankee exciter was represented by an *ieeet1* model in ISO-NE databases. As part of this study, the model was changed to the more representative *exac3a* model (shown in *Appendices D* and *F*). At the end of this study, the *exac3a* model parameters were changed to reflect the latest available information on the exciter design. Both the *ieeet1* model parameters and the latest *exac3a* model parameters are shown in *Appendix J.* The changes in *exac3a* model parameters between those studied and the latest information are highlighted in the appendix. Note that there will be no exciter change due to the uprate. The transmittal documentation from Entergy to ISO-NE is contained in *Appendix K.*

A sensitivity analysis of the impact of the three exciter models on system behavior was performed. Five fault scenarios, which exhibited the most oscillatory performance, were selected for analysis under the most severe light load conditions (slt1) for the uprate. A brief summary of each fault is shown in *Table 4-11*, which also provides hyperlinks to the plotted results. In all plots, the solid line represents the *exac3a* model with the latest parameters, the dotted line represents the *exac3a* model with the parameters used in this study, and the dashed line represents the *ieeet1* model as traditionally used.

No significant difference was observed in system performance for any of the studied faults.

Table 4-11. Vermont Yankee Exciter Model Sensitivity Results under SLT1 Conditions.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc3	Vermont Yankee 345kV	3ϕ	none	VY-Northfield 345kV
nc5	Vermont Yankee 345kV	1ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
nc10	Vermont Yankee 345kV	1ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV
ec3	Vermont Yankee 345kV	3ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer
ec8x	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV

4.8 Out of Step Protection

The results discussed in Sections 4.2 through 4.5 indicate the need for out of step protection on the uprated Vermont Yankee generator. This additional protection was required because several faults resulted in operation of the generic out of step relay function, which tripped the Vermont Yankee unit. Therefore, system performance with the out of step protection explicitly modeled was evaluated for these uprate cases. Preliminary out of step relay parameters were provided by Entergy and an out of step relay model, *ooslen*, was developed with the parameters shown in *Appendix L*.

A brief summary of each case is shown in *Table 4-12*, which also provides hyperlinks to the plotted results. In all plots, the solid line represents system performance with the individual out of step protection and the latest exciter parameters (*Appendix J*). The dotted line represents system performance with the generic out of step tripping function and the exciter model used in the bulk of the analysis (*Appendices D* and *F*).

All extreme contingencies from *Table 4-12* resulting in operation of the out of step protection were stable and met LOS and damping criteria. In all cases, the explicit out of step protection operated faster than the generic function.

Two extreme contingencies, EC6 (3-phase fault on Amherst line, 79-40 stuck breaker at Vermont Yankee) and EC7 (3-phase fault on Amherst line, 379 stuck breaker at Vermont Yankee), showed a reduced LOS with the explicit protection model under slt1 light load conditions. The difference was the NB generation rejection due to GCX relay operation in the cases with the generic protection function. All other extreme contingencies summarized in *Table 4-12* showed no difference in LOS.

Table 4-12. Vermont Yankee Out of Step Protection Results for Cases with Operation of Generic Function in Primary Analysis.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements	Generic Trip Time	OOS Relay Trip Time
slt1: light load conditions with high levels of Maine generation						
ec5	Vermont Yankee 345kV	3ϕ	79-40	VY-Coolidge 345kV VY-Amherst 345kV	0.8 sec	0.48 sec
ec6	Vermont Yankee 345kV	3ϕ	79-40	VY-Amherst 345kV VY-Coolidge 345kV	0.8 sec	0.48 sec
ec7	Vermont Yankee 345kV	3ϕ	379	VY-Amherst 345kV VY 345/115kV Autotransformer	0.8 sec	0.48 sec
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Auto VY-Amherst 345kV	0.7 sec	0.48 sec
slt2: light load conditions with high levels of New Hampshire generation						
ec5	Vermont Yankee 345kV	3ϕ	79-40	VY-Coolidge 345kV VY-Amherst 345kV	0.7 sec	0.48 sec
ec6	Vermont Yankee 345kV	3ϕ	79-40	VY-Amherst 345kV VY-Coolidge 345kV	0.7 sec	0.48 sec
ec7	Vermont Yankee 345kV	3ϕ	379	VY-Amherst 345kV VY 345/115kV Autotransformer	0.8 sec	0.48 sec
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Auto VY-Amherst 345kV	0.7 sec	0.48 sec
spk1: peak load conditions						
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV	1.1 sec	0.48 sec
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Auto VY-Amherst 345kV	1.0 sec	0.48 sec
spk4: peak load conditions with high E-W flows and all Northfield units in service						
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV	0.9 sec	0.48 sec
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Auto VY-Amherst 345kV	0.8 sec	0.48 sec
spk5: peak load conditions with high E-W flows and no Northfield units in service						
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV	0.9 sec	0.48 sec
ec9	Vermont Yankee 345kV	3ϕ	379	VY 345/115kV Auto VY-Amherst 345kV	0.8 sec	0.48 sec

The apparent impedance as seen from the Vermont Yankee generator was plotted for all cases described in Section 4. A comparison of these apparent impedances with the out of step relay protection characteristic indicated that the out of step protection could possibly operate for other cases, beyond those evaluated and summarized in *Table 4-12*. Additional analysis confirmed operation of the out of step protection for several additional extreme contingencies. These results are summarized in *Table 4-13*. Again, hyperlinks are provided to the plotted results.

Most extreme contingencies summarized in *Table 4-13* showed an increased LOS with the explicit out of step protection scheme because the Vermont Yankee unit was not tripped by the generic function in the primary analysis. All still met LOS criteria, except for the EC8X contingency (3-phase fault on autotransformer, 381 stuck breaker at Vermont Yankee with faster clearing times) under slt1 light load conditions. Additional tests showed that a maximum backup clearing time of 8.0 cycles at both Vermont Yankee and Northfield was required to meet LOS criteria (EC8Y). However, LOS criteria was met for the EC8 contingency assuming IPT operation of the Vermont Yankee 381 breaker under slt1 light load conditions.

One contingency, EC3 (3-phase fault on Northfield line, 381 stuck breaker at Vermont Yankee), showed an increased LOS with the explicit protection model under slt2 light load conditions due to operation of the zone 2 protection on Section 396 (Keswick-Orrington 345kV).

One contingency, EC8 (3-phase fault on autotransformer, 381 stuck breaker at Vermont Yankee), showed a reduced LOS with the explicit out of step relay model under slt2 light load conditions. This indicates that fast tripping of the Vermont Yankee unit may be beneficial to system performance under some conditions.

No normal contingencies resulted in operation of the out of step protection.

The results shown in *Tables 4-12* and *4-13* indicate that the preliminary out of step protection scheme will trip the Vermont Yankee unit when desired and result in acceptable system performance. These results also indicate that the required clearing times for EC8 may be too fast to implement, and that IPT breaker operation would be a preferred solution.

Table 4-13. Vermont Yankee Out of Step Protection Results for Additional Cases without Operation of Generic Function in Primary Analysis.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements	Generic Trip Time	OOS Relay Trip Time
slt1: light load conditions with high levels of Maine generation						
ec3	Vermont Yankee 345kV	3ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer	NA	0.74 sec
ec8x	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV	NA	0.75 sec
ec8y	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV	Not Run	0.79 sec
ec8ipt	Vermont Yankee 345kV	3ϕ/1ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV	NA	NA
slt2: light load conditions with high levels of New Hampshire generation						
ec3	Vermont Yankee 345kV	3ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer	NA	0.74 sec
ec8	Vermont Yankee 345kV	3ϕ	381	VY 345/115kV Autotransformer VY-Northfield 345kV	1.0 sec	0.73 sec
spk1: peak load conditions						
ec3	Vermont Yankee 345kV	3ϕ	381	VY-Northfield 345kV VY 345/115kV Autotransformer	NA	0.48 sec
ec5	Vermont Yankee 345kV	3ϕ	79-40	VY-Coolidge 345kV VY-Amherst 345kV	NA	0.48 sec
ec6	Vermont Yankee 345kV	3ϕ	79-40	VY-Amherst 345kV VY-Coolidge 345kV	NA	0.48 sec
ec7	Vermont Yankee 345kV	3ϕ	379	VY-Amherst 345kV VY 345/115kV Autotransformer	NA	0.48 sec

4.9 Amherst Project Sensitivity

Due to recent changes in the Amherst project, a sensitivity analysis was performed to determine whether those changes would have any impact on the Vermont Yankee uprate project. The Amherst substation is currently tapped off of the 379 Line (Scobie Pond-Vermont Yankee 345kV). The Amherst project will include the addition of a second 140 MVA, 345/34.5kV two-winding distribution transformer and a 345kV four circuit breaker ring bus to the Amherst Substation. The new Amherst 345 kV circuit breakers will be installed with independent pole trip (IPT) capability. The estimated in-service date is December 2003. The system impact study for the Amherst 345kV substation reconfiguration determined that the clearing times for faults on the Scobie-Amherst 345kV line should be increased by 0.5 cycles. Therefore, an evaluation of the impact of this change on the performance of the study system with the Vermont Yankee uprate was performed. Both fault scenarios involving the Scobie-Amherst 345kV line were re-evaluated under the most severe slt1 light load conditions with the uprate.

A brief summary of each case is shown in *Table 4-14*, which also provides hyperlinks to the plotted results. In all plots, the solid line represents system performance with the longer clearing times, individual out of step protection and the latest exciter parameters (*Appendix J*). The dotted line represents system performance with the original clearing times, generic out of step tripping function, and the exciter model used in the bulk of the analysis (*Appendices D* and *F*).

The difference between system performance with and without the longer clearing time at Amherst was not significant. All results were stable and met both LOS and damping criteria.

Table 4-14. Impact of Increased Clearing Times (+0.5 cycles) at Amherst.

ID	Fault Location	Type	Stuck Breaker	Cleared Elements
nc19x	Scobie 345kV	1ϕ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV
ec19x	Scobie 345kV	3ϕ	7973	Scobie-Deerfield 345kV Scobie-Amherst 345kV

5. Short Circuit Analysis

A comparison of selected machine parameters pre and post-uprate is shown in *Table 5-1*. All reactances are shown on the 626MVA base of the existing unit. The difference between the reactances are insignificant. The key data for a short circuit study is the direct axis subtransient reactance, which is 0.225pu pre and post-uprate. Therefore, no short circuit analysis was deemed necessary. Complete dynamic model data for the existing unit is shown in *Appendix D*; complete dynamic model data for the uprated unit is shown in *Appendix F*.

Table 5-1. A Comparison of Vermont Yankee Generator Reactances with and without the Uprate.

Parameter	**Description**	**Existing (on 626MVA)**	**Uprate (on 626MVA)**
Ld	d-axis synchronous reactance (pu)	1.810	1.814
L'd	d-axis transient reactance (pu)	0.345	0.350
L"d	d-axis subtransient reactance (pu)	0.225	0.225
Lq	q-axis synchronous reactance (pu)	1.750	1.747
L'q	q-axis transient reactance (pu)	0.570	0.558
L"q	q-axis subtransient reactance (pu)	0.225	0.225
Ll	Stator leakage reactance (pu)	0.190	0.191

6. Conclusions and Recommendations

Entergy is requesting approval for an uprate of the Vermont Yankee nuclear plant. The purpose of this study was to analyze the impact of this uprate on the interconnected New England system in accordance with the "NEPOOL Reliability Standards" and the NEPOOL "Minimum Interconnection Standard", and to identify any necessary facility upgrades to meet these standards under the NEPOOL Subordinate 18.4 Application Policy. Relevant queued resources for this project include the Berwick Energy Center, UAE Tewksbury, Neptune Phase 3 Boston Import, Neptune Phase 7 Wyman Export, Mystic 4,5, 6 conversion, and Millstone #3 uprate projects. Vermont Yankee is subordinate to all of these.

For this study, the existing Vermont Yankee unit was represented with a rating of 626MVA, a power output rating of 563MW, and a gross reactive power output rating of 150MVAr at rated power output. The proposed uprate project will result in a Vermont Yankee unit with a rating of 684MVA, a power output rating of 667MW, and a gross reactive power output rating of 150MVAr at rated power output. There is no expected change to the station service or cooling tower loads, which are 25.5MW, 13.5MVar and 8.5MW, 5.7MVAr, respectively. Therefore, the net rating of the uprate, as evaluated in this study with all station service and cooling loads in service under peak load conditions, was 633MW.

For the stability analysis, the Vermont Yankee exciter was modeled, both pre- and post-uprate, with an *exac3a* model representing an IEEE type AC3A excitation system. This is the manufacturer recommended model and replaced the *ieeet1* model used in prior studies. Therefore, this study also supports the exciter model change.

Power flow and stability analyses were performed, including a voltage and thermal N-1 contingency analysis, a thermal N-2 contingency analysis, a transient stability analysis, and a ΔP analysis.

No short circuit analysis was performed because there was no significant change to the generator impedances, as described in Section 5.

6.1 Power Flow Analysis

The power flow analysis indicated that the following upgrades will be required as part of the Vermont Yankee uprate project:

1. Increase the pre-contingency MVA rating on the Vermont Yankee-Northfield 345kV line (Section 381) from the current rating of 896MVA to a minimum rating of 1075MVA by replacing the limiting line relay equipment.

2. Increase the post-contingency MVA rating on the Ascutney-Coolidge 115kV line from the current LTE rating of 205MVA to 240MVA by replacing approximately 25 feet of the limiting riser conductor.

3. Ensure that the Vermont Yankee 345kV pre-contingency bus voltage is not degraded as a result of the uprate project by the addition of 60MVAr of shunt capacitors at the Vermont Yankee 115kV bus (Section 3.2). One bank of 30MVAr and two banks of 15MVAr are proposed. The 30MVAr bank should be connected such that is trips with the autotransformer. The 15MVAr banks should be connected to the 115kV bus such that they are available with the autotransformer out of service.

The study identified the Vermont Yankee-Northfield 345kV line relay replacement as a reliability upgrade required to mitigate preexisting conditions. It was not prompted by the Vermont Yankee uprate, however it is required for the uprate. The Ascutney-Coolidge 115kV line upgrade and Vermont Yankee 115kV shunt capacitors are upgrades associated with the uprate project itself. The Vermont Yankee area voltage performance was significantly better with the uprate and its associated capacitor banks than with the existing system. In addition, Entergy has verified that there is sufficient room for the capacitor banks and any associated equipment.

Overloads were also observed, both with and without the uprate, on the Wallingford Tap-Mt Holly-Ludlow 46kV line segment under peak load conditions in response to the Ascutney-Coolidge 115kV line outage. This is a pre-existing problem that is adversely impacted by the uprate. Currently, there is no proposed mitigation for this problem. The uprate is not responsible for any additional mitigation.

The N-2 power flow analysis, as described in Section 3.6, showed the need for no additional system reinforcements due to the uprate. The Vermont Yankee plant will be required to reduce power output at the rate of approximately 13MW/min in order to reduce output from 667MW to 275MW in 30 minutes. Entergy has confirmed that this ramp rate can be safely achieved.

6.2 Transient Stability

The results of the stability analysis are described in Section 4 and show that the following upgrades will be required as part of the Vermont Yankee uprate project:

1. Modification to provide a second primary protection scheme on the Vermont Yankee north bus to achieve acceptable performance in response to the normal contingency fault NC14.
2. Addition to provide a second primary protection scheme on the Vermont Yankee GSU to achieve acceptable performance in response to the normal contingency fault NC15.
3. Independent pole tripping on the Vermont Yankee 381 breaker is required to achieve acceptable performance in response to the extreme contingency fault EC8.
4. Addition of out of step protection on the Vermont Yankee generator to ensure acceptable performance in response to several extreme contingencies.

The study identified the second primary protection schemes as reliability upgrades required to mitigate preexisting conditions. It was not prompted by the Vermont Yankee uprate, however it is required for the uprate. The IPT breaker operation and the out of step protection are upgrades associated with the uprate project itself. Whether breaker 381 upgrade or replacement is required to achieve IPT capability will be determined by the facilities study.

ΔP is the sudden change in generator power output resulting from line switching; it is measured in per unit of the machine MVA rating. ΔP levels that could be imposed on the Vermont Yankee generator were calculated under relatively stressed transmission system loading conditions that would result in relatively high ΔP values. The highest level observed for the uprate with all lines in service was 0.36pu in response to reclosing Section 381 (Vermont Yankee-Northfield 345kV). The highest ΔP observed for the uprate with a line out of service was 0.39pu in response to reclosing Section 381 (Vermont Yankee-Northfield 345kV) with Section 394 (Seabrook-Tewksbury 345kV) out. The Vermont Yankee project has the option to mitigate the ΔP levels if it deems such action necessary.

After the uprate, the Vermont Yankee plant operators will continue to be required to reduce plant output to 275MW within 30 minutes of being instructed to do so by the System Operator immediately following the occurrence of certain single line outages. This requirement enables the System Operator to return the system to a secure operating state within 30 minutes of a continuous outage of a single transmission line or facility in accordance with established operating criteria.

Appendix A. Benchmark Power Flow Summaries and Diagrams for Power Flow Analysis

Case	Brief Description	Vermont One-Line	New England One-Line	Summary
tlt1r	Light load, NY/NE = 0	tlt1rvt	tlt1rne	tlt1rsum
tlt2r	Light load, NY/NE = 0, Con Ed Newington sensitivity	tlt2rvt	tlt2rne	tlt2rsum
tpk1r	Peak load, NY/NE = 0	tpk1rvt	tpk1rne	tpk1rsum
tpk2r	Peak load, NY/NE = 700MW	tpk2rvt	tpk2rne	tpk2rsum
tpk3r	Peak load, NY/NE = -700MW	tpk3rvt	tpk3rne	tpk3rsum
tsh1r	Shoulder load, NY/NE = -1200MW	tsh1rvt	tsh1rne	tsh1rsum

Appendix B. Uprate Power Flow Summaries and Diagrams for Power Flow Analysis

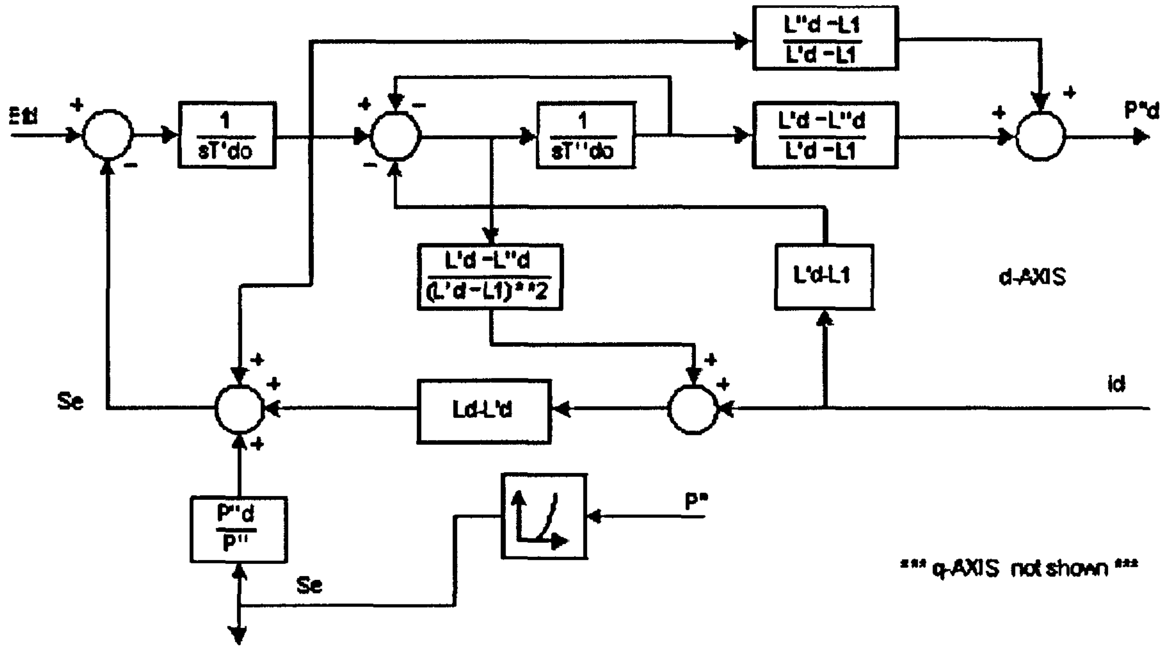
Case	Brief Description	Vermont One-Line	New England One-Line	Summary
tlt1u	Light load, NY/NE = 0	tlt1uvt	tlt1une	tlt1usum
tlt2u	Light load, NY/NE = 0, Con Ed Newington sensitivity	tlt2uvt	tlt2une	tlt2usum
tpk1u	Peak load, NY/NE = 0	tpk1uvt	tpk1une	tpk1usum
tpk2u	Peak load, NY/NE = 700MW	tpk2uvt	tpk2une	tpk2usum
tpk3u	Peak load, NY/NE = -700MW	tpk3uvt	tpk3une	tpk3usum
tsh1u	Shoulder load, NY/NE = -1200MW	tsh1uvt	tsh1une	tsh1usum

Appendix C. Benchmark Power Flow Summaries and Diagrams for Transient Stability Analysis

Case	Brief Description	Vermont One-Line	New England One-Line	Summary
slt1r	Light load with Maine generation	slt1rvt	slt1rne	slt1rsum
slt2r	Light load with Newington generation	slt2rvt	slt2rne	slt2rsum
spk1r	Peak load	spk1rvt	spk1rne	spk1rsum
spk4r	Peak load, High E-W, All Northfield	spk4rvt	spk4rne	spk4rsum
spk5r	Peak load, High E-W, No Northfield	spk5rvt	spk5rne	spk5rsum

Appendix D. Vermont Yankee Benchmark Dynamic Models

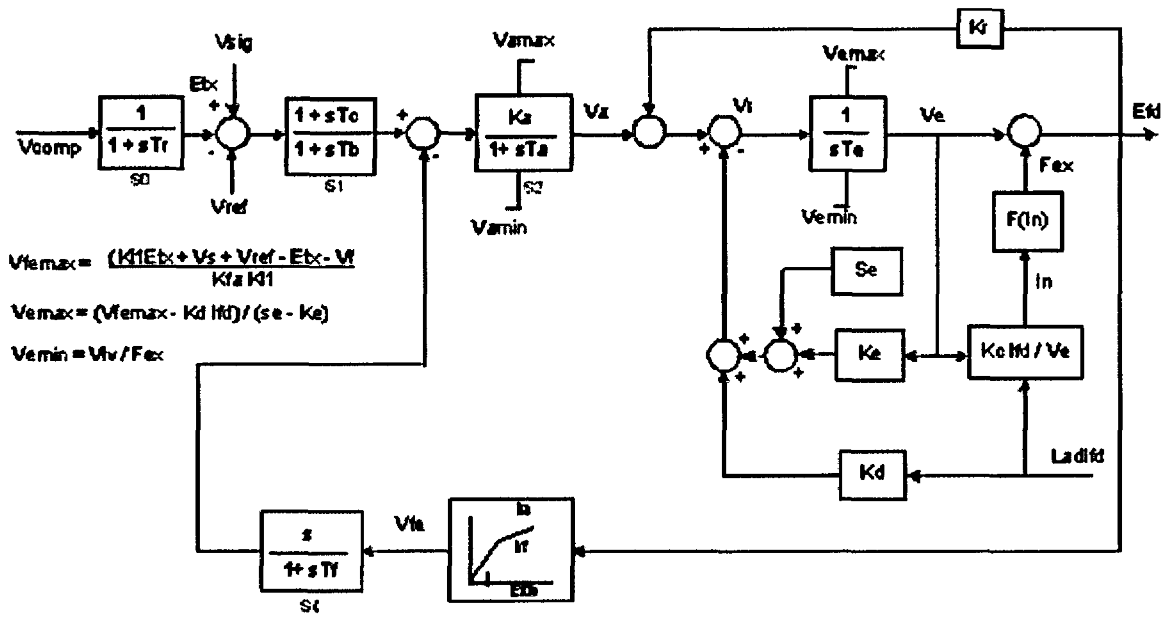
Generator Motor – GENROU Block Diagram



Generator Motor – GENROU Data

ld	1.8100	s12	0.2720
lpd	0.3450	h	3.8900
lppd	0.2250	d	0.0000
lq	1.7500	rcomp	0.0000
lpq	0.5700	xcomp	0.0000
lppq	0.2250	accel	0.0000
ll	0.1900		
ra	0.0000		
tpdo	6.7000		
tppdo	0.0350		
tpqo	0.4100		
tppqo	0.0580		
s1	0.0830		

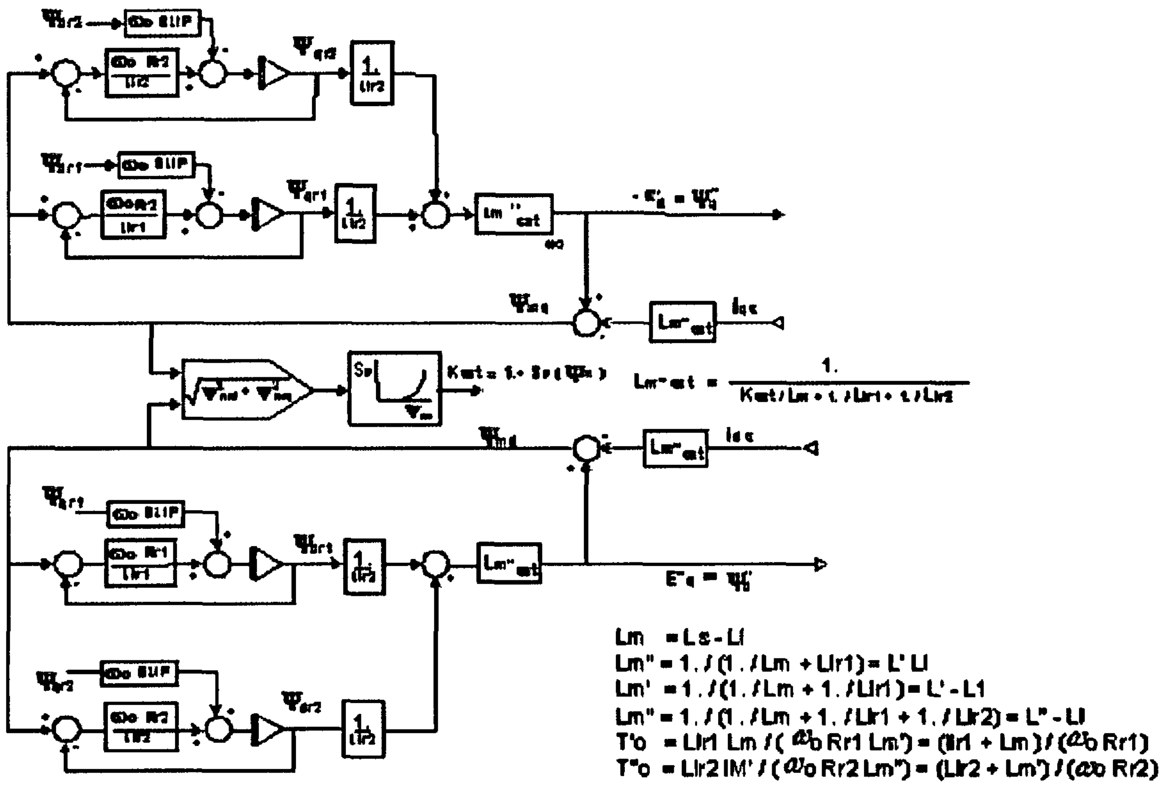
Excitation System Model – EXAC3A Block Diagram



Excitation System Model – EXAC3A Data

tr	0.0000	kc	0.1500
tb	0.0000	kd	1.0400
tc	0.0000	ke	1.0000
ka	140.1900	vlv	0.5100
ta	0.0130	e1	3.7800
vamax	1.0000	se1	0.3570
vamin	-0.9500	e2	5.0400
te	4.4200	se2	3.8650
klv	0.0800	kl1	0.5900
kr	4.6300	kfa	0.0500
kf	0.1430		
tf	1.0000		
kn	0.0500		
efdn	1.7710		

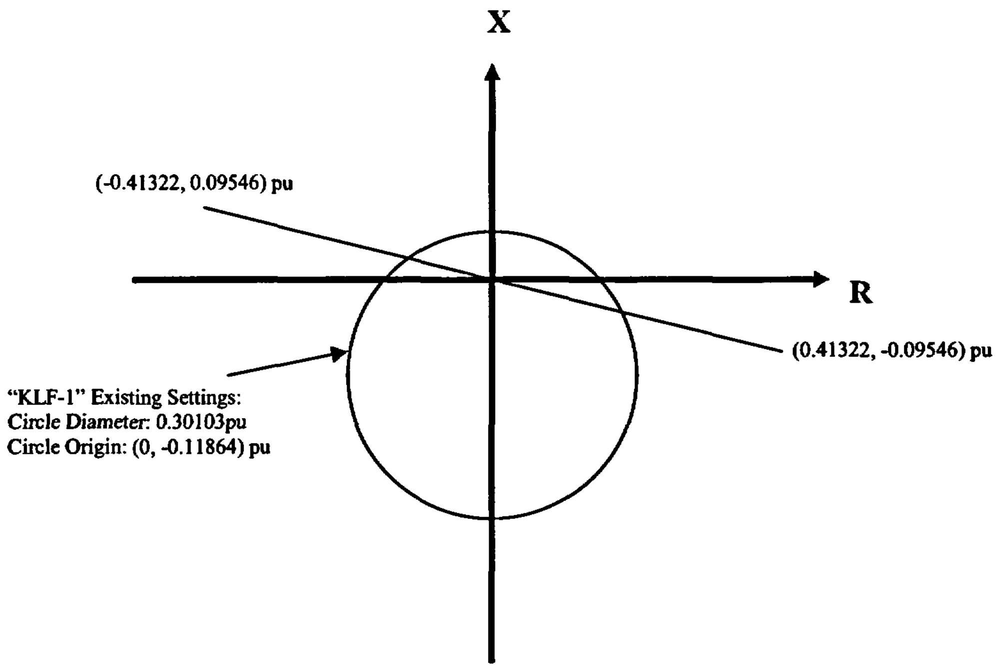
Plant Motor Load Model – MOTOR1 Block Diagram



Plant Motor Load Model – MOTOR1 Data

ls	2.5000	lpp	0.2000
lp	0.2000	ll	0.1200
ra	0.0050	tppo	0.0000
tpo	0.5000		
h	1.0000		
d	2.0000		
se1	0.0500		
se2	0.3000		
vt	0.9000		
tv	10.0000		
ft	0.0000		
tf	0.0000		
vr	0.9100		
tvr	0.0000		
acc	0.0000		

KLF-1 Relay Model – OOSLEN Relay Operation Characteristic



KLF-1 Relay Model – OOSLEN Data

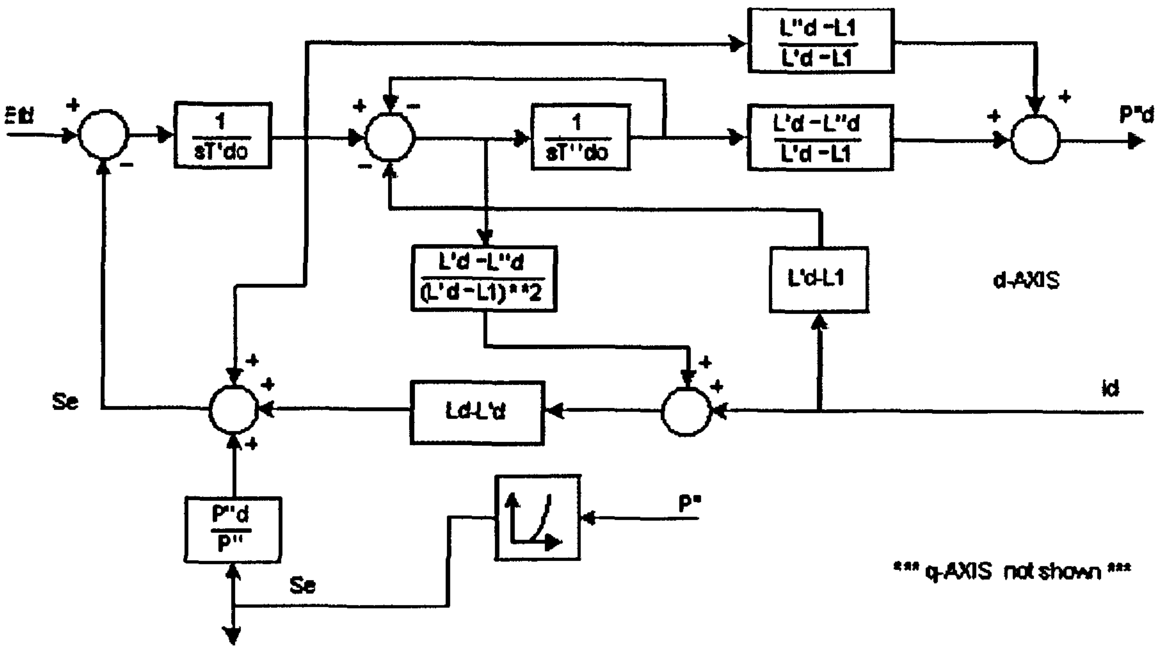
notrip	0	rr2	-99999.0
type	11	wl2	-99999.0
tcb	0.0000	t2	0.0
alpha1	90.0	alpha3	0.0
rf1	0.03188	rf3	0.0
rr1	-0.269153	rr3	0.0
wl1	0.0000	wl3	0.0
t1	0.0	t3	0.0
alpha2	77.0	vtrip	0.7998
rf2	0.0	ta	0.25

Appendix E. Uprate Power Flow Summaries and Diagrams for Transient Stability Analysis

Case	Brief Description	Vermont One-Line	New England One-Line	Summary
slt1u	Light load with Maine generation	slt1uvt	slt1une	slt1usum
slt2u	Light load with Newington generation	slt2uvt	slt2une	slt2usum
spk1u	Peak load	spk1uvt	spk1une	spk1usum
spk4u	Peak load, High E-W, All Northfield	spk4uvt	spk4une	spk4usum
spk5u	Peak load, High E-W, No Northfield	spk5uvt	spk5une	spk5usum

Appendix F. Vermont Yankee Uprate Dynamic Models

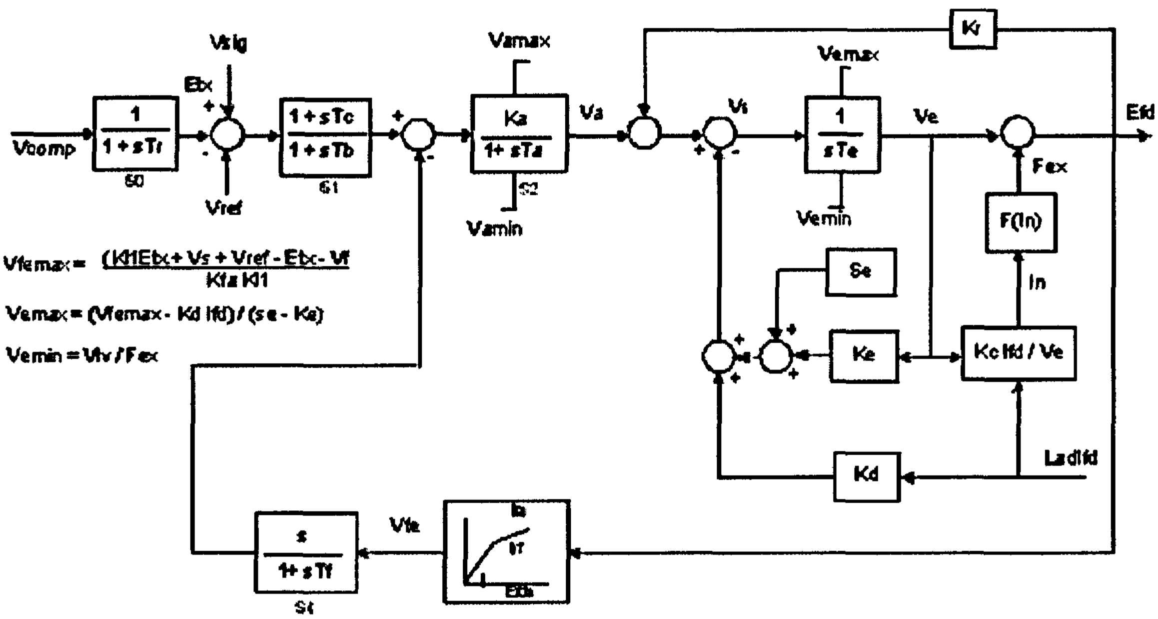
Generator Motor – GENROU Block Diagram



Generator Motor – GENROU Data

ld	1.9818	s12	0.4110
lpd	0.3827	h	3.8750
lppd	0.2456	d	0.0000
lq	1.9092	rcomp	0.0000
lpq	0.6095	xcomp	0.0000
lppq	0.2456	accel	0.0000
ll	0.2084		
ra	0.0000		
tpdo	6.7260		
tppdo	0.0350		
tpqo	0.4270		
tppqo	0.0560		
s1	0.0870		

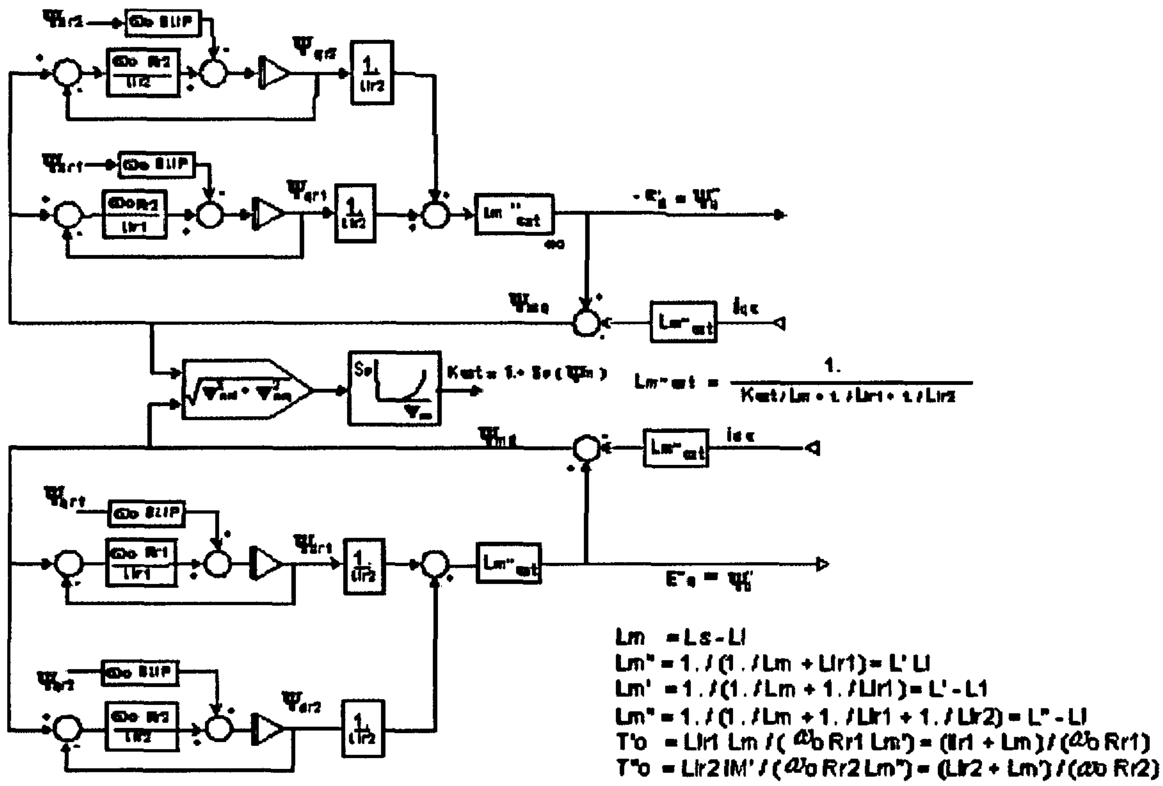
Excitation System Model – EXAC3A Block Diagram



Excitation System Model – EXAC3A Data

tr	0.0000	kc	0.1500
tb	0.0000	kd	1.0400
tc	0.0000	ke	1.0000
ka	140.1900	vlv	0.5100
ta	0.0130	el	3.7800
vamax	1.0000	sel	0.3570
vamin	-0.9500	e2	5.0400
te	4.4200	se2	3.8650
klv	0.0800	kl1	0.5900
kr	4.6300	kfa	0.0500
kf	0.1430		
tf	1.0000		
kn	0.0500		
efdn	1.7710		

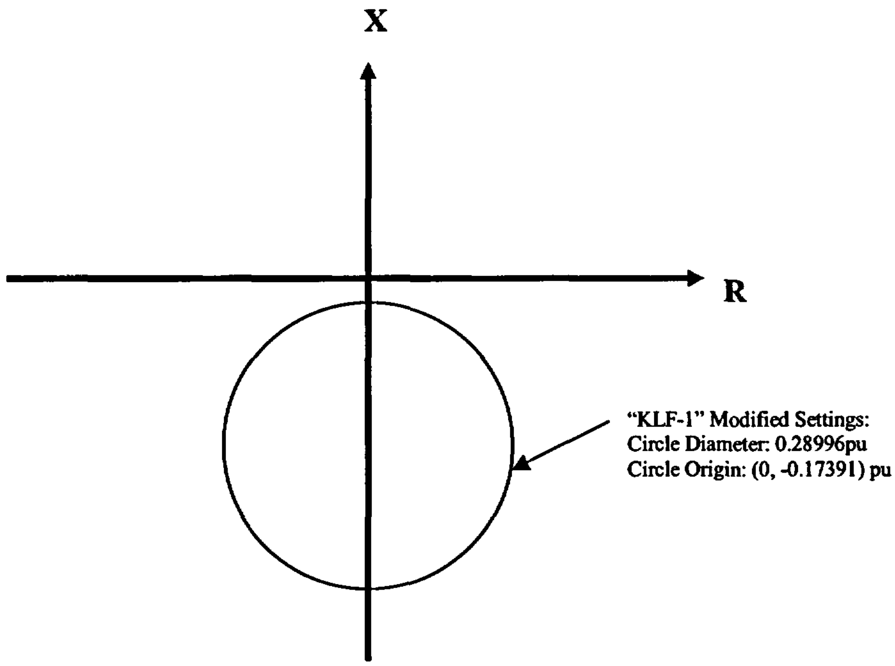
Plant Motor Load Model – MOTOR1 Block Diagram



Plant Motor Load Model – MOTOR1 Data

ls	2.5000	lpp	0.2000
lp	0.2000	ll	0.1200
ra	0.0050	tppo	0.0000
tpo	0.5000		
h	1.0000		
d	2.0000		
se1	0.0500		
se2	0.3000		
vt	0.9000		
tv	10.0000		
ft	0.0000		
tf	0.0000		
vr	0.9100		
tvr	0.0000		
acc	0.0000		

KLF-1 Relay Model – OOSLEN Relay Operation Characteristic

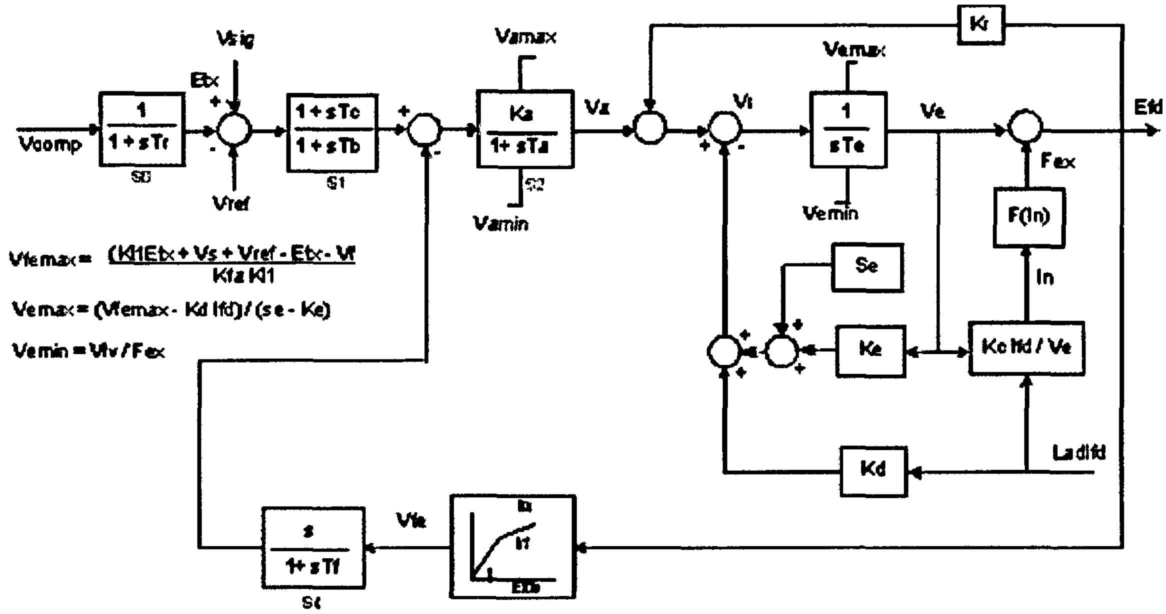


KLF-1 Relay Model – OOSLEN Data

notrip	0	rr2	-99999.0
type	11	wl2	-99999.0
tcb	0.0000	t2	0.0
alphal	90.0	alpha3	0.0
rfl	-0.0289	rf3	0.0
rrl	-0.319	rr3	0.0
wll	0.0000	wl3	0.0
tl	0.0	t3	0.0
alpha2	77.0	vtrip	0.7998
rf2	0.0	ta	0.25

Appendix G. Millstone #3 Exciter Model

Excitation System Model – EXAC3A Block Diagram



Excitation System Model – EXAC3A Data

tr	0.0000	kc	0.1300
tb	0.0000	kd	1.1400
tc	0.0000	ke	1.0000
ka	67.030	vlv	0.5400
ta	0.0130	el	5.0000
vamax	1.0000	sel	0.1560
vamin	-0.9500	e2	6.6700
te	4.4000	se2	1.9510
klv	0.100	kl1	0.5900
kr	5.9700	kfa	0.0700
kf	0.0465		
tf	1.0160		
kn	0.0500		
efdn	1.8790		

Appendix H. Out-of-Service Models for In-Service Generators

2006 Summer Light Load Condition

Bus #	Bus Name	kV	ID	Model	Type
350	SENECA#2	13.8	1	hygov	governor
2907	KITTGEN1	13.8	1	hygov	governor
2908	KITTGEN2	13.8	1	hygov	governor
2909	KITTGEN3	13.8	1	hygov	governor
4061	CONOW1-2	13.8	1	sexs	exciter
4061	CONOW1-2	13.8	2	sexs	exciter
4062	CONOW3-4	13.8	1	sexs	exciter
4062	CONOW3-4	13.8	2	sexs	exciter
4063	CONOW5-6	13.8	1	sexs	exciter
4063	CONOW5-6	13.8	2	sexs	exciter
4064	CONOW7	13.8	1	sexs	exciter
4191	MDYRN1-2	13.8	1	hygov	governor
4191	MDYRN1-2	13.8	2	hygov	governor
4192	MDYRN3-4	13.8	1	hygov	governor
4192	MDYRN3-4	13.8	2	hygov	governor
4193	MDYRN5-6	13.8	1	hygov	governor
4193	MDYRN5-6	13.8	2	hygov	governor
4194	MDYRN7-8	13.8	1	hygov	governor
4194	MDYRN7-8	13.8	2	hygov	governor
5170	NWK BAY 2	30	1	exac1	exciter
5170	NWK BAY 2	30	2	exac1	exciter
5170	NWK BAY 2	30	3	exac1	exciter
16501	1G2LEWIS	1	1	exdc1	exciter
28290	18PEREMR 1	38	1	exac4	exciter
28290	18PEREMR 1	38	1	hygov	governor
28351	18LUD12G	20	1	hygov	governor
28351	18LUD12G	20	2	hygov	governor
28352	18LUD34G	20	3	hygov	governor
28353	18LUD56G	20	5	hygov	governor
28353	18LUD56G	20	6	hygov	governor
31400	OSAGE 1	38	1	exst1	exciter
31400	OSAGE 1	38	2	exst1	exciter
31400	OSAGE 1	38	3	exst1	exciter
31400	OSAGE 1	38	4	exst1	exciter
31400	OSAGE 1	38	5	exst1	exciter
31400	OSAGE 1	38	6	exst1	exciter
31400	OSAGE 1	38	7	exst1	exciter
31400	OSAGE 1	38	8	exst1	exciter
33351	MARION 1	61	4	exst2	exciter
63598	7SIS1-6G	11	1	exdc4	exciter
63598	7SIS1-6G	11	1	ieeeg1	governor
63598	7SIS1-6G	11	2	exdc4	exciter
73083	NRTHFD12	13.8	1	pidgov	governor
73083	NRTHFD12	13.8	2	pidgov	governor
73084	NRTHFD34	13.8	3	pidgov	governor
79500	NIAG. 1	13.8	1	hygov4	governor
79501	NIAG. 2	13.8	2	hygov4	governor
79503	NIAG. 4	13.8	4	hygov4	governor
79504	NIAG. 5	13.8	5	hygov4	governor
79505	NIAG. 6	13.8	6	hygov4	governor
79507	NIAG. 8	13.8	8	hygov4	governor
79509	NIAG. 10	13.8	A	hygov4	governor
79512	NIAG. 13	13.8	D	hygov4	governor
79513	MOS17-18	13.8	1	hygov4	governor
79513	MOS17-18	13.8	2	hygov4	governor
79515	MOS19-20	13.8	1	hygov4	governor
79515	MOS19-20	13.8	2	hygov4	governor
79516	MOS21-22	13.8	1	hygov4	governor
79516	MOS21-22	13.8	2	hygov4	governor
79518	MOS25-26	13.8	1	hygov4	governor
79518	MOS25-26	13.8	2	hygov4	governor
79520	MOS23-24	13.8	1	hygov4	governor
79520	MOS23-24	13.8	2	hygov4	governor
79521	MOS27-28	13.8	1	hygov4	governor
79521	MOS27-28	13.8	2	hygov4	governor
79522	MOS29-30	13.8	1	hygov4	governor
79522	MOS29-30	13.8	2	hygov4	governor
79524	MOS31-32	13.8	1	hygov4	governor
79524	MOS31-32	13.8	2	hygov4	governor
79527	GILBOA#1	17	1	hygov	governor
79528	GILBOA#2	17	2	hygov	governor
79529	GILBOA#3	17	3	hygov	governor
79530	GILBOA#4	17	4	hygov	governor
79531	LEW 1-3	13.8	1	hygov4	governor
79531	LEW 1-3	13.8	2	hygov	governor
79531	LEW 1-3	13.8	3	hygov	governor
79532	LEW 4-6	13.8	4	hygov	governor
79532	LEW 4-6	13.8	5	hygov	governor
79532	LEW 4-6	13.8	A	hygov	governor
79533	LEW 7-9	13.8	7	hygov	governor
79533	LEW 7-9	13.8	8	hygov	governor
79533	LEW 7-9	13.8	9	hygov	governor
79534	LEW10-12	13.8	6	hygov	governor
79534	LEW10-12	13.8	B	hygov	governor
79534	LEW10-12	13.8	C	hygov	governor
80907	PIC A G3	24	1	exac1a	exciter

2006 Summer Peak Load Condition

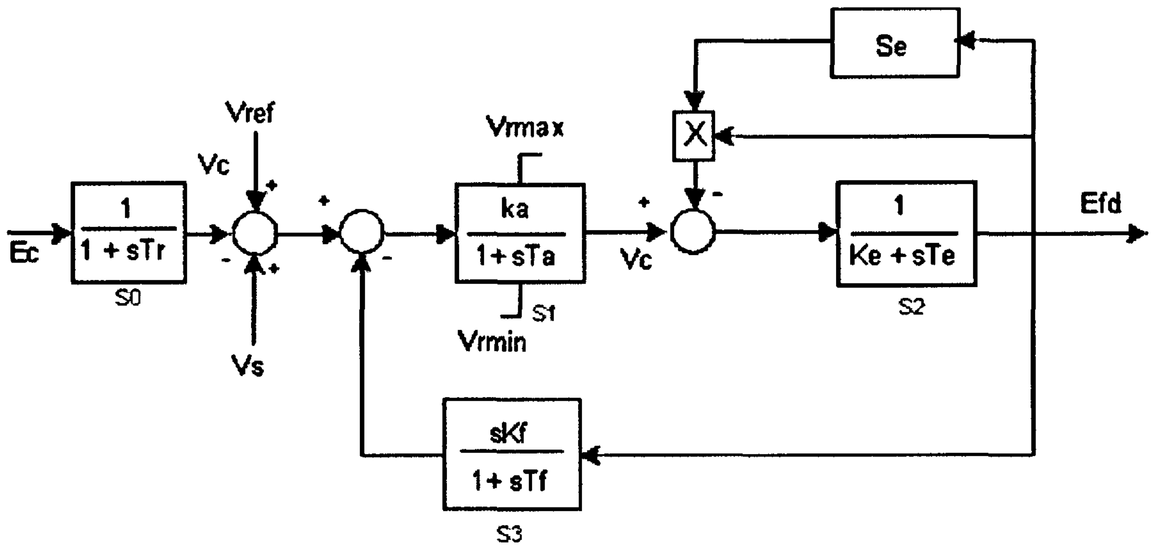
Bus #	Bus Name	kV	ID	Model	Type	Bus #	Bus Name	kV	ID	Model	Type
5170	NWK BAY	230	1	exac1	exciter	33351	MARION	161	4	exst2	exciter
5170	NWK BAY	230	2	exac1	exciter	50361	BC1 U1	13.8	1	exst2	exciter
5170	NWK BAY	230	3	exac1	exciter	50362	BC1 U2	13.8	1	exst2	exciter
8307	PCLP GT	13.8	1	exac2	exciter	55673	NICHL3 1	22	1	exst2	exciter
8307	PCLP GT	13.8	1	tgov1	governor	74193	DANSK G4	16.1	4	exst2	exciter
8885	EM5	23	1	exdc1	exciter	79500	NIAG. 1	13.8	1	hygov4	governor
11010	MARSHL1	20	1	exdc1	exciter	79501	NIAG. 2	13.8	2	hygov4	governor
11010	MARSHL1	20	1	ieeeg1	governor	79503	NIAG. 4	13.8	4	hygov4	governor
11010	MARSHL1	20	L	exdc1	exciter	79504	NIAG. 5	13.8	5	hygov4	governor
11011	MARSHL2	20	2	exdc1	exciter	79505	NIAG. 6	13.8	6	hygov4	governor
11011	MARSHL2	20	2	ieeeg1	governor	79507	NIAG. 8	13.8	8	hygov4	governor
11011	MARSHL2	20	L	exdc1	exciter	79509	NIAG. 10	13.8	A	hygov4	governor
11012	MARSHL3	24	3	exdc1	exciter	79512	NIAG. 13	13.8	D	hygov4	governor
14070	6OGDEN M	230	A	ieeet1	exciter	79513	MOS17-18	13.8	1	hygov4	governor
14070	6OGDEN M	230	A	ieeeg1	governor	79513	MOS17-18	13.8	2	hygov4	governor
14070	6OGDEN M	230	B	ieeet1	exciter	79515	MOS19-20	13.8	1	hygov4	governor
14070	6OGDEN M	230	B	ieeeg1	governor	79515	MOS19-20	13.8	2	hygov4	governor
15167	1ROCKYM1	13.8	1	exst1	exciter	79516	MOS21-22	13.8	1	hygov4	governor
15167	1ROCKYM1	13.8	1	pidgov	governor	79516	MOS21-22	13.8	2	hygov4	governor
15167	1ROCKYM1	13.8	1	ieeest	stabilizer	79518	MOS25-26	13.8	1	hygov4	governor
15168	1ROCKYM2	13.8	2	exst1	exciter	79518	MOS25-26	13.8	2	hygov4	governor
15168	1ROCKYM2	13.8	2	pidgov	governor	79520	MOS23-24	13.8	1	hygov4	governor
15168	1ROCKYM2	13.8	2	ieeest	stabilizer	79520	MOS23-24	13.8	2	hygov4	governor
15169	1ROCKYM3	13.8	3	exst1	exciter	79521	MOS27-28	13.8	1	hygov4	governor
15169	1ROCKYM3	13.8	3	pidgov	governor	79521	MOS27-28	13.8	2	hygov4	governor
15169	1ROCKYM3	13.8	3	ieeest	stabilizer	79522	MOS29-30	13.8	1	hygov4	governor
16500	1G1LEWIS	1	1	exdc1	exciter	79522	MOS29-30	13.8	2	hygov4	governor
16501	1G2LEWIS	1	1	exdc1	exciter	79524	MOS31-32	13.8	1	hygov4	governor
25932	08ZIMRHP	26	1	exbbc	exciter	79524	MOS31-32	13.8	2	hygov4	governor
25932	08ZIMRHP	26	1	ieeest	stabilizer	79531	LEW 1-3	13.8	1	hygov4	governor
25933	08ZIMRLP	22	1	exac1	exciter	33351	MARION	161	4	exst2	exciter
28290	18PEREMR	138	1	exac4	exciter	84249	LG2ABT59	13.8	1	exst1	exciter
28290	18PEREMR	138	1	hygov	governor	84249	LG2ABT59	13.8	1	ieeest	stabilizer

Appendix I. Power Flow Summaries and Diagrams for N-2 Analysis

Case	Brief Description	Vermont One-Line	New England One-Line	Summary
tpk3-379o	Peak Load, Section 379 Out	tpk3-379ovt	tpk3-379one	tpk3-379osum
tpk3-381o	Peak Load, Section 381 Out	tpk3-381ovt	tpk3-381one	tpk3-381osum

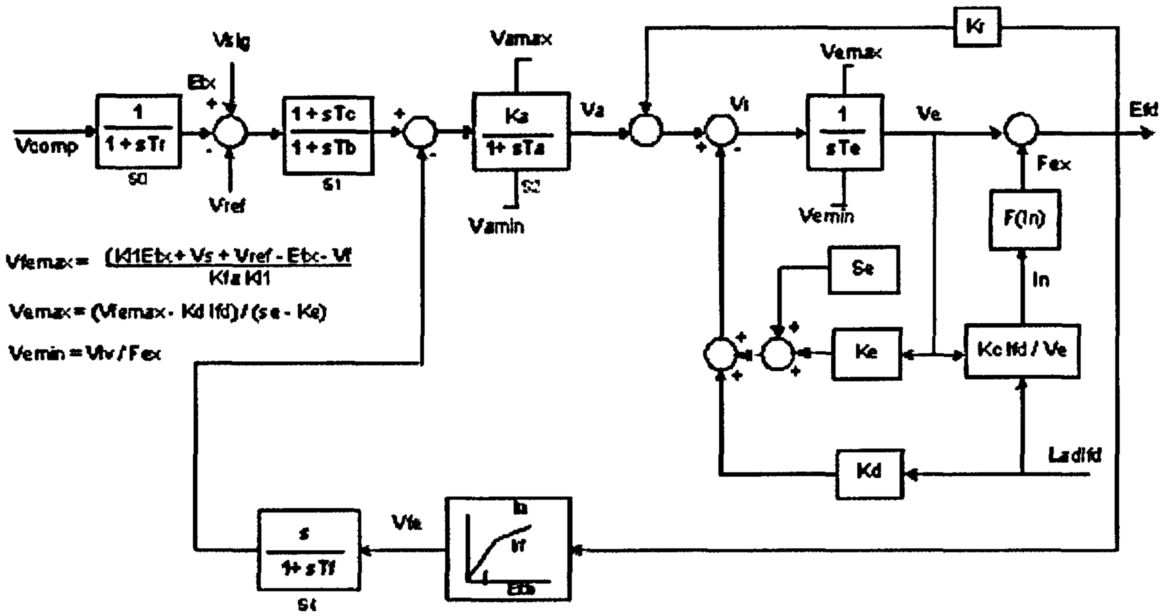
Appendix J. Vermont Yankee Exciter Models for Sensitivity Analysis

IEEET1 Block Diagram with Traditional Parameters



Tr	0.0000
ka	50.000
Ta	0.0200
Vrmax	1.0000
Vrmin	-1.000
Ke	0.0000
Te	0.5280
Kf	0.0960
Tf	1.2600
e1	3.2600
se1	0.072000
e2	4.3500
se2	0.282000

EXAC3A Block Diagram with Latest Parameters



Excitation System Model – EXAC3A Data

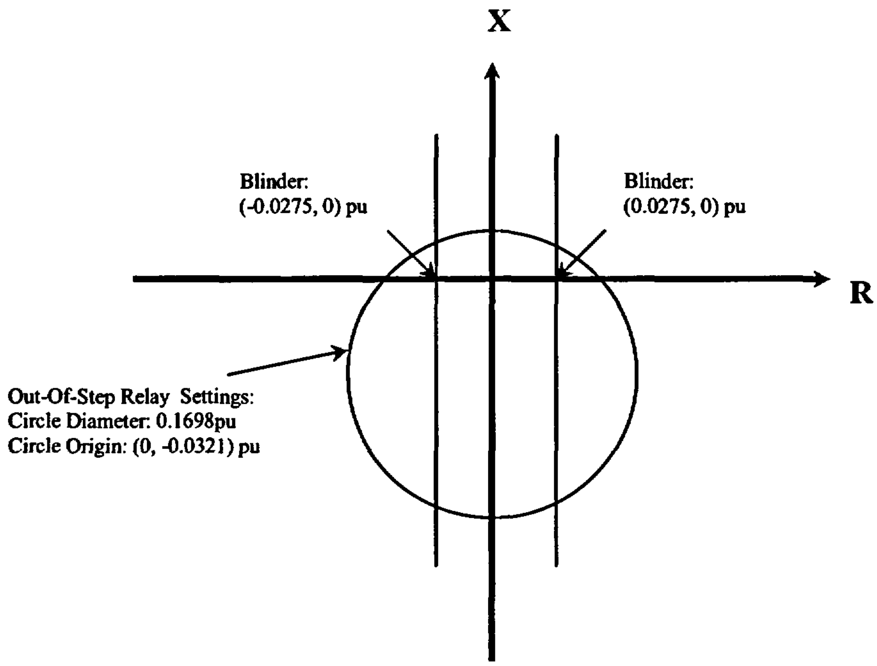
tr	0.0000	kc	0.1500
tb	0.0000	kd	1.6000
tc	0.0000	ke	1.0000
ka	112.150	vlv	0.5100
ta	0.0130	e1	5.1000
vamax	1.0000	se1	0.3570
vamin	-0.9500	e2	6.8000
te	4.4200	se2	3.8650
klv	0.1100	kl1	0.5900
kr	5.7900	kfa	0.0400
kf	0.1430		
tf	1.0000		
kn	0.0500		
efdn	1.7710		

Appendix K. Entergy Transmittal of Exciter Model Data

Both the transmittal letter and the associated exciter model block diagram and data are included in this CD report.

Appendix L. Preliminary Out of Step Relay Protection

Vermont Yankee Out of Step Relay - OOSLEN Relay Model Characteristic



type	11				
Tcb	0.0833				
alpha1	90.	alpha2	0.	alpha3	0.
Rf1	0.0528	Rf2	9999.	Rr3	0.0275
Rr1	-0.117	Rr2	-0.0275	Rr3	-9999.
Wl1	0.0	Wl2	0.	Wl3	0.
T1	0.30	T2	0.	T3	0.