System Impact Study Report
Boston Area Optimized Solution (BAOS)

April 2021

Submitted by
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1 EXECUTIVE SUMMARY

The proposed solution in this report was developed in response to the Boston 2028 Request for Proposal (RFP) as the Backstop Transmission Solution, also named as the Boston Area Optimized Solution (BAOS, The Project), to address the non-time sensitive needs identified in the Boston 2028 Needs Assessment. The Project includes the following components:

- Install two 1% (11.9 Ohms) series reactors at North Cambridge Station on the 345 kV 346 and 365 cables that extend from Eversource's Woburn Substation in Woburn, MA to Eversource's North Cambridge Substation in Cambridge, MA. A bypass breaker will be installed in parallel with each series reactor. The bypass breaker will be normally closed and will be opened when there is a need to switch in the reactor. For the purpose of this study to evaluate the impact of the series reactors, the series reactors were assumed in service in the base cases.
- Install a Direct Transfer Trip (DTT) scheme at National Grid's Ward Hill Substation in Haverhill, MA to send a trip signal to open the 345 kV breaker 2T345 at National Grid's West Amesbury Substation in Amesbury, MA when both Ward Hill Substation 345 kV breakers, 394 and 4T-94, are open or when the Ward Hill Substation 345 kV line switch, 394-3 is open.
- Install a new +/- 167 MVAR static synchronous compensator (STATCOM) at National Grid's Tewksbury 22A Substation in Tewksbury, MA. Install a new 345 kV bay position at Tewksbury 22A substation, including two (2) 345kV GIS circuit breakers and connect the STATCOM to the new bay position. The study assumed a voltage schedule of 1.028 p.u. at the 345 kV POI.

This System Impact Study (SIS) analyzes the impact of the Eversource and National Grid proposed solution on the reliability or operating characteristics of the New England bulk power transmission system as well as Eversource and National Grid transmission systems. The objective of this study is to confirm the Project does not cause a significant adverse impact on the reliability and operating characteristics of the New England transmission system, and if the project does, to recommend system modifications that would eliminate the adverse impacts.

The following summarizes the results of this study:

Steady State Analysis

Steady state N-1 and N-1-1 analyses results show that the proposed BAOS does not have any significant thermal or voltage adverse impact.
The steady state BPS analysis was also performed and none of the stations tested became BPS due to the addition of the Project.

Stability Analysis

Stability analysis results show that the proposed BAOS does not have any significant stability adverse impact. The study included Bulk Power System analysis as well as Planning and Extreme event analysis.

Short-Circuit Analysis

Short circuit analysis results show that the maximum interrupting duty seen by all 69 kV through 345 kV circuit breakers in the Transmission system around Greater Boston are less than the rated interrupting capabilities of each breaker. Therefore, the proposed upgrades do not have any significant adverse impact on the Transmission system with respect to short circuit performance.

The impact of the proposed BAOS project on the Seabrook generator circuit breaker was also analyzed. Note that it has been identified in the QP639 SIS short circuit analysis that the Seabrook 24.5 kV generator circuit breaker will need to be upgraded due to the adverse impact of QP639. However, without the information of the new ratings of the breaker, the short circuit analysis was performed based on the existing breaker rating of Seabrook generator breaker and the impact of the project was quantified in terms of increases in short circuit amps at the Seabrook generator bus. The short circuit analysis results showed that in all the scenarios analyzed, the Seabrook generator breakers are within the asymmetrical interrupting duty ratings and the momentary duty ratings of the existing generator breaker. It can be concluded that the BAOS project has no significant adverse impact on the asymmetrical interrupting duty and momentary duty of the breaker even post the QP639 mitigation of the Seabrook generator breaker overduty. With respect to the symmetrical duty, both pre and post Project were found overdutied for three of the four scenarios analyzed. The impact of the BAOS project ranges from 671 amps to 815 amps increase for the various scenarios.

Subsynchronous Torsional Interaction (SSTI) Screenings

Subsynchronous torsional interaction (SSTI) screenings were performed for normal system and system restoration conditions, respectively. The objective of this study is to perform a subsynchronous torsional interaction (SSTI) screening of a selected group of generating plants that are electrically close to the Tewksbury 22A substation, where the new Tewksbury STATCOM is interconnecting as a part of the BAOS project. The screening analysis evaluated there is a potential for the controls of the proposed power electronic converters to interact with the turbine-generator shafts that are electrically nearby and produce resonance (torsional vibrations) at shaft natural resonant frequencies of a significant amplitude enough to damage the generators. The outcome of this screening analysis is to identify system conditions under which a detailed PSCAD analysis is needed to identify SSTI concerns. The Unit Interaction Factor (UIF) index proposed by EPRI was used as a screening measure.

The sub-synchronous torsional interaction screening study indicated that there is a potential risk of torsional interactions between the Tewksbury STATCOM and several electrically nearby generators (affected generators). Three affected generators were identified as a part of the screening analysis. Since the analysis that led to the identification of the three generators for detailed SSTI evaluation included the assessment of system restoration conditions, and because the specifics of the system restoration plan are confidential under the Information Policy, the details of the generators that were identified are excluded from this report.
Note that the SSTI phenomenon is strongly dependent on the controls used in the STATCOM and the characteristics of the turbine-generator torsional models. A detailed SSTI study to determine any required mitigation of the risk of SSTI with these affected generators will be required as part of the detailed design studies for the Tewksbury STATCOM.
National Grid and the affected generator owners have agreed that a SSTI study will be completed by National Grid, as part of the detailed design studies for the Tewksbury STATCOM. This SSTI study will include:

a) The actual control system design of the Tewksbury STATCOM facilities

b) The torsional model data, torsional mode parameters, and mechanical damping assumptions provided by each of the affected generators
c) The modeling and assumptions that were included in the SSTI screening study completed under this System Impact Study.

The specific issues that will be addressed in the SSTI study and the process for National Grid and affected generator owners to reach agreement on the determination of any need for any possible mitigating measures, including, but not necessarily limited to: STATCOM control system monitoring; STATCOM auxiliary control/protective action; or affected generator protection; will be specified in bilateral agreements reasonably negotiated between the affected generator owners and National Grid.

Electromagnetic Transients Studies

The following Electromagnetic Transient (EMT) studies were performed using PSCAD:

- PSS/E – PSCAD model benchmarking for the STATCOM at Tewksbury was conducted to meet the requirement consistent with Appendix C – Requirements of PSCAD Models of Planning Procedure 5-6. The benchmarking analysis compared the performance of the PSS/E model with the PSCAD model for fault conditions. The Siemens SVC Plus PSCAD model of the STATCOM was benchmarked against a PSS/E generic SVSMO3U2 FACTS model. Comparisons generally match well (including steady-state levels) considering the inherent differences between the two modelling platforms. Most of the traces are within a +/-10% deviation range. Overall, the comparison was deemed adequate for the purpose of moving forward with design studies.
- A control interaction study was performed to evaluate any interactions between the STATCOM at Tewksbury and other power electronic devices in the electrical vicinity of the STATCOM. The study was performed using a generic DC line model to represent Phase II HVDC to test scenarios with Phase II HVDC online. Both the Tewksbury STATCOM and the Sandy Pond HVDC link successfully rode through all the contingencies tested. No adverse control interactions were observed for any of the contingencies tested. National Grid is working with ABB to develop a PSCAD model for Phase II HVDC. A detailed control interconnection study will be completed using the detailed Phase II HVDC model and the final STATCOM model prior to energization of the STATCOM. Any required mitigation for potential control interactions between the STATCOM and Phase II HVDC would be resolved by National Grid prior to the energization of the STATCOM, and if the required mitigations require a review through the I.3.9 process, then appropriate steps will be taken by National Grid.

Conclusion

The BAOS project in this study does not result in significant adverse impact on the reliability, stability or operating characteristics of the New England transmission system.

2 INTRODUCTION AND BACKGROUND INFORMATION

2.1 Background and Study Objective

The Boston 2028 Needs Assessment results were initially reported in June 2019 and were updated in October 2019. The needs assessment identified thermal overloads for N-1 and N-1-1 conditions and voltage issues for N-1-1 conditions, as well as a dynamic reactive device need for system restoration as a result of the upcoming retirement of Mystic 8 and 9 generators. All the minimum load voltage violations were determined as time-sensitive needs and are not the subject of this study. The thermal overloads and dynamic reactive device needs were determined to be non-time-sensitive needs, which triggered the competitive solution process. In December 2019 ISO issued the Boston 2028 RFP to solicit Phase One Proposals to comprehensively address the non-time sensitive needs identified in the Boston 2028 Needs Assessment. The ISO identified NSTAR Electric Company (Eversource) and New England Power Company (National Grid) as the Backstop Transmission Solution providers for the Boston 2028 RFP. The two companies jointly developed the Backstop Transmission Solution, also named as the Boston Area Optimized Solution (BAOS).

On July 17, 2020 ISO-NE posted the final Boston 2028 RFP Review of Phase One Proposals report. The ISO identified one Phase One Proposal, the BAOS, to be included in the final listing of qualifying Phase One Proposals. The BAOS resolved all the identified needs, met the Tariff and RFP instructions, met the required in-service date, and had the lowest installed cost.

Given that the BAOS was the only Phase One Proposal that was selected to move on as a Phase Two solution, the ISO determined that, consistent with Section 4.1(i) of Attachment K of the Tariff, the Solutions Study process will be utilized. Accordingly, the ISO posted the notice of initiation of the Boston 2028 Solutions Study – Mystic Retirement. The ISO worked with Eversource and National Grid, the proponents of the BAOS, on the Solutions Study and posted the final Solutions Study report on September 29, 2020.

This System Impact Study (SIS) analyzes the impact of the Eversource and National Grid proposed upgrades on the reliability or operating characteristics of the New England bulk power transmission system as well as Eversource and National Grid transmission systems. This SIS was conducted by National Grid and Eversource Energy, in accordance with applicable reliability standards, to identify and resolve any adverse effects associated with any of the proposed upgrades on the reliability, stability, and operating characteristics of the New England transmission system.

This report documents the testing and results of the analysis performed for the proposed upgrades.

The steady state analysis includes an N-1 contingency analysis performed on summer peak and minimum load cases with all lines in service, as described in Section 4. The study also includes N-1-1 initial element out testing at the same load levels, also described in Section 4. In addition, the non-BPS stations which were not classified as BPS in the transient stability BPS testing were tested in steady state BPS testing, as described in Section 4. The study includes stability analysis that tests BPS faults, Planning Events and Extreme Events and a short circuit study, as described in Sections 5 and 5. N-1 and N-1-1 transfer limit analysis was performed by ISO-NE to evaluate the Project's impact on the established transmission transfer limits and the results were presented to the Planning Advisory Committee on November 19, 2020[1].The results of the transfer analysis indicated an increase in both N-1 and N-1-1 Boston import capability with the Project, and therefore there are no adverse impacts on transfer capabilities due to the Project.

Subsynchronous Torsional Interaction (SSTI) screening studies were performed to evaluate the subsynchronous torsional interaction (SSTI) between the STATCOM at Tewksbury and of a selected group of generating plants that are electrically close to the Tewksbury 22A substation, as described in Section 7.

The following Electromagnetic Transient studies (EMT) were performed using PSCAD, as described in Section 7:

- PSS/E – PSCAD model benchmarking for the STATCOM at Tewksbury was conducted to meet the requirement consistent with Appendix C – Requirements of PSCAD Models of Planning Procedure 5-6. The benchmarking analysis compared the performance of the PSS/E model with the PSCAD model for fault conditions. The Siemens SVC Plus PSCAD model of the STATCOM was benchmarked against a PSS/E generic SVSMO3U2 FACTS model. Comparisons generally match well (including steady-state levels) considering the inherent differences between the two modelling platforms. Most of the traces are within a +/-10% deviation range. Overall, the comparison was deemed adequate for the purpose of moving forward with design studies.
- A control interaction study was performed to evaluate any interactions between the STATCOM at Tewksbury and other power electronic devices in the electrical vicinity of the STATCOM. The study was performed using a generic DC line model for the Phase II HVDC facility to test scenarios with Phase II HVDC and the Western Massachusetts DER cluster online. Both the Tewksbury STATCOM and the Sandy Pond HVDC link successfully rode through all the contingencies tested. No adverse control interactions were observed for any of the contingencies. National Grid is working with ABB to develop a PSCAD model for Phase II HVDC. A detailed control interconnection study will be completed using the detailed Phase II HVDC model and the final STATCOM model prior to energization of the STATCOM. Any required mitigation for potential control interactions between the STATCOM and Phase II would be resolved by National Grid prior to the energization of the STATCOM

2.2 Project Description

The Project consists of the following components:

- Install two 1% (11.9 Ohms) series reactors at North Cambridge Station on the 345 kV 346 and 365 cables that extend from Eversource's Woburn Substation, in Woburn, MA to Eversource's North Cambridge Substation, in Cambridge, MA. A bypass breaker will be installed in parallel with each series reactor. The bypass breaker will be normally closed and will be opened when there is a need to switch in the reactor. For the purpose of this study to evaluate the impact of the series reactors they were assumed in service in the base cases.
- Install a Direct Transfer Trip (DTT) scheme at National Grid's Ward Hill Substation, in Haverhill, MA to send a trip signal to open the 345 kV breaker 2T345 at National Grid's West Amesbury

[1] Update to the Southeast New England and Boston Import Transfer Capabilities with the Boston Area Optimized Solution

Substation, in Amesbury, MA when both Ward Hill Substation 345 kV breakers, 394 and 4T-94, are open or when the Ward Hill Substation 345 kV line switch, 394-3 is open.

- Install a new +/- 167 MVAR STATCOM at National Grid's Tewksbury 22A Substation, in Tewksbury, MA. Install a 345/38.4 kV step up transformer for the STATCOM. Install a new 345 kV bay position at Tewksbury 22A substation, including two (2) 345 kV GIS circuit breakers and connect the STATCOM to the new bay position.

The Project is expected to be in service in October 2023. The Project one-line diagrams are shown in the following figures.

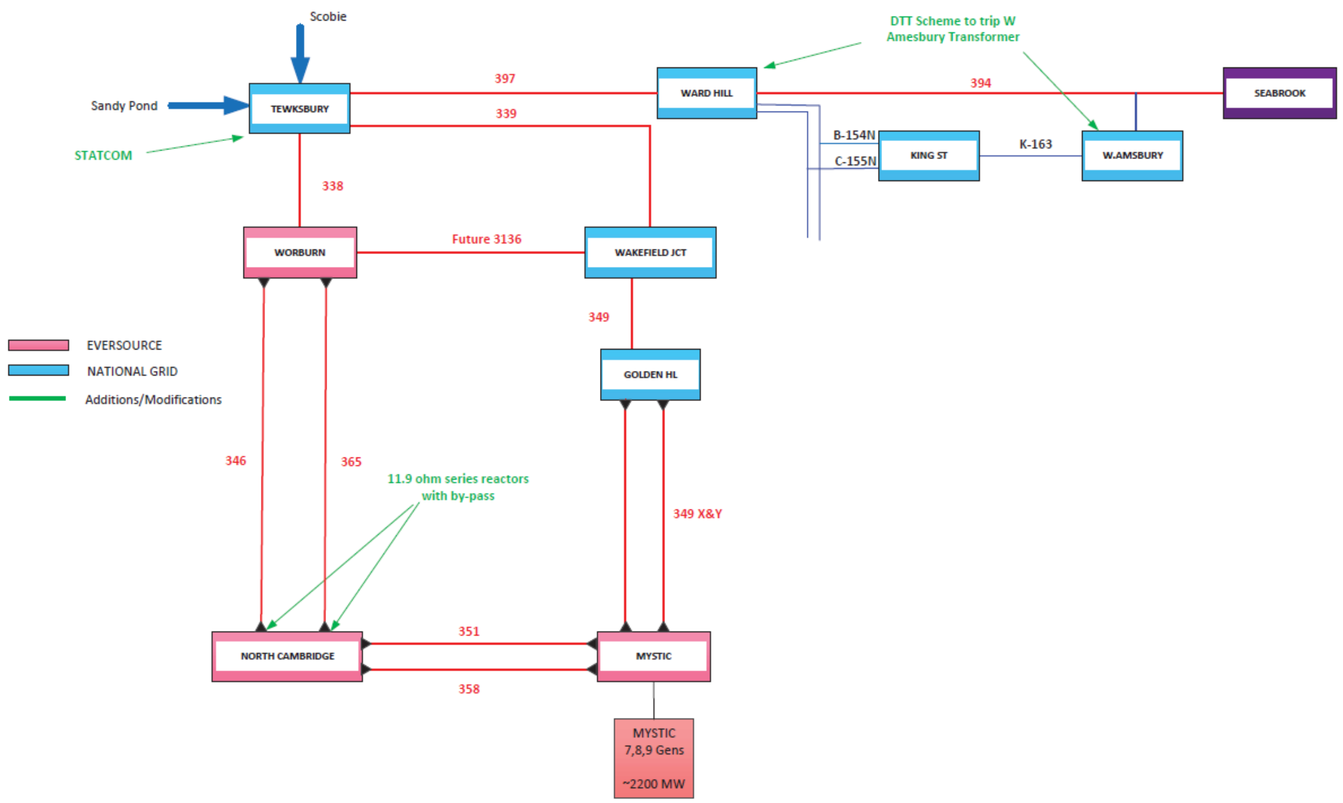

Figure 2-1 Project One-line Block Diagram

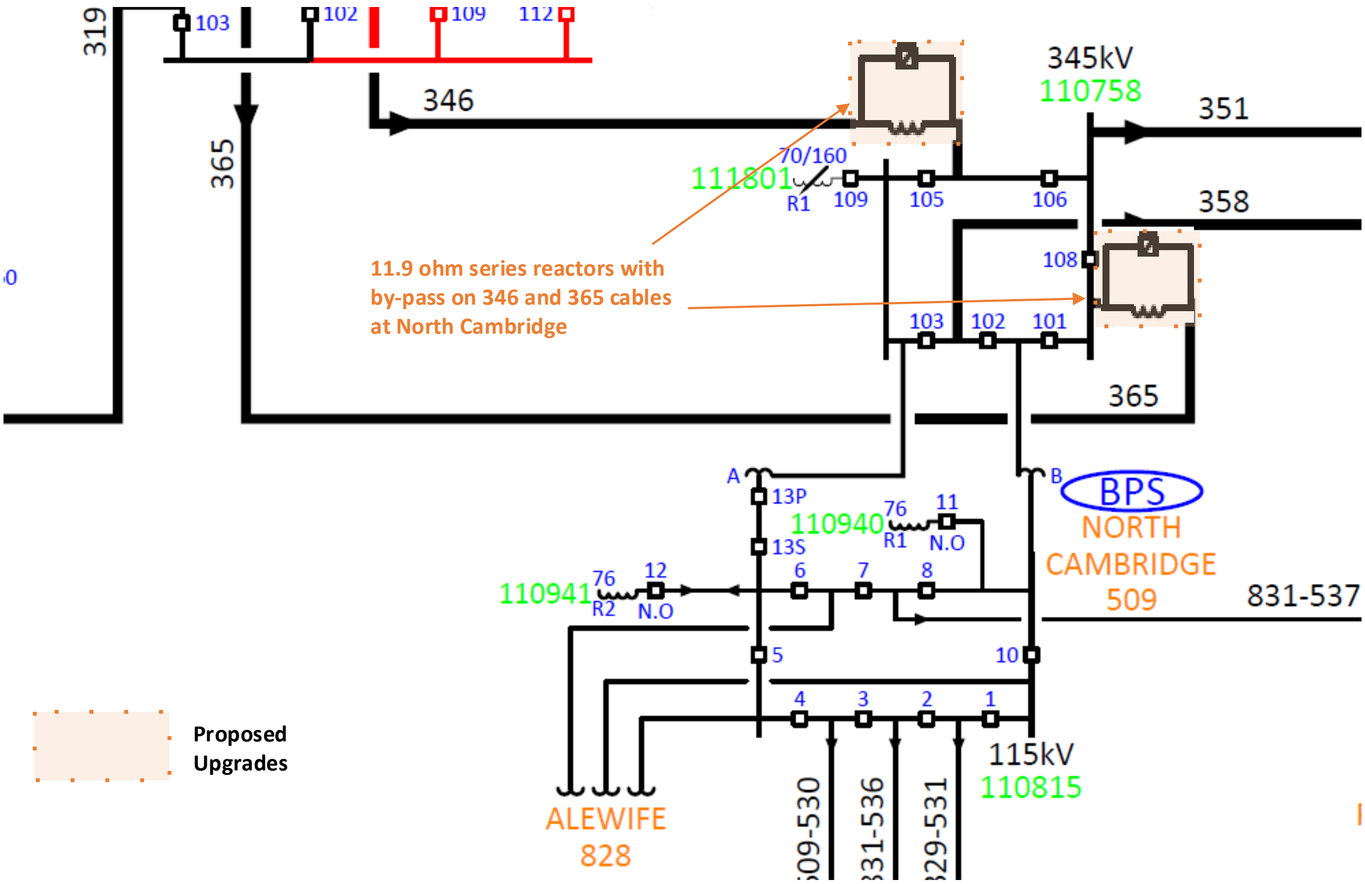

Figure 2-2 Series Reactors on 346 and 365 at North Cambridge

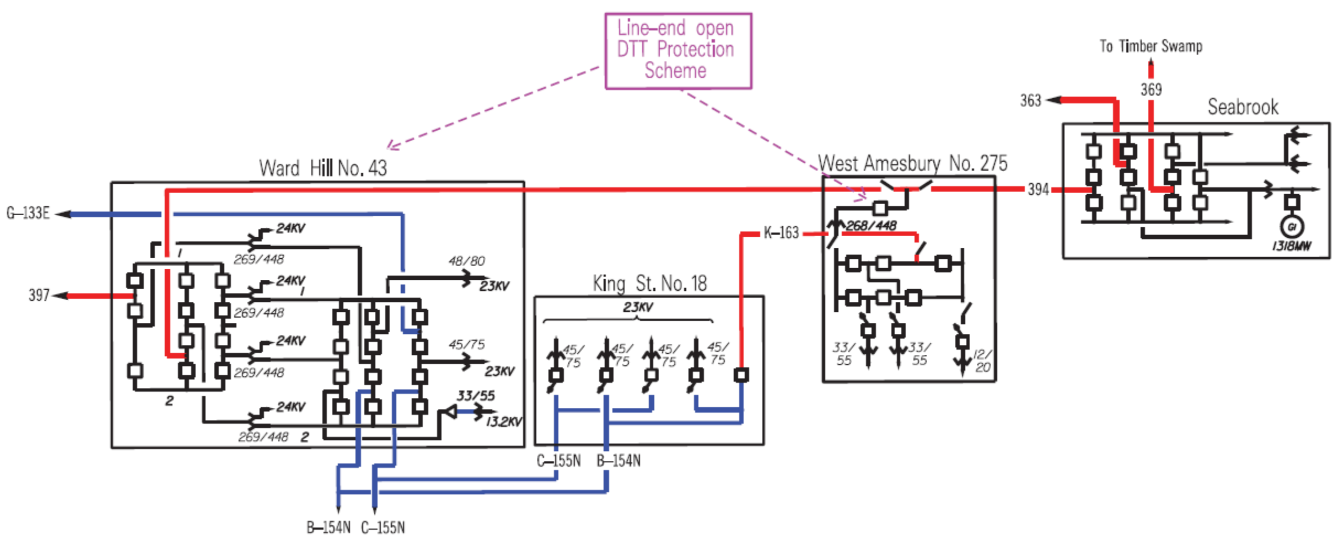

Figure 2-3 DTT on 394 at Ward Hill and West Amesbury

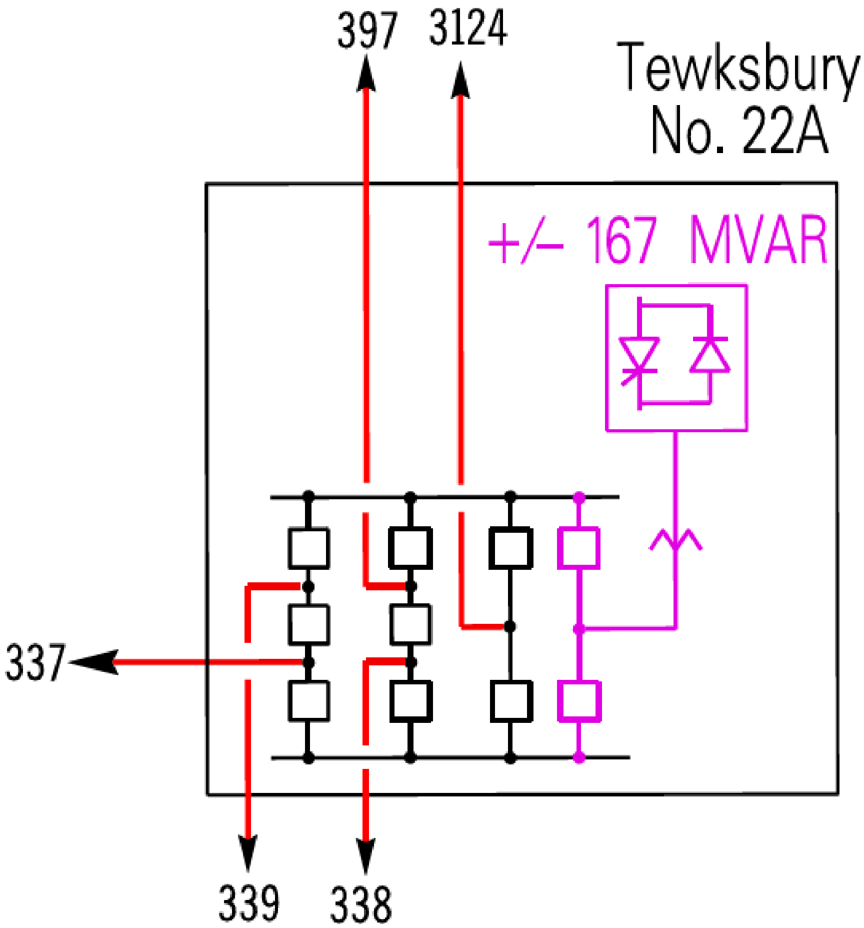

Figure 2-4 STATCOM at Tewksbury

2.3 Project Data

The IDEV files to incorporate the Project into a PSS/E version 34 system power flow model are listed in Appendix A. The dynamic model of the Project in PSS/E version 33 and the change file for ASPEN modeling is also included. The detailed information of the PSCAD model are included in the PSCAD analysis report in Appendix J.

Note that, the STATCOM automatically adjusts its controller gain based on system strength. This functionality is not available in PSSE generic model. The gain values used for the PSSE model were selected based on the PSCAD/PSSE benchmarking discussed in section 7.2.1.
The Tewksbury STATCOM will be designed such that, the gain will be set to the fixed value (gain of 5 in PSCAD model) discussed in the PSCAD/PSSE benchmarking for the planning and operating conditions assessed as part of this study.

2.4 Study Area

The transmission system geographic map and one-line diagrams of the study area are shown in Figure 2-5 and Figure 2-6.

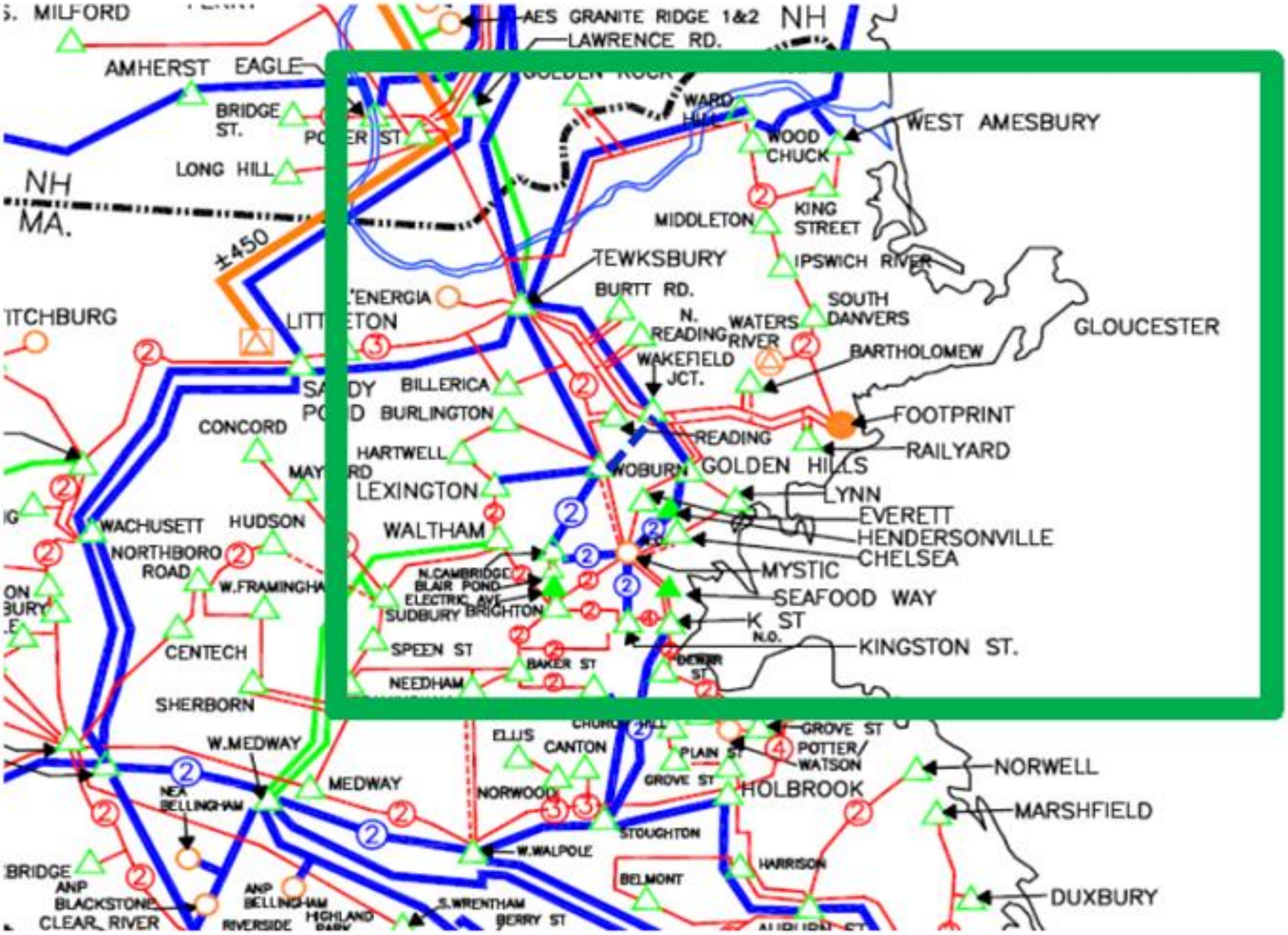

Figure 2-5 Study Area Geographic Map

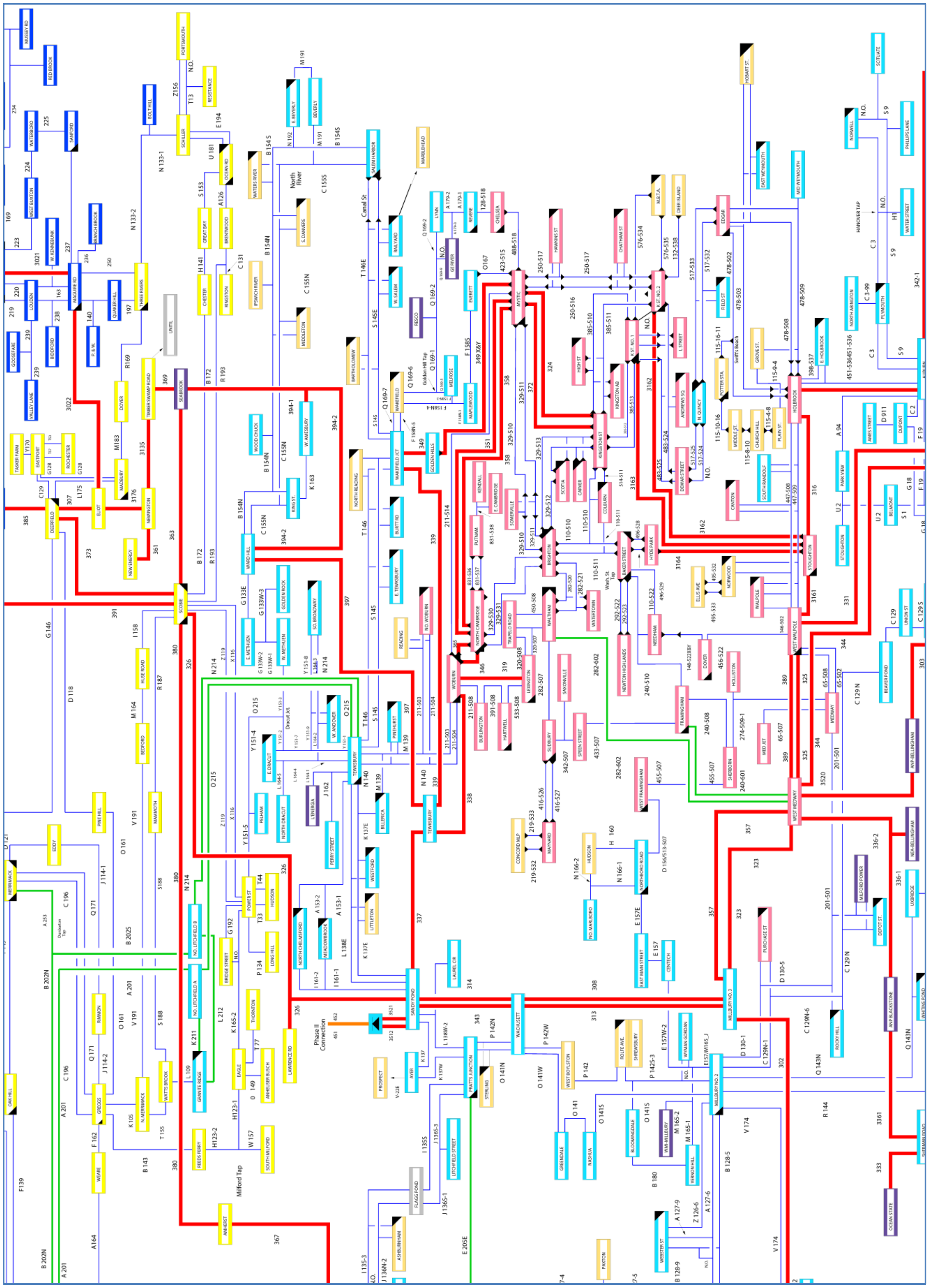

Figure 2-6 Study Area One Line Diagram (Including Related Interfaces)

3 STUDY ASSUMPTIONS AND METHODOLOGY

This section describes the applicable criteria for steady state (thermal and voltage), short circuit and stability analyses. The study was performed in accordance with the ISO-NE Planning Procedure 5-3 (PP 5-3) “Guidelines for Conducting and Evaluating Proposed Plan Application Analyses”.

3.1 Methodology and Software

3.1.1 Steady State Analysis

Steady state thermal and voltage analysis was performed with the proposed upgrades to evaluate the impact of the Project on the transmission system under both normal and contingency conditions. Siemens PTI’s PSS/E Version 34 and PowerGEM TARA 2001 was used for the analysis.

ISO-NE performed a separate Transfer Limit Analysis to evaluate the BAOS’s impact on the transfer capabilities for the Southeast New England (SENE) and Boston Import interfaces. This analysis was presented to the Planning Advisory Committee on November 20, 2020 and demonstrated that the Project results in increased Boston import and SENE import capability. Therefore, Transfer Limit Analysis was not performed in this study.

3.1.2 Short Circuit Analysis

Short circuit fault duty levels were evaluated to determine if the Project causes any breakers to exceed their short circuit duty capabilities.

The ASPEN Oneliner v14 software was used to perform this analysis. The ASPEN Breaker Rating Module was used to calculate fault duties at breakers throughout the area in the vicinity of the Project. The program calculates fault currents and X/R ratios for three-phase, phase-phase-to-ground, single-phase-to-ground, and phase-phase faults at each substation in the study area and resulting breaker duties.

3.1.3 System Adjustments in Steady State Analysis

The Boston area transmission system power flows are managed through the use of generation dispatch and phase shifting transformers located at Baker Street Substation and Waltham Substation. The phase shifters, located on the 115 kV systems inside the Boston Import area, are set to balance power flows under normal conditions, and are adjusted to mitigate thermal overloads pre-contingency and post contingency, as necessary.

For the purpose of the contingency testing conducted as part of this study, phase shifters were adjusted to angles that appeared to work best for post contingency conditions based on phase shifter optimization analysis included in the power flow testing application. This is not intended to reflect how the phase shifters would be operated under normal system conditions or to reflect the exact response to particular contingencies. Rather they were set to angles within an appropriate operating range to minimize potential post contingency overloads. This avoids reporting of overloads for which phase shifter action would serve as the mitigating measure. Post contingency adjustment of phase shifters may also be found to be effective at relieving other overloads that did not exceed STE ratings for elements on the Greater Boston transmission system.

Generation adjustments was also modeled in the analysis to reflect system adjustments that can occur between contingencies under N-1-1 contingency conditions. These adjustments are limited to generation unit redispatch and HVDC terminal adjustments. The adjustments were limited to a total of 1,200 MW across the New England system to reflect consistency with operating reserve constraints. Only the units listed in Table 3-1 were allowed to ramp up. All other units could only reduce output in response to potential overloads.

All elements operating at 69 kV and above in the Greater Boston RSP area and surrounding areas were monitored in the analysis.

Table 3-1 Reserve Units Allowed to Ramp Up Between Contingencies

High N-S Case	Low N-S Case
W. Medway J3-J5	Cape GT 4-5
W. Tisbury	Lost Nation
Oak Bluffs	Bethlehem
A.L. Pierce	White Lake Jet
TA Watson 1-2	Tamworth
Shrewsbury	Bridgewater
Cherry St Diesel 1-5	Hemphill Power
Tunnel Jet	Merrimack CT 1-2
Norwich Jet	Schiller Jet
Middletown 12-13	Comerford G1-G4
WALLINGFRDG 1-7	Moore G1-G2
NHHP G2-G4	Shrewsbury
Torrington	Cherry St Diesel 1-5
Waterbury	Tunnel Jet
QP984*	Norwich Jet
	Middletown 12-15
	Montville 10-11
	Torrington
	WALLINGFRDG 1-7
	A.L. Pierce
	Waterbury
	NHHP G2
	QP984*

*When QP984 (BESS) was in charging mode the battery was allowed to reduce charging to 0 after the first contingency in preparation for the second contingency. Note that QP984 going from full charging to 0 MW would not be a part of the 1200 MW of operating reserves.

3.1.4 Transient Stability Analysis

Transient Stability analysis was performed with the proposed upgrades to evaluate the impact of the Project on the transmission system stability. Siemens PTI's PSS/E Version 33.12 was used as the analysis software.

3.2 Study Criteria

3.2.1 Steady State Analysis Criteria

The steady state analysis was conducted in accordance with the following criteria.

- NERC Reliability Standard TPL-001-4 "Transmission System Planning Performance Requirements"[2]
- Northeast Power Coordinating Council (NPCC) Directory 1, "Design and Operation of the Bulk Power System".[3]
- ISO New England Planning Procedure #3 (PP-3) – "Reliability Standards for the New England Area Pool Transmission Facilities".[4]
- National Grid Transmission Group Procedure (TGP) #28 – "Transmission Planning Guide for the National Grid USA Service Company"[5].

Table 3-2 shows the voltage criteria that were applied in the study. The voltage of any monitored bus found to be outside the range of the post-contingency criteria is reported.

Table 3-2 Normal and Emergency Voltage Criteria

Voltage Level	Pre-Contingency Bus Voltage Limits			Post-Contingency Bus Voltage Limits		
	High Limit (pu)	Low Limit (pu)	Maximum Variation during Switching (%)	High Limit (pu)	Low Limit (pu)	Maximum Variation (%)
345 kV & 230 kV (National Grid)	1.05	0.98	5.0	1.05	0.95	5.0
345 kV & 230 kV (Eversource Energy - EMA)	1.05	0.95	3.0	1.05	0.95	n/a-
345 kV & 230 kV (Eversource Energy - NH)	1.05	0.95	2.5	1.05	0.95	6.0
345 kV (New Hampshire Transmission)	1.05	1.00	-	1.05	1.00	n/a -
115 kV[1] & 69 kV (National Grid)	1.05	0.95	10.0	1.05	0.90	10.0
115 kV (Eversource Energy - EMA)	1.05	0.95	3.0	1.05	0.95	n/a -
115 kV (Eversource Energy - NH)	1.05	0.95	2.5	1.05	0.95	6.0

[1] Buses that are part of the Bulk Power System, and other buses deemed critical by Network Operations shall meet requirements for 345 kV and 230 kV buses .

[2] https://www.nerc.com/files/TPL-001-4.pdf
[3] https://www.npcc.org/Standards/Directories/Directory1_Design%20and%20Oper_20200305.pdf
[4] https://www.iso-ne.com/static-assets/documents/2017/10/pp3_r8.pdf
[5] https://www9.nationalgridus.com/oasis/non_html/TGP28%20Issue%205%20Jan%2027%202020.pdf

Loadings on all transmission facilities rated at 69 kV and above in the study area were monitored. The use of Long-Time Emergency (LTE) and Short-Time Emergency (STE) thermal ratings in such type of studies recognizes the limited line switching, redispatch, and system reconfiguration options available to operators. These ratings provide adequate flexibility to system operations to address unique circumstances encountered on a day-to-day basis. During the contingency analysis, the loading of any monitored element found to be higher than 95% of LTE rating was reported for N-1 contingency analysis, and loadings higher than 98% were reported for N-1-1 contingency analysis. Table 3-3 shows the thermal criteria that were applied in the study.

Table 3-3 Thermal Criteria Applied in Study

SYSTEM CONDITION	TIME FRAME	MAXIMUM ALLOWABLE FACILITY LOADING
Pre-contingency (All lines in)	Continuous	Normal Rating
Post-contingency	Less than 15 minutes after contingency occurs	STE Rating
	More than 15 minutes after contingency occurs	LTE Rating

Table 3-4: Powerflow Solution Parameters shows the pre- and post-contingency solution parameters that were used in this study.

Table 3-4: Powerflow Solution Parameters

	Area Interchange	Transformer LTCs	Phase Angle Regulators	Shunt Reactive Device		DC Taps
				Discrete	Continuous[6]	
Pre-contingency	Tie Lines + Loads Regulating	Stepping	Locked[7]	Adjusting	Adjusting	Adjusting
Post-contingency pre-switching	Disabled	Disabled	Disabled	Disabled	Adjusting	Disabled
Post-contingency post-switching	Disabled	Stepping	Locked[8]	Disabled	Adjusting	Adjusting

3.2.2 Steady-State BPS Testing Methodology and Criteria

The methodology consists of opening all elements from the bus under test. If the element is a circuit that contains multiple branches, all of the branches should be opened. In cases where transformers are connected to the bus, the transformers shall be tripped by the operation of independent remote protection group capable of clearing the fault on the bus under test. In cases where the transformers connected to the bus would not be tripped, all element(s) connected to the same buses as the transformer terminals shall be tripped. If a leg of a three-terminal line is overloaded, trip the entire line, not just the overloaded branch. Following the

[6] Continuous shunt reactive device includes: FACTS devices like SVC, STATCOM, etc. that are modeled by a shunt device on continuous control in the power flow cases.
[7] Boston Area PARs set to optimized settings
[8] Boston Area PARs set to optimized settings. Immediately post-contingency the phase shifters are locked and transmission lines are monitored for STE violations. However, LTE violations that are not STE violations may be resolved by moving the phase shifters post contingency

initial powerflow solution, subsequent analysis focuses on identifying the highest percentage summer Short-Time Emergency (STE) overload, if any, and tripping that line. A cascading analysis would further address any subsequent STE overloads. The use of the STE assumption is based on the overload being significant i.e. that the line experiencing the overload would experience significant sagging and trip.

If any buses violated the Transmission Owner's voltage criteria, additional assessments were performed to further assess the system response in order to conclude if the bus is part of the Bulk Power System. This assessment should apply to both the initial post contingency loss of all elements at a bus and also at the conclusion of a cascading failure analysis due to STE violations. The objective of the voltage assessment is to confidently identify a discrete, bounded sub-area of the system that is susceptible to a voltage collapse, and determine if significant adverse impact outside the local area could occur.

3.2.2.1 Steady-State Analysis BPS Testing Procedure

These steps outline the solution parameters and steady-state analysis methodology.

Step 1: Open all elements from the substation connected to the bus of a single voltage level under test including autotransformers (e.g. At a 345/115/69 kV substation, the 115 kV bus along with all elements connected directly to the 115 kV bus will be removed from service).

Step 2: Solve the powerflow. The powerflow should be solved with the Post-Contingency pre-switching settings in Table 3-4.

Step 3: Review the results. If there are no Summer STE thermal violations, or violations of the Transmission Owner's voltage criteria, then the bus is not part of the Bulk Power System. If there are STE violations or violations of the Transmission Owner's voltage criteria, the bus can be defined as part of the BPS by inspection of the results. Proceed to Step 4 if there are STE violations, or proceed to Step 5 if there are violations of the Transmission Owner's voltage criteria.

Step 4: If there are elements in excess of their STE ratings, the following additional assessments will be conducted to further assess the system response in order to conclude if the bus is part of the Bulk Power System.

In the event that elements exceed their Summer STE limits, perform a cascading analysis by opening the element with the greatest percent STE overload, and solving the powerflow as described in Step 2. Continue with this process until there are no further STE overloads. If the element is a circuit that contains multiple branches, all of the branches should be opened. If a leg of a three-terminal line is overloaded, trip the entire line, not just the overloaded branch. Complete the simulation by continuing this iterative process until there are no more overloads or the case diverges.

If the circuit STE overloads/openings stop and the case solve without severe voltage/reactive conditions, or if the circuit STE overloads/openings continue to the point where the case will not solve, demarcate the sub-area that would separate from the rest of the system. This should be based on the cascading overload pattern evidenced by the power flows. If there are violations of the Transmission Owner's voltage criteria, or the case will not solve due to voltage/reactive performance proceed to Step 5.

Step 5: If there are violations of the Transmission Owner’s voltage criteria, the following additional assessments will be conducted to further assess the system response in order to conclude if the bus is part of the Bulk Power System.

If the case does not solve due to voltage/reactive performance add fictitious reactive compensation to the case in order to achieve a converged powerflow solution. If fictitious reactive support can be added to the distribution bus to achieve a converged powerflow solution, this should be considered first. The amount of fictitious reactive compensation should be minimized such that a solution is found but the sub-area experiencing voltage violations can be identified.

Determine if the voltage violations are contained to a discrete bounded area of the transmission system. If the voltage violations are severe enough that a voltage collapse could occur, demarcate the sub-area that would separate from the rest of the system. Following this procedure, if the net loss of source is greater than 1,200 MW, or net loss of load is greater than 1,200 MW or uncontrolled separation of major portions of the Eastern Interconnection, the bus under test would be classified as a part of the BPS.

3.2.3 Stability Analysis Criteria

3.2.3.1 Normal Contingencies/Planning Events Testing

The following criteria were used for normal contingencies:

- The system shall remain stable. Cascading and uncontrollable islanding that result in the loss or unintentional separation of major portions of the PTF transmission system shall not occur. Individual generating units $\geqslant$ 5 MW or any set of units totaling more than 20 MW shall not lose synchronism or trip.
- System damping criteria: a 53% reduction in the magnitude of an oscillation must be observed over four periods of an oscillation, measuring from the point where only a single mode of oscillation remains in the simulation.
- Transient Voltage Criteria: The voltage at all the PTF buses that serve load or buses that are connected to load-serving transformers shall not stay below 0.8 pu for longer than 10 seconds from fault inception.

The following guideline was considered when evaluating the results:

- Voltage sag guideline: the minimum post-fault positive sequence voltage sag must remain above 70% of nominal voltage and must not exceed 250 milliseconds below 80% of nominal voltage within 10 seconds following a fault. See Figure 3-1.

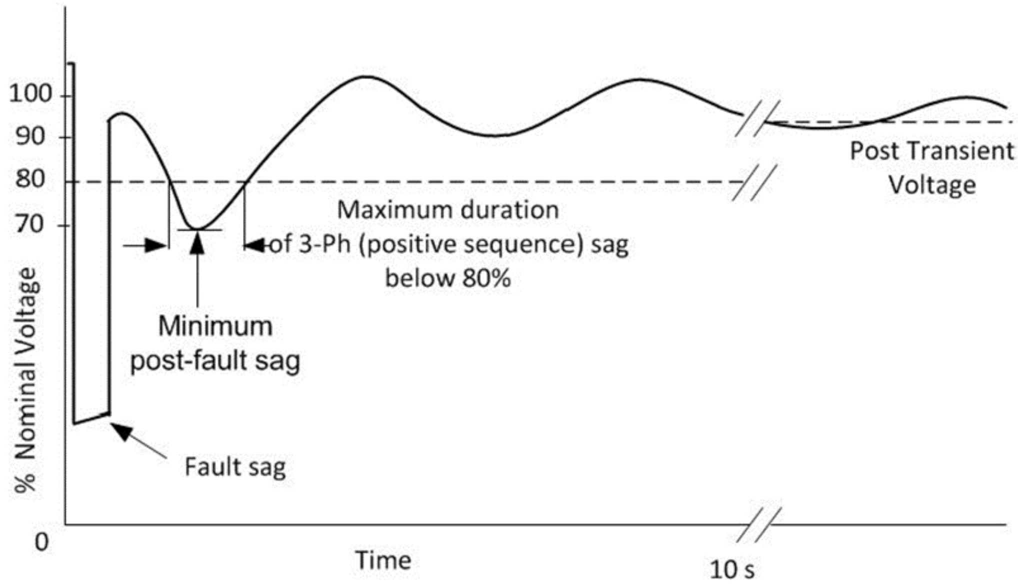

Figure 3-1 Voltage Sag Guideline

3.2.3.2 Extreme Events Testing

The following responses are considered unacceptable responses to an extreme contingency involving a three phase fault with delayed clearing due to a stuck breaker and should be mitigated:

- Transiently unstable response resulting in wide spread system collapse
- Transiently stable response with undamped or sustained power system oscillations
- A net loss of source within New England in excess of 2,200 MW resulting from any combination of the loss of synchronism of one or more generating units, generation rejection initiated by a Special Protection System, tripping of the New Brunswick-New England tie, or any other system separation. The loss of source is net of any load that is interrupted as a result of the contingency.

The following response can be considered acceptable to an extreme contingency involving a three phase fault with delayed clearing:

- A net loss of source above 1,400 MW and up to 2,200 MW[9], resulting from any combination of the loss of synchronism of one or more generating units, generation rejection initiated by a Special Protection System, or any other defined system separation, if supported by studies, on the basis of acceptable likelihood of occurrence, limited exposure to the pre-contingent operating conditions required to create the scenario, or efforts to minimize the likelihood of occurrence or to mitigate against the consequence of the contingency. The loss of source is net of any load that is interrupted as a result of the contingency.

[9]The 1,400 MW and 2,200 MW levels are documented in a NEPOOL Stability Task Force presentation to the NEPOOL Reliability Committee on September 9, 2000. This presentation is included in Appendix F – Stability Task Force Presentation to Reliability Committee – September 9, 2000, Section 5.6.

3.2.3.3 Bulk Power System Testing

For Bulk Power System (BPS) Testing, all relays for the station under test were assumed inoperable. Simulations were conducted using existing remote-end clearing times. Based on the results of these simulations, shorter clearing times will be evaluated to minimize a particular station's impact on the Bulk Power System as an alternative to BPS classification. Otherwise, the station would be classified as BPS. If a station is classified as part of the BPS, then all stations one bus away would be tested in a similar fashion until no other stations need to be classified as BPS. The stations that were tested are listed in Section 6. The BPS or non-BPS status of a bus was determined based on following criteria. The same criteria was used in evaluating the results of the extreme events analysis:

Acceptable responses (leading to a non-BPS classification):

- A 53% reduction in the magnitude of system oscillations observed over four periods
- Loss of source up to 1,200 MW

Unacceptable responses (leading to a BPS classification):

- Transient instability with widespread system collapse.
- Transiently stable, with undamped oscillations observed outside of a localized area.
- Net loss of source greater than 1,200 MW
- Net loss of load greater than 1,200 MW.
- Uncontrolled separation of major portions of the Eastern Interconnection (including any system separation that results in the islanding of another NPCC Area). For the purposes of BPS classification, a post-fault transient voltage sag below 0.5 per unit on any transmission bus is considered indicative of a system separation, regardless of whether machines remain in synchronism.

The contingencies described in Section 6 were tested and evaluated with the Project in service.

3.2.4 Short Circuit Analysis Criteria

The Short Circuit Analysis was performed using the ASPEN Oneliner Breaker Rating Module. This requires modeling of each circuit breaker at each of the substations, its connections to its projected branches, its interrupting capability and characteristics, and reclosing settings.

The program calculates fault currents and X/R ratios for three-phase, phase-phase, phase-phase-ground, and phase-ground faults at each substation for all lines in and for line out situations.

Each study area breaker's steady state fault current (I_{SC}) and breaker duty were determined based on IEEE Std. C37.010 except for the Seabrook generator breaker. The maximum fault current duty that an individual breaker would be exposed to at the expected breaker operating time were determined based on the physical arrangement of the breakers clearing the fault. Pre-fault voltages were assumed to be at a flat profile of 1.05 pu at National Grid buses, 1.03 pu at Eversource Energy - EMA buses and 1.04 per unit at the Eversource Energy - New Hampshire buses.

The short circuit criteria for transmission owners in New England require that no circuit breaker shall be operated in excess of 100 percent of its fault interrupting rating and momentary rating.

4 STEADY-STATE ANALYSIS

N-1 and N-1-1 contingency conditions were tested in steady state analysis of the power flow cases with the proposed projects in service. Assumptions such as element and interface monitoring as well as settings used for optimization of phase shifters and generator redispatch were all consistent with those used in the Boston 2028 Needs Assessment:

- Modeling of phase shifters were synchronized at Waltham and Baker St. substations
- Generation backdown was limited to 1200 MW through constraints on the number and size of units that could be dispatched up.

4.1 BASE CASE DEVELOPMENT

The cases utilized a 2024 topology that includes all PPA approved generators, transmission and ETUs through May 1, 2020. Additionally, the following projects QP639 and QP781 that received PPA approval after May 1 and are relevant to the study are included in the base cases.

Although the Project's proposed in-service date is October 2023 and prior to the expected retirement of Mystic generators 8 and 9 by June 1, 2024, sensitivities to Mystic generators 8 and 9 in service were deemed unnecessary in steady state analysis because the series reactors on the 346 and 365 lines can be bypassed while the Mystic generators are still in service. A sensitivity analysis with Mystic 8 and 9 online was not included because a) series reactors can be bypassed, and b) the Tewksbury STATCOM is not expected to cause any adverse impact for the system with Mystic 8 and 9 online that will not be observed in the system with Mystic 8 and 9 out of service.

4.1.1 Load Level, Demand Resources, and Energy Efficiency Assumptions

Power flow cases representing various 2024 peak load conditions were used in the study. The peak load represents the 2024 summer peak 90/10 load of the 2020 CELT forecast. The minimum load case models a non-manufacturing New England load of 7,680 MW.

Demand Resources (DR) and Energy Efficiency (EE) cleared in the Forward Capacity Auction (FCA) #14 for New England were modeled in the power flow base case. DR and EE load reductions were modeled by adding negative load to applicable buses.

Table 4-1 New England below, shows the New England (NE) (Area #101 in the PSSE case) loads and transmission losses for the study load levels as well as the demand resource (DR), energy efficiency (EE) and photovoltaic (PV) assumptions. The loads include station service, non-CELT, PV load, and active demand response. Details on load forecasts and DR forecast may be found in Section 9.2 – Appendix B.

Table 4-1 New England Load and Losses for 2024 Peak and Minimum Load Levels

Load Level	2020 CELT Area 101 Load & Losses (MW)	Non-CELT Manufacturing Load (MW)	Area 101 EE Forecast (MW)	Area 101 ADCR (MW)	Area 101 PhotoVoltaic (MW)	Total (MW)
Peak Load - 2024	32,235	318	-5,210	-478	-1,741	25,124
Minimum Load	7,680	0	N/A	N/A	N/A	7,680

4.1.2 Projects Included

Projects with PPA determinations and in-service dates before Summer 2024 were included in the case as relevant to the study. A specific list of projects included in the case can be found in Section 0 – Appendix C which includes, but is not limited to, the following:

- Pittsfield/Greenfield Reliability Project
- Greater Boston Reliability Project
- Southeast Massachusetts and Rhode Island Reliability Project
- Southwest Connecticut (SWCT) Reliability Project
- QP624 Vineyard Wind I
- QP618 Bay State Wind
- Boston 2028 time sensitive solution – double Mystic #4 breaker and 160 MVAR 345 kV reactor at Golden Hills
- 349X&Y cable reconductoring
- 110-510 and 110-511 cable reconductoring
- Andrew Square/Dewar Reliability Project
- New England Clean Energy Connect (NECEC)
- QP758, 73.2 MW Combined Cycle Uprate interconnecting at Sherman Road 345 kV
- QP781, 704 MW Offshore Wind interconnecting at Davisville 115 kV
- QP883, 16.45 MW Combined Cycle increase at Kendall
- QP700: 820 MW off shore wind farm interconnecting to West Barnstable 345 kV
- QP726: 150 MW batter storage interconnecting close to Carver 115 kV

The following queued generation interconnection projects do not have approved PPA's but are relevant to the study area and are included as sensitivity.

- QP844: 250 MW battery storage interconnecting to West Medway 345 kV substation
- QP806: 880 MW off shore wind farm interconnecting to West Barnstable 345 kV
- QP829: 1000 MW off shore interconnecting to 322 and 399 lines
- QP830: 876 MW off shore wind farm interconnecting to West Barnstable 345 kV

- QP984: 150 MW storage on National Grid 115kV line 1/2 mile to the East of Billerica 70 substation

4.1.3 Project Dispatches and Transfer Levels

Since the Project is in the Greater Boston area, the following interfaces were stressed for the study:

- Boston Import
- North-South
- SEMA/RI

The transmission system peak load cases were modeled using the following transfer level scenarios.

- Stress 1 - High North-South & Low SEMA/RI Export
- Stress 2 - High SEMA-RI Export with existing generation
- Stress 3 - Low North-South & High SEMA/RI Export
- Stress 4 - High SEMA-RI Export with high offshore wind

4.1.3.1 Base Case Summaries

A summary of the study cases, which provides an overview of the various transfer level and dispatch scenarios included in the study is provided in Table 4-2. A full listing of all the base case summaries can be found in Section 0 – Appendix D.

Table 4-2 Steady State Study Case Summaries

Case Identifier	Interface Stress Condition	Description
2024_Peak_Low_SEMA_RI	Peak Load	High North-South transfer, High SEMA/RI Import
2024_Peak_High_SEMA_RI_base	Peak Load	High North-South transfer, High SEMA/RI Export
2024_Peak_High_SEMA_RI_osw	Peak Load	High North-South transfer, High SEMA/RI Export high offshore wind and QP873 ETU on
2024_Peak_Low_NS	Peak Load	Low North-South transfer, High SEMA/RI Export
2024_MinLoad_NE	Minimum Load	Minimum Load, Low NE transfers

4.1.3.2 Transfer Levels

The Boston Import interface is considered as internal to the study area and flows across the interface are based on the modeled dispatch condition for units inside the interface. Table 4-3 2024 Cases Interface Transfers shows the transfer levels studied for the 2024 Base Cases. Interface levels and area generation dispatches vary among four Peak Load cases to stress the transmission system of the study area differently. North South and SEMA/RI Interface levels are stressed such that circuits around the Boston area are heavily loaded. The minimum load case is dispatched such that the worst voltage scenario is realized. More information of the minimum load testing assumptions is in section 4.1.3.4.

Table 4-3 2024 Cases Interface Transfers

Case Identifier	EAST-WEST	NNE-Scobie+394	NE-BOSTON	NORTH-SOUTH	SEMA/RI - NE	SNDYPD_IMP
2024_Peak_Low_SEMA_RI	-2738	3427	4560	2714	-1799	2000
2024_Peak_High_SEMA_RI_base	2741	3156	4628	2757	3440	2000
2024_Peak_Low_NS	-403	2247	4751	1374	1856	2000
2024_Peak_High_SEMA_RI_osw	2428	3320	4893	2720	3496	2000
2024_MinLoad_NE	-757	-13	1703	719	321	500

4.1.3.3 Generation Dispatch Conditions

The unit dispatch levels shown in Table 4-4 below were modeled in the cases to reflect a reasonable range and combination of unit unavailability conditions in the Greater Boston area. The detailed case summaries are listed in Section 0 – Appendix D.

Table 4-4 Modeled Generation Dispatch Conditions

Case Identifier	2024_Peak_Low_SEMA_RI	2024_Peak_High_SEMA_RI_base	2024_Peak_Low_NS	2024_Peak_High_SEMA_RI_osw	2024_MinLoad_NE
EDGAR GT1	273	0	0	0	0
EDGAR GT2	273	0	0	0	0
EDGAR ST	269	0	0	0	0
FOOTPRNT 5CT	0	221	221	0	0
FOOTPRNT 5ST	0	145	145	0	0
FOOTPRNT 6CT	221	221	221	221	0
FOOTPRNT 6ST	145	145	145	145	0
Waters River J1	20	0	0	0	0
Waters River J2	39	39	39	39	0
MMWEC Waters River	65	65	65	65	0
KENDALL CT	223	0	0	223	0
MYSTIC 7GT	0	0	0	0	0
MYSTIC 8ST	0	0	0	0	0
MYSTIC GT 8A	0	0	0	0	0
MYSTIC GT 8B	0	0	0	0	0
MYSTIC 9ST	0	0	0	0	0
MYSTIC GT 9A	0	0	0	0	0
MYSTIC GT 9B	0	0	0	0	0
W. Medway J4	0	108	108	0	0

W. Medway J5	0	108	108	0	0
Seabrook	1309	1309	1309	1309	0
Bay State Wind	0	800	800	800	0
Revolution Wind	0	700	700	700	0
QP624	400	800	800	800	369
QP726	-150	0	0	150	0
QP844	-250	0	0	250	0
QP984	0	-150	-150	-150	0
QP700	0	0	0	800	0
QP806	0	0	0	0	0
QP829	0	0	0	662	0
QP830	0	0	0	0	0

4.1.3.4 Minimum Load Testing Assumptions

The assumptions for minimum load testing are listed below.

- 7680 MW New England load level
- Low New England transfers
- The pumped hydro units in western Massachusetts are off-line.
- NY-NE and NB-NE at 0 MW
- The min load case is dispatched such that the worst voltage scenario is realized. BESS generation is off-line. Minimal Off-Shore Wind generation is dispatched in the minimum load case. This dispatch produces the worst voltage response since the reactive capability of the generating resources is not available, and the transmission system power transfers remain low.
- All Boston area shunt reactors in-service.
- The load tap changer on the Woburn 345/115 kV transformer was used to increase the effectiveness of the Woburn 115 kV reactors to absorb reactive flows from the 345 kV system.

4.2 N-1 Contingency List

All area NERC, NPCC, and ISO-NE design contingencies were included in the N-1 Contingency List. Contingencies tested include both Bulk Power System (BPS) and non-BPS facilities from 69 kV to 345 kV. The addition of new contingencies introduced by the solution listed in Table 4-5 was also tested. The following rules was used to include contingencies that are critical to the Boston study area:

1. All 345 kV and 230 kV contingencies in the RSP subareas of Boston, New Hampshire (NH), Southeastern Massachusetts (SEMA), Rhode Island (RI) and Central Massachusetts (MA).
2. All 115 kV and below contingencies in the RSP subarea of Boston was included
3. All 115 kV and below contingencies in the PSS/E zones corresponding to Eversource NSTAR buses in Southern Massachusetts (Zones 1020-1023), National Grid Merrimack Valley (Zone 1120) and National Grid SEMA (Zone 1140) was included
4. All 115 kV and below contingencies that are connected to the following buses was included. Wachusett 115 kV and 69 kV, Millbury 115 kV and 69 kV, and Power Street 115 kV.

The full list of N-1 contingencies tested in the study can be found in Section 9.5 - Appendix E.

Table 4-5 shows the added, modified and removed contingencies by the Project.

Table 4-5 New, Modified and Removed Contingencies by the Project

Contingency ID	kV	Add/Modify/Remove	Description
STAT_TWKS	345	Add	Loss of Tewksbury STATCOM
NF_394_WRDHL	345	Remove	No fault contingency 394 circuit between Ward Hill and West Amesbury
LN_346	345	Modify	Loss of 346 Circuit between Woburn and N Cambridge
LN_365	345	Modify	Loss of 365 Circuit between Woburn and N Cambridge
BF_NCAMB_105	345	Modify	Loss of 346 Circuit between Woburn and N Cambridge and 345A Autotransformer and Reactor R1 at N Cambridge
BF_NCAMB_106	345	Modify	Loss of 346 Circuit between Woburn and N Cambridge and 351 between N Cambridge and Mystic
BF_NCAMB_108	345	Modify	Loss of 365 Circuit between Woburn and N Cambridge and 351 between N Cambridge and Mystic
BF_NCAMB_101	345	Modify	Loss of 365 Circuit between Woburn and N Cambridge and 345B Autotransformer and Reactor R1 at N Cambridge

4.3 N-1-1 Contingency List

Transmission lines, transformers, reactive devices and generators are considered as the initial element out for N-1-1 testing. The set of contingencies tested in the N-1-1 analysis is the same set used in N-1 contingency analysis as described in section 4.2. A full listing of the contingencies selected based on the described selection criteria can be found in Section 9.5 – Appendix F. The Project proposes 345 kV upgrades therefore testing of the 345 kV element outages as the first contingency is more relevant. In addition, all the contingencies in the study area including 115 kV contingencies was tested as the second contingency. Hence outages of 115 kV elements was not tested as the first contingency.

- 345 kV transmission lines, autotransformers, reactive devices in Central and Eastern Massachusetts and Southern New Hampshire;
- 230 kV transmission lines in Massachusetts and Southern New Hampshire;
- HVDC – Sandy Pond, NECEC
- Major generation – Seabrook, Canal, Kendall CT, Footprint (2 units)

4.4 Bulk Power System (BPS) Contingency List

If the non-BPS stations in Table 5-6 List of BPS Contingencies are not classified as BPS in the transient stability BPS testing as described in Section 5.2.2, they will be tested in steady state simulation which will:

- Remove all elements that were disconnected by the end of the transient stability test, including generators that lose synchronism or are tripped due to voltage, frequency or other protection.
- Reflect operation of all automatic devices.

The following base cases used for the stability BPS testing will be used for the steady state BPS testing. In addition, one peak load case with high Boston Import will be added for the steady state BPS testing.

- ME_C
- ME_C_NECEC
- NHBOS
- BOS

- SEMA
- PEAK
- PEAK_NECEC
- PEAK_Boston_Imp

4.5 Steady State Analysis Results

The results in this section includes the Pool Transmission Facilities (PTF) elements. The project does not address non-PTF needs in the area or has any impact on them.

4.5.1 N-0 Results

N-0 steady state results do not show any N-0 thermal or voltage violations under peak or minimum load conditions.

4.5.2 N-1 Results

Table 4-6 N-1 Thermal Violation Results summarizes the N-1 thermal violation results and includes all PTF facilities that are over 100% of LTE pre project or post project. The project does not have any adverse impacts. Detailed N-1 steady state analysis can be found in Appendix I.

The N-140 overload below is as an adverse impact of QP984 in charging mode. The overload does occur in pre or post project cases if QP984 is offline. The QP984 system impact study shows that this circuit needs to be upgraded to 190 MVA (LTE rating). The upgrade will resolve the overload below.

Table 4-6 N-1 Thermal Violation Results

Monitored Facility	LTE Rating (MVA)	Voltage (kV)	Contingency	Worst Case Scenario	% Loading Pre Project	% Loading Post Project	Percent change
N-140 Reading-Reading Muni	153	115	NF_M139-2 Tewksbury - Billerica	Sum PK High SEMA OSW	116.46	115.64	-0.82

The peak and minimum load voltage analysis results do not identify any N-1 voltage adverse impact. There are pre project low voltages at two 115 kV buses listed in Table 4-7. The Project does not have an adverse impact on these low voltage violations.

Table 4-7 N-1 Voltage Violation Results

Bus Name	Base kV	Min Volt Limit	Max Volt Limit	%V Change Limit	Contingency	Worst Case Scenario	Base Volt	Cont Volt Post Switching	%Vdrop
IPSWCH_RV_55	115	0.9	1.05	10	DC_B154C155S_NPCC	Sum PK Low SEMA BAOS	1.0041	0.8995	10.462

Bus Name	Base kV	Min Volt Limit	Max Volt Limit	%V Change Limit	Contingency	Worst Case Scenario	Base Volt	Cont Volt Post Switching	%Vdrop
IPSWCH_RV_55	115	0.9	1.05	10	DC_B154C155S_NPCC	Sum PK Low SEMA	1.0028	0.8927	11.009
S DANVERS_55	115	0.9	1.05	10	DC_B154C155S_NPCC	Sum PK Low SEMA BAOS	1.005	0.883	12.205
S DANVERS_55	115	0.9	1.05	10	DC_B154C155S_NPCC	Sum PK Low SEMA	1.0042	0.8764	12.782

4.5.3 N-1-1 Results

Table 4-8 summarizes the N-1-1 thermal violation results and includes all PTF facilities that are over 100% of LTE pre project or post project. The Project does not have any adverse thermal impacts under N-1-1 conditions. Detailed N-1 steady state analysis can be found in Appendix I.

Table 4-8 N-1-1 Thermal Violation Results

Monitored Facility	LTE Rating (MVA)	Voltage (kV)	Initial Element OOS	Contingency	Scenario	% Loading Pre Project	% Loading Post Project	Percent change
Line 365 N Cambridge-Woburn	657	345	LN_346	BF_WAKE_491T (Ln 349 + Wakefield Jct 1T)	Sum Pk Low SEMA (Peak Load)	111.8	84.2	-27.6
Line 346 N Cambridge-Woburn	657	345	LN_365	BF_WAKE_491T (Ln 349 + Wakefield Jct 1T)	Sum Pk Low SEMA (Peak Load)	111.8	84.2	-27.6
Line 358 N Cambridge-Mystic	585	345	LN_351	BF_WAKE_491T (Ln 349 + Wakefield Jct 1T)	Sum Pk Low SEMA	102.5	89.6	-12.9

The peak and minimum load voltage analysis results do not identify any N-1-1 voltage violations.

4.5.4 Steady State Bulk Power System (BPS) Test Results

Steady state BPS testing was performed for all eight (8) steady state cases listed in Section 4.4. Eleven (11) stations were examined as part of the steady state BPS evaluation: Burlington Station #391, East Cambridge Station #875, Everett Station #37, Hartwell Station #533, Kendall Station #800, Maplewood Station #16, North Woburn Station #375, Reading Station #494, Salem Harbor Station, Scotia Street Station #492, and Trapelo Road Station #450.

The BPS tests all converged and did not result in more than 5 steps cascading tripping due to STE violations. No voltage collapse, nor more than 1,200MW source or load loss was observed in the system. Therefore, steady state BPS testing demonstrated that none of the stations tested were classified as part of BPS due to the addition of the Project.

5 STABILITY ANALYSIS

Planning Event, Extreme Event and Bulk Power System (BPS) testing were performed on the post project cases to determine if the Project has any adverse impact on the stability of New England bulk Transmission System or it causes a substation to be classified as part of the New England Bulk Power System. If potential adverse impact was observed in the post project system then a simulation was performed with the pre project system to identify the impact of the project.

Two light load and one peak load cases were used to test Planning Events.

Four light load and two peak load cases were used to test the BPS status of the selected non-BPS stations in Boston area with the Greater Boston Reliability Solution in-service. The same cases were used to test Extreme Events.

5.1 BASE CASE DEVELOPMENT

All New England relevant interfaces were stressed simultaneously in the first light load case used for testing Planning Events. A sensitivity light load case to Mystic units with high Boston generation was also tested to evaluate the impact of the project for the period before Mystic retirement. The interfaces were stressed to the extent possible in the peak load case. The cases represent the 2025 topology and are released by ISO-NE in June 2020. Area generation was turned on in the Planning Event cases.

Projects with PPA approval through May 1, 2020 and in-service dates before Summer 2024 were included as listed in Section 4.1.2, with the exception of Revolution Wind and NECEC that are included but received PPAs after May 1. The following queue projects were also modeled due to their possible impact even though QP700 and QP726 received PPA approval after May 1, 2020 and QP844 and QP984 do not have PPA approval at the time of this study.

- QP700: 820 MW off shore wind farm interconnecting to West Barnstable 345 kV
- QP726: 150 MW batter storage interconnecting close to Carver 115 kV
- QP844: 250 MW battery storage interconnecting to West Medway 345 kV substation
- QP984: 150 MW storage on National Grid 115kV line 1/2 mile to the East of Billerica 70 substation

The BPS cases do not include the four queue projects listed above. There is a BPS ME_C bias light load case and a peak case with NECEC online to test the sensitivity to that project. This study uses BPS cases released by ISO-NE in June 2020 for a 2025 topology. In the 2020 CELT report, the summer 90/10 gross load forecast for year 2025 is 31,635MW for NE and 7,139MW for NEMA area, compared to 31,377MW for NE and 7,058MW for NEMA area in year 2024. The difference is small therefore no load adjustment was made. There are also no new transmission or generation interconnection project that is modeled in year 2025 case in the study area but would not be in the 2024 case. Hence the 2025 BPS peak cases were used for the study.

All the stability cases are in PSS/E version 33 format.

5.1.1 Project Dispatches and Transfer Levels

Since the Project is in the Greater Boston area, the following BPS cases were used for the study:

- ME_C
- ME_C_NECEC
- NHBOS
- BOS
- SEMA
- PEAK
- PEAK_NECEC

5.1.1.1 Base Case Summaries

A summary of the cases modeled for the study, which provides an overview of the various transfer level and dispatch scenarios included in the study, is provided in Table 5-1. A full listing of all the base case summaries can be found in Section 0 – Appendix F.

Table 5-1 Stability Study BPS Case Summaries

Case Identifier	Interface Stress Condition	Description	Test
LL-1_2025	Light Load	All relevant interfaces stressed simultaneously	Planning Event
LL-2_2025	Light Load	Sensitivity to LL-1 with high Boston generation including Mystic 8 and 9	Planning Event
PK_2025	Peak Load	All interfaces stressed simultaneously to the extent possible	Planning Event
ME_C	Light Load	Maine-Central stress	BPS/Extreme Event
ME_C_NECEC	Light Load	Maine-Central stress – Sensitivity to QP639 New England Clean Connect (NECEC)	BPS/Extreme Event
NHBOS	Light Load	New Hampshire-Boston stress	BPS/Extreme Event
BOS	Light Load	Boston stress	BPS/Extreme Event
SEMA	Light Load	Southeast Massachusetts stress	BPS/Extreme Event
PEAK_BASE	Peak Load	Peak load stress	BPS/Extreme Event
PEAK_NECEC	Peak Load	Peak load stress with NECEC at full output	BPS/Extreme Event

5.1.1.2 Transfer Levels

Table 4-3 2024 Cases Interface Transfers shows the transfer levels studied for the stability analysis.

Table 5-2 Stability Cases Interface Transfers

Case Identifier	EAST-WEST	ME-NH	NB-NE	Bos-Import	NNE-SCOB+394	North-South	NE-NY	SEMA/RI-NE	ORR_South	SURW_South
Interface limit	3500	2000	1050	5150	3650	2840	1200	-	1375	2200
LL-1_2025	3500	2000	1050	2810	3650	3270	1195	3650	1375	2200
LL-2_2025	3495	1975	1050	-360	3650	3275	1195	415	1375	1440
PK_2025	2055	1575	1050	4400	3305	3275	1215	2655	1375	1475
ME_C	3090	2005	1050	2170	3655	3420	1205	2415	1375	1600

ME_C_NECEC	3080	2000	1050	2170	3660	3410	1205	2415	1375	2200
NHBOS	3510	1985	1050	1815	3655	3335	1200	2580	1375	1595
BOS	3510	1715	915	1805	3200	2810	1200	3010	1195	1350
SEMA	3510	1720	915	2215	3200	2810	1205	3510	1195	1355
PEAK_BASE	-210	2005	1050	4565	3550	3235	1200	600	1375	1470
PEAK_NECEC	-210	2005	1050	4560	3560	3235	1200	590	1375	2200

5.1.1.3 Generation Dispatch Conditions

Table 5-3 shows a list of Boston area and the queued generation dispatch for the stability cases. A full listing of all the base case summaries can be found in Section 0 – Appendix F.

Table 5-3 Modeled Generation Dispatch Conditions

Case Identifier	LL-1_2025	LL-2_2025	PK-1_2025	ME_C	ME_C_NECEC	NHBOS	BOS	SEMA	PEAK_BASE	PEAK_NECEC
EDGAR GT1	287	287	287	287	287	287	287	287	287	287
EDGAR GT2	287	287	287	287	287	287	287	287	287	287
EDGAR ST	284	284	284	284	284	284	284	284	284	284
Salem 5CT	0	220	220	220	220	220	220	220	220	220
Salem 5ST	0	145	145	145	145	145	145	145	145	145
Salem 6CT	0	220	220	0	0	220	220	0	220	220
Salem 6ST	0	145	145	0	0	145	145	0	145	145
Waters River J1	0	22	0	0	0	0	0	0	0	0
Waters River J2	0	45	0	0	0	0	0	0	0	0
MMWEC Waters River	0	70	70	0	0	0	0	0	70	70
KENDALL CT	0	223	223	0	0	0	0	0	223	223
MYSTIC 7GT	0	0	0	0	0	0	0	0	0	0
MYSTIC 8ST	0	282	0	0	0	0	0	0	0	0
MYSTIC GT 8A	0	286	0	0	0	0	0	0	0	0
MYSTIC GT 8B	0	286	0	0	0	0	0	0	0	0
MYSTIC 9ST	0	288	0	0	0	0	0	0	0	0
MYSTIC GT 9A	0	292	0	0	0	0	0	0	0	0
MYSTIC GT 9B	0	292	0	0	0	0	0	0	0	0
Seabrook	1310	1310	1310	1310	1310	1310	1310	1310	1310	1310
QP639-NECEC	1200	0	0	0	1200	0	0	0	0	1200
QP700	800	0	0	0	0	0	0	0	0	0
QP726	150	0	0	0	0	0	0	0	0	0
QP844	250	0	0	0	0	0	0	0	0	0
QP984	-150	150	0	0	0	0	0	0	0	0

5.2 Contingency List

5.2.1 Planning and Extreme Events

Planning and Extreme contingencies in the study area were tested to analyze the performance of the Project on the New England system stability. Table 5-4 shows the list of Planning and Extreme events tested. For

BPS facilities, the fastest protection scheme is assumed out of service and for non-BPS the fastest protection scheme is assumed to clear the fault. Reclosing is assumed to be operative as designed in the Planning events.

Table 5-4 Stability Planning and Extreme Event List

Contingency ID	Contingency Type	kV	Fault Description	Clearing Time (cycle)	Protection Scheme
NG_sdy-326	Planning	345	3ph fault at Sandy Pond on 326 line, normal cleared	4.5c at Sandy Pond 4.5c at Scobie Pond 15 s reclosing at Scobie Pond	*326* S1: DCCB S2: POTT
NG_sdy-337	Planning	345	3ph fault at Sandy Pond on 337 line, normal cleared	4.5c at Sandy Pond 4.5c at Tewksbury 10 s reclosing at Tewksbury 15 s reclosing at Sandy Pond	*337* S1: DCCB S2: POTT
NG_sdy-3521	Planning	345 kV	3-phase fault at Sandy Pond on 3512 line, normal cleared	4.5c at Sandy Pond 15 s reclosing at Sandy Pond	*3521* S1: LD S2: LD
NG_twk-3124	Planning	345	3ph fault at Tewksbury on 3124 line, normal cleared	4.5c at Tewksbury 4.5c at Scobie Pond 5 s reclosing at Tewksbury	*3124* S1: POTT S2: LD
NG_twk-337	Planning	345	3ph fault at Tewksbury on 337 line, normal cleared	4.5c at Tewksbury 4.5c at Sandy Pond 10 s reclosing at Tewksbury 15 s reclosing at Sandy Pond	*337* S1: DCCB S2: POTT
NG_twk-338	Planning	345	3ph fault at Tewksbury on 338 line, normal cleared	4.5c at Tewksbury 4.5c at Woburn 10 s reclosing at Tewksbury 15 s reclosing at Woburn	*338* S1: DCCB S2: POTT
NG_twk-397	Planning	345	3ph fault at Tewksbury on 397 line, normal cleared	4.5c at Tewksbury 4.5c at Ward Hill 5 s reclosing at Ward Hill 10 s reclosing at Tewksbury	*397* S1: DCCB S2: POTT
NG_wh-394	Planning	345	3ph fault at Ward Hill on 394 line, normal cleared	4.5c at Seabrook 4.5c at W. Amesbury 4.5c at Ward Hill 5 s reclosing at Ward Hill	*394* S1: DCCB S2: POTT
NG_wh-397	Planning	345	3ph fault at Ward Hill on 397 line, normal cleared	4.5c at Tewksbury 4.5c at Ward Hill 5 s reclosing at Ward Hill 10 s reclosing at Tewksbury	*397* S1: DCCB S2: POTT
NG_wkf-339	Planning	345	3ph fault at Wakefield Junction on 339 line, normal cleared	4.5c at Tewksbury 4.5c at Wakefield Jct. 5 s reclosing at Wakefield JCT 10 s reclosing at Tewksbury	*339* S1: DCCB S2: POTT
NG_sdy-HVDC-bf-slg	Planning	345	SLG fault at Sandy Pond HVDC filter bus, with filter breaker failure	6c at Sandy Pond (POTT) fault downgraded to SLG fault (Y=1123-j6399MVA) 26c opens 1412 and 3512 at Sandy Pond, block pole 2	3521 S1: Line diff S2: Line diff

Contingency ID	Contingency Type	kV	Fault Description	Clearing Time (cycle)	Protection Scheme
NG_twk-10c4-bf-slg	Planning	345	SLG fault on Bus #2 at Tewksbury with 10C4 stuck breaker	10.5c at Tewksbury (BF) 11.5c at Scobie Pond (DTT)	*3124* S1: POTT S2: LD
NG_twk-372-bf-slg	Planning	115	SLG fault at Tewksbury w/ 37-2 breaker failure	15c at Tewksbury 115 (BF) 15c at Tewksbury 230 (BF) 16c at Sandy Pond (DTT)	*K-137E* S1: DCCB S2: SD
NG_wh-4t94-bf-slg	Planning	345	SLG fault between breakers 4T94 and 4T with 4T-94 stuck breaker in Ward Hill	10.5c at Ward Hill 345 (BF) 6c at Ward Hill 115 11.5c at Seabrook (DTT) 11.5c at W. Amesbury (DTT)	*394* S1: DCCB S2: POTT
NG_wkf-491T-bf-slg	Planning	345	SLG fault between breakers 491T and 1T at Wakefield with failure of 491T breaker	6c at Wakefield 115 11.5c at Wakefield 345 (BF) 12.5c at Mystic (DTT)	*349* S1: POTT S2: LD
NG_wkf-393T-bf-slg	Planning	345	SLG fault between breakers 393T and 3T at Wakefield 345 kV Bus with failure of the 393T breaker	11c at Wakefield 345 (BF) 6c at Wakefield 115 12c at Tewksbury (DTT)	*339* S1: DCCB S2: POTT
NG_dct_339_s145	Extreme[10]	345/115	3ph fault on 339/S-145 DCT4	3c at Wakefield Jct. (339) 4c.5 at Tewksbury (339) 6c at Wakefield Jct. (S-145) 6c at Tewksbury (S-145)	*339* S1: DCCB S2: POTT *S-145* S1: DCCB S2: POTT
NG_sdy-2137-bf-ipt	Extreme	345	3ph fault at Sandy Pond on 337 w/ 2137 (IPT) breaker failure	6c at Tewksbury(DCCB) 11c at Sandy Pond 345 (BF) 12.5c at Sandy Pond HVDC(DTT)	*3521* S1: LD S2: LD *337* S1: DCCB S2: POTT
NG_twk-3739-bf-ipt	Extreme	345	3ph fault on line 339 with the failure of 3739 (IPT) breaker in Tewksbury	4.5c at Wakefield 10.5c at Tewksbury (BF) 11.5c at Sandy Pond (DTT)	*339* S1: DCCB S2: POTT *337* S1: DCCB S2: POTT

[10] This is the 3ph fault version of the DCT which is more severe than the design contingency DCT which involves SLG faults at two different phases of two circuits on the same tower.

Contingency ID	Contingency Type	kV	Fault Description	Clearing Time (cycle)	Protection Scheme
NG_twk-3897-bf-ipt	Extreme	345	3ph fault on line 338 with failure of 38-97 (IPT) breaker in Tewksbury	10.5c at Tewksbury (BF) 11.5c at Ward Hill (DTT) 4.5c at Woburn	*338* S1: DCCB S2: POTT *397* S1: DCCB S2: POTT
NG_wh-5T97-bf-ipt	Extreme	345	3ph fault between breakers 5T-97 and 5T in Ward Hill with 5T-97 stuck breaker	6c at Ward Hill 115 11c at Ward Hill 345 (BF) 12c at Tewksbury (DTT)	*397* S1: DCCB S2: POTT
NG_wkf-10A3-bf-ipt	Extreme	345	3ph fault between breakers 10A3 and 2T at Wakefield 345 kV Bus with failure of the 10A3 breaker	6c at Wakefield 115 10.5c at Wakefield 345 (BF) 11.5c at Woburn (DTT)	*3136* S1: LD S2: LD
ES_346_Wob	Planning	345	3-Ph fault on 346 at Woburn	4 at Woburn 4 at North Cambridge	346 S1: LD S2: LD
ES_365_NCamb	Planning	345	3-Ph fault on 365 at North Cambridge	4 at Woburn 4 at North Cambridge	365 S1: LD S2: LD
ES_338_Wob	Planning	345	3-Ph fault on 338 at Woburn	5.25 at Woburn 5.25 at Tewksbury 10 s reclosing at Tewksbury 15 s reclosing at Woburn	338 S1: POTT S2: DCB
ES_3136_Wob	Planning	345	3-Ph fault on 3136 at Woburn	4 at Woburn 4 at Wakefield	3136 S1: LD S2: LD
ES_319_Wob	Planning	345	3-Ph fault on 319 at Woburn	4 at Woburn 4 at Lexington 15 s reclosing at Lexington 15 s reclosing at Woburn	319 S1: LD S2: POTT
ES_349_Mys	Planning	345	3-Ph fault on 349 at Mystic	4 at Mystic 4 at Wakefield Jct	349 S1: POTT S2: LD
ES_358_NCamb	Planning	345	3-Ph fault on 358 at N Cambridge	5.25 at N Cambridge 5.25 at Mystic	358 S1: DCB S2: POTT
ES_831-536_NCamb	Planning	115	3-Ph fault on 831-536 at N Cambridge	5 at NCambridge 5 at Putnam	831-536 S1: LD S2: POTT
ES_108-BF-Wob	Planning	345	SLG fault on 345A with failure of 108 Breaker at Woburn	9 at Woburn (107) 4 at Woburn (115kV) 10.25 at Tewksbury	338 S1: POTT S2: DCB *345A* S1: LD S2:LD
ES_110_BF_Mys	Planning	345	SLG fault on 345A at Mysitc with breaker 110 stuck	4 at Mystic (115 kV) 9 at Mystic (109) 10.25 at N.Cambridge	351 S1: LD S2: LD 345A S1: LD

Contingency ID	Contingency Type	kV	Fault Description	Clearing Time (cycle)	Protection Scheme
					S2: LD
ES_102_BF_Mys	Planning	345	SLG fault on 349 at Mystic with breaker 102 stuck	4 at Wakefield Jct 9 at Mystic (103,111) 10.25 at Kingston St.	349 S1: POTT S2: LD 372 S1: LD S2: POTT
ES_102-BF-NCamb	Planning	345	SLG fault on 345B at N Cambridge with failure of 102 Breaker	4 at N Cambridge (115 kV) 10.25 at Mystic 9 at N Cambridge (103)	358 S1: DCB S2: POTT 345B S1: LD S2:LD
ES_106-BF-NCamb	Planning	345	SLG fault on 346 at N Cambridge with failure of 106 Breaker	4 at Woburn 10.25 at Mystic 9 at N Cambridge (108)	346 S1: LD S2:LD 351 S1: LD S2: LD
ES_108-BF-Wob	Extreme	345	3-ph fault on 345A with failure of 108 Breaker at Woburn	9 at Woburn (107) 4 at Woburn (115kV) 10.25 at Tewksbury	338 S1: POTT S2: DCB 345A S1: Current Differential S2:Current Differential
ES_110_BF_Mys	Extreme	345	3-ph fault on 345A at Mystic with breaker 110 stuck	4 at Mystic (115 kV) 9 at Mystic (109) 10.25 at N.Cambridge	351 S1: LD S2: LD 345A S1: LD S2: LD
ES_102_BF_Mys	Extreme	345	3-ph fault on 349 at Mystic with breaker 102 stuck	4 at Wakefield Jct 9 at Mystic (103,111) 10.25 at Kingston St.	349 S1: POTT S2: LD 372 S1: LD S2: POTT
ES_102-BF-NCamb	Extreme	345	3-ph fault on 345B at N Cambridge with failure of 102 Breaker	4 at N Cambridge (115 kV) 10.25 at Mystic 9 at N Cambridge (103)	358 S1: DCB S2: POTT 345B S1: LD S2:LD
ES_106-BF-NCamb	Extreme	345	3-ph fault on 346 at N Cambridge with failure of 106 Breaker	4 at Woburn 10.25 at Mystic 9 at N Cambridge (108)	346 S1: LD S2: LD 351 S1: LD S2: LD

Table 5-5 shows the list of line out conditions that were tested in N-1-1 stability analysis. The relevant Planning Events with the prefix ES or NG in Table 5-4 were tested as the second level contingency for each line out condition.

Table 5-5 N-1-1 Stability Testing Line Out Conditions

Element ID	kV	Description	2nd Level Contingency ID
349	345	Wakefield Junction – Mystic	ES
346	345	Woburn – North Cambridge Ckt 1	ES
351	345	North Cambridge – Mystic Ckt 2	ES
338	345	Tewksbury – Woburn	ES
Tewksbury STATCOM	345	Tewksbury STATCOM out	ES & NG
337	345	Sandy Pond - Tewksbury	NG
3124	345	Scobie Pond - Tewksbury	NG

5.2.2 Bulk Power System Testing

All project area non-BPS stations were tested for BPS status. If a station is classified as part of the BPS, then all stations one bus away would be tested in a similar fashion until no other station needs to be classified as BPS. The list of BPS contingencies is shown in Table 5-6 List of BPS Contingencies.

Table 5-6 List of BPS Contingencies

SUBSTATION	BUS VOLTAGE (kV)	STATE	OWNER	TRANSMISSION CIRCUITS TRIPPED	REMOTE ENDS	CLEARING TIMES (cycles)
Burlington	115	MA	ES	391-508 211-508	Hartwell Woburn	29 29
East Cambridge	115	MA	ES	831-538 831-540 875-539	Putnam Street Putnam Street Kendall	29 29 29
Everett	115	MA	NGrid	F-158S O-167 / 423-515	Maplewod Mystic	23 29
Hartwell	115	MA	ES	533-508 391-508	Lexington Burlington	29 29
Kendall	115	MA	ES	875-539	East Cambridge	29
Maplewood	115	MA	NGrid	F-158N F-158S	Wakefield Junction Everett	36 30
North Woburn Bus 1	115	MA	ES	211-503 211-503 M-139	Reading Woburn Tewksbury	29 53 53
North Woburn Bus 2	115	MA	ES	211-504 211-504 N-140	Reading Woburn Tewksbury	29 53 53
Reading	115	MA	ES	211-503 211-503 M-139 211-504 211-504 N-140	North Woburn Woburn Tewksbury North Woburn Woburn Tewksbury	No Breaker 53 53 No Breaker 53 53

SUBSTATION	BUS VOLTAGE (kV)	STATE	OWNER	TRANSMISSION CIRCUITS TRIPPED	REMOTE ENDS	CLEARING TIMES (cycles)
Salem Harbor	115	MA	NGrid	B-154S / C-155S B-154S / C-155S B-154S / C-155S C-155S S-145E / T-146E S-145E / T-146E S-145E / T-146E S-145E / T-146E	South Danvers Waters River East Beverly Beverly Wakefield Jct. Railyard West Salem Bartholomew	24 No Breaker No Breaker No Breaker 30 No Breaker No Breaker No Breaker
Scotia Street Bus 1	115	MA	ES	329-513 514-513	Brighton Kingston St	5 5
Scotia Street Bus 2	115	MA	ES	329-512 514-512	Brighton Kingston St	5 5
Trapelo Road	115	MA	ES	320-508	Lexington	29
				450-508	Waltham	29
Tewksbury (STATCOM)	34.5	MW	NGrid	N/A	N/A	600

5.3 Stability Analysis Results

5.3.1 Planning and Extreme Event Analysis Results

The Planning and Extreme Event analysis results in Table 5-7 and Table 5-8 do not show any adverse impact caused by the project. Appendix G – Stability Simulation Plots includes the stability analysis simulation plots.

The line out conditions listed in Table 5-5 were tested and the results do not show any adverse stability impact due to the Project. The stability plots are included in Appendix G.

Table 5-7 Planning Events Testing Results

Contingency ID	Contingency Type	Clearing Time (cycle)	Results		
			LL-1	LL-2	Peak
sdy-326	Planning	4.5 at Sandy Pond 4.5 at Scobie Pond	Stable	Stable	Stable
sdy-337	Planning	4.5 at Sandy Pond 4.5 at Tewksbury	Stable	Stable	Stable
sdy-3521	Planning	4.5 at Sandy Pond	Stable	Stable	Stable Source Loss with the contingency: 750 MW Phase II
twk-3124	Planning	4.5 at Tewksbury 4.5 at Scobie Pond	Stable	Stable	Stable

Contingency ID	Contingency Type	Clearing Time (cycle)	Results		
			LL-1	LL-2	Peak
twk-337	Planning	4.5 at Tewksbury 4.5 at Sandy Pond	Stable	Stable	Stable
twk-338	Planning	4.5 at Tewksbury 4.5 at Woburn	Stable	Stable	Stable
twk-397	Planning	4.5 at Tewksbury 4.5 at Ward Hill	Stable	Stable	Stable
wh-394	Planning	4.5 at Seabrook 4.5 at W. Amesbury 4.5 at Ward Hill	Stable	Stable	Stable
wh-397	Planning	4.5 at Tewksbury 4.5 at Ward Hill	Stable	Stable	Stable
wkf-339	Planning	4.5 at Tewksbury 4.5 at Wakefield Jct.	Stable	Stable	Stable
sdy-HVDC-bf-slg	Planning	26 opens breaker 1412 and 3512 at Sandy Pond, block pole 2	Stable	Stable	Stable Source Loss with the contingency: 750 MW Phase II
twk-10c4-bf-slg	Planning	10.5 at Tewksbury (BF) 11.5 at Scobie Pond (DTT)	Stable	Stable	Stable
twk-372-bf-slg	Planning	15 at Tewksbury 115 (BF) 15 at Tewksbury 230 (BF) 16 at Sandy Pond (DTT)	Stable	Stable	Stable
wh-4t94-bf-slg	Planning	10.5 at Ward Hill 345 (BF) 6 at Ward Hill 115 11.5 at Seabrook (DTT) 11.5 at W. Amesbury (DTT)	Stable	Stable	Stable
wkf-491T-bf-slg	Planning	6 at Wakefield 115 11.5 at Wakefield 345 (BF) 12.5 at Mystic (DTT)	Stable	Stable	Stable
wkf-393T-bf-slg	Planning	11 at Wakefield 345 (BF) 6 at Wakefield 115 12 at Tewksbury (DTT)	Stable	Stable	Stable
SLG_BF_GoldenHills	Planning	4.5 at Golden Hills Downgraded to SLG 10.5 at Wakefield 345 and Mystic 345(BF+DTT)	Stable	Stable	Stable
346_Wob	Planning	Woburn: 4 North Cambridge: 4	Stable	Stable	Stable
365_NCamb	Planning	Woburn: 4 North Cambridge: 4	Stable	Stable	Stable

Contingency ID	Contingency Type	Clearing Time (cycle)	Results		
			LL-1	LL-2	Peak
338_Wob	Planning	Woburn: 5.25 Tewksbury: 5.25	Stable	Stable	Stable Source Loss: 18 MW Boot Hydro G1 and G2 tripped pre and post project
3136_Wob	Planning	Woburn: 4 Wakefield:4	Stable	Stable	Stable
319_Wob	Planning	Woburn: 4 Lexington: 4	Stable	Stable	Stable
349_Mys	Planning	Mystic: 4 Wakefield Jct: 4	Stable	Stable	Stable
358_NCamb	Planning	N Cambridge:5.25 Mystic: 5.25	Stable	Stable	Stable Source Loss: 18 MW Boot Hydro G1 and G2 tripped pre and post project
831-536_NCamb	Planning	North Cambridge:5 Putnam: 5	Stable	Stable	Stable
108-BF-Wob	Planning	Woburn (107): 9 Woburn (115kV): 4 Tewksbury: 10.25	Stable	Stable	Stable
110_BF_Mys	Planning	Mystic (115 kV): 4 Mystic (109): 9 N.Cambridge: 10.25	Stable	Stable	Stable
102_BF_Mys	Planning	Wakefield Jct: 4 Mystic (103,111): 9 Kingston St.: 10.25	Stable	Stable	Stable
102-BF-NCamb	Planning	N Cambridge (115 kV): 4 Mystic : 10.25 N Cambridge (103): 9	Stable	Stable	Stable
106-BF-NCamb	Planning	Woburn : 4 Mystic : 10.25 N Cambridge (108): 9	Stable	Stable	Stable

Table 5-8 Extreme Event Testing Results

Contingency ID	Contingency Type	Clearing Time (cycle)	Result						
			ME_C	ME_C-NECEC	BOS	NHBOS	SEMA	PEAK_BASE	PEAK_NECEC
108-BF-Wob	Extreme	Woburn (107): 9 Woburn (115kV): 4 Tewksbury: 10.25	Stable	Stable	Stable	Stable	Stable	Stable	Stable
110_BF_Mys	Extreme	Mystic (115 kV): 4 Mystic (109): 9 N.Cambridge: 10.25	Stable	Stable	Stable	Stable	Stable	Stable	Stable
102_BF_Mys	Extreme	Wakefield Jct: 4 Mystic (103,111): 9 Kingston St.: 10.25	Stable	Stable	Stable	Stable	Stable	Stable	Stable
102-BF-NCamb	Extreme	N Cambridge (115 kV): 4 Mystic : 10.25 N Cambridge (103): 9	Stable	Stable	Stable	Stable	Stable	Stable	Stable
106-BF-NCamb	Extreme	Woburn : 4 Mystic : 10.25 N Cambridge (108): 9	Stable	Stable	Stable	Stable	Stable	Stable	Stable
dct_339_s145	Extreme[11]	3 at Wakefield Jct. (339) 4.5 at Tewksbury (339) 6 at Wakefield Jct. (S-145) 6 at Tewksbury (S-145)	Stable	Stable	Stable	Stable	Stable	Stable	Stable
sdy-2137-bf-ipt	Extreme	4.5 at Tewksbury(DCCB) 11 at Sandy Pond 345 (BF) 12 at Sandy Pond HVDC(DTT)	Stable	Stable	Stable	Stable	Stable	Stable	Stable
twk-3739-bf-ipt	Extreme	4.5 at Wakefield 10.5 at Tewksbury (BF) 11.5 at Sandy Pond (DTT)	Stable	Stable	Stable	Stable	Stable	Stable	Stable
twk-3897-bf-ipt	Extreme	4.5 at Woburn 10.5 at Tewksbury (BF) 11.5 at Ward Hill (DTT)	Stable	Stable	Stable	Stable	Stable	Stable	Stable
wh-5T97-bf-ipt	Extreme	6 at Ward Hill 115 11 at Ward Hill 345 (BF)	Stable	Stable	Stable	Stable	Stable	Stable	Stable

[11] This is the 3ph fault version of the DCT which is more severe than the design contingency DCT which involves SLG faults at two different phases of two circuits on the same tower.

Contingency ID	Contingency Type	Clearing Time (cycle)	Result						
			ME_C	ME_C-NECEC	BOS	NHBOS	SEMA	PEAK_BASE	PEAK_NECEC
		12 at Tewksbury (DTT)							
wkf-10A3-bf-ipt	Extreme	6 at Wakefield 115 10.5 at Wakefield 345 (BF) 11.5 at Woburn (DTT)	Stable	Stable	Stable	Stable	Stable	Stable	Stable
gh-3ph_BF_ipt	Extreme	4.5 at Golden Hills Downgraded to SLG 10.5 at Wakefield 345 and Mystic 345(BF+DTT)	Stable	Stable	Stable	Stable	Stable	Stable	Stable

5.3.2 Bulk Power System Testing Results

The stability analysis included eleven BPS Contingencies at the 115kV substations listed in Table 5-6 List of BPS Contingencies. All BPS fault conditions simulated resulted in acceptable power system response. The BPS stability results are listed in Table 5-9 below. Appendix G – Stability Simulation Plots includes the BPS stability analysis simulation plots.

Table 5-9 BPS Testing Results

Contingency ID	Clearing Time (cycle)	Result						
		ME_C	ME_C-NECEC	BOS	NHBOS	SEMA	PEAK_BASE	PEAK_NECEC
BPS_Burlington	29 at Woburn; 29 at Hartwell	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS_ECambridge	29 at Kendall; 29 at Putnam	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 28.9 MW Kendall St with fault clearing	STABLE Source Loss: 28.9 MW Kendall St with fault clearing	STABLE Source Loss: 0	STABLE Source Loss: 223.3 MW Kendall Ct with fault clearing	STABLE Source Loss: 223.3 MW Kendall Ct with fault clearing
BPS_Everett	23 at Maplewood; 29 at Mystic	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS_Hartwell	29 at Burlington; 29 at Leixington	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0

Contingency ID	Clearing Time (cycle)	Result						
		ME_C	ME_C-NECEC	BOS	NHBOS	SEMA	PEAK_BASE	PEAK_NECEC
BPS_Kendall	29 at ECambridge;	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 28.9 MW Kendall St with fault clearing	STABLE Source Loss: 28.9 MW Kendall St with fault clearing	STABLE Source Loss: 0	STABLE Source Loss: 223.3 MW Kendall Ct with fault clearing	STABLE Source Loss: 223.3 MW Kendall Ct with fault clearing
BPS_Maplewood	30 at Everett; 36 at Wakefield Jct.	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS_NWoburn	29 at Reading; 53 at Woburn Ring; 54 at Billerica;	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS_Reading	53 at Woburn Ring; 53 at North Woburn; 54 at Billerica;	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS_Salem Harbor	24 at S. Danvers; 30 at Wakefield Jct.	STABLE Source Loss: 366 MW Salem 5 with fault clearing	STABLE Source Loss: 366 MW Salem 5 with fault clearing	STABLE Source Loss: 731 MW Salem 5 and 6 with fault clearing	STABLE Source Loss: 731 MW Salem 5 and 6 with fault clearing	STABLE Source Loss: 366 MW Salem 5 with fault clearing	STABLE Source Loss: 817 MW Salem 5 and 6 MMWEC WR	STABLE Source Loss: 817 MW Salem 5 and 6 MMWEC WR
BPS_ScotiaSt_512	5 at Brighton; 5 at Carver st	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS_ScotiaSt_513	5 at Brighton; 5 at Carver st	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS_TrapeloRoad	29 at Lexington; 29 at Waltham	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0
BPS-TWKS-STATCOM-34kV	10 sec uncleared fault	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0	STABLE Source Loss: 0

6 SHORT CIRCUIT ANALYSIS

6.1 Short Circuit Study Cases

The short circuit study case was developed based on the ISO-NE's 2025 Master Short Circuit case. Additional QP projects that have an in-service date beyond the in-service date of the Project were also modeled to ensure the Project has no adverse impact on previously approved projects and queue projects that are in the System Impact Study phase. The proposed solution was then added to form the Project study case. The series reactors were assumed bypassed for the short circuit analysis because more fault currents would be seen compared to when is the series reactors are in-service. The data of the circuit breakers in the study area (NSTAR, PSNH, (both currently d/b/a Eversource Energy) and National Grid) were also added to the case. The case boundaries were consistent with the New England short circuit database model assumptions and no additional equivalent source models were added to the case.

The following queued generation interconnection projects that are relevant to the study area and were modeled in the short circuit case. QP700 and QP726 received PPA approval and other projects below do not have approval PPAs.

- QP700: 820 MW off shore wind farm interconnecting to West Barnstable 345 kV
- QP726: 150 MW batter storage interconnecting close to Carver 115 kV
- QP844: 250 MW battery storage interconnecting to West Medway 345 kV substation
- QP806: 880 MW off shore wind farm interconnecting to West Barnstable 345 kV
- QP829: 1000 MW off shore interconnecting to 322 and 399 lines
- QP830: 876 MW off shore wind farm interconnecting to West Barnstable 345 kV
- QP984: 150 MW storage on National Grid 115kV line 1/2 mile to the East of Billerica 70 substation

Given that the in-service date of the project is prior to the retirement of Mystic 8 and 9, two scenarios were analyzed to evaluate the short circuit impact of the project on the EMA area.

- Mystic 8 and 9 in-service
- Mystic 8 and 9 out of service

6.2 Short Circuit Study Assumptions

Short circuit analysis was performed in accordance with the ISO-NE's recommended settings. The following fault simulation options in ASPEN OneLiner Version 14.7 were used:

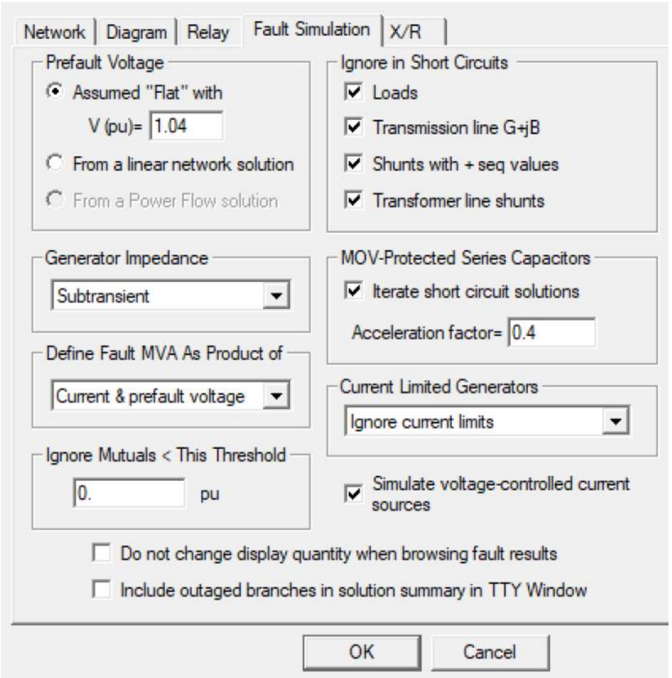

Figure 6-1 ASPEN Fault Simulation Solution Parameters

The pre-fault voltage of 69, 115, 230, and 345 kV buses were set to 1.05 pu at National Grid, 1.03 pu at Eversource Energy - EMA buses and 1.04 pu at New Hampshire buses as per respective company-specific practices. The following X/R options were used:

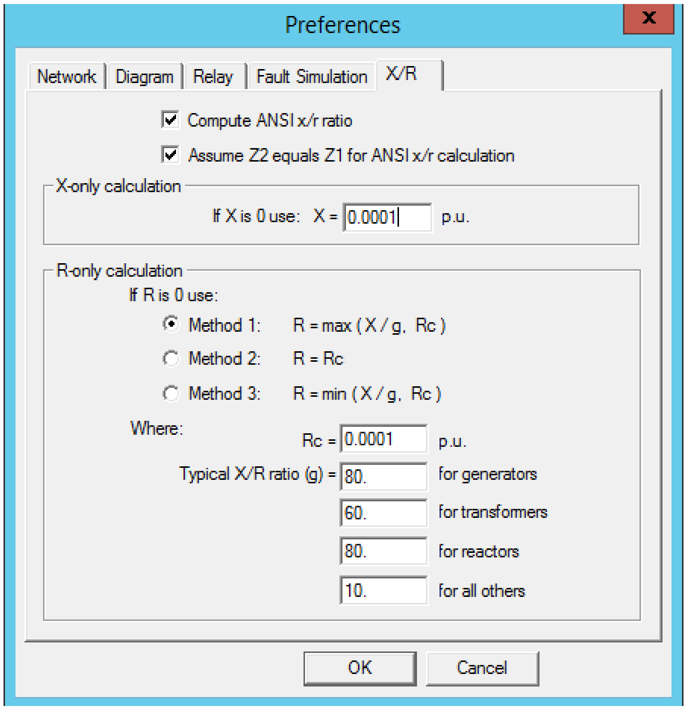

Figure 6-2 ASPEN X/R Parameters

All breaker duties were tested by using the ASPEN Breaker Rating Module, except for the Seabrook generator breaker as its capability is determined by a different IEEE standard than the transmission system circuit breakers. The following shows the assumptions that were used in the Breaker Rating Module:

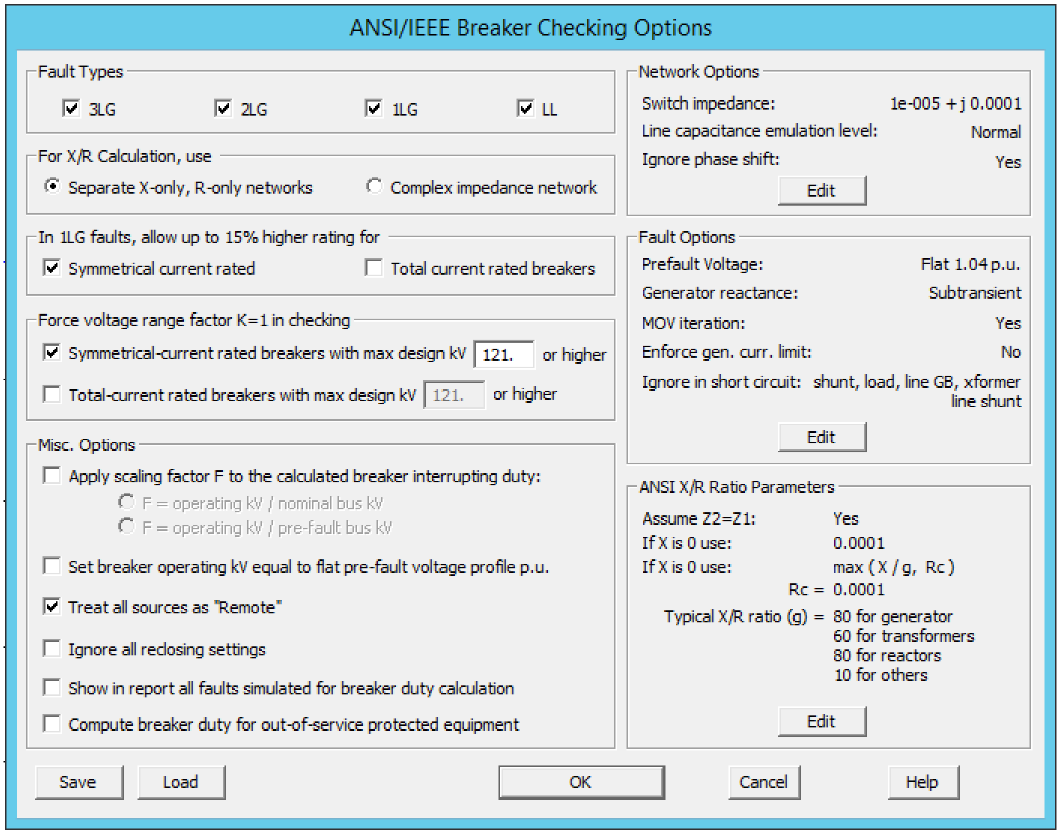

Figure 6-3 Aspen Circuit Breaker Checking Options

Circuit breaker fault interrupting duties were evaluated for each of the stations shown in Table 6-1 below.

Table 6-1 Stations Analyzed in Short Circuit Analysis

Station Bus	Station Bus	Station Bus	Station Bus
Andrew Square 115 kV	Holbrook 115 kV	Mystic 115 kV	Tewksbury 230 kV
Baker St. 115 kV	Holbrook 345 kV	Mystic 345 kV	W. Amesbury 345 kV
Belmont 115 kV	Hyde Park 115 kV	Mystic GIS 115 kV	W. Amesbury 115 kV
Brighton A 115 kV	Hyde Park 345 kV	N. Cambridge 115 kV	W. Boylston 115 kV
Brighton B 115 kV	K Street 1&4 115 kV	N. Cambridge 345 kV	W. Framingham 115 kV
Burlington 115 kV	K Street 2&3 115 kV	N. Quincy 1 115 kV	W. Medway 345 kV
Canton A 115 kV	K Street A 115 kV	N. Quincy 2 115 kV	W. Methuen 115 kV
Canton B 115 kV	K Street A 345 kV	Needham 115 kV	W. Walpole 115 kV
Chelsea 115 kV	K Street B 115 kV	Northboro Rd 115 kV	W. Walpole 345 kV
Colburn A 115 kV	K Street B 345 kV	Pelham 115 kV	Wachusett 115 kV
Colburn B 115 kV	K Street C 345 kV	Pilgrim 345 kV	Wakefield Jct 345 kV
Deer Island 115 kV	Kendall 115 kV	Power St 115 kV	Wakefield Jct. 115 kV
Deerfield 115 kV	King St. 115 kV	Pratts Jct. 115 kV	Walpole A 115 kV
Deerfield 345 kV	Kingston 324 345 kV	Putnum St 115kV	Walpole C 115 kV
Dewar 115 kV	Kingston 372 345 kV	Revere 115 kV	Waltham 115 kV
Dover 115 kV	Kingston 514 A 115 kV	Rolfe Ave 115 kV	Ward Hill 115 kV
E. Cambridge 115 kV	Kingston 514 A 345 kV	S. Danvers 4 115 kV	Ward Hill 345 kV
E. Holbrook 1 115 kV	Kingston 514 B 115 kV	Salem Harbor 115 kV	Washington 115 kV
E. Holbrook 2 115 kV	Kingston 514 B 345 kV	Sandy Pond 115 kV	Woburn 115 kV
E. Methuen 115 kV	Lexington 115 kV	Sandy Pond 345 kV	Woburn 345 kV
East Eagle 115 kV	Lexington 345 kV	Scobie Pond 115 kV	292 Newton 115 kV
Edgar 115 kV	Lynn 225 115 kV	Scobie Pond 345 kV	309 Blackstone 345 k
Ellis Ave 115 kV	Maplewood 115 kV	Seabrook 345 kV	315 Electric Ave
Everett 115 kV	Maynard A 115 kV	Sherborn 115 kV	492 Scotia St 115 kV
Fitch Road 69 kV	Maynard B 115 kV	Speen St. 115 kV	576 MBTA 115 kV
Framingham 115 kV	Medway 115 kV	Stoughton 345 kV	71 Carver St 115 kV
Golden Hills 115 kV	Merrimack B1 115 kV	Sudbury 115 kV	99 Seafood Way 115 kV
Golden Rock (NG) 115 kV	Merrimack B2 115 kV	Tewksbury 115 kV	
Greendale 115 kV	Merrimack B3 115 kV	Tewksbury 345 kV	

6.3 Short Circuit Study Results

Error! Reference source not found. to **Error! Reference source not found.**5 show pre- and post-Project fault currents and breaker fault duties at substations in Eversource and National Grid transmission system with >90% breaker interrupting duties. Table 6-2 and Table 6-3 shows the breaker duty results with Mystic 8&9 online in Eversource and National Grid system respectively, while Table 6-4 and Table 6-5 shows the breaker duty results with Mystic 8&9 out of service in Eversource and National Grid system respectively. For the detailed short circuit analysis results of all the transmission breakers, please see Appendix H.

Table 6-2 Short Circuit Duties with Mystic 8&9 in service (Eversource Stations with Breaker Interrupting Duty>90%)

BUS	BREAKER	BKR_ Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_ (%)	DUTY_ (A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_ (%)	DUTY_ (A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
K Street 1&4	K ST 10	63000	93.6	58966.2	88.5	89190.3	94	59233	88.9	89596.5	0.4	0.4
K Street 2&3	K ST 13	63000	93.3	58805.2	88.2	88942.7	93.8	59086.1	88.7	89370.3	0.5	0.5
K Street A	K ST 29	63000	93.4	58866.4	88.2	88866.9	93.9	59144.1	88.6	89288.8	0.5	0.4
K Street B	K ST 29S	63000	93.4	58840.9	88.2	88918.7	93.8	59113.5	88.6	89333.3	0.4	0.4
Kingston 514 A	KINGSTON 12	63000	90.7	57131	54.1	91903.5	91	57326.9	54.2	92218.2	0.3	0.1
Kingston 514 B	KINGSTON 11T	63000	90.7	57121.8	54.1	91891.3	91	57317.7	54.2	92206	0.3	0.1
Merrimack B3	P145	40000	94.3	37702.4	79.7	50990.7	94.3	37728.3	79.7	51025.8	0	0
Mystic	93EY	63000	95.6	60235.4	76.1	76709.1	96	60482.3	76.4	77024.6	0.4	0.3
Mystic GIS	MYSTICGIS 28	63000	97.5	61415.6	85.9	86555.1	97.7	61556	86.1	86754.5	0.2	0.2
Putnum St	Putnam 3	40000	90.8	36336.1	87.5	55997.7	91.1	36442.7	87.8	56160.6	0.3	0.3
Scobie Pond	191	63000	91.9	57879.2	78.2	78848	92.2	58090.6	78.5	79136.3	0.3	0.3
W. Medway	W MEDW 111	50000	93.7	46831.8	92.7	74165	93.8	46908.5	92.9	74286.4	0.1	0.2

Table 6-3 Short Circuit Duties with Mystic 8&9 in service (National Grid Stations with Breaker Interrupting Duty>90%)

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY (%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
SANDY 115 115.kV	SANDY P 1612	50000	80000	91.7	45847.6	85.2	68172.6	30.3	91.3	45649.1	84.8	67869.6	0.4	0.4
SANDY 115 115.kV	SANDY P 3T	50000	80000	92.7	46356.3	86.2	68976.7	30.2	92.3	46158.4	85.8	68674	0.4	0.4
SANDY 115 115.kV	SANDY P 3T61	50000	80000	92.7	46356.3	86.2	68976.7	30.2	92.3	46158.4	85.8	68674	0.4	0.4
SANDY 115 115.kV	SANDY P I161	50000	80000	91.7	45847.6	85.2	68172.6	30.3	91.3	45649.1	84.8	67869.6	0.4	0.4

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY (%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
TEWKSBURY_22 115.kV	TWKS222T	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS2237-2	50000	80000	94.1	47036.8	88.5	70767.1	13.7	93.8	46879.9	88.2	70531.2	0.3	0.3
TEWKSBURY_22 115.kV	TWKS2238-3	50000	80000	95.8	47891	89.9	71957	13.5	95.5	47733.7	89.7	71720.9	0.3	0.2
TEWKSBURY_22 115.kV	TWKS2239-46	50000	80000	90.1	45049.7	85	67977.2	14	89.8	44906.7	84.7	67761.7	0.3	0.3
TEWKSBURY_22 115.kV	TWKS223T	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS224T	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS2253-51	50000	80000	95.5	47737.7	89.6	71658.5	13.4	95.2	47581.1	89.3	71423.7	0.3	0.3
TEWKSBURY_22 115.kV	TWKS2262-1	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS2264-4	50000	80000	95.6	47796.1	89.7	71752.8	13.5	95.3	47639.2	89.4	71517.5	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22A153	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22C1	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22C2	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22J162	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22K137	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22L138	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22L164	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22M139	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22N140	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22S145	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22T146	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22Y151	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY (%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
WAKEJCT5XTP 115.kV	WAKFLD 3T-46	65000	104000	90	58471.5	85.3	88720.4	27.3	89.5	58200.3	84.9	88272.8	0.5	0.4
WAKEJCT5XTP 115.kV	WAKFLD 45-3T	65000	104000	90	58471.5	85.3	88720.4	27.3	89.5	58200.3	84.9	88272.8	0.5	0.4
WAKEJCT5XTP 115.kV	WAKFLD 46-4T	65000	104000	92.4	60053.5	87.1	90568.8	28.2	92	59781.4	86.6	90114.5	0.4	0.5
WAKEJCT5XTP 115.kV	WAKFLD 4T-69	65000	104000	92.3	60015.2	86.9	90401.1	28.1	91.9	59742.6	86.5	89954.2	0.4	0.4
WAKEJCT5XTP 115.kV	WAKFLD 58-45	65000	104000	92.4	60053.5	87.1	90568.8	28.2	92	59781.4	86.6	90114.5	0.4	0.5
WAKEJCT5XTP 115.kV	WAKFLD F158	65000	104000	91.4	59403.8	85.8	89227.2	28.5	91	59134.3	85.4	88785.9	0.4	0.4
WAKEJCT5XTP 115.kV	WAKFLD Proxy	65000	104000	95.7	62226.7	90.4	94057.9	27.2	95.3	61950.4	90	93635.3	0.4	0.4
WAKEJCT5XTP 115.kV	WAKFLD Q169	65000	104000	92.3	60015.2	86.9	90401.1	28.1	91.9	59742.6	86.5	89954.2	0.4	0.4
WAKEJCT5XTP 115.kV	WAKFLD S145	65000	104000	92.4	60053.5	87.1	90568.8	28.2	92	59781.4	86.6	90114.5	0.4	0.5
WAKEJCT5XTP 115.kV	WAKFLD S145E	65000	104000	90	58471.5	85.3	88719.7	27.3	89.5	58200.3	84.9	88272.1	0.5	0.4
WAKEJCT5XTP 115.kV	WAKFLD T146	65000	104000	92.4	60076.4	87.1	90595.2	28.2	92	59804.4	86.7	90122.3	0.4	0.4
WAKEJCT5XTP 115.kV	WAKFLD T146E	65000	104000	90	58471.5	85.3	88720.4	27.3	89.5	58200.3	84.9	88272.8	0.5	0.4

Table 6-4 Short Circuit Duties with Mystic 8&9 Out of Service (Eversource Stations with Breaker Interrupting Duty>90%)

			Pre-project				Post-project				Project Impact	
BUS	BREAKER	BKR_Capability (A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Merrimack B3	P145	40000	94.1	37621.5	79.5	50872	94.1	37651.8	79.6	50913	0	0.1
Scobie Pond	191	63000	90.3	56907.4	76.9	77562.1	90.7	57146.5	77.3	77888	0.4	0.4
W. Medway	W MEDW 111	50000	92.6	46302.8	91.3	73051.2	92.7	46332.6	91.5	73192.6	0.1	0.2

Table 6-5 Short Circuit Duties with Mystic 8&9 Out of Service (National Grid Stations with Breaker Interrupting Duty>90%)

				Post Project					Pre Project				Project Impact (%)	
BUS	BREAKER	BKR Capability (A)	BKR MNTCapability (A)	DUTY(%)	DUTY(A)	M_DUTY(%)	M_DUTY(A)	X/R	DUTY(%)	DUTY(A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY(%)	delta_M_DUTY(%)
SANDY 115 115.kV	SANDY P 1612	50000	80000	90	44989.3	83.7	66937.5	30.2	89.5	44763.2	83.2	66593.7	0.5	0.5
SANDY 115 115.kV	SANDY P 3T	50000	80000	90.9	45473	84.6	67701.2	30.1	90.5	45246.9	84.2	67357	0.4	0.4
SANDY 115 115.kV	SANDY P 3T61	50000	80000	90.9	45473	84.6	67701.2	30.1	90.5	45246.9	84.2	67357	0.4	0.4
SANDY 115 115.kV	SANDY P I161	50000	80000	90	44989.3	83.7	66937.5	30.2	89.5	44763.2	83.2	66593.7	0.5	0.5
TEWKSBURY_22 115.kV	TWKS22 2T	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 38-3	50000	80000	91.4	45711.6	86.2	68939	13.9	91	45520.7	85.8	68651.2	0.4	0.4
TEWKSBURY_22 115.kV	TWKS22 3T	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 4T	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 53-51	50000	80000	91.1	45568.4	85.8	68659.9	13.8	90.8	45378.2	85.5	68373.6	0.3	0.3

BUS	BREAKER	BKR Capability (A)	BKR MNTCapability (A)	Post Project					Pre Project				Project Impact (%)	
				DUTY(%)	DUTY(A)	M_DUTY(%)	M_DUTY(A)	X/R	DUTY(%)	DUTY(A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY(%)	delta_M_DUTY(%)
TEWKSBURY_22 115.kV	TWKS22 62-1	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 64-4	50000	80000	91.2	45621.7	85.9	68744.8	13.8	90.9	45431.2	85.6	68457.8	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 A153	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 C1	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 C2	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 J162	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 K137	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 L138	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 L164	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 M139	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 N140	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 S145	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 T146	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22 Y151	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4

Breaker interrupting duties are very similar between pre- and post- project short circuit cases. The Project's impact on the breaker duty are less than 1%. None of the transmission breakers tested were found overdutied. Therefore, the Project does not cause a significant adverse impact on the transmission breakers in the study area.

6.4 Short Circuit Analysis for Seabrook Generator Circuit Breaker

To assess the Seabrook 24.5kV generator breaker's breaker duty, all major queue projects listed below that are in NH and ME which have either completed SIS or are in the SIS study phase were also added for the Seabrook generator breaker assessment:

- QP 655 – 15.3 MW wind farm interconnecting to 34.5 kV Bus at Roxbury Substation, Roxbury, Maine
- QP 670 – 113.4 MW Solar interconnecting to CMP Albion Rd 115kV substation, Maine
- QP 760 – 126 MW wind farm interconnecting to Emera Maine 115 line 52 near Epping switching station
- QP 803 – 50 MW Solar interconnecting to CMP existing 115 kV line section 225 approximately 2.25 miles from Sanford 115 kV Substation
- QP 833 – 100 MW Solar interconnecting to 15 kV Line 93 (Emera Maine) between Bull Hill & Deblois
- QP 874 – 175 MW battery storage interconnecting to CMP Mosher 115kV Substation
- QP 888 – 126 MW battery storage interconnecting to 115/34.5 kV Powersville Rd Substation and Millinocket Sub 4, 34.5 kV Bus
- QP 896 – 19.6 MW Solar interconnecting to CMPCO 34.5kV Louden Substation Saco, Maine
- QP 931 – 55 MW Solar interconnecting to CMP Roxbury substation 115 kV bus
- QP 945 – 8 MW generation interconnecting to Emera Maine 46 kV Line 5/7 / Old Town Maine @ Penobscot River

Also, the review of the impact of inverter based resources on Seabrook gen breaker has resulted in a recommendation to turn off two inverter based resources: QP781 and QP618. Keeping these inverters offline increases the fault current at Seabrook generator bus.

QP 889, an ETU in the vicinity of Seabrook generator breaker is under study in the SIS phase, however at the time of finalization of this PPA study, the models to add QP889 to the short circuit base case were not available. In lieu of the actual study models being used, proxy upgrades to resemble the STATCOMs being proposed by QP889 are included as sensitivity cases for the Seabrook generator breaker assessment.

In summary, there were 4 scenarios analyzed:

- Mystic 8 & 9 Online (No QP 889 upgrades)
- Mystic 8 & 9 Offline (No QP 889 upgrades)

- Mystic 8 & 9 Online with proxy QP 889 upgrades
- Mystic 8 & 9 Offline with proxy QP 889 upgrades

6.4.1 Seabrook Generator Circuit Breaker Study Assumptions

This short circuit analysis for the Seabrook Generator Circuit Breaker was performed in accordance with IEEE Standard C37.013-1997 and Seabrook Letter (SBK-L-16195) dated on November 17, 2016. Short circuit studies were conducted to assess the impact of the Project on fault current levels and breaker duty of the Seabrook Generator Circuit Breaker.

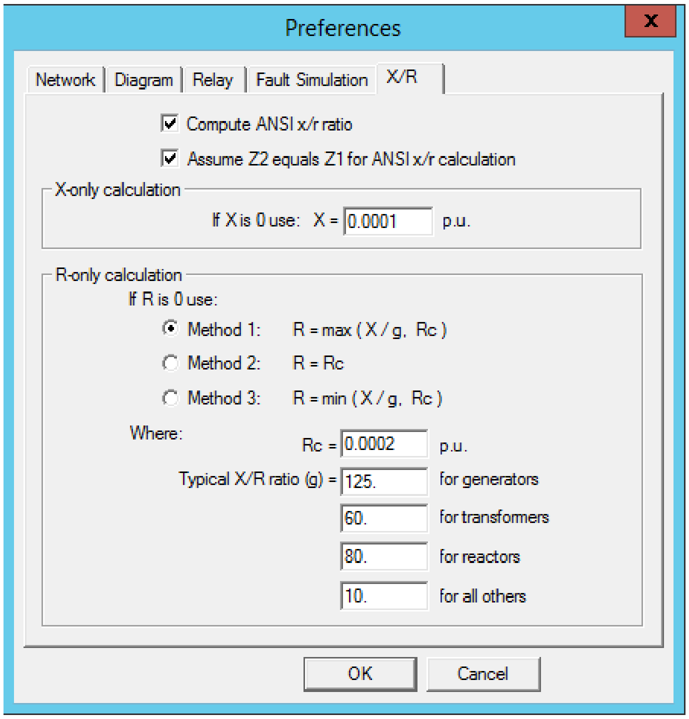

Figure 6-4 ASPEN X/R Parameters for Seabrook Breaker Analysis

The Seabrook Aspen one-line representation, generator, generator circuit breaker, generator step-up transformer, and UAT transformer models are shown in the figures below.

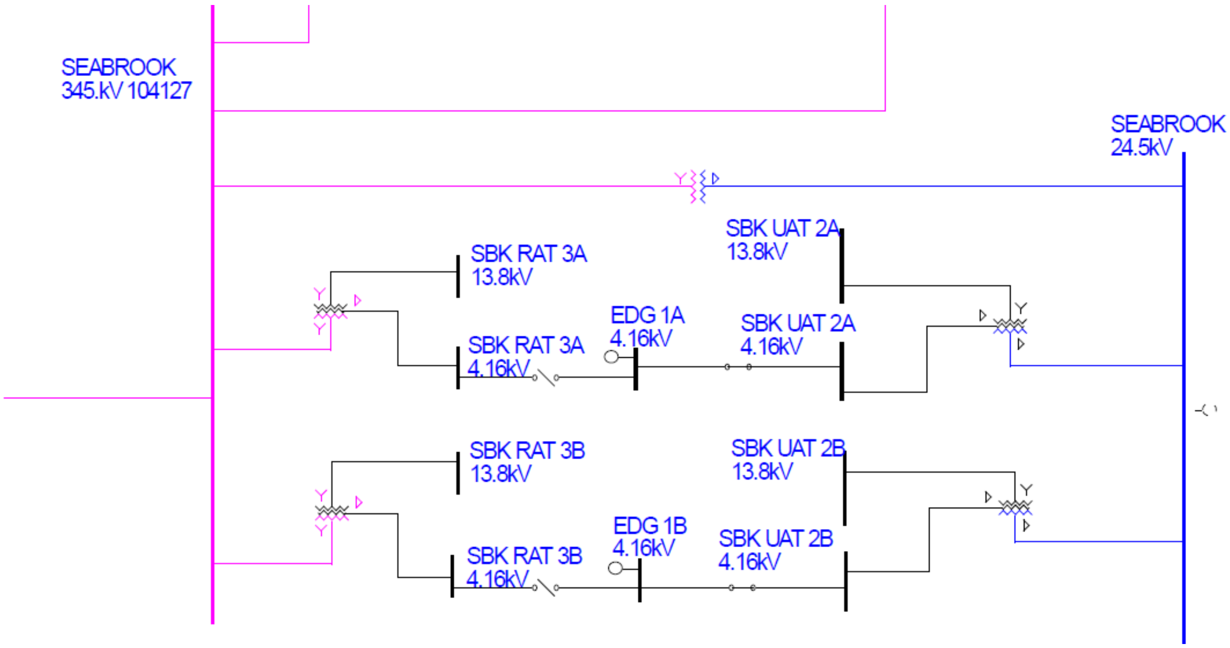

Figure 6-5 Seabrook Aspen One-Line Model

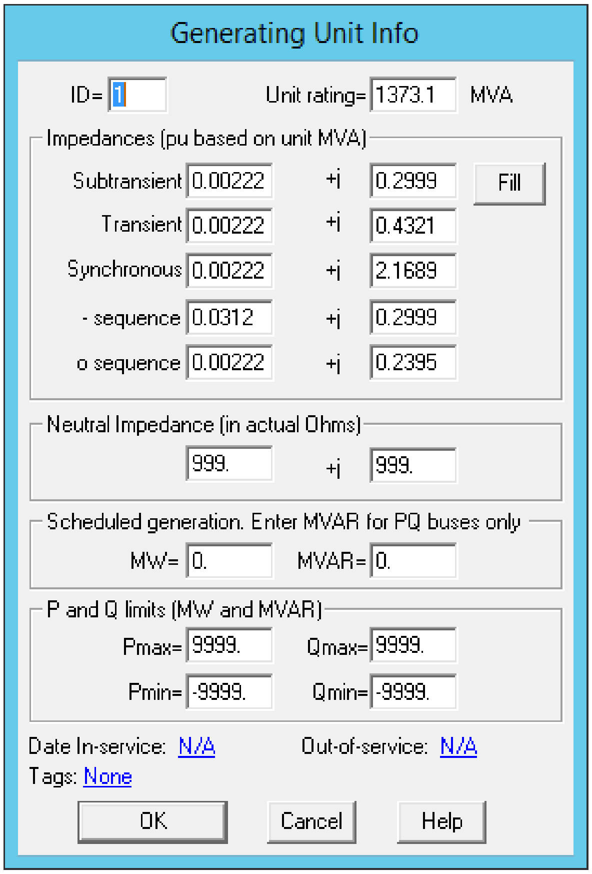

Figure 6-6 Seabrook Generator Model

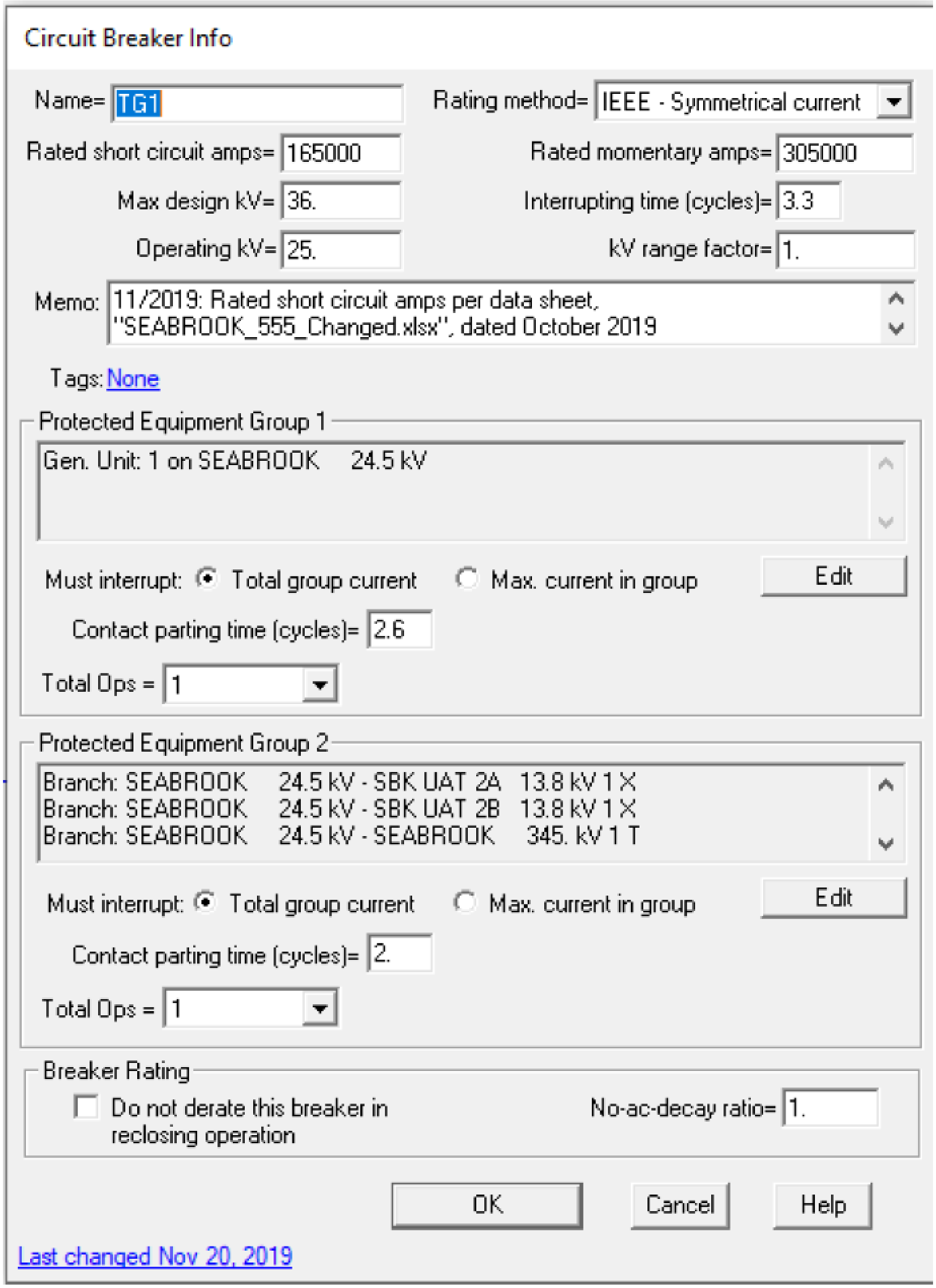

Figure 6-7 Seabrook 24.5 kV Generator Circuit Breaker Model

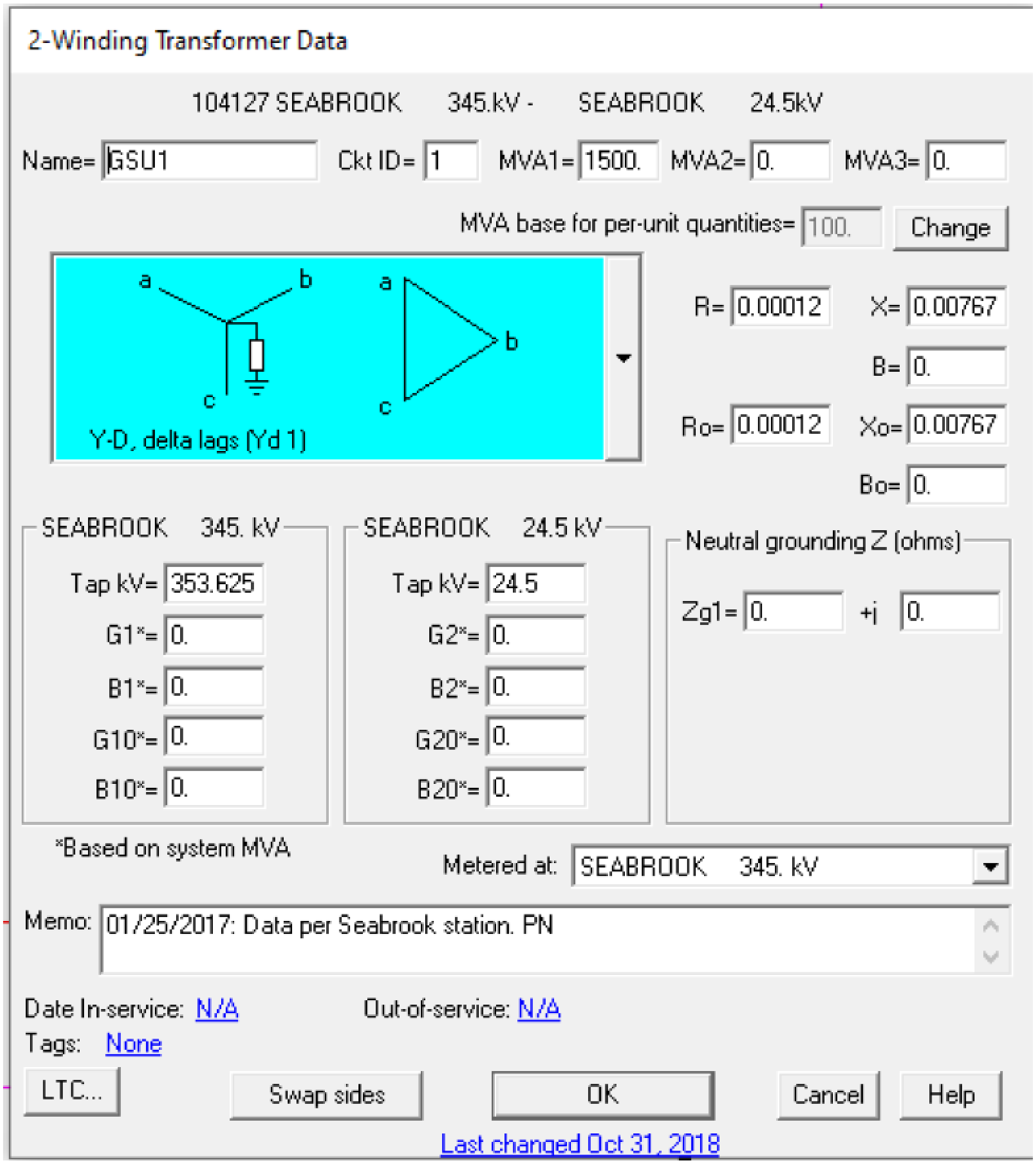

Figure 6-8 Seabrook 345/24.5 kV Generator Step-Up Transformer Model

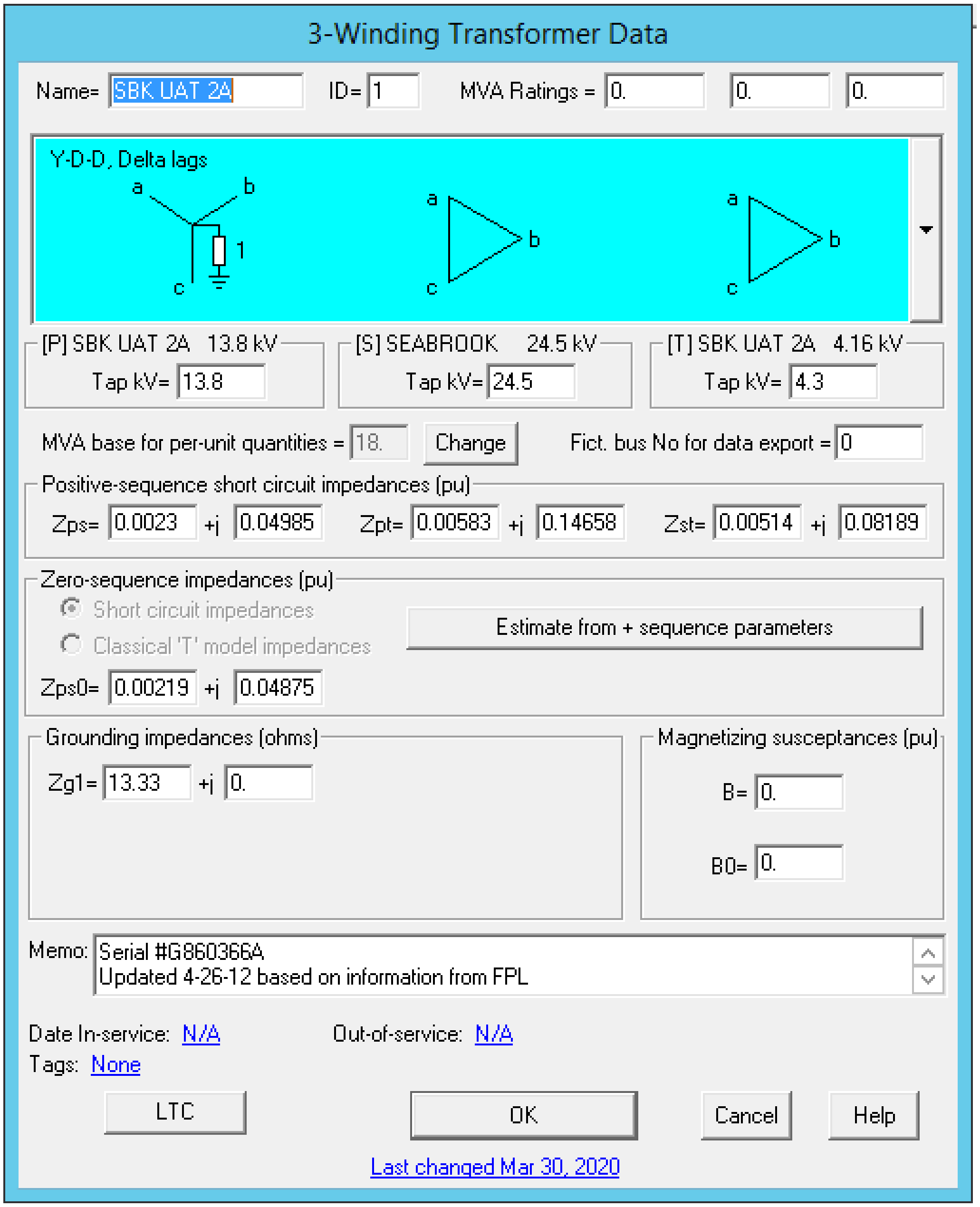

Figure 6-9 Seabrook UAT 2A Transformer Model

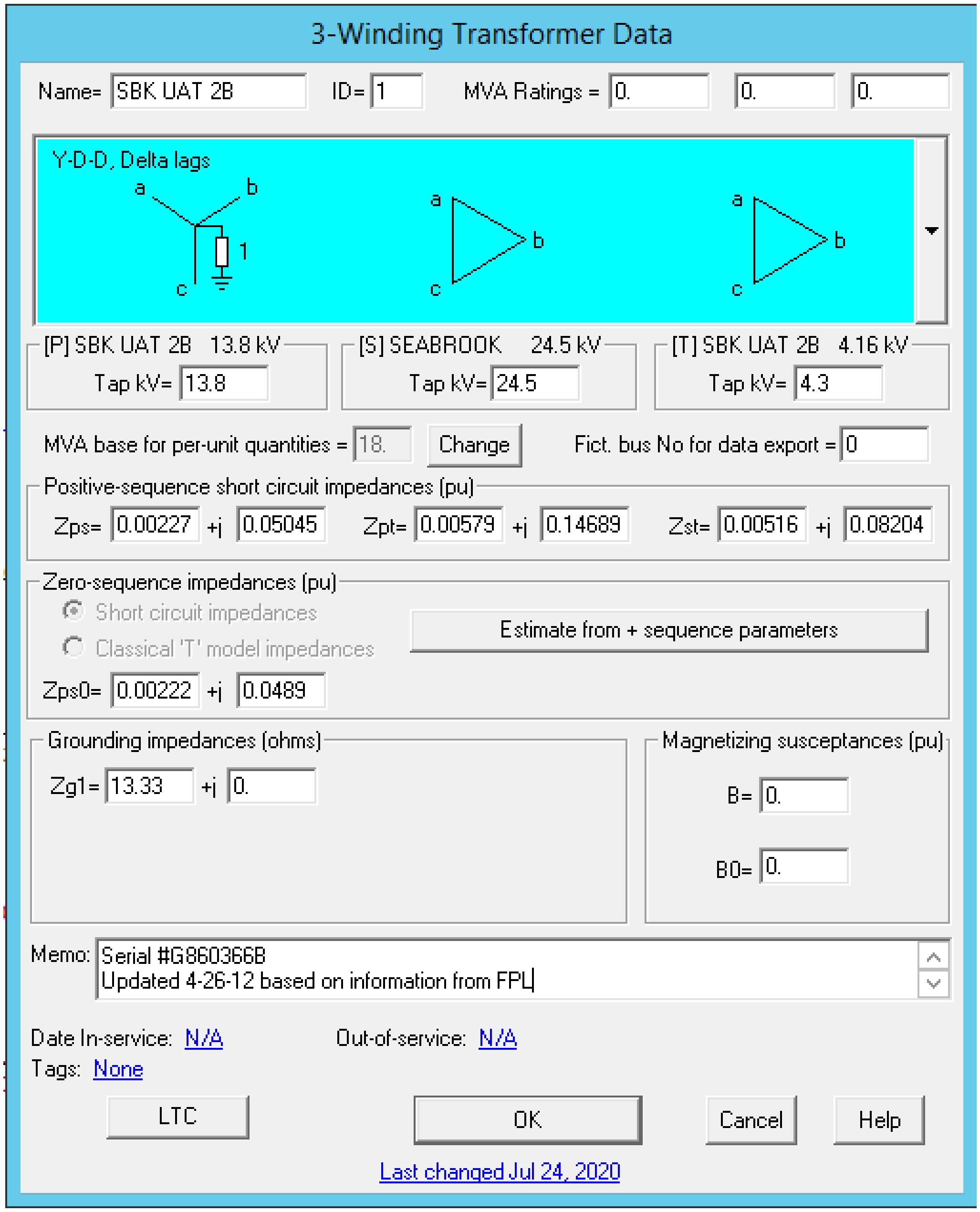

Figure 6-10 Seabrook UAT 2B Transformer Model

6.4.2 Seabrook Generator Circuit Breaker Fault Duty Evaluation

The Seabrook Generator Circuit Breaker was explicitly evaluated. To accurately capture the interrupting and momentary duty of the Seabrook Generator Circuit Breaker, two scenarios were evaluated:

- Case 1: Seabrook main generator was offline. This case was used to calculate the short circuit current contributed from the system, which was higher than the fault current contributed from the generator. The results provided the maximum short circuit current that the Seabrook main generator circuit breaker would be required to interrupt.

- Case 2: Seabrook main generator was online. In this case, the Seabrook generator breaker fault currents were calculated using the total fault currents less the contributions from the generator. Because the X/R ratio was higher in this case, it was more conservative to use this case to determine the momentary duty of the Seabrook generator breaker.

The pre-fault voltage used for the 24.5 kV breakers was 1.04 p.u. that was previously provided by NextEra Energy. It has been identified in the QP639 SIS short circuit analysis that the Seabrook 24.5 kV generator circuit breaker will need to be upgraded due to the adverse impact of QP639. QP639 increased the symmetrical interrupting current by 2,510A (1.2%) which exceeds the breaker's 165,000A symmetrical interrupting capacity. The Seabrook generator circuit breaker needs to be uprated due to QP639. However, without the information of the new ratings of the breaker, the short circuit analysis was performed based on the existing breaker rating of Seabrook generator breaker and the impact of the project was reported in terms of increased Short circuit amperes.

6.4.3 Seabrook Generator Circuit Breaker Short Circuit Analysis Result

Table 6-6 to Table 6-9 shows the contribution of fault current by the Project to the Seabrook generator breaker. The Seabrook diesel units were modeled in the cases. Their fault current contributions (on a 1.04 p.u. pre-fault voltage) at the 24.5 kV bus from their transformers are:

- SBK UAT 2A: 3654 Amps, and

- SBK UAT 2B: 2298 Amps.

The delta amperes and the percentages changes between pre and post projects are reported in Table 6-6 and Table 6-7 without the QP889 modeled, and in Table 6-8 and Table 6-9 with the proxy QP889 modeled. The tables also detail the impact that BAOS has on the Seabrook generator circuit breaker interrupting and momentary duties.

Table 6-6 Seabrook Generator Breaker Short Circuit Results with Seabrook Generator Offline (No QP 889 upgrades)

Scenario	Fault Current Type	Symmetrical Breaker Capability (A)	Asymmetrical Short Circuit Current Capability (A)	Pre-project					Post-project					Project Impact	
				Symmetrical Short Circuit Current (A)	% Symmetrical Duty of Existing Breaker	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	Symmetrical Short Circuit Current (A)	% Symmetrical Duty of Existing Breaker	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	delta_ Symmetrical current (A)	delta_ Asymmetrical current (A)
Mystic 8&9 Online	Interrupting	165000	196000	166302	100.79	29.1	190525	97.21	166973	101.20	29.1	191291	97.60	671	767
	Momentary	N/A	305000	166302	N/A	29.1	268748	88.11	166973	N/A	29.1	269831	88.47	N/A	1083
Mystic 8&9 Offline	Interrupting	165000	196000	163821	99.29	29	187611	95.72	164636	99.78	29	188544	96.20	815	932
	Momentary	N/A	305000	163821	N/A	29	264705	86.79	164636	N/A	29	266021	87.22	N/A	1316

Table 6-7 Seabrook Generator Breaker Short Circuit Results with Seabrook Generator Online (No QP 889 upgrades)

Scenario	Fault Current Type	Asymmetrical Short Circuit Current Capability (A)	Pre-project						Post-project						Project Impact
			Max 24.5kV Bus Fault Current (A)	Main Generator Contribution (A)	Short Circuit Current (A)	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	Max 24.5kV Bus Fault Current (A)	Main Generator Contribution (A)	Short Circuit Current (A)	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	delta Asymmetrical current (A)
Mystic 8&9 Online	Momentary	305000	278416.4@-87.6	112207.01@-89.6	166324	71.9	279933	91.78	279088@-87.6	112207.1@-89.6	166994	71.9	281062	92.15	1129
Mystic 8&9 Offline	Momentary	305000	275918.0@-87.5	112207.1@-89.6	163838	72.3	275787	90.42	276733.8@-87.5	112207.1@-89.6	164652	72.3	277159	90.87	1371

Table 6-8 Short Circuit Results with Seabrook Generator Offline (with proxy QP 889 upgrades)

Scenario	Fault Current Type	Symmetrical Breaker Capability (A)	Asymmetrical Short Circuit Current Capability (A)	Pre-project					Post-project					Project Impact	
				Symmetrical Short Circuit Current (A)	% Symmetrical Duty of Existing Breaker	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	Symmetrical Short Circuit Current (A)	% Symmetrical Duty of Existing Breaker	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	delta_ Symmetrical current (A)	delta_ Asymmetrical current (A)
Mystic 8&9 Online	Interrupting	165000	196000	168444	102.09	29.1	192979	98.46	169163	102.52	29.1	193800	98.88	719	822
	Momentary	N/A	305000	168444	N/A	29.1	272210	89.25	169163	N/A	29.1	273370	89.63	N/A	1160.4
Mystic 8&9 Offline	Interrupting	165000	196000	166094	100.66	29	190214	97.05	166909	101.16	29	191147	97.52	815	933
	Momentary	N/A	305000	166094	N/A	29	268378	87.99	166909	N/A	29	269694	88.42	N/A	1316

Table 6-9 Short Circuit Results with Seabrook Generator Online (with proxy QP 889 upgrades)

Scenario	Fault Current Type	Asymmetrical Short Circuit Current Capability (A)	Pre-project						Post-project						Project Impact
			Max 24.5kV Bus Fault Current (A)	Main Generator Contribution (A)	Short Circuit Current (A)	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	Max 24.5kV Bus Fault Current (A)	Main Generator Contribution (A)	Short Circuit Current (A)	ANSI X/R	Asymmetrical Short Circuit Current (A)	% Asymmetrical Duty of Existing Breaker	delta Asymmetrical current (A)
Mystic 8&9 Online	Momentary	305000	280558.3@ -87.6	112207.1 @-89.6	168466	71.9	283538	92.96	281278 @-87.6	112207.1 @-89.6	169185	71.9	284748	93.36	1210
Mystic 8&9 Offline	Momentary	305000	278190.8@ -87.5	112207.1 @-89.6	166111	72.3	279613	91.68	279007 @-87.5	112207.1 @-89.6	166926	72.3	280985	92.13	1372

In all the scenarios analyzed, the Seabrook generator breakers are within the asymmetrical interrupting duty ratings and the momentary duty ratings of the existing generator breaker. It can be concluded that the BAOS project has no significant adverse impact on the asymmetrical interrupting duty and momentary duty of the breaker even post the QP639 mitigation of the Seabrook generator breaker overduty. With respect to the symmetrical duty, both pre and post Project were found overdutied for three of the four scenarios analyzed. The impact of the BAOS project ranges from 671 amps to 815 amps increase for the various scenarios.

7 SPECIAL STUDIES

7.1 Subsynchronous Torsional Interaction (SSTI) Screenings

Subsynchronous torsional interaction (SSTI) screenings were performed for normal system and system restoration conditions, respectively. The objective of this study is to perform a subsynchronous torsional interaction (SSTI) screening of a selected group of generating plants that are electrically close to the Tewksbury 22A substation, where the new Tewksbury STATCOM is interconnecting as a part of the BAOS project. The screening analysis evaluated there is a potential for the controls of the proposed power electronic converters to interact with the turbine-generator shafts that are electrically nearby and produce resonance (torsional vibrations) at shaft natural resonant frequencies of a significant amplitude enough to damage the generators. The outcome of this screening analysis is to identify system conditions under which a detailed PSCAD analysis is needed to identify SSTI concerns. The Unit Interaction Factor (UIF) index proposed by EPRI was used as a screening measure.

The sub-synchronous torsional interaction screening study indicated that there is a potential risk of torsional interactions between the Tewksbury STATCOM and several electrically nearby generators (affected generators). Three affected generators were identified as a part of the screening analysis. Since the analysis that led to the identification of the three generators for detailed SSTI evaluation included the assessment of system restoration conditions, and because the specifics of the system restoration plan are confidential under the Information Policy, the details of the generators that were identified are excluded from this report.
Note that the SSTI phenomenon is strongly dependent on the controls used in the STATCOM and the characteristics of the turbine-generator torsional models. A detailed SSTI study to determine any required mitigation of the risk of SSTI with these affected generators will be required as part of the detailed design studies for the Tewksbury STATCOM.
National Grid and the affected generator owners have agreed that a SSTI study will be completed by National Grid, as part of the detailed design studies for the Tewksbury STATCOM. This SSTI study will include:

a) The actual control system design of the Tewksbury STATCOM facilities
b) The torsional model data, torsional mode parameters, and mechanical damping assumptions provided by each of the affected generators
c) The modeling and assumptions that were included in the SSTI screening study completed under this System Impact Study.

The specific issues that will be addressed in the SSTI study and the process for National Grid and affected generator owners to reach agreement on the determination of any need for any possible mitigating measures, including, but not necessarily limited to: STATCOM control system monitoring; STATCOM auxiliary control/protective action; or affected generator protection; will be specified in bilateral agreements reasonably negotiated between the affected generator owners and National Grid.

7.2 Electromagnetic Transient (EMT) studies

The following Electromagnetic Transient (EMT) studies in this section were performed using PSCAD:

7.2.1 Tewksbury STATCOM PSS/E – PSCAD Model Benchmarking

PSS/E – PSCAD model benchmarking for the STATCOM at Tewksbury was conducted to meet the requirement consistent with Appendix C – Requirements of PSCAD Models of Planning Procedure 5-6. The benchmarking analysis compared the performance of the PSS/E model with the PSCAD model for fault conditions. The Siemens SVC Plus PSCAD model of the STATCOM was benchmarked against a PSS/E generic SVSMO3U2 FACTS model. Comparisons generally match well (including steady-state levels) considering the inherent differences between the two modelling platforms. Most of the traces are within a +/-10% deviation range. Overall, the comparison was deemed adequate for the purpose of moving forward with design studies.

7.2.2 Control Interaction Study

A Control Interaction study was performed to evaluate any interactions between the STATCOM at Tewksbury and other power electronic devices in the electrical vicinity of the STATCOM. The study was performed using a generic DC line model for Phase II HVDC and examined sensitivities to the Western Massachusetts DER cluster. Both the Tewksbury STATCOM and the Sandy Pond HVDC link successfully rode through all the contingencies tested. No adverse control interactions were observed for any of the contingencies. National Grid is working with ABB to develop an actual PSCAD model for Phase II HVDC. A detailed Control Interconnection study will be completed using the actual detailed Phase II HVDC model and the final STATCOM model prior to energization of the STATCOM. Any required mitigation for potential control interactions between the STATCOM and Phase II HVDC would be resolved by National Grid prior to the energization of the STATCOM and if the required mitigations require a review through the I.3.9 process, then appropriate steps will be taken by National Grid.

Details of the special studies performed in this section can be found in the report in Appendix J.

Table 7-1 Events Analyzed in the Control Interaction Study

Event numb er	Fault location	Event Type	Prior Outage	Branch Removed	Reason for Event
1	Sandy Pond	3LG, BF	Sandy Pond - Wachusett 1	Sandy Pond - Wachusett 2	Severe fault at DC terminals, Removes strong connection to Millbury, and creates higher IF between Tewksbury and SP
2	Sandy Pond	SLG, BF	Sandy Pond - Wachusett 2	Sandy Pond - Wachusett 1	Long duration unbalanced, higher IF
3	None	Switch in	Tewksbury – Sandy Pond	None	switching event between devices
4	None	Switch in	349 Mystic-Wakefield Jct.	None	Voltage change from cable charging
5	Tewksb ury	SLG, BF	Tewksbury - Wakefield Jct.	Tewksbury-Ward Hill, Tewk-Woburn	Weaken ties from Tewksbury to rest of the system
6	Tewksb ury	3LG	Tewksbury - Wakefield Jct.	Tewksbury-Ward Hill	Severe fault at STATCOM terminals
7	Sandy Pond	Loss of DC	None	DC Lines	To compare with a similar fault ran for WMASS DER study
8	Sandy Pond	3LG.	Sandy Pond Bus 1	Sandy Pond Bus 2	One pole radial to Tewksbury
9	Sandy Pond	SLG	Sandy Pond Bus 1	Sandy Pond Bus 2	One pole radial to Tewksbury

8 CONCLUSION

The steady state contingency analysis, stability analysis, and short circuit analysis, and special studies documented in this report demonstrated that the New England transmission system continues to meet the transmission system reliability standards following the addition of the proposed BAOS project. The Project does not have any significant adverse impact on the operation or reliability of the transmission system.

9 APPENDICIES

9.1 Appendix A –Models for The Project

- **IDEV for the power flow case**

```
// Adding 11.9 Ohms Series reactors and bypass switches to North Cambridge - Woburn cables
BAT_SPLT,110758,9998,'NCAMB_R1', 345.0
BAT_MOVEBRN,110756,110758,'1',9998,'1'
BAT_BRANCH_CHNG,9998,110758,'1',,,,,,, 0.001, 0.01,, 538.0, 657.0, 1349.0,,,,,,,,,,;
BAT_BRANCH_DATA,110758,9998,'2',0,110758,400,0,0,0,0.0, 0.0001,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0, 1.0, 1.0,
1.0, 1.0
BAT_SPLT,110758,9999,'NCAMB_R2', 345.0
BAT_MOVEBRN,110756,110758,'2',9999,'2'
BAT_BRANCH_CHNG,9999,110758,'1',,,,,,, 0.001, 0.01,, 538.0, 657.0, 1349.0,,,,,,,,,,;
BAT_BRANCH_DATA,110758,9999,'2',0,110758,400,0,0,0,0.0, 0.0001,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0, 1.0, 1.0,
1.0, 1.0

// Adding a STATCOM at Tewksbury 22A
BAT_BUS_DATA_3,1,1,1,1,1,0.0, 1.0,0.0, 1.1, 0.9, 1.1, 0.9," "
BAT_BUS_CHNG_3,1,,,,, 345.0,,,,,,,'TWKS-STAT'
BAT_BUS_NUMBER,1,114089
BAT_BUS_CHNG_3,114089,,101,1120,600,,,,,,,,,;
BAT_BRANCH_DATA,113951,114089,'1',1,113951,600,0,0,0,0.0, 0.0001,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0, 1.0,
1.0, 1.0, 1.0
BAT_BUS_DATA_3,201,1,1,1,1,0.0, 1.0,0.0, 1.1, 0.9, 1.1, 0.9," "
BAT_BUS_CHNG_3,201,2,,,, 34.5,,,,,,,'TWKS-STAT'
BAT_BUS_NUMBER,201,114090
BAT_BUS_CHNG_3,114090,,101,1120,600,,,,,,,,,;
BAT_TWO_WINDING_DATA_4,114089,114090,'1',1,114089,1,0,0,0,33,0,114089,0,1,0,1,1,1,0.001166, 0.116600,
150.0, 1.0,345.0,0.0, 1.0,34.5,167.0,167.0,167.0, 1.0, 1.0, 1.0, 1.0,0.0,0.0, 1.1, 0.9, 1.1, 0.9,0.0,0.0,0.0," "," "
BAT_FACTS_DATA_2,'FACTS 1',114090,0,1,1,0,0,0.0,0.0, 1.0, 9999.0, 9999.0, 0.9, 1.1, 1.0,0.0, 0.05,
100.0,0.0,0.0,'           TëFACTS 1'
BAT_FACTS_CHNG_2,'FACTS 1',,,,,,114089,,, 1.028, 167.0,,,,,,,,,,,;
BAT_MBIDFACTS,'FACTS 1','TWK_STATCM'
```

- **Dynamic model for stability**

```
'TWK_STATCM'   'USRFCT'  'SVSMO3U2' 21    1   20    44   6    27
  114089       0     0     0
     0     '0 '         0     '0 '         0     '0 '
     0     '0 '         0     '0 '         0     '0 '
     0     '0 '         0     '0 '
     0.2000E-01    0.000       0.005       1.5        300
      1.000       -1.000       0.1500E-02    1.000        0.000
      0.000        0.000        0.000        0.000        0.000
      0.000        0.000        1.150       0.3500       0.3000
      3.000        3.000        2.000        2.000       0.3300E-01
      1.100       0.9000       0.5000E-02    0.2000E-02    0.000
      0.000        0.000        0.000        0.000        0.000
      0.000        0.000        0.000        0.000        0.000
      0.000        0.000        0.000        167.0         /
```

- **CHF file for short circuit**

[ADD BUS DATA]
'BUS117' 345= 0 400 1000 '' 1 1 0 0 0 0 0 0 '' ''
'BUS122' 345= 0 400 1000 '' 1 1 0 0 0 0 0 0 '' ''
'TWKS-STAT' 34.5= 114090 643 5 'Tewks' 0 1 0 0 0 0 0 '' ''

[ADD VOLTAGE CONTROLLED CURRENT SOURCE]
'TWKS-STAT' 34.5= 1 0 167 1.05 0.05 10 1 2794.71 -90 0.9 2794.71 -90 0.7 2794.71 -90 0.5 2794.71 -90 0.3 2794.71 -90 0.29 0 -90 0 0 0 0 0 0 0 0 0 0 0 0 /
'' '' 0 0

[DELETE TRANSMISSION LINE]
'211-Woburn' 345 '509-NCambrid' 345 '1'= 1 0 '346' '' 0 'ft' /
  0.00025 0.00133 0 0 0 0 0.00267 0.00288 0 0 0 0 4 0 0 0 0 0 0 0
'211-Woburn' 345 '509-NCambrid' 345 '2'= 1 0 '365' '' 0 'ft' /
  0.00025 0.0013266 0 0 0 0 0.00267425 0.00288482 0 0 0 0 4 0 0 0 0 0 0 0

[ADD TRANSMISSION LINE]
'BUS117' 345 '211-Woburn' 345 '1'= 1 0 '365' '' 0 'ft' /
  0.0002475 0.00131333 0 0 0 0 0.00264751 0.00285597 0 0 0 0 4 0 0 0 0 0 0 0
'BUS122' 345 '211-Woburn' 345 '1'= 1 0 '346' '' 0 'ft' /
  0.0002475 0.0013167 0 0 0 0 0.0026433 0.0028512 0 0 0 0 4 0 0 0 0 0 0 0
'509-NCambrid' 345 'BUS117' 345 '1'= 1 0 'Reactor' '' 0 'ft' /
  0.001 0.01 0 0 0 0 0.001 0.01 0 0 0 0 4 0 0 0 0 5.2 1 0 /
'Concept 11.9 ohm reactor' /
'' 0 0
'509-NCambrid' 345 'BUS122' 345 '1'= 1 0 'Reactor' '' 0 'ft' /
  0.001 0.01 0 0 0 0 0.001 0.01 0 0 0 0 4 0 0 0 0 5.2 1 0 /
'Concept 11.9 ohm reactor' /
'' 0 0

[ADD 2W TRANSFORMER]
'TEWKSBURY22A' 345 'TWKS-STAT' 34.5 '1'= 1 0 'TWKS-STATCOM' 345 34.5 0 0.00116 0.1166 0 0.00116 0.1166 0 /
G D D 0 0 0 0 0 0 3 167 167 167 0 0 0.51 1.5 0.00625 0.51 1.5 '' 0 /
0 0 0 0 0 0 0 0 100 0 0 0

[ADD BREAKER]
'TEWKSBURY22A' 345= 'TWK22A D1' 1 2 0 1.5 1.5 63000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'' /
'' /
1 1 /
B /
T 'TEWKSBURY22A' 345 'TWKS-STAT' 34.5 '1'
'TEWKSBURY22A' 345= 'TWK22A D2' 1 2 0 1.5 1.5 63000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'' /
'' /
1 1 /
B /
T 'TEWKSBURY22A' 345 'TWKS-STAT' 34.5 '1'

[ADD SWITCH DATA]
'BUS117' 345 '509-NCambrid' 345 '2' = 1 '365B' 1 2 0
'509-NCambrid' 345 'BUS122' 345 '2' = 1 '346B' 1 2 0

[MODIFY BREAKER]
'509-NCambrid' 345= 'N CAMB 105' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'300-SFMT-50E' /
'' /
2 2 /
B /
S 'R1' /
L '509-NCambrid' 345 'BUS122' 345 '1' /
W '509-NCambrid' 345 'BUS122' 345 '2'
'509-NCambrid' 345= 'N CAMB 106' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'300-SFMT-50E' /
'' /
1 2 /
L '509-NCambrid' 345 '250Mystic345' 345 ' ' /
L '509-NCambrid' 345 'BUS122' 345 '1' /
W '509-NCambrid' 345 'BUS122' 345 '2'
'509-NCambrid' 345= 'N CAMB 101' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'362-PMI-50-30\nSF6' /
'' /
2 1 /
L '509-NCambrid' 345 'BUS117' 345 '1' /

W '509-NCambrid' 345 'BUS117' 345 '2' /
X '509-NCambrid' 345 '509-NCambrid' 115 '2'
'509-NCambrid' 345= 'N CAMB 108' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'362-PMI-50-30\nSF6' /
'' /
2 1 /
L '509-NCambrid' 345 'BUS117' 345 '1' /
W '509-NCambrid' 345 'BUS117' 345 '2' /
L '509-NCambrid' 345 '250Mystic345' 345 ' '
'211-Woburn' 345= 'WOBURN 105' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'Generic 50-kA Breaker Future' /
'' /
1 1 /
L '211-Woburn' 345 'BUS122' 345 '1' /
B
'211-Woburn' 345= 'WOBURN 101' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'300-SFMT-50E\nSF6' /
'' /
1 1 /
L '211-Woburn' 345 'BUS122' 345 '1' /
B
'211-Woburn' 345= 'WOBURN 104P' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'300-SFMT-50E\nSF6' /
'' /
1 1 /
L '211-Woburn' 345 'BUS117' 345 '1' /
B
'211-Woburn' 345= 'WOBURN 106' 1 2 0 2 2 50000 0 1 0 0 0 1 0 0 0 345 362 1 0 0 0 1 /
'300-SFMT-50E\nSF6' /
'' /
1 1 /
L '211-Woburn' 345 'BUS117' 345 '1' /
B

[DELETE RELAYGROUP]
RELAYGROUP
0; '509-NCambrid'; 345; 0; '211-Woburn'; 345; '1'; 1;
'';
'';
0; 0;0;0;
'';'';

[DELETE RELAYGROUP]
RELAYGROUP
0; '509-NCambrid'; 345; 0; '211-Woburn'; 345; '2'; 1;
'';

'';
0; 0;0;0;
'';'';

[DELETE RELAYGROUP]
RELAYGROUP
0; '211-Woburn'; 345; 0; '509-NCambrid'; 345; '1'; 1;
'';
'';
0; 0;0;0;
'';'';

[DELETE RELAYGROUP]
RELAYGROUP
0; '211-Woburn'; 345; 0; '509-NCambrid'; 345; '2'; 1;
'';
'';
0; 0;0;0;
'';'';

9.2 Appendix B - Details on load, energy efficiency and PV forecast

		Peak Load Forecast at Milder-than-Expected Weather				Gross Forecast at Expected Weather	Peak Load Forecast at More-Extreme-than-Expected Weather				
Probability of Forecast Being Exceeded		**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**
Summer (MW)	2020	26,984	27,368	27,756	28,088	28,438	28,953	29,301	29,719	30,396	30,863
	2021	27,166	27,564	27,947	28,276	28,634	29,157	29,523	29,945	30,611	31,104
	2022	27,362	27,773	28,150	28,487	28,844	29,375	29,758	30,178	30,855	31,358
	2023	27,582	28,003	28,380	28,724	29,083	29,620	30,019	30,437	31,130	31,638
	2024	27,771	28,202	28,581	28,933	29,303	29,836	30,251	30,667	31,377	31,889
	2025	27,971	28,411	28,793	29,153	29,534	30,065	30,495	30,909	31,635	32,152
	2026	28,176	28,625	29,010	29,378	29,770	30,305	30,740	31,155	31,898	32,419
	2027	28,388	28,842	29,234	29,610	30,013	30,551	30,991	31,409	32,168	32,694
	2028	28,596	29,055	29,450	29,838	30,253	30,794	31,239	31,659	32,435	32,965
	2029	28,802	29,265	29,659	30,064	30,489	31,034	31,485	31,905	32,698	33,233
Probability of Forecast Being Exceeded		**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**	**5%**
Winter (MW)	2020-2021	23,017	23,120	23,197	23,281	23,373	23,493	23,653	23,811	24,013	24,179
	2021-2022	23,257	23,365	23,443	23,530	23,622	23,742	23,904	24,067	24,270	24,438
	2022-2023	23,481	23,594	23,675	23,765	23,853	23,977	24,140	24,309	24,513	24,683
	2023-2024	23,716	23,831	23,914	24,008	24,088	24,218	24,384	24,559	24,764	24,937
	2024-2025	23,958	24,073	24,158	24,255	24,329	24,464	24,634	24,814	25,020	25,195
	2025-2026	24,206	24,324	24,411	24,509	24,583	24,720	24,893	25,080	25,286	25,464
	2026-2027	24,466	24,587	24,677	24,776	24,851	24,988	25,165	25,358	25,566	25,747
	2027-2028	24,741	24,864	24,957	25,057	25,133	25,272	25,451	25,651	25,860	26,043
	2028-2029	25,013	25,134	25,231	25,332	25,408	25,551	25,731	25,938	26,149	26,335
	2029-2030	25,289	25,407	25,508	25,609	25,687	25,833	26,014	26,230	26,442	26,632

2020 CELT

ISO New England Basecase DB - Load File Report by Company

Study Date :	06/01/2025	**Study Name :**	2025_Projects		
File Created :	2020-06-26	**CELT Forecast :**	2020	**Forecast Year :**	2024
Season :	Summer Peak	**Weather :**	90/10	**Load Distribution :**	N+10_SUM
ISO-NE CELT :	32315 MW	**% of Peak :**	100.000%	**Tx Losses :**	2.50%

State CELT L&L	-	2.50% Tx Losses	+	Non-CELT Load	+	Station Service	-	Area 104 NE Load	=	Area 101 Load
32314 MW		748.0 MW		319.1 MW		842.7 MW		24.5MW		32696.1 MW

1: State CELT L&L: This represents the sum of the 6 State CELT forecasts. This number can sometimes be 5-10 MW different than the ISO-NE CELT forecast number due to round-off error.
2: Non-CELT Load: This is the sum of all load modeled in the case that is not included in the CELT forecast. An example is the "behind the meter" paper mill load in Maine.
3: Station Service: This is the amount of generator station service modeled. If station service is off-line, the Area 101 report totals will be different since off-line load is not counted in totals.

Maine State Load = 2401 MW - 2.50% Tx Losses = 2345.42 MW

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CMP	86.44%	2027.37	595.42	0.959	153.40
EM	13.56%	318.07	96.83	0.957	

New Hampshire State Load = 2674 MW - 2.50% Tx Losses = 2612.10 MW

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
PSNH	78.73%	2056.48	293.10	0.990	5.80
UNITIL	12.01%	313.72	44.72	0.990	
GSE	9.26%	240.78	4.19	1.000	1.85

Vermont State Load = 1174 MW - 2.50% Tx Losses = 1146.82 MW

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
VELCO	100.00%	1146.78	193.14	0.986	79.42

Massachusetts State Load = 15722 MW - 2.50% Tx Losses = 15358.06 MW

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
BECO	28.53%	4381.68	1118.54	0.969	37.79
COMEL	11.41%	1752.34	362.66	0.979	
MA-NGRID	39.74%	6103.31	355.25	0.998	104.61
WMECO	6.00%	914.60	130.33	0.990	
MUNI:BOST-NGR	3.52%	540.58	93.22	0.985	
MUNI:BOST-NST	1.43%	219.62	34.14	0.988	
MUNI:CNEMA-NGR	1.90%	291.80	39.92	0.991	
MUNI:RI-NGR	0.86%	132.07	16.08	0.993	
MUNI:SEMA-NGR	1.79%	274.92	23.24	0.996	
MUNI:SEMA-NST	1.77%	271.82	54.64	0.980	
MUNI:WMA-NGR	0.88%	135.14	5.65	0.999	
MUNI:WMA-NU	2.17%	333.27	47.49	0.990	

Rhode Island State Load = 2496 MW - 2.50% Tx Losses = 2438.22 MW

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
RI-NGRID	100.00%	2438.22	158.99	0.998	45.44

Connecticut State Load = 7847 MW - 2.50% Tx Losses = 7665.36 MW

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CLP	76.59%	5870.96	836.58	0.990	100.50
CMEEC	4.34%	332.69	47.38	0.990	
UI	19.08%	1462.56	146.86	0.995	10.00

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ISO New England Basecase DB - Solar PV File Summary Report

Study Name :	2025_Projects				
Study Date :	06/01/2025	**Distrib Losses :**	5.50%	**Load Season :**	2024
File Created :	2020-06-26	**PMax Value :**	50degF (NRC)	**Availability :**	26%
CELT Year :	2020	**Load Distrib :**	N+10_SUM		

(**Forecasted PV in Load Season** 5830.96 MW + **Distribution Losses Gross-Up** 320.703 MW) x **Availability** 26.00% = **Total PV** 1599.432 MW

Formula is applicable to 'Dispatch Zone PV' as well as the entire New England Region PV, 'Total PV'

Total Calculated PV per Dispatch Zone (Units are MW unless noted)

		PV Forecast Information (Excludes Losses)				PV Modeled as Negative Load	
ID	**Dispatch Zone Description**	**Total PV Forecasted**	**Total PV Gen**	**Total PV Discrete**	**Total PD**	**Total P (MW)**	**Total Q (MVAR)**
30	ME - Emera Maine	50.25	0	8	11.59	13.78	3.53
31	ME - Maine	185.21	0	115.88	19.02	50.80	5.48
32	ME - Portland Maine	143.29	0	31.97	30.54	39.30	8.34
33	NH - New Hampshire	163.01	0	34.4	35.28	44.71	4.71
34	NH - Seacoast	24.15	0	0	6.62	6.62	0.94
35	VT - Northwest Vermont	295.51	0	72.89	61.06	81.06	10.00
36	VT - Vermont	172.91	0	45.25	35.02	47.43	7.36
37	MA - Boston	380.28	0.69	74.25	83.75	104.12	21.23
38	MA - North Shore	184.72	0	75.31	30.01	50.67	3.34
39	MA - Central Massachusetts	468.65	9.96	132.81	89.39	125.82	7.91
40	MA - Springfield	288.15	0	142.5	39.95	79.04	5.31
41	MA - Western Massachusetts	874.18	68.82	550.75	69.84	220.91	5.03
42	MA - Lower Southeast Massachusetts	503.02	8	252.22	66.60	135.78	11.10
43	MA - Southeast Massachusetts	692.43	0	346.44	94.90	189.93	7.57
44	RI - Rhode Island	355.54	0	184.51	46.91	97.52	2.42
45	CT - Eastern Connecticut	191.64	0	60.97	35.84	52.57	5.11
46	CT - Northern Connecticut	199.48	0	35.11	45.09	54.72	6.42
47	CT - Norwalk-Stamford	77.94	0	0	21.38	21.38	2.92
48	CT - Western Connecticut	580.60	0	58.8	143.13	159.26	18.73
	New England Totals	5830.96	87.47	2222.04	965.94	1599.43	137.45

PD is defined as : The Distributed PV that is spread across a Dispatch Zone. It is calculated on a bus-by-bus basis using the following for

$$PD = \left((PV_{Total} - PV_{Discrete} - PV_{Gen}) * (1 + DistribLosses)\right) * \left(\frac{BusLoad[w/o\ PV]}{DispatchZoneLoad[w/o\ PV]}\right) * Availability$$

Total PD is calculated by the summation of all bus PD values in a Dispatch Zone

Total PV Gen is the total PV in the PV forecast that is modeled as a generator

Total PV Discrete is the total PV in the PV forecast for which locational information is available

Total PD is the remainder of the PV forecast for which locational information is not available

Total P is calculated by adding the adjusted PVDiscrete values (adjusted for Availability and Distribution Losses) to the PD

$$P = \left((PV_{Discrete}) * (1 + DistribLosses) * Availability\right) + PD$$

ISO New England Basecase DB - Demand Resources File Report

Study Date :	06/01/2025	Study Name :	2025_Projects		
File Created :	2020-06-26	CCP :	2023/2024	Load Season :	2024 - Summer Peak
Load Distrb :	N+10_SUM	Distrb Losses :	5.50%	DR Season :	SUM

	Demand Reduction Value (DRV)		Availability (Avail)		Distribution Losses Gross-Up		Area 104 DR		Area 101 DR
Passive DCR :	N/A		N/A		N/A		N/A		N/A
Forecast EE :	4259.29 MW	x	100.00%	+	234.26 MW	-	4.01 MW	=	4489.54 MW
ADCR :	697.81 MW	x	75.00%	+	28.78 MW	-	1.07 MW	=	551.08 MW
RTEG :	N/A		N/A		N/A		N/A		N/A

Demand Reduction Value (DRV): Amount of DR measured at the customer meter without any gross-up values for transmission or distribution losses.
Availability Factor: De-rate factor applied based on expected performance of DR after a dispatch signal from Operations.
Area 104 DR: This load is modeled in northern VT and is electrically served from Hydro Quebec. To make Area Interchange load independent, this load is assigned Area 104.
Real-Time Emergency Generation will no longer exist after 5/31/2018 and will be replaced by ADCR. RTEGs are left to model historical CCPs.

Forecasted Energy Efficiency

DR Modeled = (DRV_EE * 100.00% Availability) + 5.50% Distrb Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_P_ME	20	Load Zone - Maine	-240.77	-254.01	-72.40
DR_P_NH	21	Load Zone - New Hampshire	-215.18	-227.02	-30.64
DR_P_VT	22	Load Zone - Vermont	-165.24	-174.33	-23.77
DR_P_NEMABOS	23	Load Zone - Northeast Massachusetts & Boston	-1089.00	-1148.89	-243.49
DR_P_SEMA	24	Load Zone - Southeast Massachusetts	-657.79	-693.96	-67.52
DR_P_WCMA	25	Load Zone - West Central Massachusetts	-678.97	-716.31	-64.12
DR_P_RI	26	Load Zone - Rhode Island	-348.49	-367.66	-18.97
DR_P_CT	27	Load Zone - Connecticut	-863.86	-911.37	-122.47

Active Demand Capacity Resources - (Demand Response Resource)

ADCR Modeled = (DRV_SUM * 75.00% Availability) + 5.50% Losses Gross-Up

Zone	ID	Description	DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_A_ME_EME	30	Dispatch Zone - ME - Emera Maine	-2.25	-1.78	-0.54
DR_A_ME_MAIN	31	Dispatch Zone - ME - Maine	-111.58	-88.29	-25.43
DR_A_ME_PORT	32	Dispatch Zone - ME - Portland Maine	-15.38	-12.17	-3.32
DR_A_NH_NEWH	33	Dispatch Zone - NH - New Hampshire	-32.61	-25.81	-3.44
DR_A_NH_SEAC	34	Dispatch Zone - NH - Seacoast	-12.28	-9.71	-1.39
DR_A_VT_NWVT	35	Dispatch Zone - VT - Northwest Vermont	-35.39	-28.00	-3.58
DR_A_VT_VERM	36	Dispatch Zone - VT - Vermont	-13.36	-10.58	-1.60
DR_A_MA_BOST	37	Dispatch Zone - MA - Boston	-77.18	-61.07	-15.26
DR_A_MA_NSHR	38	Dispatch Zone - MA - North Shore	-17.70	-14.01	-1.50
DR_A_MA_CMA	39	Dispatch Zone - MA - Central Massachusetts	-37.48	-29.66	-2.54
DR_A_MA_SPFD	40	Dispatch Zone - MA - Springfield	-27.86	-22.04	-2.85
DR_A_MA_WMA	41	Dispatch Zone - MA - Western Massachusetts	-39.99	-31.64	-2.03
DR_A_MA_LSM	42	Dispatch Zone - MA - Lower Southeast Massachusetts	-14.65	-11.59	-1.88
DR_A_MA_SEMA	43	Dispatch Zone - MA - Southeast Massachusetts	-38.80	-30.70	-2.07
DR_A_RI_RHOD	44	Dispatch Zone - RI - Rhode Island	-42.75	-33.83	-1.74
DR_A_CT_EAST	45	Dispatch Zone - CT - Eastern Connecticut	-41.22	-32.62	-4.65
DR_A_CT_NRTH	46	Dispatch Zone - CT - Northern Connecticut	-54.57	-43.18	-6.15
DR_A_CT_NRST	47	Dispatch Zone - CT - Norwalk-Stamford	-3.81	-3.01	-0.41
DR_A_CT_WEST	48	Dispatch Zone - CT - Western Connecticut	-78.96	-62.47	-8.11

9.3 Appendix C – List of PPA approved projects included

Maine	
County Road Substation	RSP ID: 1514
Queue Position 639 New England Clean Energy Connect HVDC	
New Hampshire	
Seacoast New Hampshire Solution	RSP ID: 1316-1318
Queue Position 501	RSP ID: 1697, 1757-1758
Vermont	
Queue Position 501	RSP ID: 1545, 1749-1750, 1752-1754
Massachusetts	
Greater Boston Reliability Project	RSP ID: 965, 1327, 1335-1336, 1352, 1354-1357, 1516, 1518, 1550-1552, 1646, 1672
Pittsfield/Greenfield Project	RSP ID: 1663
Southeast Massachusetts/Rhode Island Reliability Project	RSP ID: 1714-1723, 1725-1733, 1737, 1741
Somerset Asset Condition	RSP ID: 1635
New East Eagle 115 kV Substation	RSP ID: 1745
North Oxford Breaker Addition	RSP ID: 1624
Queue Position 501	RSP ID: 1699
Queue Position 592	RSP ID: 1781
Andrew Square/Dewar Reliability Project	LSP
349X&Y cable reconductoring	ACL ID: 107
110-510 and 110-511 cable reconductoring	ACL ID: 194
Greater Boston 2028 time sensitive solution	RSP ID: 1806, 1807
Queue Position 624 Vineyard Wind I	RSP ID: 1800, 1801
Queue Position 618 Bay State Wind	RSP ID: 1783-1788
Queue Position 883, 16.45 MW Combined Cycle Increase at Kendall,	
Queue Position 700 – 820 MW offshore wind farm interconnecting to West Barnstable 345 kV	
Queue Position 726 – 150MW BESS at Carver 115 kV	
Rhode Island	
Southeast Massachusetts/Rhode Island Reliability Project	RSP ID: 1724, 1742
Aquidneck Island Reliability Project	RSP ID: 1669,1670
Queue Position 781, 704 MW Offshore Wind	
Queue Position 758, 73.2 MW Combined Cycle Uprate interconnecting at Sherman Road 345 kV	
Connecticut	
Southwest Connecticut Reliability Project	RSP ID: 1622
Greater Hartford and Central Connecticut Reliability Project	RSP ID: 1590, 1596
Cos Cob Substation Breaker Addition	RSP ID: 1533

9.4 Appendix D – Steady State Case Summaries

See folder.

9.5 Appendix E – Steady State Contingency Files

See folder.

9.6 Appendix F – Stability Case Summaries

See folder.

9.7 Appendix G – Stability Simulation Plots

See folder for stability plots.

9.8 Appendix H – Short Circuit Analysis Results

Table 9-1 Short Circuit Duties with Mystic 8&9 in service (Eversource Stations)

			Pre-project				Post-project				Project Impact	
BUS	BREAKER	BKR_Capability (A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
292 Newton 115 kV	Newton 1	63000	40.8	25686.7	36.1	36351.1	40.8	25710.9	36.1	36385.3	0	0
309 Blackstone 345 k	ANP BLK 101	50000	67.2	33585.6	66.2	52962.4	67.3	33636.8	66.3	53043.2	0.1	0.1
315 Electric Ave	GCB 1	63000	78.7	49554.9	73.9	74452.7	78.6	49494.9	73.8	74362.6	-0.1	-0.1
492 Scotia St 115 kV	GCB 1	63000	74	46618.6	67.8	68375.6	74.2	46755.2	68.1	68621.3	0.2	0.3
576 MBTA 115 kV	BT	80000	62	49628.5	59.4	76076.6	62.2	49794.1	59.6	76330.8	0.2	0.2
71 Carver St	GCB 1	63000	79.9	50351.5	76.5	77081.6	80.2	50524.1	76.7	77345.8	0.3	0.2
99 Seafood Way 115 kV	Sta99_GCB1	63000	81.4	51290.7	79.4	80035.2	81.2	51133.1	79.1	79734.9	-0.2	-0.3
Andrew Square	ANDRW SQ 1	63000	70.3	44298.2	66.4	66910.1	70.6	44454	66.6	67145.7	0.3	0.2
Baker St.	BAKER ST 11	63000	49.5	31213	47.2	47604.7	49.6	31256.2	47.3	47670.5	0.1	0.1
Belmont	BELMONT 9801	50000	31.7	15869.2	27.1	21695	31.8	15877.3	27.1	21706.1	0.1	0
Brighton A	BRGHTN 5	63000	86.5	54463.9	83	83620.3	86.8	54662.9	83.2	83905.6	0.3	0.2
Brighton B	BRGHTN 10	63000	86.3	54382.4	82.8	83468.7	86.6	54580.9	83.1	83753.2	0.3	0.3
Burlington	BURLNGTN 1	63000	38.6	24334.9	35.6	35876.7	38.8	24413.4	35.7	35991.6	0.2	0.1
Canton A	CANTON 2	63000	25.7	16159.5	22	22156.6	25.7	16168.6	22	22169.1	0	0
Canton B	CANTON 5	63000	21.7	13664.7	18.1	18291.6	21.7	13672.5	18.2	18302	0	0.1
Chelsea	CHELSEA 2	63000	54.1	34058.9	52.3	52697.6	54.3	34184.6	52.5	52892	0.2	0.2
Colburn A	COLBURN 3	63000	56.6	35648.5	50.8	51211.5	56.8	35808.9	51	51442.1	0.2	0.2
Colburn B	COLBURN 1	63000	57	35925	51.3	51693.3	57.3	36073.5	51.5	51907.2	0.3	0.2

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_ (%)	DUTY_ (A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_ (%)	DUTY_ (A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Deer Island	DEER ISL 1	50000	51.6	25784.2	43.5	34776	51.7	25853.3	43.6	34869.4	0.1	0.1
Deerfield	292	63000	58.3	36704.3	52.9	53322.4	58.4	36787.3	53	53442.9	0.1	0.1
Deerfield	3220	50000	46.7	23337.8	44.7	35729	46.8	23409.6	44.8	35838.9	0.1	0.1
Dewar	DEWAR ST 2	63000	59.2	37306.3	53.4	53850.3	59.4	37432.1	53.6	54032.4	0.2	0.2
Dover	DOVER 1	63000	38.4	24175.7	35	35289.3	38.4	24202.9	35	35329	0	0
E. Cambridge	E CAMB 1	40000	80.2	32087.5	77	49306.4	80.4	32157.8	77.2	49413.9	0.2	0.2
E. Holbrook 1	E HOLBRK 101	40000	69.4	27759.2	64	40950.6	69.6	27838.9	64.2	41068.2	0.2	0.2
E. Holbrook 2	E HOLBRK 202	40000	66.8	26713.7	61.3	39214.4	66.8	26725.7	61.3	39232	0	0
E. Methuen	E METHN G133	40000	60.5	24184.5	56.9	36438.4	60.8	24304.3	57.2	36618.8	0.3	0.3
East Eagle	E. Eagle 1	63000	54.5	34344.7	53.4	53871.3	54.7	34471.5	53.6	54070.2	0.2	0.2
Edgar	15EY	50000	86.2	43078.8	67.2	53736.8	86.2	43088.9	67.2	53749.4	0	0
Ellis Ave	GCB 1	40000	40.6	16255.4	21	21840.2	40.7	16264.7	21	21852.8	0.1	0
Everett	EVERET 58-67	40000	64.9	25967.2	59.7	38225.4	65.1	26041.3	59.9	38334.4	0.2	0.2
Fitch Road	FITCH 40-B2	40000	16.3	6529.2	14.3	9151.8	16.3	6532.9	14.3	9157	0	0
Framingham	FRAMNGHM 1	63000	43.9	27635.9	41.8	42140.9	43.9	27668.3	41.9	42190.3	0	0.1
Golden Hills	G HILLS F158	50000	60.5	30272.2	57.3	45825.1	60.8	30406.1	57.5	46027.5	0.3	0.2
Golden Rock (NG)	GLDRK 115kV	40000	30.7	12283.2	28.7	18394.7	30.8	12325.8	28.8	18458.5	0.1	0.1
Greendale	GREENDL 141	40000	39.2	15688.1	33.5	21422.5	39.3	15714.8	33.5	21459	0.1	0
Holbrook	HOLBROOK 1	63000	69	43447.7	68.4	68973.7	69	43476.4	68.5	69019.2	0	0.1
Holbrook	HOLBROOK 102	40000	57.8	23120.4	56.6	36212.4	57.9	23159	56.7	36272.9	0.1	0.1

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Hyde Park	HYDE PARK 1	63000	47.2	29747.4	45.8	46168.1	47.3	29775.4	45.8	46211.8	0.1	0
Hyde Park	HYDE PRK 101	50000	42.5	21228.8	38.8	31079.2	42.5	21257.8	38.9	31121.7	0	0.1
K Street 1&4	K ST 10	63000	93.6	58966.2	88.5	89190.3	94	59233	88.9	89596.5	0.4	0.4
K Street 2&3	K ST 13	63000	93.3	58805.2	88.2	88942.7	93.8	59086.1	88.7	89370.3	0.5	0.5
K Street A	K ST 29	63000	93.4	58866.4	88.2	88866.9	93.9	59144.1	88.6	89288.8	0.5	0.4
K Street A	K STREET 107	50000	48.4	24191.4	47.2	37725.5	48.5	24236.5	47.2	37798.6	0.1	0
K Street B	K ST 29S	63000	93.4	58840.9	88.2	88918.7	93.8	59113.5	88.6	89333.3	0.4	0.4
K Street B	K STREET 108	50000	48.3	24172	47.2	37726.6	48.4	24217.1	47.2	37783.3	0.1	0
K Street C	K STREET 111	50000	48.1	24067.2	46.9	37540.1	48.2	24105	47	37596	0.1	0.1
Kendall	52S	40000	76.8	30723.1	73.7	47183	77	30792.8	73.9	47289.3	0.2	0.2
King St.	KING ST 5463	50000	22.2	11122.9	17.8	14266.3	22.3	11157.3	17.9	14311.8	0.1	0.1
Kingston 324	102	50000	57.7	28849.4	53.9	43149.1	58.1	29037.7	54.3	43426.7	0.4	0.4
Kingston 372	104	50000	54.9	27439.3	52.9	42312.5	55.2	27578.2	53.2	42528.6	0.3	0.3
Kingston 514 A	KINGSTON 12	63000	90.7	57131	54.1	91903.5	91	57326.9	54.2	92218.2	0.3	0.1
Kingston 514 A	103	50000	59.1	29538	56.5	45223.1	59.4	29724.5	56.9	45505	0.3	0.4
Kingston 514 B	KINGSTON 11T	63000	90.7	57121.8	54.1	91891.3	91	57317.7	54.2	92206	0.3	0.1
Kingston 514 B	101	50000	56.5	28263.4	55.2	44165.3	56.8	28403.8	55.5	44386.2	0.3	0.3
Lexington	LEXINGTON 1	63000	46.6	29334.6	46	46352.9	46.7	29451.7	46.2	46536.4	0.1	0.2
Lexington	LEXINGTN 101	50000	36.9	18449.3	35.3	28252	37.1	18542.9	35.5	28394.5	0.2	0.2
Lynn 225	GE LYNN 7969	40000	29.2	11698	25.6	16359.8	29.3	11713.4	25.6	16381.4	0.1	0
Maplewood	MAPLWD 158	40000	62.7	25068.3	55.5	35507.8	62.9	25150.1	55.7	35623.7	0.2	0.2

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Maynard A	MAYNARD 1	40000	39.3	15702.3	31.6	20233.8	39.3	15718.2	31.6	20254.3	0	0
Maynard B	MAYNARD 2	40000	39.3	15702.3	31.6	20233.8	39.3	15718.2	31.6	20254.3	0	0
Medway	W MED 6	40000	86.5	34601.2	81.2	51965	86.6	34627.8	81.3	52004.8	0.1	0.1
Merrimack B1	D121	40000	89.3	35724.2	78.9	50478.8	89.4	35747.4	78.9	50511.6	0.1	0
Merrimack B2	BT12S	63000	57.8	36402	49.8	50202.3	57.8	36425.2	49.8	50234.4	0	0
Merrimack B3	P145	40000	94.3	37702.4	79.7	50990.7	94.3	37728.3	79.7	51025.8	0	0
Mystic	93EY	63000	95.6	60235.4	76.1	76709.1	96	60482.3	76.4	77024.6	0.4	0.3
Mystic	MYSTIC 111	50000	69.8	34877.2	68.3	54611.7	70.3	35126.8	68.8	55021.2	0.5	0.5
Mystic GIS	MYSTICGIS 28	63000	97.5	61415.6	85.9	86555.1	97.7	61556	86.1	86754.5	0.2	0.2
N. Cambridge	N CAMB 1	63000	71.4	44973.5	70.6	71125	71.6	45080.5	70.7	71297.4	0.2	0.1
N. Cambridge	N CAMB 105	50000	67.3	33643.6	66.1	52917.5	67.7	33847	66.5	53229.6	0.4	0.4
N. Quincy 1	N QUNCY 3224	63000	36.1	22730	28.3	28527.3	36.1	22738.3	28.3	28537.8	0	0
N. Quincy 2	N QUNCY 3325	63000	36.1	22730.1	28.3	28527.4	36.1	22738.4	28.3	28537.8	0	0
Needham	NEEDHAM 1	63000	45	28350.7	42.1	42442.7	45.1	28386.9	42.2	42496.8	0.1	0.1
Northboro Rd	NBRO RD C6	50000	36.4	18222.2	31.1	24858.9	36.5	18236.8	31.1	24878.8	0.1	0
Pelham	PELHAM Y151	40000	26.6	10638.2	23.1	14770.6	26.6	10655.2	23.1	14794.3	0	0
Pilgrim 345 kV	GCB 101	63000	36	22692.2	33.3	33613.3	36	22707.9	33.4	33636.6	0	0.1
Power St	161	63000	39.8	25069.1	36.8	37077.5	39.9	25141.8	36.9	37185	0.1	0.1
Pratts Jct.	PRATTSJ 1110	40000	76	30404.8	68.3	43689.3	76.2	30472.4	68.4	43786.4	0.2	0.1
Putnum St	Putnam 3	40000	90.8	36336.1	87.5	55997.7	91.1	36442.7	87.8	56160.6	0.3	0.3
Revere	REVERE C1	40000	68.7	27489.3	63.2	40475.2	68.9	27571.2	63.4	40595.7	0.2	0.2

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Rolfe Ave	ROLFE P-142	40000	29.3	11708.6	25.2	16102.8	29.3	11714.8	25.2	16111.3	0	0
S. Danvers 4	S DANVR B154	40000	32.5	12984.3	30.8	19693.6	32.5	12999.2	30.8	19716.2	0	0
Salem Harbor	SALEM C1	63000	83.2	52399.6	74.8	75385.6	83.3	52497.8	74.9	75527	0.1	0.1
Sandy Pond	SANDYP 3T	50000	90.5	45252.9	84.2	67326.9	90.9	45449.4	84.5	67627.2	0.4	0.3
Sandy Pond	SANDY P 337	50000	62.9	31441.2	59.7	47725.7	63.2	31592.4	59.9	47955.1	0.3	0.2
Scobie Pond	191	63000	91.9	57879.2	78.2	78848	92.2	58090.6	78.5	79136.3	0.3	0.3
Scobie Pond	731	50000	71	35518.6	66.7	53331.1	71.3	35670.3	66.9	53559.1	0.3	0.2
Seabrook	363 - 632	50000	56.2	28091.5	49.5	39611	56.3	28171.9	49.7	39724.5	0.1	0.2
Sherborn	SHERBRN 1	63000	34.5	21756.8	31.2	31496.5	34.6	21772.9	31.3	31519.8	0.1	0.1
Speen St.	SPEEN 1	63000	17.7	11135.2	15.9	15980.2	17.7	11147.8	15.9	15998.3	0	0
Stoughton	STOUGH 104	50000	56.9	28448.4	56.1	44882	57	28498.1	56.2	44960.5	0.1	0.1
Sudbury	SUDBURY 1	63000	39.7	24990.5	37.9	38235.4	39.7	25027.9	38	38292.5	0	0.1
Tewksbury	TWKS222T	50000	93.7	46863.2	88	70405.9	94	47019.7	88.3	70640.7	0.3	0.3
Tewksbury	TWK22A 2B24	50000	72	35999.6	69.2	55356.1	72	35990.3	69.2	55343.4	0	0
Tewksbury	TEK230 41T	50000	34.2	17081.5	32.7	26183.5	34.2	17118.8	32.8	26230	0	0.1
W. Amesbury	2T	50000	46.6	23311.3	43.3	34610.4	46.8	23419.7	43.5	34771.3	0.2	0.2
W. Amesbury	WAMB 3T	63000	36.2	22820	31.9	32111.7	36.4	22907.8	32	32235.3	0.2	0.1
W. Boylston	W BOYLST 142	63000	52.6	33161.3	51.3	51685	52.8	33238.6	51.4	51805.6	0.2	0.1
W. Framingham	W FRMNG 1	63000	24.8	15614.7	21	21197.5	24.8	15626.9	21	21214.1	0	0
W. Medway	W MEDW 111	50000	93.7	46831.8	92.7	74165	93.8	46908.5	92.9	74286.4	0.1	0.2

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
W. Methuen	W METHU 5133	40000	28.7	11461.8	26.6	17035.2	28.7	11499.8	26.7	17091.7	0	0.1
W. Walpole	WALPOLE 113	50000	73	36487.5	71.5	57164.1	73.1	36546.4	71.6	57256.2	0.1	0.1
W. Walpole	W WALPL 3	63000	60.2	37922.2	59.9	60394.4	60.2	37955.9	60	60448.1	0	0.1
Wachusett (NGRID)	WACH 13-8T	63000	81.1	51096.8	78.4	79022.8	81.5	51352.6	78.8	79418.6	0.4	0.4
Wakefield Jct	WAKFLD 1T	50000	67.5	33749.5	64.4	51489.5	67.9	33939.1	64.8	51846.5	0.4	0.4
Wakefield Jct.	WAKFLD Proxy	65000	93.5	60751.4	88.3	91823.2	93.9	61027.1	88.7	92244.7	0.4	0.4
Walpole A	W WALPOLE 5	63000	45	28378.3	43	43364.8	45.1	28394.8	43	43390.1	0.1	0
Walpole C	W WALPOLE 1	63000	45.9	28916.3	43.8	44108	45.9	28933.9	43.8	44134.8	0	0
Waltham	WALTH 1	63000	48.7	30708.9	46.3	46629.3	48.9	30793	46.4	46757	0.2	0.1
Ward Hill	WARD H 1T	56000	85.9	48125.1	82.3	73763.1	86.4	48382.4	82.8	74157.7	0.5	0.5
Ward Hill	WH 394	50000	47.2	23579.8	45.3	36253.5	47.4	23718.7	45.6	36467.1	0.2	0.3
Washington	WASHNG 2601	40000	32	12782.1	28.1	18004.9	32	12787.6	28.1	18012.6	0	0
Woburn	WOBRN1 15 1	63000	69.6	43845.9	68.7	69278.1	69.9	44022.1	69	69548.9	0.3	0.3
Woburn	WOBURN 101	50000	66.8	33424	65.6	52517.5	67.2	33622.6	66	52822.5	0.4	0.4

Table 9-2 Short Circuit Duties with Mystic 8&9 in service (National Grid Stations)

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
E_METHUEN 115.kV	E METHN G133	40000	64000	62	24796.2	58.4	37359.9	13.8	61.7	24676.2	58.1	37179.2	0.3	0.3
EVERET 115B4 115.kV	EVERET 58-67	40000	64000	82.8	33115.8	75.8	48522.3	11.3	82.5	32991.8	75.5	48340.6	0.3	0.3
FITCH BUS 69.kV	FITCH 39-23	40000	64000	16.7	6674.2	14.6	9355	8.6	16.7	6670.5	14.6	9349.9	0	0
FITCH BUS 69.kV	FITCH 40-B2	40000	64000	16.7	6674.2	14.6	9355	8.6	16.7	6670.5	14.6	9349.9	0	0
FITCH BUS 69.kV	FITCH M-39	40000	64000	16.7	6674.2	14.6	9355	8.6	16.7	6670.5	14.6	9349.9	0	0
FITCH BUS 69.kV	FITCH N-40	40000	64000	16.7	6674.2	14.6	9355	8.6	16.7	6670.5	14.6	9349.9	0	0
FITCH BUS 69.kV	FITCH W-23	40000	64000	16.7	6674.2	14.6	9355	8.6	16.7	6670.5	14.6	9349.9	0	0
GLDNRCK 115.kV	GLDRK 115kV	40000	64000	52.8	21117.2	48.9	31280.7	12.2	52.7	21060.6	48.7	31196.8	0.1	0.2
GOLDNHL45-58 115.kV	G HILLS F158	50000	80000	62	31020.3	58.7	46957.2	14.4	61.8	30886	58.4	46754.3	0.2	0.3
GREENDALE 115.kV	GREENDL 141	40000	64000	49.8	19901.8	42.3	27057.2	7.3	49.7	19871.4	42.2	27016	0.1	0.1
KING_ST 1 115.kV	KING ST 5463	50000	80000	37.2	18619.1	32.5	26033.2	8.5	37.1	18567.5	32.5	25961	0.1	0
LYNN A179 115.kV	GE LYNN 7969	40000	64000	50.5	20206.5	45.5	29125	10.2	50.4	20162.1	45.4	29060.9	0.1	0.1
MAPLEWD 115 115.kV	MAPLWD 158	40000	64000	64.1	25657.9	56.8	36343	9.1	63.9	25576.5	56.6	36227.7	0.2	0.2
N QUINCY T1 115.kV	N QUNCY 3224	63000	100800	36.8	23207.7	28.9	29126.9	5	36.8	23199	28.9	29115.9	0	0
N QUINCY T2 115.kV	N QUNCY 3325	63000	100800	36.8	23207.8	28.9	29126.9	5	36.8	23199.1	28.9	29116	0	0
NORTHBORO RD 69.kV	Proxy - 69kv	31500	50400	52.8	16634	48.6	24470.4	10.4	52.8	16620.5	48.5	24450.8	0	0.1
NORTHBORO RD 115.kV	NBRO RD 5666	50000	80000	37.2	18606.8	31.7	25383.6	7.5	37.2	18591.4	31.7	25362.7	0	0
NORTHBORO RD 115.kV	NBRO RD 5760	50000	80000	37.2	18606.8	31.7	25383.6	7.5	37.2	18591.4	31.7	25362.7	0	0

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
NORTHBORO RD 115.kV	NBRO RD C6	50000	80000	37.2	18606.8	31.7	25383.6	7.5	37.2	18591.4	31.7	25362.7	0	0
NORTHBORO RD 115.kV	NBRO RD D156	50000	80000	37.2	18606.8	31.7	25383.6	7.5	37.2	18591.4	31.7	25362.7	0	0
NORTHBORO RD 115.kV	NBRO RD E157	50000	80000	37.2	18606.8	31.7	25383.6	7.5	37.2	18591.4	31.7	25362.7	0	0
NORTHBORO RD 115.kV	NBRO RD H160	50000	80000	37.2	18606.8	31.7	25383.6	7.5	37.2	18591.4	31.7	25362.7	0	0
NORTHBORO RD 115.kV	NBRO RD N166	251021.9	25100	7.5	18745.4	100.5	25217.5	7.5	7.5	18729.9	100.4	25196.6	0	0.1
PELHAM 115.kV	PELHAM Y151	40000	64000	43.8	17520	38.5	24610.6	8.7	43.7	17480.9	38.4	24555.7	0.1	0.1
PRATTS 115 115.kV	PRATTSJ 1110	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ 2110	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ 3741	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ 3842	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ 4A	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ 801	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ 802	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ I135	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ J136	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ K137	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ L138	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ O141	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
PRATTS 115 115.kV	PRATTSJ P142	40000	64000	77.7	31081.7	69.8	44662	10	77.5	31013.5	69.6	44563.9	0.2	0.2
REVERE 115.kV	REVERE 68-79	40000	64000	70.4	28154.7	64.8	41450.9	11.7	70.2	28073.2	64.6	41330.8	0.2	0.2

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
REVERE 115.kV	REVERE C1	40000	64000	70.4	28154.7	64.8	41450.9	11.7	70.2	28073.2	64.6	41330.8	0.2	0.2
ROLFE 115.kV	ROLFE P-142	40000	64000	54.9	21975.2	48.1	30810.1	8.6	54.9	21947.8	48.1	30771.7	0	0
S_DANVERS 4 115.kV	S DANVR B154	40000	64000	45.1	18054.3	42.6	27280.7	14.2	45	18016.5	42.5	27223.7	0.1	0.1
SALEM_HAR 115.kV	SALEM C1	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM C2	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 1145	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 11T	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 2246	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 22T	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 3354	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 33T	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 555T	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 5T	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 6T	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H 6T2B	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H B154	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H C155	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H S145	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SALEM_HAR 115.kV	SALEM H T146	63000	100800	85	53543.3	76.4	77031.2	38	84.8	53446.2	76.3	76891.4	0.2	0.1
SANDY 115 115.kV	SANDYP 137T	50000	80000	89	44491.8	82.3	65827.2	31.4	88.6	44295	81.9	65528.3	0.4	0.4

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
SANDY 115 115.kV	SANDYP 138T	50000	80000	88.5	44267.7	81.9	65505.2	31.3	88.1	44070.5	81.5	65207.1	0.4	0.4
SANDY 115 115.kV	SANDYP 1612	50000	80000	91.7	45847.6	85.2	68172.6	30.3	91.3	45649.1	84.8	67869.6	0.4	0.4
SANDY 115 115.kV	SANDYP 3T	50000	80000	92.7	46356.3	86.2	68976.7	30.2	92.3	46158.4	85.8	68674	0.4	0.4
SANDY 115 115.kV	SANDYP 3T61	50000	80000	92.7	46356.3	86.2	68976.7	30.2	92.3	46158.4	85.8	68674	0.4	0.4
SANDY 115 115.kV	SANDYP I161	50000	80000	91.7	45847.6	85.2	68172.6	30.3	91.3	45649.1	84.8	67869.6	0.4	0.4
SANDY 115 115.kV	SANDYP K137E	50000	80000	86.8	43396.7	80.3	64229.1	31.3	86.5	43240.3	80	63990.7	0.3	0.3
SANDY 115 115.kV	SANDYP K137W	50000	80000	89	44491.8	82.3	65827.2	31.4	88.6	44295	81.9	65528.3	0.4	0.4
SANDY 115 115.kV	SANDYP L138E	50000	80000	86.6	43288.9	80	64039.2	31.4	86.3	43169.6	79.8	63855.4	0.3	0.2
SANDY 115 115.kV	SANDYP L138W	50000	80000	88.5	44267.7	81.9	65505.2	31.3	88.1	44070.5	81.5	65207.1	0.4	0.4
SANDY 345 345.kV	SANDY P 1412	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 2137	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 2643	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 314	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 326	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 337	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 343	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 3512	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
SANDY 345 345.kV	SANDY P 3521	50000	80000	65.4	32723.7	62	49603.8	14.5	65.1	32571.9	61.7	49373.9	0.3	0.3
TEWKSBURY22A 345.kV	TWK22A 2B24	50000	80000	73.3	36648.2	70.4	56355.1	19	73.3	36657.9	70.5	56368.3	0	-0.1
TEWKSBURY22A 345.kV	TWK22A 3124	50000	80000	73.3	36648.2	70.4	56355.1	19	73.3	36657.9	70.5	56368.3	0	-0.1

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
TEWKSBURY22A 345.kV	TWK22A 337	63000	100800	58.2	36648.2	55.9	56355.1	19	58.2	36657.9	55.9	56368.3	0	0
TEWKSBURY22A 345.kV	TWK22A 338	63000	100800	58.2	36648.2	55.9	56355.1	19	58.2	36657.9	55.9	56368.3	0	0
TEWKSBURY22A 345.kV	TWK22A 339	63000	100800	58.2	36648.2	55.9	56355.1	19	58.2	36657.9	55.9	56368.3	0	0
TEWKSBURY22A 345.kV	TWK22A 37-39	63000	100800	58.2	36648.2	55.9	56355.1	19	58.2	36657.9	55.9	56368.3	0	0
TEWKSBURY22A 345.kV	TWK22A 38-97	50000	80000	73.3	36648.2	70.4	56355.1	19	73.3	36657.9	70.5	56368.3	0	-0.1
TEWKSBURY22A 345.kV	TWK22A 397	50000	80000	73.3	36648.2	70.4	56355.1	19	73.3	36657.9	70.5	56368.3	0	-0.1
TEWKSBURY22A 345.kV	TWK22A D1	63000	100800	58.2	36648.2	55.9	56355.1	19						
TEWKSBURY22A 345.kV	TWK22A D2	63000	100800	58.2	36648.2	55.9	56355.1	19						
TEWKSBURY_22 115.kV	TWKS22 2T	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 37-2	50000	80000	94.1	47036.8	88.5	70767.1	13.7	93.8	46879.9	88.2	70531.2	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 38-3	50000	80000	95.8	47891	89.9	71957	13.5	95.5	47733.7	89.7	71720.9	0.3	0.2
TEWKSBURY_22 115.kV	TWKS22 39-46	50000	80000	90.1	45049.7	85	67977.2	14	89.8	44906.7	84.7	67761.7	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 3T	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 40-45	50000	80000	89.9	44956	84.8	67819.6	14	89.6	44812.9	84.5	67604.1	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 4T	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 53-51	50000	80000	95.5	47737.7	89.6	71658.5	13.4	95.2	47581.1	89.3	71423.7	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 62-1	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 64-4	50000	80000	95.6	47796.1	89.7	71752.8	13.5	95.3	47639.2	89.4	71517.5	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 A153	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22 C1	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
TEWKSBURY_22 115.kV	TWKS22C2	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22J162	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22K137	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22L138	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22L164	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22M139	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22N140	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22S145	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22T146	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22Y151	50000	80000	95.9	47952.8	90.1	72042.5	13.5	95.6	47795.4	89.8	71806.3	0.3	0.3
TEWKSBURY_22 230.kV	TEK23041T	50000	80000	34.9	17463.6	33.4	26758.2	17.2	34.9	17426.5	33.4	26712.3	0	0
TEWKSBURY_22 230.kV	TWK23014-2T	50000	80000	34.9	17463.6	33.4	26758.2	17.2	34.9	17426.5	33.4	26712.3	0	0
TEWKSBURY_22 230.kV	TWK23022T	50000	80000	34.9	17463.6	33.4	26758.2	17.2	34.9	17426.5	33.4	26712.3	0	0
TEWKSBURY_22 230.kV	TWK23032T	50000	80000	34.9	17463.6	33.4	26758.2	17.2	34.9	17426.5	33.4	26712.3	0	0
TEWKSBURY_22 230.kV	TWK2304-3	50000	80000	34.9	17463.6	33.4	26758.2	17.2	34.9	17426.5	33.4	26712.3	0	0
W AMESBURY 115.kV	WAMB3T	63000	100800	37.1	23369.9	32.6	32885.6	44.7	37	23282.1	32.5	32762	0.1	0.1
W AMESBURY 115.kV	WAMB4T	63000	100800	37.1	23369.9	32.6	32885.6	44.7	37	23282.1	32.5	32762	0.1	0.1
W AMESBURY 115.kV	WAMB4T3T	63000	100800	37.1	23369.9	32.6	32885.6	44.7	37	23282.1	32.5	32762	0.1	0.1
W AMESBURY 115.kV	WAMB6T	63000	100800	37.1	23369.9	32.6	32885.6	44.7	37	23282.1	32.5	32762	0.1	0.1
W AMESBURY 115.kV	WAMB6T2B	63000	100800	37.1	23369.9	32.6	32885.6	44.7	37	23282.1	32.5	32762	0.1	0.1

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
W AMESBURY 115.kV	WAMB K163	63000	100800	37.1	23369.9	32.6	32885.6	44.7	37	23282.1	32.5	32762	0.1	0.1
W_METHUEN 115.kV	W METHU 5133	40000	64000	51.7	20661.6	47.6	30447.6	11.7	51.5	20589	47.4	30340.6	0.2	0.2
WACHSET 115 115.kV	WACH 13-8T	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH 13T	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH 24-41	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH 24T	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH 42-7T	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH 7T-2B	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH O-141W	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH O141N	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH P142N	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHSET 115 115.kV	WACH P142W	63000	100800	82.9	52227	80.1	80770.9	23.4	82.7	52086.8	79.9	80553.9	0.2	0.2
WACHUSET 345 345.kV	14-7T	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	308	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	313	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	314	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	343	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	43-6T	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	5T	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
WACHUSET 345 345.kV	6T	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	7T	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WACHUSET 345 345.kV	8T	50000	80000	70	34983.5	66.2	52963.8	14.4	69.8	34879.9	66	52807	0.2	0.2
WAKEJCT M345 345.kV	WAKFLD 10A2	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 10A3	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 1T	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 2T	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 2T-1B	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 339	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 349	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 39-3T	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 3T	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 49-1T	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT M345 345.kV	WAKFLD 4T	50000	80000	69.1	34536.3	66.1	52854.9	21.5	68.7	34345.7	65.6	52496.7	0.4	0.5
WAKEJCT5X TP 115.kV	WAKFLD 3T-46	65000	104000	90	58471.5	85.3	88720.4	27.3	89.5	58200.3	84.9	88272.8	0.5	0.4
WAKEJCT5X TP 115.kV	WAKFLD 45-3T	65000	104000	90	58471.5	85.3	88720.4	27.3	89.5	58200.3	84.9	88272.8	0.5	0.4
WAKEJCT5X TP 115.kV	WAKFLD 46-4T	65000	104000	92.4	60053.5	87.1	90568.8	28.2	92	59781.4	86.6	90114.5	0.4	0.5
WAKEJCT5X TP 115.kV	WAKFLD 4T-69	65000	104000	92.3	60015.2	86.9	90401.1	28.1	91.9	59742.6	86.5	89954.2	0.4	0.4
WAKEJCT5X TP 115.kV	WAKFLD 58-45	65000	104000	92.4	60053.5	87.1	90568.8	28.2	92	59781.4	86.6	90114.5	0.4	0.5
WAKEJCT5X TP 115.kV	WAKFLD F158	65000	104000	91.4	59403.8	85.8	89227.2	28.5	91	59134.3	85.4	88785.9	0.4	0.4

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
WAKEJCT5X TP 115.kV	WAKFLD Proxy	65000	104000	95.7	62226.7	90.4	94057.9	27.2	95.3	61950.4	90	93635.3	0.4	0.4
WAKEJCT5X TP 115.kV	WAKFLD Q169	65000	104000	92.3	60015.2	86.9	90401.1	28.1	91.9	59742.6	86.5	89954.2	0.4	0.4
WAKEJCT5X TP 115.kV	WAKFLD S145	65000	104000	92.4	60053.5	87.1	90568.8	28.2	92	59781.4	86.6	90114.5	0.4	0.5
WAKEJCT5X TP 115.kV	WAKFLD S145E	65000	104000	90	58471.5	85.3	88719.7	27.3	89.5	58200.3	84.9	88272.1	0.5	0.4
WAKEJCT5X TP 115.kV	WAKFLD T146	65000	104000	92.4	60076.4	87.1	90595.2	28.2	92	59804.4	86.7	90122.3	0.4	0.4
WAKEJCT5X TP 115.kV	WAKFLD T146E	65000	104000	90	58471.5	85.3	88720.4	27.3	89.5	58200.3	84.9	88272.8	0.5	0.4
WARD_HILL 345.kV	WH 394	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 397	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 3T	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 3T-6T	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 4T	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 4T-1B	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 4T-94	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 5T	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 5T-97	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 6T	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL 345.kV	WH 6T-2B	50000	80000	48.4	24177.2	46.5	37172.1	19	48.1	24038.3	46.2	36958.4	0.3	0.3
WARD_HILL115 115.kV	WARD H 1T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H 1T-5T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H 2T-55	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
WARD_HILL115 115.kV	WARD H 33-2T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H 54-5T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H 7T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H 7T-6T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H 8T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H 8T-6T	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H B154	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H C155	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4
WARD_HILL115 115.kV	WARD H G133	56000	89600	88.1	49341.2	84.4	75627.4	24.9	87.6	49083.3	84	75231.6	0.5	0.4

Table 9-3 Short Circuit Duties with Mystic 8&9 Out of Service (Eversource Stations)

			Pre-project				Post-project				Project Impact	
BUS	BREAKER	BKR_Capability (A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
292 Newton 115 kV	Newton 1	63000	40.5	25487.2	35.8	36037.2	40.5	25516.7	35.8	36078.8	0	0
309 Blackstone 345 k	ANP BLK 101	50000	66.6	33320.2	65.7	52558.9	66.8	33404.2	65.9	52691.5	0.2	0.2
315 Electric Ave	GCB 1	63000	75.1	47293.7	70.1	70655	75.4	47495.7	70.4	70956.3	0.3	0.3
492 Scotia St 115 kV	GCB 1	63000	71.1	44814.6	64.4	64929.5	71.5	45017.2	64.7	65222.5	0.4	0.3
576 MBTA 115 kV	BT	80000	59.5	47566	56.8	72675.3	59.5	47618.7	56.8	72761.2	0	0
71 Carver St	GCB 1	63000	76	47859.1	72.1	72669.5	76.3	48065.7	72.4	72982.6	0.3	0.3
99 Seafood Way 115 kV	Sta99_GCB1	63000	77.7	48951.4	75.2	75776.8	78.1	49177.2	75.5	76095.3	0.4	0.3
Andrew Square	ANDRW SQ 1	63000	67.8	42745.5	63.9	64392.2	68.1	42917.2	64.1	64651	0.3	0.2
Baker St.	BAKER ST 11	63000	49.1	30928.8	46.7	47088.3	49.2	30981.7	46.8	47168.7	0.1	0.1
Belmont	BELMONT 9801	50000	31.7	15847.3	27.1	21666.2	31.7	15857.1	27.1	21679.6	0	0
Brighton A	BRGHTN 5	63000	82.7	52132.3	78.3	78893.3	83.1	52354.8	78.6	79230.5	0.4	0.3
Brighton B	BRGHTN 10	63000	82.6	52061.4	78.1	78759.2	82.9	52250.7	78.5	79095.4	0.3	0.4
Burlington	BURLNGTN 1	63000	36.1	22763.8	33.4	33617.1	36.3	22888.5	33.5	33800.7	0.2	0.1
Canton A	CANTON 2	63000	25.6	16130.1	21.9	22116.5	25.6	16141.1	22	22131.6	0	0.1
Canton B	CANTON 5	63000	21.7	13643.1	18.1	18263.5	21.7	13652.6	18.1	18276.1	0	0
Chelsea	CHELSEA 2	63000	42.4	26720.5	40.9	41268.1	42.7	26877.5	41.2	41510.4	0.3	0.3
Colburn A	COLBURN 3	63000	54.7	34429.9	48.9	49289.7	54.9	34580.5	49.1	49505.3	0.2	0.2
Colburn B	COLBURN 1	63000	55.1	34699.4	49.4	49763	55.3	34850.3	49.6	49979.4	0.2	0.2
Deer Island	DEER ISL 1	50000	50.3	25174	42.6	34044.1	50.5	25259.9	42.7	34160.7	0.2	0.1
Deerfield	292	63000	57.9	36482.4	52.6	52982.9	58.1	36577	52.7	53120.3	0.2	0.1

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Deerfield	3220	50000	45.9	22970.5	44	35207.5	46.1	23051.4	44.2	35331.6	0.2	0.2
Dewar	DEWAR ST 2	63000	57.2	36061.6	51.6	52018.7	57.5	36214.7	51.8	52239.8	0.3	0.2
Dover	DOVER 1	63000	38.2	24042.8	34.8	35087.7	38.2	24076.2	34.9	35136.3	0	0.1
E. Cambridge	E CAMB 1	40000	78.2	31296.1	75.1	48035.8	78.5	31408.4	75.3	48207.5	0.3	0.2
E. Holbrook 1	E HOLBRK 101	40000	69.3	27723.5	63.9	40886.6	69.6	27857.9	64.2	41084.8	0.3	0.3
E. Holbrook 2	E HOLBRK 202	40000	66.7	26662	61.1	39128.4	66.7	26676.5	61.2	39149.7	0	0.1
E. Methuen	E METHNG133	40000	59.3	23732.6	56	35809.3	59.7	23869.8	56.3	36016.3	0.4	0.3
East Eagle	E. Eagle 1	63000	42.4	26684.9	41.3	41653	42.6	26842.6	41.6	41898.9	0.2	0.3
Edgar	15EY	50000	86	43014.2	67.1	53655.6	86.1	43036.8	67.1	53683.9	0.1	0
Ellis Ave	GCB 1	40000	40.6	16224.8	21	21800.3	40.6	16236	21	21815.4	0	0
Everett	EVERET 58-67	40000	50.8	20317.7	47.3	30281.8	51.1	20439.1	47.6	30462.5	0.3	0.3
Fitch Road	FITCH 40-B2	40000	16.3	6521.8	14.3	9142.3	16.3	6530.2	14.3	9154.1	0	0
Framingham	FRAMNGHM 1	63000	43.6	27446	41.5	41859	43.6	27485.7	41.6	41919.5	0	0.1
Golden Hills	G HILLS F158	50000	55.3	27658.7	52.4	41921	55.6	27823.9	52.7	42171.5	0.3	0.3
Golden Rock (NG)	GLDRK 115kV	40000	30.4	12162.4	28.5	18228.3	30.6	12226	28.6	18323.5	0.2	0.1
Greendale	GREENDL 141	40000	39.1	15625.9	33.4	21346.7	39.1	15656.7	33.4	21388.8	0	0
Holbrook	HOLBROOK 1	63000	68.8	43318	68.2	68720.3	68.8	43352.8	68.2	68775.3	0	0
Holbrook	HOLBROOK 102	40000	57.2	22881.7	55.9	35773.3	57.3	22928.3	56	35845.9	0.1	0.1
Hyde Park	HYDE PARK 1	63000	46.7	29445.8	45.4	45804	46.8	29479.8	45.5	45857.1	0.1	0.1
Hyde Park	HYDE PRK 101	50000	42.1	21027.5	38.4	30755.4	42.1	21063.9	38.5	30808.7	0	0.1

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
K Street 1&4	K ST 10	63000	88.2	55543	84.4	85056.4	88.5	55752.2	84.7	85380.5	0.3	0.3
K Street 2&3	K ST 13	63000	88	55410.4	84.2	84838.9	88.3	55618.9	84.5	85161.9	0.3	0.3
K Street A	K ST 29	63000	88.1	55477.7	84.1	84781.9	88.4	55686.3	84.4	85104.4	0.3	0.3
K Street A	K STREET 107	50000	47.8	23879.9	46.2	36938.4	47.9	23934.2	46.3	37022	0.1	0.1
K Street B	K ST 29S	63000	88	55452	84.2	84825.8	88.4	55660.6	84.5	85148.5	0.4	0.3
K Street B	K STREET 108	50000	47.7	23860.9	46.1	36911.3	47.8	23915.2	46.2	36994.8	0.1	0.1
K Street C	K STREET 111	50000	47.4	23717	45.8	36674.2	47.5	23771	46.1	36900.1	0.1	0.3
Kendall	52S	40000	74.9	29948.3	71.8	45948.1	75.1	30059.3	72.1	46117.8	0.2	0.3
King St.	KING ST 5463	50000	22	11024.7	17.6	14100.7	22.1	11063.1	17.7	14168.4	0.1	0.1
Kingston 324	102	50000	48.4	24191.3	44.3	35449.4	48.8	24388.5	44.7	35733.8	0.4	0.4
Kingston 372	104	50000	45.3	22649.5	42.7	34125.7	45.7	22829.1	43	34392.9	0.4	0.3
Kingston 514 A	KINGSTON 12	63000	86.4	54403.3	50.6	86087.1	86.5	54506.3	50.7	86247	0.1	0.1
Kingston 514 A	103	50000	50	24977.5	47.1	37681	50.3	25173.2	47.5	37972.3	0.3	0.4
Kingston 514 B	KINGSTON 11T	63000	86.3	54394.2	50.6	86077	86.5	54492.4	50.7	86229.5	0.2	0.1
Kingston 514 B	101	50000	47.3	23648.1	45.3	36277	47.7	23828.1	45.7	36550.1	0.4	0.4
Lexington	LEXINGTON 1	63000	44.3	27936.5	43.6	43938.6	44.6	28082.2	43.8	44166.9	0.3	0.2
Lexington	LEXINGTN 101	50000	32.4	16223.4	30.9	24752.1	32.7	16334.3	31.2	24921.2	0.3	0.3
Lynn 225	GE LYNN 7969	40000	26.7	10699.9	23.6	15104	26.8	10734.4	23.7	15152.8	0.1	0.1
Maplewood	MAPLWD 158	40000	54.9	21943.5	49	31379.5	55.2	22074.7	49.3	31567.3	0.3	0.3
Maynard A	MAYNARD 1	40000	39	15580.5	31.4	20091.8	39	15610	31.5	20129.9	0	0.1
Maynard B	MAYNARD 2	40000	39	15580.5	31.4	20091.8	39	15610	31.5	20129.9	0	0.1

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Medway	W MED 6	40000	86.2	34495.8	81	51820.5	86.3	34527.7	81	51868.5	0.1	0
Merrimack B1	D121	40000	89.1	35654.2	78.7	50369.1	89.2	35681.8	78.8	50408.1	0.1	0.1
Merrimack B2	BT12S	63000	57.7	36332.8	49.7	50097.8	57.7	36360.2	49.7	50135.6	0	0
Merrimack B3	P145	40000	94.1	37621.5	79.5	50872	94.1	37651.8	79.6	50913	0	0.1
Mystic	93EY	63000	75.7	47717	61.1	61626.1	76	47892	61.4	61853.2	0.3	0.3
Mystic	MYSTIC 111	50000	57.2	28596.6	56.2	44956.8	57.7	28845.7	56.7	45339.1	0.5	0.5
Mystic GIS	MYSTICGIS 28	63000	69.7	43897.8	64.1	64651.1	70	44105.7	64.4	64959.6	0.3	0.3
N. Cambridge	N CAMB 1	63000	67.9	42757.2	67.6	68120.2	68.1	42885.7	67.8	68322.5	0.2	0.2
N. Cambridge	N CAMB 105	50000	56.2	28105.6	54.3	43475.4	56.7	28328	54.8	43812	0.5	0.5
N. Quincy 1	N QUNCY 3224	63000	36	22705.8	28.3	28502	36.1	22715.8	28.3	28514.7	0.1	0
N. Quincy 2	N QUNCY 3325	63000	36	22705.8	28.3	28502.1	36.1	22715.9	28.3	28514.8	0.1	0
Needham	NEEDHAM 1	63000	44.6	28103	41.7	42039.5	44.7	28147.4	41.8	42105.9	0.1	0.1
Northboro Rd	NBRO RD C6	50000	36.3	18132.9	30.9	24747	36.3	18159.8	31	24783.8	0	0.1
Pelham	PELHAM Y151	40000	26.3	10520.7	22.9	14629.6	26.4	10551.7	22.9	14672.6	0.1	0
Pilgrim 345 kV	GCB 101	63000	35.9	22605.8	33.2	33489.7	35.9	22628.9	33.3	33523.8	0	0.1
Power St	161	63000	39.4	24848.7	36.4	36734.3	39.6	24932.5	36.6	36858.2	0.2	0.2
Pratts Jct.	PRATTSJ 1110	40000	75.5	30181.1	67.8	43389.3	75.6	30259.2	68	43501.6	0.1	0.2
Putnum St	Putnam 3	40000	88.1	35248.6	84.5	54053.8	88.5	35381.3	84.8	54255.4	0.4	0.3
Revere	REVERE C1	40000	57.2	22889.7	53.1	33966.8	57.6	23022.4	53.4	34163.6	0.4	0.3
Rolfe Ave	ROLFE P-142	40000	29.2	11695.2	25.1	16086.6	29.3	11702.5	25.2	16096.7	0.1	0.1
S. Danvers 4	S DANVR B154	40000	32.2	12863.2	30.5	19527.8	32.2	12891.3	30.6	19570.4	0	0.1
Salem Harbor	SALEM C1	63000	81.6	51386.6	73.2	73789.1	81.8	51507	73.4	73962	0.2	0.2

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Sandy Pond	SANDYP 3T	50000	88.7	44361.3	82.5	66038.6	89.2	44585.7	83	66380.3	0.5	0.5
Sandy Pond	SANDY P 337	50000	59.7	29865.9	56.8	45411.5	60.1	30031.2	57.1	45662.8	0.4	0.3
Scobie Pond	191	63000	90.3	56907.4	76.9	77562.1	90.7	57146.5	77.3	77888	0.4	0.4
Scobie Pond	731	50000	68.4	34183.3	64.1	51280.8	68.7	34344.4	64.4	51522.5	0.3	0.3
Seabrook	363 - 632	50000	55.4	27710.9	48.8	39048.7	55.6	27801.7	49	39176.8	0.2	0.2
Sherborn	SHERBRN 1	63000	34.4	21653.1	31.1	31357.5	34.4	21682.6	31.2	31400.3	0	0.1
Speen St.	SPEEN 1	63000	17.5	11053.9	15.7	15865.6	17.6	11069.7	15.8	15888.2	0.1	0.1
Stoughton	STOUGH 104	50000	56.1	28039.6	55.1	44116.6	56.2	28099.3	55.3	44210.3	0.1	0.2
Sudbury	SUDBURY 1	63000	39.2	24691.3	37.5	37753.4	39.3	24736.5	37.5	37822.5	0.1	0
Tewksbury	TWKS22 2T	50000	89.4	44694.1	84.2	67397.7	89.8	44884.2	84.6	67684.2	0.4	0.4
Tewksbury	TWK22A 2B24	50000	63.1	31561.5	60.8	48645.7	63.1	31557.2	60.8	48639.5	0	0
Tewksbury	TEK230 41T	50000	33.5	16737.5	32	25625.6	33.6	16794.8	32.1	25702.8	0.1	0.1
W. Amesbury	2T	50000	45.3	22635.8	41.9	33546.8	45.5	22756.5	42.2	33725.7	0.2	0.3
W. Amesbury	WAMB 3T	63000	35.8	22572.5	31.5	31750	36	22672.4	31.6	31890.6	0.2	0.1
W. Boylston	W BOYLST 142	63000	52.2	32908.4	50.9	51292.5	52.4	32998.2	51	51432.6	0.2	0.1
W. Framingham	W FRMNG 1	63000	24.7	15552.9	21	21121.4	24.7	15567.8	21	21141.7	0	0
W. Medway	W MEDW 111	50000	92.6	46302.8	91.3	73051.2	92.7	46332.6	91.5	73192.6	0.1	0.2
W. Methuen	W METHU 5133	40000	28.4	11355.6	26.4	16891	28.5	11399.6	26.5	16956.5	0.1	0.1
W. Walpole	WALPOLE 113	50000	72	36005.8	70.4	56349.3	72.2	36075.5	70.6	56458.4	0.2	0.2
W. Walpole	W WALPL 3	63000	60.1	37854.9	59.8	60256.5	59.6	37528.9	59.3	59737.5	-0.5	-0.5

BUS	BREAKER	BKR_Capability (A)	Pre-project				Post-project				Project Impact	
			DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	DUTY_(%)	DUTY_(A)	M_DUTY_(%)	M_DUTY_(A)	delta_DUTY_(%)	delta_M_DUTY_(%)
Wachusett (NGRID)	WACH 13-8T	63000	80.2	50521.4	77.5	78165.5	80.4	50682.5	77.8	78414.7	0.2	0.3
Wakefield Jct	WAKFLD 1T	50000	55.6	27814.2	53.7	42927.6	56.1	28057.7	54.1	43295.8	0.5	0.4
Wakefield Jct.	WAKFLD Proxy	65000	81.5	52971.3	79.3	82507.9	82	53303.2	79.8	83028.5	0.5	0.5
Walpole A	W WALPOLE 5	63000	44.9	28266.6	42.8	43185.2	44.9	28298.4	42.9	43233.7	0	0.1
Walpole C	W WALPOLE 1	63000	45.7	28803.7	43.6	43926.9	45.8	28835.8	43.6	43975.8	0.1	0
Waltham	WALTH 1	63000	47.2	29707.2	44.7	45059.5	47.4	29837.7	44.9	45257.5	0.2	0.2
Ward Hill	WARD H 1T	56000	83.2	46613.9	79.6	71316.6	83.8	46902.1	80.1	71757.6	0.6	0.5
Ward Hill	WH 394	50000	44.9	22449.7	43	34404.5	45.2	22601.7	43.3	34637.4	0.3	0.3
Washington	WASHNG 2601	40000	31.9	12772.2	28.1	17992.4	31.9	12778.7	28.1	18001.5	0	0
Woburn	WOBRN1 15 1	63000	61.4	38680.5	60.3	60762.1	61.6	38820.3	60.6	61067.7	0.2	0.3
Woburn	WOBURN 101	50000	56.4	28175.1	54.7	43780.5	56.8	28377.9	55.1	44093	0.4	0.4

Table 9-4 Short Circuit Duties with Mystic 8&9 Out of Service (National Grid Stations)

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
E_METHUEN 115.kV	E METHN G133	40000	64000	60.9	24355.5	57.4	36749.2	14	60.5	24217.9	57.1	36541.6	0.4	0.3
EVERET 115B4 115.kV	EVERET 58-67	40000	64000	66.8	26716	61.7	39503.5	12	66.4	26560.1	61.4	39272.9	0.4	0.3
FITCH BUS 69.kV	FITCH 39-23	40000	64000	16.7	6671.9	14.6	9352.6	8.6	16.7	6663.7	14.6	9341.1	0	0
FITCH BUS 69.kV	FITCH 40-B2	40000	64000	16.7	6671.9	14.6	9352.6	8.6	16.7	6663.7	14.6	9341.1	0	0
FITCH BUS 69.kV	FITCH M-39	40000	64000	16.7	6671.9	14.6	9352.6	8.6	16.7	6663.7	14.6	9341.1	0	0
FITCH BUS 69.kV	FITCH N-40	40000	64000	16.7	6671.9	14.6	9352.6	8.6	16.7	6663.7	14.6	9341.1	0	0
FITCH BUS 69.kV	FITCH W-23	40000	64000	16.7	6671.9	14.6	9352.6	8.6	16.7	6663.7	14.6	9341.1	0	0
GLDNRCK 115.kV	GLDRK 115kV	40000	64000	52.1	20832.8	48.3	30904.7	12.3	51.8	20721.6	48	30739.7	0.3	0.3
GOLDNHL45-58 115.kV	G HILLS F158	50000	80000	56.8	28388.8	53.8	43027.7	14.5	56.4	28222.7	53.5	42776	0.4	0.3
GREENDALE 115.kV	GREENDL 141	40000	64000	49.6	19824.5	42.1	26964.7	7.3	49.5	19789.3	42.1	26916.9	0.1	0
KING_ST 1 115.kV	KING ST 5463	50000	80000	36.8	18423.8	32.3	25806.6	8.6	36.7	18341.1	32.1	25690.8	0.1	0.2
LYNN A179 115.kV	GE LYNN 7969	40000	64000	46.5	18611.1	42.2	27031.3	10.7	46.3	18531.2	42.1	26915.1	0.2	0.1
MAPLEWD 115 115.kV	MAPLWD 158	40000	64000	56.3	22526.9	50.3	32214	9.7	56	22395.3	50	32025.7	0.3	0.3
N QUINCY T1 115.kV	N QUNCY 3224	63000	100800	36.8	23185.3	28.9	29104	5	36.8	23174.7	28.9	29090.7	0	0
N QUINCY T2 115.kV	N QUNCY 3325	63000	100800	36.8	23185.3	28.9	29104	5	36.8	23174.8	28.9	29090.7	0	0
NORTHBORO RD 69.kV	Proxy - 69kv	31500	50400	52.7	16595.5	48.5	24422.2	10.4	52.6	16579	48.4	24398	0.1	0.1
NORTHBORO RD 115.kV	NBRO RD 5666	50000	80000	37.1	18527.6	31.6	25285.7	7.5	37	18499.7	31.6	25247.6	0.1	0
NORTHBORO RD 115.kV	NBRO RD 5760	50000	80000	37.1	18527.6	31.6	25285.7	7.5	37	18499.7	31.6	25247.6	0.1	0

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
NORTHBORO RD 115.kV	NBRO RD C6	50000	80000	37.1	18527.6	31.6	25285.7	7.5	37	18499.7	31.6	25247.6	0.1	0
NORTHBORO RD 115.kV	NBRO RD D156	50000	80000	37.1	18527.6	31.6	25285.7	7.5	37	18499.7	31.6	25247.6	0.1	0
NORTHBORO RD 115.kV	NBRO RD E157	50000	80000	37.1	18527.6	31.6	25285.7	7.5	37	18499.7	31.6	25247.6	0.1	0
NORTHBORO RD 115.kV	NBRO RD H160	50000	80000	37.1	18527.6	31.6	25285.7	7.5	37	18499.7	31.6	25247.6	0.1	0
NORTHBORO RD 115.kV	NBRO RD N166	251021.9	25100	7.4	18667.9	100.1	25120.1	7.5	7.4	18639.7	99.9	25082.1	0	0.2
PELHAM 115.kV	PELHAM Y151	40000	64000	43.4	17342.1	38.1	24395.7	8.8	43.3	17300.2	38	24336.8	0.1	0.1
PRATTS 115 115.kV	PRATTSJ 1110	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ 2110	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ 3741	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ 3842	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ 4A	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ 801	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ 802	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ I135	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ J136	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ K137	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ L138	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ O141	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
PRATTS 115 115.kV	PRATTSJ P142	40000	64000	77.2	30862.9	69.3	44369.6	10	77	30784	69.2	44256.1	0.2	0.1
REVERE 115.kV	REVERE 68-79	40000	64000	58.8	23518.9	54.5	34896.8	12.3	58.5	23385.7	54.2	34699.2	0.3	0.3

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
REVERE 115.kV	REVERE C1	40000	64000	58.8	23518.9	54.5	34896.8	12.3	58.5	23385.7	54.2	34699.2	0.3	0.3
ROLFE 115.kV	ROLFE P-142	40000	64000	54.8	21904.2	48	30721.4	8.6	54.7	21872.2	47.9	30676.6	0.1	0.1
S_DANVERS 4 115.kV	S DANVR B154	40000	64000	44.6	17838.1	42.2	26987.1	14.3	44.5	17792.5	42.1	26918.1	0.1	0.1
SALEM_HAR 115.kV	SALEM C1	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM C2	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 1145	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 11T	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 2246	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 22T	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 3354	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 33T	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 555T	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 5T	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 6T	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H 6T2B	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H B154	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H C155	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H S145	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SALEM_HAR 115.kV	SALEM H T146	63000	100800	83.4	52542.8	74.9	75449.3	38.5	83.2	52423.4	74.7	75277.8	0.2	0.2
SANDY 115 115.kV	SANDYP 137T	50000	80000	87.3	43638.9	80.8	64601.1	31.3	86.8	43414	80.3	64260.8	0.5	0.5

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
SANDY 115 115.kV	SANDYP 138T	50000	80000	86.8	43420.3	80.4	64286.6	31.2	86.4	43194.8	79.9	63946.9	0.4	0.5
SANDY 115 115.kV	SANDYP 1612	50000	80000	90	44989.3	83.7	66937.5	30.2	89.5	44763.2	83.2	66593.7	0.5	0.5
SANDY 115 115.kV	SANDYP 3T	50000	80000	90.9	45473	84.6	67701.2	30.1	90.5	45246.9	84.2	67357	0.4	0.4
SANDY 115 115.kV	SANDYP 3T61	50000	80000	90.9	45473	84.6	67701.2	30.1	90.5	45246.9	84.2	67357	0.4	0.4
SANDY 115 115.kV	SANDYP I161	50000	80000	90	44989.3	83.7	66937.5	30.2	89.5	44763.2	83.2	66593.7	0.5	0.5
SANDY 115 115.kV	SANDYP K137E	50000	80000	85.4	42716.3	79.1	63277.2	31.1	85	42498.8	78.7	62948.3	0.4	0.4
SANDY 115 115.kV	SANDYP K137W	50000	80000	87.3	43638.9	80.8	64601.1	31.3	86.8	43414	80.3	64260.8	0.5	0.5
SANDY 115 115.kV	SANDYP L138E	50000	80000	85.3	42643.1	78.9	63138.9	31.2	84.9	42427.6	78.5	62812.8	0.4	0.4
SANDY 115 115.kV	SANDYP L138W	50000	80000	86.8	43420.3	80.4	64286.6	31.2	86.4	43194.8	79.9	63946.9	0.4	0.5
SANDY 345 345.kV	SANDY P 1412	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 2137	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 2643	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 314	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 326	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 337	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 343	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 3512	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
SANDY 345 345.kV	SANDY P 3521	50000	80000	62.1	31061.5	59	47168.7	14.7	61.8	30895.3	58.6	46916.4	0.3	0.4
TEWKSBURY 22A 345.kV	TWK22A 2B24	50000	80000	64.3	32130.1	61.9	49522.5	18.6	64.3	32134.4	61.9	49528.7	0	0
TEWKSBURY 22A 345.kV	TWK22A 3124	50000	80000	64.3	32130.1	61.9	49522.5	18.6	64.3	32134.4	61.9	49528.7	0	0

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
TEWKSBURY 22A 345.kV	TWK22A337	63000	100800	51	32130.1	49.1	49522.5	18.6	51	32134.4	49.1	49528.7	0	0
TEWKSBURY 22A 345.kV	TWK22A338	63000	100800	51	32130.1	49.1	49522.5	18.6	51	32134.4	49.1	49528.7	0	0
TEWKSBURY 22A 345.kV	TWK22A339	63000	100800	51	32130.1	49.1	49522.5	18.6	51	32134.4	49.1	49528.7	0	0
TEWKSBURY 22A 345.kV	TWK22A37-39	63000	100800	51	32130.1	49.1	49522.5	18.6	51	32134.4	49.1	49528.7	0	0
TEWKSBURY 22A 345.kV	TWK22A38-97	50000	80000	64.3	32130.1	61.9	49522.5	18.6	64.3	32134.4	61.9	49528.7	0	0
TEWKSBURY 22A 345.kV	TWK22A397	50000	80000	64.3	32130.1	61.9	49522.5	18.6	64.3	32134.4	61.9	49528.7	0	0
TEWKSBURY 22A 345.kV	TWK22AD1	63000	100800	51	32130.1	49.1	49522.5	18.6						
TEWKSBURY 22A 345.kV	TWK22AD2	63000	100800	51	32130.1	49.1	49522.5	18.6						
TEWKSBURY_22 115.kV	TWKS222T	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS2238-3	50000	80000	91.4	45711.6	86.2	68939	13.9	91	45520.7	85.8	68651.2	0.4	0.4
TEWKSBURY_22 115.kV	TWKS223T	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS224T	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS2253-51	50000	80000	91.1	45568.4	85.8	68659.9	13.8	90.8	45378.2	85.5	68373.6	0.3	0.3
TEWKSBURY_22 115.kV	TWKS2262-1	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS2264-4	50000	80000	91.2	45621.7	85.9	68744.8	13.8	90.9	45431.2	85.6	68457.8	0.3	0.3
TEWKSBURY_22 115.kV	TWKS22A153	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22C1	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22C2	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22J162	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22K137	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
TEWKSBURY_22 115.kV	TWKS22L138	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22L164	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22M139	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22N140	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22S145	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22T146	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 115.kV	TWKS22Y151	50000	80000	91.5	45772.4	86.3	69023.5	13.9	91.2	45581.4	85.9	68735.6	0.3	0.4
TEWKSBURY_22 230.kV	TEK23041T	50000	80000	34.3	17136.2	32.8	26225.3	17.4	34.2	17078.7	32.7	26148	0.1	0.1
TEWKSBURY_22 230.kV	TWK23014-2T	50000	80000	34.3	17136.2	32.8	26225.3	17.4	34.2	17078.7	32.7	26148	0.1	0.1
TEWKSBURY_22 230.kV	TWK23022T	50000	80000	34.3	17136.2	32.8	26225.3	17.4	34.2	17078.7	32.7	26148	0.1	0.1
TEWKSBURY_22 230.kV	TWK23032T	50000	80000	34.3	17136.2	32.8	26225.3	17.4	34.2	17078.7	32.7	26148	0.1	0.1
TEWKSBURY_22 230.kV	TWK2304-3	50000	80000	34.3	17136.2	32.8	26225.3	17.4	34.2	17078.7	32.7	26148	0.1	0.1
W AMESBURY 115.kV	WAMB 3T	63000	100800	36.7	23133	32.3	32538.4	44.9	36.6	23033	32.1	32397.8	0.1	0.2
W AMESBURY 115.kV	WAMB 4T	63000	100800	36.7	23133	32.3	32538.4	44.9	36.6	23033	32.1	32397.8	0.1	0.2
W AMESBURY 115.kV	WAMB 4T3T	63000	100800	36.7	23133	32.3	32538.4	44.9	36.6	23033	32.1	32397.8	0.1	0.2
W AMESBURY 115.kV	WAMB 6T	63000	100800	36.7	23133	32.3	32538.4	44.9	36.6	23033	32.1	32397.8	0.1	0.2
W AMESBURY 115.kV	WAMB 6T2B	63000	100800	36.7	23133	32.3	32538.4	44.9	36.6	23033	32.1	32397.8	0.1	0.2
W AMESBURY 115.kV	WAMB K163	63000	100800	36.7	23133	32.3	32538.4	44.9	36.6	23033	32.1	32397.8	0.1	0.2

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
W_METHUEN 115.kV	W METHU 5133	40000	64000	50.9	20366.6	47	30058.2	11.9	50.7	20281.7	46.8	29932.9	0.2	0.2
WACHSET 115 115.kV	WACH 13-8T	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH 13T	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH 24-41	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH 24T	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH 42-7T	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH 7T-2B	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH O-141W	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH O141N	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH P142N	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHSET 115 115.kV	WACH P142W	63000	100800	82	51641.6	79.3	79898.6	23.4	81.7	51480.2	79	79648.9	0.3	0.3
WACHUSET 345 345.kV	14-7T	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	308	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	313	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	314	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	343	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	43-6T	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	5T	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	6T	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WACHUSET 345 345.kV	7T	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
WACHUSET 345 345.kV	8T	50000	80000	68.4	34184.6	64.8	51804.2	14.5	68.1	34071.1	64.5	51632.3	0.3	0.3
WAKEJCT M345 345.kV	WAKFLD 10A2	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 10A3	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 1T	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 2T	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 2T-1B	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 339	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 349	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 39-3T	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 3T	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 49-1T	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT M345 345.kV	WAKFLD 4T	50000	80000	57.2	28601.6	55.2	44135	17	56.7	28357.2	54.7	43765.6	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD 3T-46	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD 45-3T	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD 46-4T	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD 4T-69	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD 58-45	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD F158	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD Proxy	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD Q169	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
WAKEJCT5XTP 115.kV	WAKFLD S145	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD S145E	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD T146	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WAKEJCT5XTP 115.kV	WAKFLD T146E	65000	104000	83.6	54371.3	81.4	84692.3	22.3	83.1	54037.5	80.9	84168.7	0.5	0.5
WARD_HILL 345.kV	WH 394	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 397	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 3T	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 3T-6T	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 4T	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 4T-1B	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 4T-94	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 5T	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 5T-97	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 6T	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 345.kV	WH 6T-2B	50000	80000	46.1	23037.2	44.1	35304.8	19.6	45.8	22885.2	43.8	35071.8	0.3	0.3
WARD_HILL 115 115.kV	WARD H 1T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H 1T-5T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H 2T-55	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H 33-2T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H 54-5T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5

BUS	BREAKER	BKR Capability (A)	BKR MNT Capability (A)	Post Project				X/R	Pre Project				Project Impact (%)	
				DUTY (%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)		DUTY(%)	DUTY (A)	M_DUTY(%)	M_DUTY(A)	delta_DUTY (%)	delta_M_DUTY (%)
WARD_HILL 115 115.kV	WARD H 7T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H 7T-6T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H 8T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H 8T-6T	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H B154	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H C155	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5
WARD_HILL 115 115.kV	WARD H G133	56000	89600	85.4	47828.5	81.7	73174.9	25.2	84.9	47539.4	81.2	72732.5	0.5	0.5

9.9 Appendix I - Steady State Analysis Results

See folder.

9.10 Appendix J – Special Studies Report

Case summaries of the special studies can be found in the Appendix J folder.

Tewksbury STATCOM Benchmarking and Control Interaction Study

March 24, 2021

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National Grid

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Contents

1 Executive Summary

1.1 Background

A nominally rated 167 MVAR STATCOM is planned for interconnection at Tewksbury in Massachusetts. See Figure 1.1 for a map of the area. This STATCOM is electrically close to the Sandy Pond HVDC link, which is a 450 kV DC link that connects New England with Quebec. This preliminary study was conducted to help evaluate risk of adverse control interactions between the Tewksbury STATCOM and Sandy Pond HVDC in advance of receiving final models pending detailed design of the device. Additionally, the PSCAD and PSS/E STACOM models were benchmarked to ensure relative model equivalency across simulation platforms.

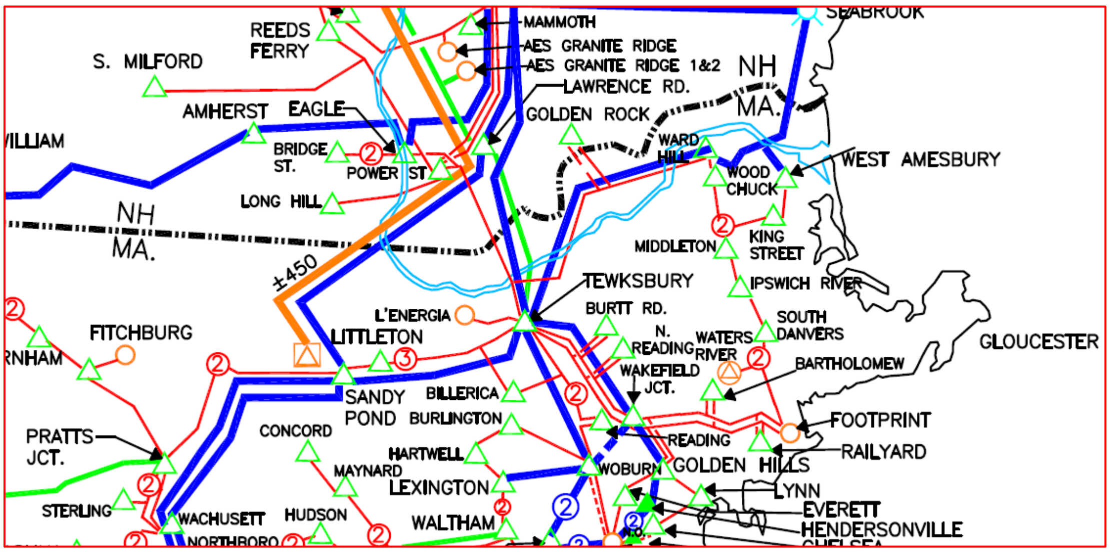

Figure 1.1 Map of New England System Around Tewksbury

1.2 Key Results and Recommendations

- A list of severe contingencies was selected by Electranix in partnership with National Grid and ISONE. Both the Tewksbury STATCOM and the Sandy Pond HVDC link successfully rode through all the contingencies tested. No adverse control interactions were observed for any of the contingencies.

- Benchmarking of the PSCAD STATCOM model against a PSS/E generic model was conducted. There was general agreement between the two models with acceptable differences that are discussed in this report.

- The STATCOM has the option to operate with either a manually set gain or an automatically calculated gain which is a function of the system strength. It was found that using the automatic gain functionality, at the system strengths studied, the STATCOM would set its gain to approximately 20, and trip for certain contingencies. To avoid this issue, a manual gain of five was defined for the STATCOM.

- To determine if the modeling of Western Massachusetts (WMASS) DERs would have an impact on the study results, two scenarios (each for peak and light load base cases) were simulated for the disturbance of loss of Sandy Pond HVDC line. Powerflow and system voltage results were compared against the results of WMASS DER study, conducted earlier by Electranix. Based on the results of this comparison it is unlikely that modelling the DER will have a significant impact on the study results.

1.3 Acknowledgements

The technical advice and support of Seyed Arash Nezam Sarmadi and the planning team from National Grid, as well as the planning and operations teams from ISONE and the design team from Siemens are gratefully acknowledged.

2 Methodology and Assumptions

2.1 PSCAD and E-Tran Software

Inverter-based resource control interactions and instabilities are often not detectable using positive sequence simulation tools such as PSSE software since these models usually do not represent the fast-inner loop controllers that are responsible for the unstable modes, or protection circuits which can cause ride-through failure. More complex studies using Electromagnetic transient (EMT) tools such as PSCAD software are required to identify undesirable control interactions or control instability for power electronic based resources connected to weak grids.

The studies in this report were completed using the PSCAD/EMTDC program (V4.6.3). The E-Tran program (5.2.0.5) was used to translate PSS/E .raw load flow cases into PSCAD models.

2.2 PSCAD System Model

The PSCAD system model consists of an E-tran translation of PSS/E data of the kept study area. The translation contained generator models from .dyr files provided by National Grid. The model was augmented with frequency dependent transmission lines from busses near the Tewksbury STATCOM and the Sandy Pond HVDC link. Both the Tewksbury STATCOM and the Sandy Pond HVDC link were modeled using detailed models as discussed below.

2.2.1 Siemens SVC Plus STATCOM Model

The STATCOM model used in the study was the SVC Plus model provided by Siemens, shown in Figure 2.1. The Tewksbury STATCOM is nominally rated for +/- 167 MVARs. There are two features to note about the STATCOM controls. Firstly, there is an algorithm to set the gain based on the strength of the system the STATCOM is connected to. The STATCOM will apply a perturbation test to measure the short circuit level of the system. This algorithm provides a gain of approximately 20 (In both studied base cases) which will cause the STATCOM to trip at some system strengths studied, so a manual gain of five was used for these preliminary studies to assist ride-through. In addition, the STATCOM has the option to enable/disable hunting detection and this setting was set to enable during all simulations. This causes the gain to drop to prevent oscillations, this was observed following faults in some contingencies. A full list of the control parameters for the STATCOM is attached in appendix A.

The following PSCAD files were provided by National Grid to use for this study:

- ETRAN_IF9.lib
- Pscad_v2.4.2-r21916_if9_i386.lib
- SVC_P_CONTROL_new_1.lib
- TDC_2v0_IVF.lib
- Test_Tewksbury_02.xml
- SIEMENS_SVC_PLUS_Model_BB3.pscx

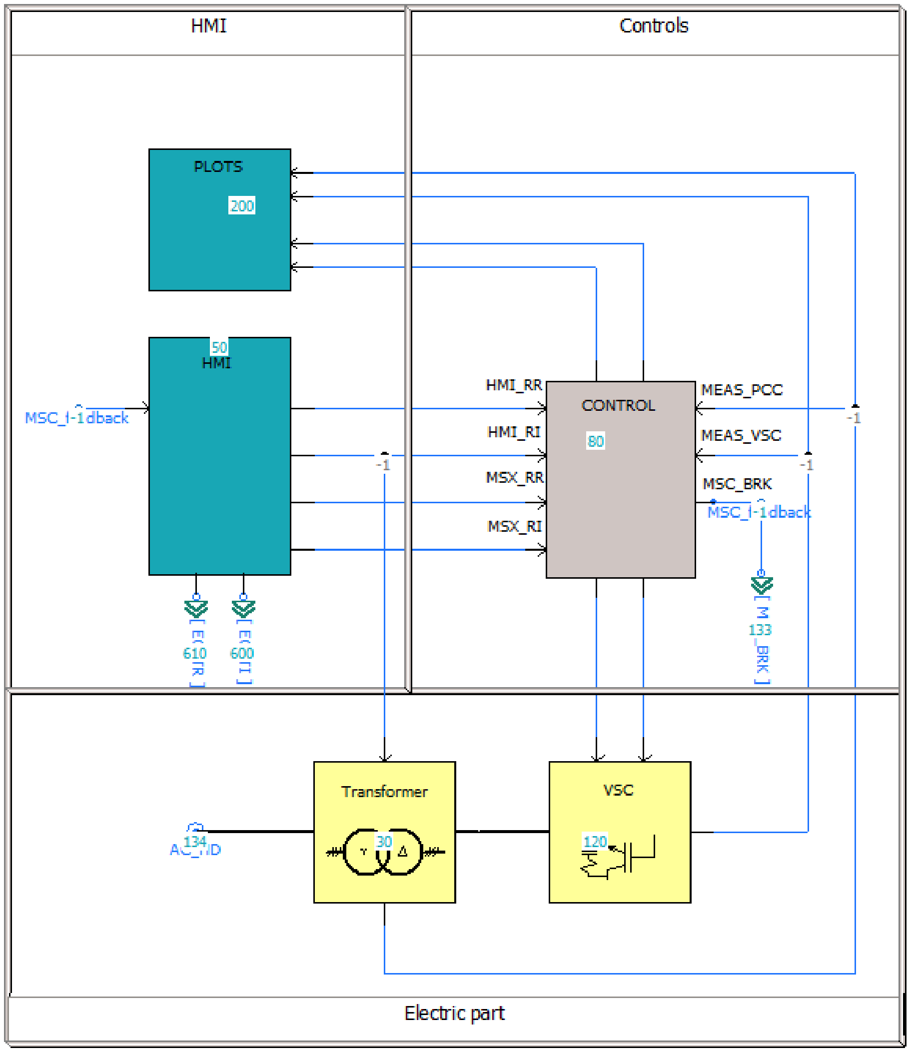

Figure 2.1 Siemens SVC Plus STATCOM

2.2.1.1 STATCOM Benchmarking

The Siemens SVC Plus PSCAD model of the STATCOM was benchmarked against a PSS/E generic SVSMO3U2 FACTS model. The benchmarking was conducted by applying the same disturbance in both PSCAD and PSS/E simulations in a SMIB system (see Figure 2.2 and Figure 2.3). The following scenarios in Table 2.1 were simulated for benchmarking. Comparisons between PSS/E and PSCAD were not performed for the dynamic performance scenarios, as the primary purpose of the analysis was to evaluate the potential for control interactions using PSCAD.

Table 2.1 STATCOM Benchmarking Scenarios

Scenario	Description
1	Bolted 3LG fault at bus 113951 (R=0.0001ohm, X=0.0015ohm), Retain voltage at bus 113951 = 0.0

2	Impedance 3LG Fault at bus 113951 (R=1.5ohm, X=22.5ohm), Retain voltage at bus 113951 = 0.35 pu
3	Impedance 3LG Fault at bus 113951 (R=3.5ohm, X=52.5ohm), Retain voltage at bus 113951 = 0.60 pu
4	Impedance 3LG Fault at bus 113951 (R=8.5ohm, X=127.5ohm), Retain voltage at bus 113951 = 0.80 pu
5	Vsch for STATCOM is changed as follows: 1.032 -> 1.05 -> 1.02 -> 1.032

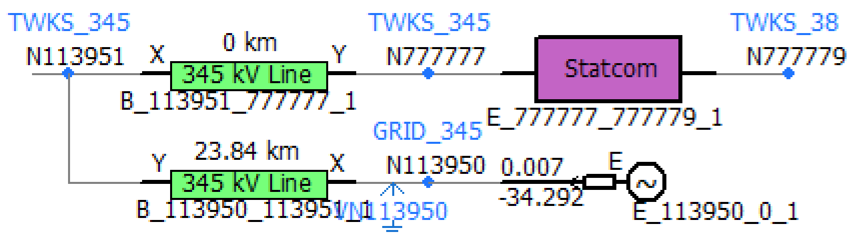

Figure 2.2 PSCAD SMIB System of Benchmark Study

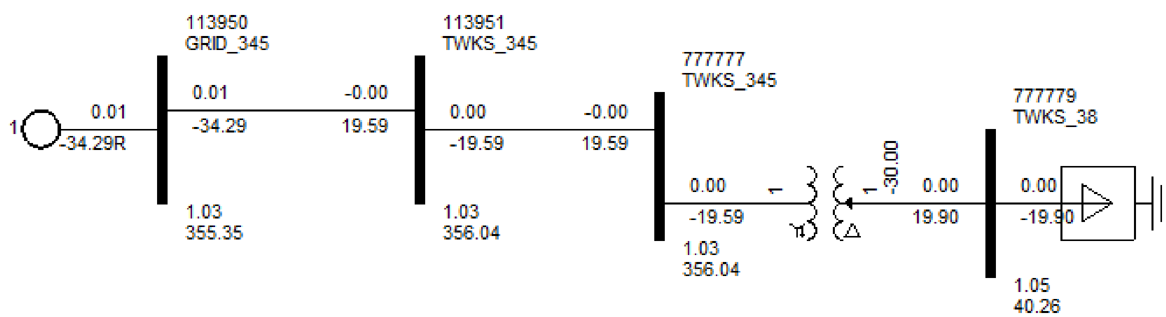

Figure 2.3 PSS/E SMIB System of Benchmark Study

2.2.2 Generic HVDC Model

A detailed model for the Sandy Pond HVDC link was not available, so a generic bipole HVDC model developed by Electranix was used. The model contains basic controls and protections. The voltage ratings and DC line values were changed to match the PSS/E values of the DC link . Additionally, the model has detailed RLC filters replacing the shunt capacitors to filter the 11th, 13th, and 24th harmonics.

2.2.3 Transmission Line Modelling

To improve model accuracy transmission lines close to Sandy Pond HVDC and the Tewksbury STATCOM were modelled as frequency dependent lines. National Grid provided the conductor data and tower geometries. Voltages, real power flows, and reactive power flows were monitored for key transmission lines/substations. Fault automation (Figure 2.4) was added to transmission lines to model the contingencies of this study.

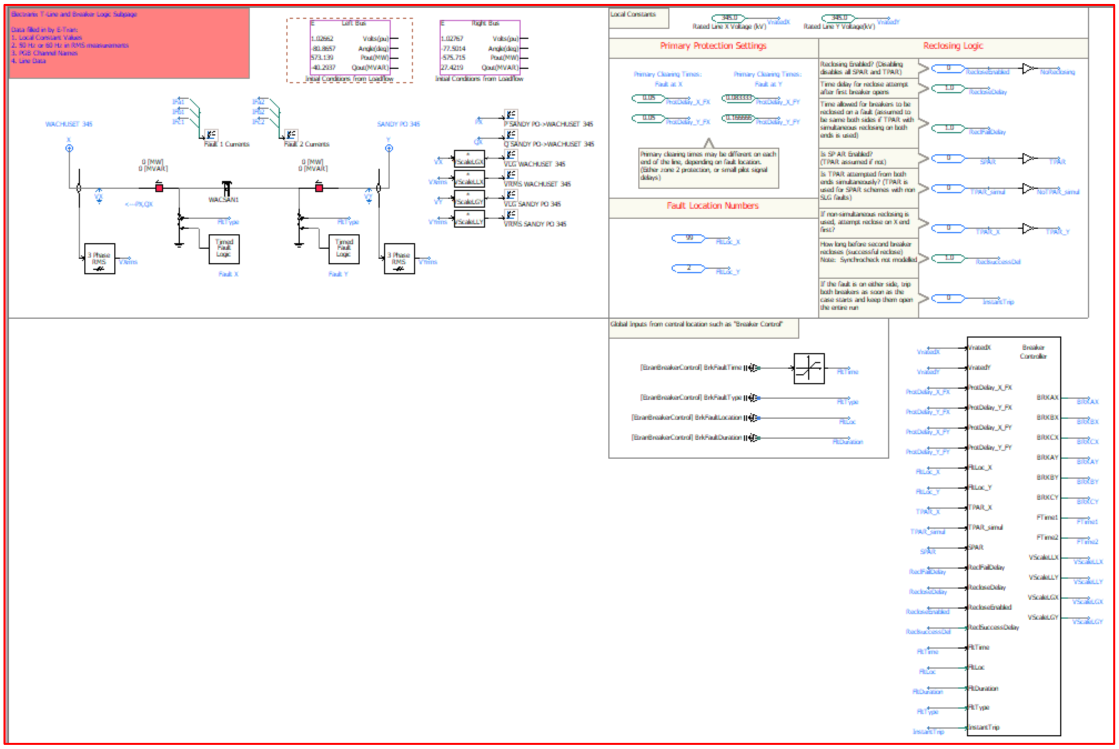

Figure 2.4 Transmission Line with Fault Automation and Monitoring

2.3 Study Case Contingencies

The contingencies that were studied are shown below in Table 2.2. These contingencies were run on both peak load (scenarios 1 – 9) and light load (scenarios 10 – 18) base cases.

Table 2.2 Study Contingencies

Scenario Peak,Light	Disturbance Type	Description
1,10	3LG Fault	Fault at Sandy Pond. Fault Cleared after 5 cycles. Sandy Pond - Wachusett 2 removed. Prior Outage of Sandy Pond - Wachusett 1
2,11	SLG Fault	Fault at Sandy Pond. Breaker Failure: Fault Cleared after 11 cycles. Sandy Pond - Wachusett 1 and Sandy Pond - Scobie removed. Prior Outage of Sandy Pond - Wachusett 2
3,12	Line Switch	Tewksbury - Sandy Pond Switches In
4,13	Line Switch	349 Mystic - Wakefield Jct. Switches In, Golden Hills Reactor Switches In Simultaneously.
5,14	SLG Fault	Fault at Tewksbury. Breaker Failure: Fault Cleared after 11 cycles. Tewksbury - Ward Hill and Tewksbury - Woburn removed. Prior outage of Tewksbury - Wakefield Jct.
6,15	3LG Fault	Fault at Tewksbury. Fault Cleared after 5 cycles. Tewksbury - Ward Hill removed. Prior outage of Tewskbury Wakefield Jct.
7,16	Loss of HVDC	Sandy Pond HVDC disconnected
8,17	3LG Fault	Fault at Sandy Pond. Fault Cleared in 6 cycles. Prior outage of Sandy Pond transformer 1 leaving 1 HVDC pole radial to Tewksbury and 1 HVDC pole radial to Wachusett.

9,18	SLG Fault	Fault at Sandy Pond. Fault Cleared in 6 cycles. Prior outage of Sandy Pond transformer 1 leaving 1 HVDC pole radial to Tewksbury and 1 HVDC pole radial to Wachusett.
19,20	Loss of HVDC	Sandy Pond HVDC disconnected and compared against WMASS DER study results. (Repeat of scenarios 7 and 16 with special dispatch to match WMASS DER study) See Discussion in section 2.5.

2.4 AC System Representation

The AC system is translated from E-tran using following base cases:

- Light Load
  - LL-1_2025-Control_Interaction.sav
  - LL-1_2025-AllPlants.dyr
- Peak Load
  - Peak-1_2025_mod.sav
  - Peak-1_2025-AllPlants.dyr

Powerflow case summaries are added in appendix J of the System Impact Study report.

The busses that were modeled in detail in the PSCAD study area were chosen with the agreement of National Grid and ISONE to represent the vicinity most likely to be impacted by the STATCOM project. A list of these busses follows:

Table 2.3 Busses Used in the Study

Bus Number	Bus Name	Base kV	Bus Number	Bus Name	Base kV	Bus Number	Bus Name	Base kV
9998	NCAMB_R1	345	104803	HUSE ROAD	115	113952	WARD HILL	345
9999	NCAMB_R2	345	104814	BEDFORD	115	113958	LITTLETN37_T	115
100089	SOUTH GORHAM	345	104825	N-MERRIMACK	115	113959	LITTLETN38_T	115
100090	BUXTON	345	104836	GREGGS	115	113972	E METHUEN_33	115
100098	MAGUIRE ROAD	345	104847	RIMMON	115	113977	KING ST 54_T	115
100163	MAGUIRE ROAD	115	104869	GREGGS_R	115	113978	KING ST 55_T	115
100575	LONEPINE_POI	345	104990	FITZWILLIAM	115	113979	MEADOWBRK T2	115
103710	ELIOT	345	105012	REEDS FERRY	115	113986	SANDY POND	115
103712	ES_3022_CMP	345	105078	POWER STREET	115	113987	TEWKSBURY	115
103730	N133_SOUTH_T	115	105450	SCHILLER_G4	13.8	113993	WARD HILL	115
104059	ES_385_CMP	345	105451	SCHILLER_G5	13.8	114001	WESTFRD L138	115
104063	ES_391_CMP	345	105452	SCHILLER_G6	13.8	114002	WESTFORD T2	13.2
104079	NEWINGTON	345	105454	SCHILLER JET	13.8	114005	WARD HL T1_R	23
104080	NEWINGTON EN	345	105464	NEWINGTON_G1	24	114006	WARD HL T2_R	23
104095	DEERFIELD	345	105476	NEWINGTON_C1	18	114061	PHII HVDC SS	23
104111	MERRIMACK	230	105477	NEWINGTON_C2	18	114063	W AMESBURY	345
104119	TIMBER SWAMP	345	105478	NEWINGTON_S1	18	114065	WARD HILL T8	13.2
104126	ES_369_SBK	345	105568	SEABROOK_G1	25	114071	SNDYPD HVDC1	345

104127	SEABROOK	345	105633	GRANITE R ST	16	114072	SNDYPD HVDC2	345
104128	ES_394_SBK	345	105867	LAWRENCE RD	34.5	114075	W AMESBURY	115
104129	ES_363_SBK	345	106086	GOLDHLR	345	114398	GOLDNHL349XY	345
104135	ES_394_NGR	345	110756	WOBURN	345	114401	GH TAP Q169	115
104143	SCOBIE POND	345	110757	LEXINGTON	345	114405	RAILYARD_45	115
104148	ES_3124_NGR	345	110758	N. CAMBRIDGE	345	114406	RAILYARD_46	115
104151	LAWRENCE RD	345	110759	MYSTIC MA	345	114417	SALEM HARBOR	115
104159	ES_326_NGR	345	110760	349XY	345	114418	W SALEM_45	115
104162	EAGLE	345	110762	MYSTIC G8	345	114419	W SALEM_46	115
104167	AMHERST	345	110799	WOBURN	115	114423	BARTHOLMW_45	115
104175	FITZWILLIAM	345	110816	SOMERVIL 510	115	114424	BARTHOLMW_46	115
104494	MERRIMACK-1	115	110817	SOMERVIL 511	115	114476	WAKEFLD JCT	345
104495	MERRIMACK-2	115	110818	MYSTIC MA	115	114481	SALEM HBR_C1	115
104496	MERRIMACK-3	115	110820	MYSTIC GIS	115	114482	SALEM HBR_C2	115
104502	PINE HILL	115	110821	MYSTIC_R	115	114483	SALEM G5	115
104604	SCHILLER_C1	115	110823	MYSTIC_C	115	114484	SALEM 5CT	18
104605	SCHILLER	115	110844	HAWKINS 516	115	114485	SALEM 5ST	13.8
104606	SCHILLER_C2	115	110845	HAWKINS 517	115	114489	WAKEFIELD_R	345
104647	T13_T	115	110934	MYSTIC 110C	99	114491	NGR_G5_FPRT	115
104649	PORTSMOUTH	115	110986	WOBURN_R	345	115010	NGR_338_NST	345
104658	MILL POND_T	115	111063	MYSTIC 7GT	22	115017	NGR_349X_NST	345
104671	OCEANRD-E194	115	111067	MYSTIC GT 8A	16	115018	NGR_349Y_NST	345
104672	OCEANRDE19_C	115	111069	MYSTIC GT 9A	16	123789	DUM	315
104704	BRENTWOOD	115	111071	MYSTIC GT 8B	16	180249	LG2ABT	13.8
104715	V103_T	115	111072	MYSTIC GT 9B	16	180320	RAD315	315
104737	PULPIT ROCK	115	111802	MYSTIC_R	345	180349	LG2315	315
104747	SCOBIEPOND_R	115	113264	MILLBURY	345	180361	LG1315	315
104748	SCOBIE POND	115	113265	WACHUSETT	345	180720	RAD735	735
104750	SCOBIE T30	115	113267	STERLING_TP1	115	181020	RAD315 A	315
104752	SCOBIE T90	115	113272	STERLING_TP2	115	182007	NIC230	230
104753	SCOBIE T120	115	113274	AYER	115	777777	TWKS-STAT	345
104758	B172_T	115	113292	PRATTS JCT	115	777779	TWKS-STAT	34.5
104759	SCOBIE PD D	115	113299	WACHUSETT	115	789789	TMP4	345
104770	MAMMOTH ROAD	115	113303	LAUREL CIRCL	115	565656	TMP2	345
104781	WATTS BROOK	115	113341	OAKDALE_A53	69	454545	TMP3	345
104789	ES_L109_GRE	115	113415	STERLING 41N	115	676767	TMP1	345
104792	GRANITE RIDG	115	113950	SANDY POND	345			
104802	HUSE ROAD 2	115	113951	TEWKSBURY	345			

Busses in green are only used in scenarios 8, 9, 17, and 18

2.5 AC System Representation for Western Massachusetts DER Comparison (Scenario 19 and 20)

In order to compare whether the DER models will have an impact on the results of the study, the loss of the Sandy Pond HVDC was compared between this study model and a prior study evaluating WMASS DER interconnection (this study is titled "Transmission System Impact Study Report for Group 1 of Distributed Energy Resource (DER) Additions in Western Massachusetts and is published on November, 2019). If the two models responded the same within the vicinity of the HVDC tie with and without DER modelled, it would be assumed that the DER had only a minor impact on the study area, and in order to reduce study complexity the DER would be left out of the study models going forward. To control differences between the two studies and allow an effective comparison, the following changes were made to the AC system of scenarios 7 and 16 (loss of HVDC scenario) in the Tewksbury study cases. The DER study cases remained unchanged.:

The following base case and .dyr files were used in the E-tran translation of the Tewksbury Control Interaction Study:

- Light load:
  - 2023_SLL_EW_DG_2.10.20_postfeeders.sav
  - 2020_SLL_PPA.dyr
- Peak Load:
  - 2023_SUM_DG-2.10.20_postfeeders.sav
  - 2023_SUM_PPA.dyr

The following other changes were made to control differences between the scenarios:

- The busses in the study area were changed to include large dynamic generator models that were used in the WMASS DER study and to remove large dynamic generators used in the Tewksbury STATCOM control interaction study. This change controlled for the effect of the generators on the transient response and power flow change that followed the loss of Sandy Pond HVDC.
- No frequency dependant lines were used
- In this control interaction study, several minor updates were included to the generic HVDC model. For the comparisons between the studies, the HVDC model was rolled back to the same model used in the WMASS DER study
- The Tewksbury STATCOM was not present in this study

Since the comparison between the cases was very close (See Appendix C cases 19 and 20), it was assumed that the presence of detailed PSCAD DER models had minimal impact on the Tewksbury study area, and the study was carried out without these additional models.

2.6 Additional Assumptions

- Transmission lines are ideally transposed
- No arresters were modelled for the control interaction study
- Transformer saturation was not modelled

- Loads translated using E-tran were modelled as constant current loads for the active power portion of the load and constant impedance loads for the reactive power portion of the load
- The simulation was run at a timestep of 10µs
- In the peak load base case, a number of active power loads had negative values and were in parallel with each other. These negative active power loads were subtracted from the active power of loads on the same bus and modeled the equivalent load.
- The .dyr records for the generators at busses 105476 and 105477 had transient impedance data that resulted in numerically unstable simulations. These impedances were replaced with typical values. The modified impedance data is shown in Table 2.4.

Table 2.4 Modified .dyr Parameters

Parameter	Original Value	Modified Value
X_q'	1.856	1
$X_d''=X_q''$	0.185	0.25

3 Results and Discussion

3.1 PSS/E vs. PSCAD Benchmark Evaluation

Comparisons generally match well (including steady-state levels) considering the inherent differences between the two modelling platforms. The full set of plots is attached in appendix B. Most of the traces are within a +/-10% deviation range, however several differences are noted. The identified differences fall into 3 categories:

1) Post-fault behavior due to PLL (phase locked loop) frequency tracking effects
2) Transient behavior due to inherent differences of the two simulation platforms
3) Parameter differences in measurement filtering

Differences in the immediate post-fault behavior were observed in some comparisons. This is typical for these types of comparisons, as the reduced level of detail in synchronization control in the generic PSS/E model precludes a perfectly accurate representation of the control behavior during the resynchronization and immediate post-fault clearing period. This can set the post-fault recovery period on a slightly different track between the programs and show as differences in reactive power recovery comparisons.

In PSCAD, some minor spikes and transient behaviour can occur at the moment a fault clears as the PLL re-synchronizes with the system and regains control of the IGBT firing (related to phenomena 1 as the PLL is not represented in PSS/E), but can also occur in PSS/E due to the numerical convergence properties of the simulation program. It is not possible to directly match PSS/E and PSCAD in the immediate transient region because of these differences in the solution engines.

The mismatches in the reactive power rise time at fault application are mainly related to parameter mismatches in the filtering components of measured voltage. Adjusting these parameters in the PSS/E platform may cause more severe mismatches in response upon fault clearing, likely due to wind-up of PI integrator state variables in the generic SVSMO3U2 PSS/E model and due to simplifications in fault clearing recovery logic in the positive sequence RMS based tool.

Overall, the comparison was deemed adequate for the purpose of moving forward with design studies.

3.2 Dynamic Performance Study

Below in Table 3.1 and Table 3.2 are summaries of the simulations for the peak and light load base cases respectfully. From these tables we can see that both the Tewksbury STATCOM and Sandy Pond HVDC rode through the faults successfully and no adverse control interactions were observed. The full set of plots is attached in appendix C.

Table 3.1 Summary of Peak Load Contingencies

Scenario	Fault Type	Fault Location	Branch Removed	Prior Outage	Pre Event Q	Post Event Q	Pre Event Gain[1]	Post Event Gain	STATCOM ride through	HVDC Ride Through
1	3LG	Sandy Pond	Sandy Pond - Wachusett 2	Sandy Pond - Wachusett 1	-38.68	-31.75	8.33	6.67	Yes[2]	Yes
2	SLG	Sandy Pond	Sandy Pond - Wachusett 1, Sandy Pond - Scobie	Sandy Pond - Wachusett 2	-39.47	-78.89	8.33	6.67	Yes[2]	Yes
3	Switch In	-	None	Tewksbury - Sandy Pond	48.50	18.80	8.33	8.33	Yes	Yes
4	Switch In	-	None	349 Mystic - Wakefield Jct.	55.21	-58.64	8.33	8.33	Yes	Yes
5	SLG	Tewksbury	Tewksbury - Ward Hill, Tewksbury - Woburn	Tewksbury - Wakefield Jct.	-26.85	-27.56	8.33	8.33	Yes	Yes
6	3LG	Tewksbury	Tewksbury - Ward Hill	Tewksbury - Wakefield Jct.	-26.85	-36.78	8.33	8.33	Yes	Yes
7	Loss of HVDC	-	Sandy Pond HVDC	None	-50.81	108.43	8.33	8.33	Yes	Yes
8	3LG	Sandy Pond	HVDC Pole 1 Radial to Tewksbury, HVDC Pole 2 Radial to Wachusett	Sandy Pond 345 kV - 115 kv transformer	-47.25	-60.00	8.33	4.27	Yes[2]	Yes
9	SLG	Sandy Pond	HVDC Pole 1 Radial to Tewksbury, HVDC Pole 2 Radial to Wachusett	Sandy Pond 345 kV - 115 kv transformer	-47.25	-60.19	8.33	6.67	Yes[2]	Yes

Table 3.2 Summary of Light Load Contingencies

Scenario	Fault Type	Fault Location	Branch Removed	Prior Outage	Pre Event Q	Post Event Q	Pre Event Gain[1]	Post Event Gain	STATCOM ride through	HVDC Ride Through
10	3LG	Sandy Pond	Sandy Pond - Wachusett 2	Sandy Pond - Wachusett 1	-61.19	-18.75	8.33	8.33	Yes	Yes
11	SLG	Sandy Pond	Sandy Pond - Wachusett 1, Sandy Pond - Scobie	Sandy Pond - Wachusett 2	-31.99	-8.42	8.33	2.18	Yes[2]	Yes[3]
12	Switch In	-	None	Tewksbury - Sandy Pond	-26.49	-77.27	8.33	8.33	Yes	Yes
13	Switch In	-	None	349 Mystic - Wakefield Jct.	43.56	-86.37	8.33	8.33	Yes	Yes
14	SLG	Tewksbury	Tewksbury - Ward Hill, Tewksbury - Woburn	Tewksbury - Wakefield Jct.	-15.72	92.27	8.33	8.33	Yes	Yes
15	3LG	Tewksbury	Tewksbury - Ward Hill	Tewksbury - Wakefield Jct.	-15.72	-22.29	8.33	8.33	Yes	Yes
16	Loss of HVDC	-	Sandy Pond HVDC	None	-46.92	155.29	8.33	8.33	Yes	Yes
17	3LG	Sandy Pond	HVDC Pole 1 Radial to Tewksbury, HVDC Pole 2 Radial to Wachusett	Sandy Pond 345 kV - 115 kv transformer	-54.97	-34.68	8.33	4.27	Yes[2]	Yes
18	SLG	Sandy Pond	HVDC Pole 1 Radial to Tewksbury, HVDC Pole 2 Radial to Wachusett	Sandy Pond 345 kV - 115 kv transformer	-54.97	-35.06	8.33	8.33	Yes	Yes

[1]The STATCOM has a factor of 1.666 multiplied to the gain which results in the gain of 8.33

[2]STATCOM initiated an automatic gain reduction based on hunting protection

[3]The HVDC Link temporarily blocked following the fault in this scenario

Appendix A

PSCAD Control Parameters for Tewksbury STATCOM used in the Control Interaction and Benchmarking Study:

Parameter	Control Interaction Study Setting	Benchmark Study Setting
SVCONC	1	1
GA	0	0
GAIN	5	5
K_FAC	1	1
SLOPE	0.02[1]	0.0001[1]
VrefTst	1.028 (Light Load)/1.022 (Peak Load)	1.032
StepTst	0	0
Step	0.02	0.02
St_Time	3.5	3.5
FQMOD	1	1
FSREF	0	0
QCONT	0	0
QREF	0	0
VQMAX	1.1	1.1
VQMIN	0.9	0.9
HUNTDE	1	1

[1]To benchmark the PSCAD and PSS/E STATCOM models we neglected droop by setting the slope setting to 0.0001 in both PSS/E and PSCAD. PSS/E Powerflow initializes the STATCOM to the reference voltage whereas, The PSCAD STATCOM model does not initialize from the reference. Therefore, a difference in pre-fault voltage will be observed between PSCAD and PSS/E which is an artifact of the simulation tool differences, not the model parameters.

The .dyr record of the STATCOM and the infinite bus equivalent used for benchmarking are shown below.

```
113950 'GENCLS' 1 1000 0 /

'TWK_STATCOM'   'USRFCT'  'SVSMO3U2' 21    1   20    44   6    27
 777777      0     0     0
     0    '0 '        0    '0 '        0    '0 '
     0    '0 '        0    '0 '        0    '0 '
     0    '0 '        0    '0 '
         0.0001        0.000        0.005         1.5        300
      1.000       -1.000       0.1500E-02    1.000        0.000
      0.000        0.000        0.000         0.000        0.000
      0.000        0.000        1.150    0.3500       0.3000
      3.000        3.000        2.000         2.000       0.3300E-01
      1.100        0.9000       0.5000E-02    0.2000E-02    0.000
      0.000        0.000        0.000         0.000        0.000
```


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0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000		

4 Appendix B

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5 Appendix C

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