New England East-West Solution (NEEWS): Interstate Reliability Project Component Updated Solution Study Report

Southern New England Regional Working Group

(ISO New England, National Grid, Northeast Utilities, and NSTAR)

[redacted]

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Section 1
Executive Summary

1.1 Needs Assessment Results and Problem Statement

The objective of this analysis was to identify regulated transmission solutions that address the needs identified in the "*New England East-West Solution (NEEWS): Interstate Reliability Project Component Updated Needs Assessment,*" dated April 2011[1]. This solutions study was performed consistent with Section 4.2.(b), of the Attachment K to the ISO New England (ISO) Open Access Transmission Tariff (OATT), which requires that the cost effective, regulated transmission solution which meets reliability criteria be identified.

The updated needs assessment study evaluated the reliability of the southern New England transmission system for 2015 and 2020 projected system conditions. The system was tested with all-lines-in-service (N-0) and under first (N-1) and second (N-1-1) contingency conditions for a number of possible operating scenarios. The ability to reliably serve load in the following four areas was analyzed:

- Western New England
- Eastern New England
- Connecticut
- Rhode Island

The results demonstrated widespread N-1 and N-1-1 thermal and voltage violations in the study areas for the two study years tested. The reliability assessment of the Rhode Island area [redacted] there were wide spread thermal and voltage violations on the 115 kV network. These violations are seen in today's system and on linear extrapolation based on the 2015 and 2020 loadings seen in the updated needs analysis, the first violations would have been in 2003-2004[2]. These violations indicated the need for an additional 345 kV line into Rhode Island.

The analysis also assessed the adequacy of the transmission transfer capability into eastern New England, western New England and Connecticut. The study results demonstrate that the eastern New England area would have insufficient transfer capability to deliver resources to serve its load under N-1-1 conditions starting in 2011, the western New England area in 2017-2018 and the Connecticut area in 2014-2015.

In summary, the following needs were identified in the updated needs analysis:

- Reinforce the 345 kV system into the West Farnum substation for Rhode Island reliability.
- Increase the transmission transfer capability from western New England and Greater Rhode Island to reliably serve load in eastern New England. With the retirement of Salem Harbor, there is an increased need for additional transmission transfer capability to eastern New England.

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[1] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2011/index.html

[2] The year of need if at load levels less than the 2010 forecast is calculated based on historic forecasted 90/10 peaks.

- Increase the transmission transfer capability from eastern New England and Greater Rhode Island to reliably serve load in western New England, if additional resources were available in the east.
- Increase the transmission transfer capability into the state of Connecticut to reliably serve load.

Many of these issues were seen in the original Southern New England Transmission Reliability (SNETR) study at today's load levels and the updated Interstate needs assessment continues to show criteria violations within the 10-year planning horizon.

1.2 Recommended Solution

1.2.1 Background

In the 2004 to 2008 time frame, the southern New England regional working group, which included representatives from ISO, National Grid USA (NGRID), and Northeast Utilities (NU), performed a study that has been referred to as the SNETR study. The findings of this study and the regional needs identified are documented in the report entitled "*Southern New England Transmission Reliability Report 1: Needs Analysis,*" dated January 2008[3] (2008 needs analysis). The proposed regional solution that was developed as a result of this study effort has been labeled the New England East-West Solution (NEEWS). The results of this study are documented in the report entitled "*New England East-West Solutions (Formerly Southern New England Transmission Reliability (SNETR)) Report 2, Options Analysis,*" dated June 2008[3] (2008 options analysis). Because the needs that were resolved by the original Interstate project were still seen in the updated needs assessment, the first step in the solution study process was to review the different alternatives that were considered in the original NEEWS analysis.

The five final alternatives (A, B, C, D, and E) considered for the 2008 Options Analysis for the Interstate project were revisited as a part of this updated solutions study. The components of each option and their relative system performance are summarized below. The system performance for each of the five options is based on the 2008 options analysis.

Interstate Option A – This option included a new 345 kV transmission line from the Millbury switching station in Millbury, Massachusetts to the West Farnum substation in North Smithfield, Rhode Island, a new 345 kV transmission line from the West Farnum substation to the Lake Road switching station in Killingly, Connecticut, and a new 345 kV transmission line from the Lake Road switching station to the Card Street substation in Lebanon, Connecticut. This option was the cost effective solution that met reliability criteria and hence was originally chosen as the preferred alternative.

Interstate Option B – This option included a new 345 kV transmission line from the West Farnum substation to the Kent County substation in Warwick, Rhode Island and a new 345 kV line from Kent County substation to the Montville substation in Montville, Connecticut. (The 345 kV transmission line from the West Farnum substation to the Kent County substation is part of the Rhode Island Reliability Project). Option B was eliminated in the original analysis based on inferior system benefits and a higher projected cost. This option had the greatest number of highly loaded lines and low system voltages post-contingency among the five options analyzed. This option also showed the least increase in N-1 transfer capability into Connecticut and across the East-West interface. Furthermore,

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[3] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2008/index.html

[redacted]

option B did not add a line into Massachusetts and the new need identified in the updated needs analysis indicated a need to bolster the transmission system into eastern New England. Thus, to make option B a viable alternative more transmission upgrades would have to be added and since option B was already a more expensive alternative, adding more upgrades to that plan would make that option a less desirable alternative.

Interstate Option C – This option included 345 kV transmission lines from the Millbury switching station to the Carpenter Hill substation in Charlton, Massachusetts and from the Carpenter Hill substation to the Manchester substation in Manchester, Connecticut. This plan also required a new 345 kV transmission line from the Sherman Road switching station to the West Farnum substation. Option C, which would have been in large part on new right-of-way (ROW) adjacent to an interstate highway corridor (Interstate 84), for the section between Carpenter Hill and Manchester, was found to be impractical and excessively costly. To make this alternative constructible the existing ROW from Carpenter Hill to Ludlow to Manchester had to be used. This alternative was designated option C-2.

Interstate Option D – This option included a new 345 kV transmission line from the Millbury switching station to the Carpenter Hill substation and a new 345 kV transmission line from the Carpenter Hill substation to the Ludlow substation in Ludlow, Massachusetts. The plan also included a 345 kV line from the Ludlow substation to the Agawam substation in Agawam, Massachusetts and a 345 kV line from the Agawam substation to the North Bloomfield substation in Bloomfield, Connecticut. (The 345 kV transmission line from the Ludlow substation to the Agawam substation to the North Bloomfield substation is part of the Greater Springfield Reliability Project). As a part of this plan the existing 345 kV line between Ludlow and Manchester would be reconductored. This plan also required a new 345 kV transmission line from the Sherman Road switching station to the West Farnum substation. Option D was determined to be impractical in the form envisioned in the 2008 Options Analysis. It was determined that construction outages and ROW constraints between Ludlow and Manchester made this plan extremely difficult to implement. It was more practical to add a new circuit between Ludlow and Manchester and with this modification option D was virtually indistinguishable from option C-2, except for its 345 kV connection to Ludlow substation.

Interstate Option E – This option included a new 1,200 MW high-voltage direct-current (HVDC) transmission line from the Millbury switching station to the Southington substation in Southington, Connecticut. This plan also required a new 345 kV transmission line from the Sherman Road switching station to the West Farnum substation. In terms of thermal and voltage problems this solution was ranked fourth amongst the five options in the original Interstate analysis. Being an HVDC facility this option provided very little flexibility in terms of expandability since any expansion of an HVDC system would involve an additional converter station. Option E was eliminated on grounds of system disadvantages and high cost.

Options A and C-2 were evaluated in detail in the current analyses, because they had better system performance and were more easily constructible compared to options B, C, D, and E. The decisive differences in cost and/or system performance between these options and the original option A and C-2 were significant. The additional cost and impacts of the modifications needed for options A and C-2 to meet the enhanced system need were modest and hence would not offset the difference that existed. Therefore, options B, C, D, and E were not analyzed further.

1.2.2 Interstate Alternatives

Both options A and C-2 were redesigned to meet the requirements of the updated needs analysis. The modification of original option C-2 was designated option C-2.1 and four distinct variants of the original option A were designated options A-1 through A-4.

The following upgrades[4] of NSTAR, NU and Connecticut Municipal Electric Cooperative (CMEEC) facilities are already in progress and were assumed in the evaluations of all options:

- NSTAR – Reconductor a 1.2-mile section of the 345 kV 336 line (ANP Blackstone to NEA Bellingham Tap) and upgrade terminal equipment at the West Medway substation to [redacted] rated equipment.
- NSTAR - Add a new breaker in series with the [redacted] 345 kV substation
- NU/CMEEC – Eliminate the sag limit on the thermal rating of the 115 kV 1410 line (Montville to Buddington) in Connecticut.

All three upgrades address overloads seen on each facility under high West-East conditions or under high eastern NE import conditions.

The four A-series options all contain the same 345 kV construction plans within Connecticut. However, these variations have a slightly different configuration in Massachusetts and Rhode Island. These options all contain three primary components:

- A new 345 kV line from the Card substation to the Lake Road switching station in eastern Connecticut.
- A new 345 kV line from the Lake Road switching station in eastern Connecticut to the West Farnum substation in northern Rhode Island; in one A-series option this line loops in and out of the Sherman Road switching station enroute.
- A new 345 kV line from the West Farnum substation (or the Sherman Road switching station) in Rhode Island to the Millbury switching station in central Massachusetts.

Descriptions of the four A-series options and option C-2.1 are provided in the following sections.

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[4] These three upgrade projects will seek PPA approval and be advanced independently of the Interstate Reliability project. Accordingly, they are not further considered in comparisons of the Interstate solution options.

[redacted]

1.2.2.1 Option A-1

In option A-1, a new 345 kV transmission line emanates from the Card substation in Lebanon, Connecticut and follows the existing transmission corridor (330 line) to the Lake Road switching station in Killingly, Connecticut. From the Lake Road switching station, a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) northeasterly to the vicinity of the Sherman Road switching station in Burrillville, Rhode Island. In option A-1, this new 345 kV transmission line does not connect to the Sherman Road switching station but goes by it and continues in a southeasterly direction on an existing transmission corridor (328 line) to terminate at the West Farnum substation in North Smithfield, Rhode Island. A new 345 kV transmission line would also be constructed on the existing transmission corridor (Q-143 and R-144 lines) between the West Farnum substation and the Millbury switching station in Millbury, Massachusetts. The existing 345 kV 328 line (Sherman Road to West Farnum) must also be rebuilt with higher capacity conductors under this plan.

The one-line description of option A-1 is shown in Figure 1-1.

[redacted]

Figure 1-1: One-line Diagram of Option A-1

[redacted]

1.2.2.2 Option A-2

In option A-2, a new 345 kV transmission line emanates from the Card substation and follows the existing transmission corridor (330 line) to the Lake Road switching station. From the Lake Road switching station a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) northeasterly to the Sherman Road switching station. Another new 345 kV transmission line emanates from the Sherman Road switching station and follows the existing transmission corridor (328 line) in a southeasterly direction to the West Farnum substation. In addition, a second new 345 kV line emanates from the Sherman Road switching station and follows the existing NSTAR transmission corridor (3361 line) in a northeasterly direction until it intersects with the existing National Grid transmission corridor (Q-143 and R-144 lines) between the Millbury switching station and the West Farnum substation. At this intersection, this new 345 kV transmission line turns and follows the existing National Grid transmission corridor in a northwesterly direction to the Millbury switching station.

The one-line description of option A-2 is shown in Figure 1-2.

[redacted]

Figure 1-2: One-line Diagram of Option A-2

[redacted]

1.2.2.3 Option A-3

In option A-3, a new 345 kV transmission line emanates from the Card substation and follows the existing transmission corridor (330 line) to the Lake Road switching station. From the Lake Road switching station a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) northeasterly to the vicinity of the Sherman Road switching station. However under this plan, the new 345 kV line does not connect to the Sherman Road switching station but goes by it and continues in a southeasterly direction on an existing transmission corridor (328 line) to the West Farnum substation. A new 345 kV line would be constructed on the existing transmission corridor (Q-143 and R-144 lines) between the West Farnum substation and the Millbury switching station. At the location where the new 345 kV West Farnum to Millbury line intersects with the existing 345 kV 3361 line (ANP Blackstone to Sherman Road) in Uxbridge, Massachusetts, a new 345 kV breaker-and-a-half switching station would be constructed. Both the new West Farnum to Millbury line and the existing 3361 line would be interconnected at the new switching station. As a part of this plan, the segment of the existing 3361 line between Sherman Road and the new switching station at Uxbridge will be upgraded by replacing limiting terminal equipment at Sherman Road and eliminating sag limits on the 3361 line.

The one-line description of option A-3 is shown in Figure 1-3.

[redacted]

Figure 1-3: One-line Diagram of Option A-3

[redacted]

1.2.2.4 Option A-4

In option A-4, a new 345 kV transmission line emanates from the Card substation and follows the existing transmission corridor (330 line) to the Lake Road switching station. From the Lake Road switching station a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) in a northeasterly direction to the vicinity of the Sherman Road switching station. In option A-4, the new 345 kV line does not connect to the Sherman Road switching station but goes by it and extends in a southeasterly direction on an existing transmission corridor (328 line) to the West Farnum substation. A new 345 kV line would also be constructed on the existing transmission corridor (Q-143 and R-144 lines) between the West Farnum substation and the Millbury switching station. In addition, a new 345 kV transmission line would be constructed between the Sherman Road switching station and the West Farnum substation within the same transmission corridor as the 328 line and the new 345 kV Lake Road to West Farnum transmission line.

The one-line description of option A-4 is shown in Figure 1-4

[redacted]

Figure 1-4: One-line Diagram of Option A-4

[redacted]

1.2.2.5 Option C-2.1

Option C-2.1 would involve the construction of a new 345 kV transmission line in a westerly direction within the existing transmission corridor (302 line) from the Millbury switching station to the Carpenter Hill substation in Charlton, Massachusetts. From the expanded 345 kV switchyard at the Carpenter Hill substation, a new 345 kV transmission line would be constructed in a westerly direction within the existing transmission corridor (301 line) to the vicinity of the Ludlow substation in Ludlow, Massachusetts. This line would not connect to the Ludlow substation, rather it would turn south within the existing transmission corridor (3419 line and then 395 line) to the Manchester substation in Manchester, Connecticut. In addition, a new 345 kV transmission line would be constructed between the Sherman Road switching station and the West Farnum substation. This new 345 kV transmission line would be located within the existing transmission corridor with the existing 328 line.

The one-line description of option C-2.1 is shown in Figure 1-5

[redacted]

Figure 1-5: One-line Diagram of Option C-2.1

[redacted]

1.2.2.6 Sherman Road Switching Station

Each of the five Interstate options required substantial work at the Sherman Road switching station due to a combination of issues including short circuit capability, thermal overloads, Bulk Power System designation, and antiquated equipment. Sherman Road alternatives were developed based on the specific needs of each Interstate option and then evaluated based on cost and a number of other considerations as outlined in Section 5.5. The conclusion of that alternatives analysis is as follows:

- **For Interstate Options A-1 and A-3**: Both these options do not add any new elements into the Sherman Road switching station, and are hence grouped together. Building a new 2-bay Air-Insulated Station (AIS) station adjacent to the existing station was determined to be the cost-effective solution based on low cost, low equipment outage requirements, minimal construction sequencing difficulties, opportunity for future expansion, and the least environmental impact.
- **For Interstate Options A-4 and C-2.1:** Both these options add one new element into the Sherman Road switching station, and are hence grouped together. Building a new 3-bay Air-Insulated Station (AIS) using a 2-stage process that makes use of both the adjacent space and the existing station space was determined to be the cost-effective solution to bring an additional transmission line into Sherman Road.
- **For Interstate Option A-2:** This option adds 3 new elements into the Sherman Road switching station and all other options add either one or no new elements into Sherman Road. Building a new 4-bay Gas-Insulated Station (GIS) adjacent to the existing station was determined to be the only feasible and practical alternative for the addition of three transmission lines into Sherman Road.

1.2.3 Comparison of Alternatives

Consistent with the updated needs assessment, the performance of the transmission system with the addition of each of these solution alternatives was simulated under a broad range of system conditions, including line out-of-service (OOS) conditions, and a variety of generation dispatches that stressed the transmission system. The objective of these analyses was to determine the preferred option by comparing them in three categories:

- Electrical Performance
- Costs
- Impact on Natural and Human Environments

1.2.3.1 Electrical Performance

Electrical performance factors are used to compare the overall system benefits provided by each of the five options. The system upgrades associated with each option were designed to resolve all of the reliability criteria violations identified in the updated needs analysis for the southern New England transmission system over the projected planning horizon. Each option was next evaluated to see differences in the following areas:

- Improve the capability of the transmission system to move power into and within the load centers of southern New England.
- Increase the New England East-West and West-East transfer level capability as well as the transfer capability across the Connecticut import interface.
- Short circuit impact at area 345 kV stations.
- Stability performance to faults at area 345 kV stations in southern New England.

- Impact of the alternatives on delta P special protection systems (SPSs) along the Card – Lake Road – Sherman Road – West Medway corridor.
- Improve system expandability and flexibility.

The five Interstate options all provide a level of electrical system performance that meets design requirements for satisfying the North American Electric Reliability Corporation (NERC), Northeast Power Coordinating Council (NPCC), and ISO reliability standards and criteria. Based on the electrical performance the four A-series options provide very comparable results in all the performance metrics tested. In terms of increased transfer capabilities and number of highly-loaded lines, the A-series options are superior to the C-2.1 option. The C-2.1 option has a lesser impact in terms of increased fault currents on area 345 kV stations in southern New England.

All 5 Interstate options demonstrated satisfactory performance in the stability testing. No option could be distinguished as providing a better stability performance.

Overall, the A-series options performed better than the C-2.1 option in terms of most of the metrics tested for electric performance evaluation. Within the A-series options A-1 provided the maximum system expandability and flexibility.

1.2.3.2 Cost Estimates

For each of the five options, cost estimates were prepared using a process consistent with ISO-NE procedures as defined in Attachment D of the ISO Planning Procedure 4[5], *"Procedure for Pool-Supported PTF Cost Review"*. Table 1-1 summarizes these conceptual[6] grade cost estimates (+50% / -25%) for each option. The detailed cost estimates for each option are provided in Appendix I: Detailed Cost Estimates for Interstate Alternatives

Table 1-1
Summary of Cost Estimates[7] of Interstate Options

Interstate Components	A-1	A-2	A-3	A-4	C-2.1
Substations	$131M	$168M	$175M	$148M	$164M
Transmission Lines	$411M	$375M	$378M	$422M	$550M
Total	**$542M**	**$543M**	**$553M**	**$570M**	**$714M**

While all the A-series options were comparable in cost, the estimate for option A-1 was the lowest. The A-series options cost estimates were substantially less than the estimate for option C-1.2. The

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[5] http://www.iso-ne.com/rules_proceds/isone_plan/pp4_0_attachment_d.pdf

[6] The term "conceptual" used here for the estimate grade should not be confused with when it is used to describe a "Concept" project, which is a transmission project that may be considered a potential solution, but for which there is little or no analysis available to support the transmission project. . A conceptual grade estimate is used to move a project from the "concept" stage to the "proposed" stage.

[7] The above estimates reflect capitalized Allowance for Funds Used During Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

[redacted]

difference between the estimated cost for option C-2.1 ($714 million) and the highest estimated cost amongst the A-series options, option A-4 ($570 million) was $144 million. Thus, the estimated cost for C-2.1 is over 25% higher than the highest estimate amongst the A-series options.

1.2.3.3 Natural and Human Environment Impacts

In comparison to the A-series options, option C-2.1 included more length through wetlands, watercourse crossings, and length of upland and wetland forest traversed. Option C-2.1 also has more overall miles and residences within 500-feet of the centerline of the new lines. Based on these factors, the A-series options have lower expected natural and human environment impacts.

Due to the similarities of the four A-series options, more detailed analysis was necessary to evaluate these options. Each option has common facilities in Connecticut[8] and thus, all four of the A-series options would have the same natural and human environment impacts within Connecticut. Therefore, the analysis concentrated only on the Massachusetts and Rhode Island portions of these options.

- Option A-1 uses a previously cleared portion of ROW along the Millbury to West Farnum segment and includes the installation of a new line along the decommissioned 69 kV portion of this ROW. Hence, option A-1 minimizes tree clearing and its associated human and environment impacts on this ROW.
- Option A-3 also benefits from use of the same existing ROWs as option A-1, but the need for a switching station in Uxbridge increases environmental impacts.
- Option A-4 requires additional ROW clearing between Sherman Road and West Farnum when compared to option A-1.
- Option A-2 requires use of an un-cleared portion of an NSTAR ROW (3361 line) and increasing the cleared width of this ROW would impact wetlands, rare species habitat and open up views to abutters.

Based on a comparison of natural and human environment factors, option A-1 represents the least impact of the four A-series options.

1.2.4 Preferred Alternative

The A-series options provide better electrical performance than the C-2.1 option. Within the A-series options, A-1 provides more expandability and flexibility compared to the other options. The A-series options also have a significantly lower estimated cost compared to option C-2.1. The A-1 option also has less human and environment impact compared to option C-2.1. Within the A-series options, option A-1 had the lowest estimated cost and the least environmental impact. Based on all these factors, option A-1 was selected as the recommended solution for the needs identified in the updated needs analysis.

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[8] In Connecticut, Options A-1, A-2, A-3, and A-4 all would include a new 345 kV transmission line that would emanate from the Card substation in Lebanon, Connecticut, follow NU's existing 345 kV transmission corridor (330 Line), and terminate at the Lake Road switching station in Killingly, Connecticut. Further, each of the four options would include a second 345 kV transmission line that would extend east from the Lake Road switching station along the existing transmission corridor to the Connecticut/Rhode Island border. In addition, all of the A-series series options would involve the same modifications to the Card substation, Lake Road switching station, and Killingly substation in Connecticut.

The major 345 kV components of option A-1 are:

- A new 345 kV line from Card substation to the Lake Road switching station in eastern Connecticut.
- A new 345 kV line from the Lake Road switching station in Connecticut to the West Farnum substation in Rhode Island.
- A new 345 kV line from the West Farnum substation in Rhode Island to the Millbury switching station in Massachusetts.

The new line to Millbury from West Farnum provides a new import line into eastern New England and allows for the movement of power from western New England and Greater Rhode Island to reliably serve load in eastern New England during capacity deficiency conditions in eastern New England. Option A-1 provides an increase in the eastern New England import capability of 1,350-1,850 MW under N-1 conditions and 1,900-2,300 MW under N-1-1 conditions.

Similarly, the line into Card substation via Lake Road and West Farnum provides a new import path into Connecticut and western New England and allows for the movement of power from eastern New England and Greater Rhode Island to reliably serve load in Connecticut and western New England during capacity deficiency conditions in the west. Option A-1 provides an increase in the western New England import capability of 750-1,650 MW under N-1 conditions and 850-1,650 MW under N-1-1 conditions. It also provides an increase in the Connecticut import capability of 550-1,050 MW under N-1 conditions and 850-1,350 MW under N-1-1 conditions.

The project also provides two new 345 kV lines into West Farnum which resolves the criteria violations in Rhode Island seen for the loss of the two existing 345 kV lines into West Farnum from Sherman Road and Brayton Point.

The preferred solution option A-1 not only resolves all the needs identified in the updated needs analysis, but also stands out as the best option after a comparison of electrical performance factors, costs and natural/human environment impact factors.

1.3 NERC Compliance Statement

In accordance with NERC TPL standards, this assessment provides:

- A written summary of plans to address the system performance issues described in the *"New England East-West Solution (NEEWS): Interstate Reliability Project Component Updated Needs Assessment,"* dated April 2011.
- A schedule for implementation as shown in Section 8.3.
- A discussion of expected required in-service dates of facilities and associated load level when required as shown in Section 8.2.
- A discussion of lead times necessary to implement plans in Section 8.3.

This assessment documents the continuing need for identified system facilities.

[redacted]

Section 2
Needs Assessment Results Summary

2.1 Introduction

The objective of this analysis was to identify regulated transmission solutions that address the needs identified in the *"New England East-West Solution (NEEWS): Interstate Reliability Project Component Updated Needs Assessment,"* dated April 2011[9]. This solutions study was performed consistent with Section 4.2.(b) of Attachment K to the ISO New England (ISO) Open Access Transmission Tariff (OATT) which requires that the cost effective, regulated transmission solution which meets reliability criteria be identified.

2.2 Background

In the 2004 to 2008 time frame, the ISO-led southern New England regional working group, which included representatives from National Grid USA (NGRID) and Northeast Utilities (NU), performed a study that has been referred to as the Southern New England Transmission Reliability (SNETR) study. The findings of this study and the regional needs identified are documented in the report entitled *"Southern New England Transmission Reliability Report 1: Needs Analysis,"* dated January, 2008[10] (2008 Needs Analysis). The proposed regional solution that was developed as a result of this study effort has been labeled the New England East-West Solution (NEEWS). The results of this study are documented in the report entitled *"New England East-West Solutions (Formerly Southern New England Transmission Reliability (SNETR)) Report 2, Options Analysis,"* dated June 2008[10] (2008 Options Analysis). The Interstate Reliability Project (Interstate) was one of the four components identified as a part of NEEWS. The solutions study identified five alternatives to resolve the original needs associated with the Interstate component. These alternatives are described in detail in Section 5.3.

Since a majority of the needs associated with the original Interstate project were still seen in the updated needs assessment, the alternatives associated with the original Interstate project were considered in developing a regulated transmission solution. In addition to the need identified in the original SNETR study, some new needs were identified in the updated needs assessment. To address these new needs, additions/enhancements to the original Interstate alternatives were included.

2.3 Areas Studied

The study included portions of the three southern New England states of Massachusetts, Rhode Island and Connecticut. Figure 2-1 is a geographic map of the 345 kV transmission system in the study area.

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[9] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2011/index.html

[10] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2008/index.html

[redacted]

Figure 2-1: Study Area 345 kV Transmission System

For purposes of this study, the New England system was split into three subareas (eastern New England, western New England and Greater Rhode Island) based on weak transmission system connections to neighboring subareas. Figure 2-2 is a map that shows how the three subareas were divided geographically. For the eastern New England reliability study, Greater Rhode Island was considered as part of the western New England subarea shown in Figure 2-3 (left). For the western New England reliability study, the Greater Rhode Island subarea was considered as part of the eastern New England subarea shown in Figure 2-3 (right).

The fact that the Greater Rhode Island area is part of the east when moving power westward and then becomes part of the west when moving power eastward is the direct result of where the transmission constraints develop under the two scenarios. A significant amount of generation enters the system via the 345 kV path between the West Medway and Card Street substations, and constraints exist in moving power in both the westerly and easterly directions. With power flow from east to west (to cover for unavailable western resources), the Greater Rhode Island generation gets constrained to its west; hence, Greater Rhode Island is in the east and vice versa when power moves from west to east (to cover for unavailable eastern resources).

This is very similar to the Lake Road issue in Connecticut. Lake Road is considered outside of Connecticut under Connecticut Import conditions but, conversely, is considered within Connecticut when Connecticut Export is modeled.

[redacted]

[redacted]

Figure 2-2: Interstate Needs New England Subareas

[redacted]

Figure 2-3: Eastern and Western New England Subareas by Direction of Power Flow

[redacted]

A further detailed description of the subareas and the transmission lines defining the associated interfaces is provided in the *"New England East-West Solution (NEEWS): Interstate Reliability Project Component Updated Needs Assessment,"* dated April 2011[11].

2.4 Needs Assessment Review

The results of the updated needs analysis indicated a need to:

- Reinforce the 345 kV system into the West Farnum substation for Rhode Island reliability.
- Increase the transmission transfer capability from western New England and Greater Rhode Island to reliably serve load in eastern New England. With the retirement of Salem Harbor, there was a need for additional transmission transfer capability to eastern New England.
- Increase the transmission transfer capability from eastern New England and Greater Rhode Island to reliably serve load in western New England, if additional resources were available in the east.
- Increase the transmission transfer capability into the state of Connecticut to reliably serve load.

2.5 Year of Need Analysis

The updated needs assessment provides approximate timeframes[12] when criteria violations were seen for the different needs described above.

- Violations related to [redacted] are seen in today's system. On linear extrapolation based on the 2015 and 2020 loadings seen in the updated needs analysis, the first violations would have been in 2003-2004[13].
- The need for additional transmission transfer capability from western New England and Greater Rhode Island to eastern New England was forecasted to occur in 2011. With generation retirements, the need for additional eastern New England transmission transfer capability would be greater.
- The need for additional transmission transfer capability from eastern New England and Greater Rhode Island to western New England was forecasted to occur between 2017 and 2018.
- The need for additional transmission transfer capability into the state of Connecticut was forecasted to occur between 2014 and 2015.

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[11] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2011/index.html

[12] The year of need beyond 2010 is based on the 2010 CELT report.

[13] The year of need, if at load levels less than the 2010 forecast is calculated based on historic forecasted 90/10 peaks.

Section 3
Study Assumptions

3.1 Analysis Description

Because the needs that were resolved by the original Interstate project were still seen in the updated needs assessment, the first step in the solution study process was to review the different alternatives that were considered in the original NEEWS analysis. Originally, there were fourteen alternatives developed to address the violations related to the Interstate component. The alternatives are described in the 2008 Options Report[14]. Some of the original alternatives were eliminated based on either inferior performance or feasibility and constructability issues. There were five remaining alternatives after the initial screening process. These alternatives were then subject to an iterative process to enhance and finalize each alternative to meet the reliability needs identified in the original SNETR analysis. The five final alternatives were thoroughly reviewed for performance and cost-effectiveness as a part of the original solution study and were likely to be adaptable to meet the updated needs cost effectively. The details of the five alternatives is provided in Section 5.1

The five final alternatives considered for the original NEEWS analysis for the Interstate component were revisited as a part of this updated solutions study. Again, a few of these alternatives were removed from further consideration based on feasibility and costs. The alternatives that were selected after the screening process were then subject to an iterative process of adding and removing additional components until a complete plan that resolves all forecasted criteria violations was developed. As a part of this iterative process some of the components of the original 14 Interstate alternatives, were reevaluated, and some new components were evaluated.

Consistent with the updated needs assessment, the performance of the transmission system with the addition of each of these selected alternatives was simulated under a broad range of system conditions, including line out-of-service (OOS) conditions, and a variety of generation dispatches that stressed the transmission system. The selected alternatives were modified in light of the results of these simulations with the objective of eliminating remaining violations of reliability standards and criteria. The performance of the modified alternatives was then simulated. This process was repeated until a workable alternative that resolved all criteria violations in the planning horizon was identified.

A number of factors were considered in evaluating the performance of each alternative. These factors included the impacts of an alternative on the power flows across the regional interfaces, such as from west to east and vice versa, and the performance of the southern New England transmission system with respect to steady-state, thermal transfer capability, stability, short-circuit, and delta P performance. A short description of these analyses is as follows:

- **Thermal analysis** – studies to determine the level of steady-state power flows on transmission facilities under base case conditions and following contingency events. These flows are compared to the applicable facility rating to determine if the equipment will be operated within its capabilities.

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[14] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2008/index.html

[redacted]

- **Voltage analysis** – studies to determine system voltage levels and performance under base case conditions and following contingency events. These voltages are then compared to applicable voltage criteria.
- **Thermal Transmission Transfer Capability Analysis** – studies to determine the capability of the transmission system from one portion of the system to a specific subarea.
- **Stability analysis** – screening studies to determine the dynamic performance of electric machines with respect to rotor angle displacement, system voltage stability and system frequency deviations following fault conditions.
- **Short-circuit analysis** – screening studies to determine the short-circuit levels at system locations and the relative impact of each alternative on the required interrupting capability at major substations in the study area.
- **Delta P analysis** – limited studies to determine the mechanical stress put on local machines in the area due to line switching associated with system contingency events.

Once each alternative resolved all criteria violations in the planning horizon the alternatives were compared based on relative performance, flexibility, expandability, longevity, constructability, cost effectiveness, and impact on the natural and human environments. Based on this comparison a preferred alternative was selected.

3.2 Steady State Model

3.2.1 Study Assumptions

The regional steady state model was developed to be representative of the 10-year projection of the 90/10 summer peak system demand levels to assess reliability performance under stressed system conditions. The model assumptions included consideration of area generation unit unavailability conditions as well as variations in surrounding area regional interface transfer levels. These study assumptions were consistent with ISO Planning Procedure 3 (PP-3), *"Reliability Standards for the New England Area Bulk Power Supply System,"* and were the same as those used in the updated needs assessment.

In the updated needs assessment two load levels were utilized to analyze the steady state performance of the system, 5-year and 10-year summer peak demands. The analysis was restricted to peak load conditions and the thermal and voltage criteria violations seen for the 10-year projection of summer peak conditions was more severe than the violations seen for the 5-year projections. Hence to test the performance of the different alternatives the steady state performance of each alternative was only tested for the 10-year projected system demand.

3.2.2 Source of Power Flow Models

The power flow study cases used in this study were obtained from the ISO Model on Demand system with selected upgrades to reflect the system conditions in 2020. A detailed description of the system upgrades included is described in later sections of this report.

[redacted]

3.2.3 Transmission Topology Changes

Transmission projects with Proposed Plan Application (PPA) approval in accordance with Section I.3.9 of the ISO Tariff as of the June 2010 Regional System Plan (RSP) Project Listing[15] were included in the updated needs assessment base case. A listing of the major projects is included below.

Maine
- Maine Power Reliability Program (RSP ID: 905-909, 1025-1030, 1158)
- Down East Reliability Improvement (RSP ID: 143)

New Hampshire
- Second Deerfield 345/115 kV Autotransformer Project (RSP ID: 277, 1137-1141)

Vermont
- Northwest Vermont Reliability Projects (RSP ID: 139)[16]
- Vermont Southern Loop Project (RSP ID: 323, 1032-1035)

Massachusetts
- Auburn Area Transmission System Upgrades (RSP ID: 59, 887, 921, 919)
- Merrimack Valley / North Shore Reliability Project (RSP ID: 775-776, 782-783, 840)
- Long Term Lower SEMA Upgrades (RSP ID: 592, 1068, 1118)
- Central/Western Massachusetts Upgrades (RSP ID: 924- 929, 931-932, 934-935, 937-950, 952- 955)
- NEEWS – Greater Springfield Reliability Project (RSP ID: 196, 259, 687-688, 818-820, 823, 826, 828-829, 1010, 1070-1075, 1078-1080, 1100-1105)

Rhode Island
- Greater Rhode Island Transmission Reinforcements (RSP ID: 484, 786, 788, 790-793, 913-918, 1098)
- NEEWS – Rhode Island Reliability Project (RSP ID: 795, 798-799, 1096-1097, 1099, 1106, 1109)

Connecticut
- NEEWS – Greater Springfield Reliability Project (RSP ID: 816, 1054[17], 1092)

The aforementioned base case upgrades were also utilized for the solution study base cases. In addition to the above projects, the following RSP project received PPA approval after the needs assessment was finalized and was also included:

- Millstone 345 kV circuit separation and Severe Line Outage Detection (SLOD) Special Protection System (SPS) Retirement – RSP ID 1218 (April 2011 RSP Project Listing[18])

Transmission projects that have not been fully developed and have not received PPA approval as of the April 2011 RSP Project Listing and generation projects that did not clear in FCA 1-4 were not modeled in the study base case due to the uncertainty concerning their final development.

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[15] http://www.ISO.com/committees/comm_wkgrps/prtcpnts_comm/pac/projects/2010/index.html

[16] Majority of project is currently in service as of 2010 with the exception of new synchronous condensers at the Granite substation.

[17] RSP 1054 – Meekville to Manchester Project was modified to reflect changes from the Connecticut Siting Council decision for GSRP in 2009 to now separate the 345 kV 3-terminal 395 line (Manchester – N. Bloomfield – Barbour Hill) into two separate 345 kV lines, 3557 line (Barbour Hill – Manchester) and 3642 line (N. Bloomfield – Manchester).

[18] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/projects/2011/index.html

Additionally, the originally planned NEEWS – Interstate Reliability Project component was not included in the base case since it was the project under study. The NEEWS – Central Connecticut Reliability Project (CCRP) component was also not included in the base case since it is being re-evaluated as part of the ongoing Greater Hartford and Central Connecticut (GHCC) needs assessment.

3.2.4 Generation

Generation Projects with a Forward Capacity Market (FCM) Capacity Supply Obligation as of the Forward Capacity Auction #4 (FCA-4) commitment period (June 1, 2013 – May 31, 2014) were included in the study base case. A listing of the recent major new FCA-1 through 4 cleared projects is included below.

Maine
- QP 138 – Kibby Wind Farm (FCA-2)
- QP 197 – Record Hill Wind (FCA-2)
- QP 215 – Longfellow Wind Project (FCA-2)
- QP 244 – Wind Project (FCA-4)

New Hampshire
- QP 166 – Granite Wind Farm (FCA-2)
- QP 220 – Indeck Energy Alexandria (FCA-2)
- QP 251 – Laidlaw Berlin Biomass Energy Plant (FCA-4)
- QP 256 – Granite Reliable Power (FCA-2)
- QP 307 – Biomass Project (FCA-4)

Vermont
- QP 172 – Sheffield Wind Farm (FCA-1)
- QP 224 – Swanton Gas Turbines (FCA-1)

Massachusetts
- QP 077 – Berkshire Wind (FCA-3)
- QP 171 – Thomas A Watson (FCA-1)
- QP 231 – Steam Turbine Capacity Uprate (FCA-3)
- QP 243 – Steam Turbine Capacity Uprate (FCA-3)
- Northfield Mountain Uprate 30 MW (FCA-4)

Rhode Island
- QP 233 – Ridgewood Landfill (FCA-2)

Connecticut
- QP 095 – Kleen Energy (FCA-2)
- QP 125 – Cos Cob 13&14 (FCA-1)
- QP 140 – A.L. Pierce (FCA-1)
- QP 150 – Plainfield Renewable Energy Project (FCA-3)
- QP 161 – Devon 15-18 (FCA-2)
- QP 161 – Middletown 12-15 (FCA-2)
- QP 193 – Ansonia Generation (FCA-1)
- QP 199 – Waterbury Generation (FCA-1)
- QP 206 – Kimberly Clark Energy (FCA-2)
- QP 248 – New Haven Harbor 2-4 (FCA-3)
- QP 289 – Fuel Cell Project in New Haven, CT (FCA-4)
- QP 155.6 – Fuel Cell Project in Fairfield, CT (FCA-4) QP 289 + QP 155.6 = 18 MW

Due to recent issues concerning the operation of the Vermont Yankee Nuclear station in Vernon, Vermont after March 2012, the unit (604 MW) was assumed out of service (OOS) as a base case condition.

In February 2011, the Salem Harbor station, located on the north shore area of Massachusetts, submitted a Non-Price Retirement (NPR) request into the ISO Forward Capacity Market for FCA-5. On May 9, 2011, the ISO presented the NPR determination to the New England Power Pool (NEPOOL) Reliability Committee and as a part of the determination accepted the NPR request for Salem Harbor 1 & 2. The NPR request for Salem Harbor 3 & 4 was rejected by the ISO for reliability. However, on May 11, 2011, Dominion Energy provided notice of its intent to retire the entire Salem Harbor station, units 1, 2, 3, & 4 on June 1, 2014.

At the initiation of the solutions study the Salem Harbor NPR was still being evaluated and thus the Salem Harbor station was assumed in service in the west to east stressed cases. However, an additional retirement scenario with Salem Harbor OOS and an increase in New Brunswick imports to 700 MW was evaluated for the preferred solution.

The results of Forward Capacity Auction #5[19] (FCA-5) for the commitment period of June 1, 2014 to May 31, 2015 were available at the time of finalization of this report. These were not available at the time of the initiation of the solutions study and hence were excluded from the base cases. However, throughout New England a little over 42 MW of new generation cleared the auction. These new generation resources would not have a significant impact on the conclusions from this analysis.

3.2.5 Forecasted Load

A ten-year planning horizon was used for this study based on the most recently available *"2010-2019 Forecast Report of Capacity, Energy, Loads, And Transmission"* (CELT), issued in April 2010[20] at the time the study commenced. This study was focused on the projected 2020[21] peak demand load levels[22] for the ten-year horizon. The models reflected the following peak load condition:

2020 system load level tested:

- The summer peak 90/10 demand forecast of 33,555 MW for New England[23]

The CELT load forecast includes both system demand and losses (transmission & distribution) from the power system. Since power flow modeling programs calculate losses on the transmission system, the actual system load modeled in the case was reduced to account for transmission system losses which are explicitly calculated in the system model. A more detailed report of the loads modeled and

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[19] http://www.iso-ne.com/markets/othrmkts_data/fcm/cal_results/ccp15/fca15/fca5_monthly_ob.xlsx

[20] http://www.iso-ne.com/trans/celt/report/2010/index.html

[21] The 2010 CELT forecast only has projected peak demands for the years 2010 to 2019. To determine the 2020 peak demand forecasted load, the growth rate from years 2018 to 2019 was applied to the 2019 forecast.

[22] To determine if shunt reactors are needed for the preferred plan, a minimum load study will be conducted as a part of the PPA analysis for the preferred solution.

[23] Prior to the completion of this report, the 2011 CELT Report forecast was issued by ISO. The 90/10 summer forecast for 2020 was 33,700 MW which is slightly higher than the 2010 CELT forecast that was extended out to the same demand period of 2020.

how the numbers were derived from the CELT values can be found in Appendix A: 2010 CELT Load Forecast.

Demand Resources (DR) are treated as capacity resources in the forward capacity auctions. Demand Resources are split into two major categories; passive and active. Passive Demand Resources are largely comprised of energy efficiency (EE) programs and are expected to lower the system demand during designated peak hours in the summer and winter. Active demand resources are commonly known as demand side management (DSM) and are dispatchable on a zonal basis if a forecasted or real-time capacity shortage occurs on the system.

As per Attachment K of the ISO OATT, demand resources are modeled in the base case based on the most recent forward capacity auction. When the updated needs assessment was started, the values from FCA-4 were the most recently available values. The values used at that time were carried forward into this solutions study, since the same cases are typically used for both studies.

Starting in 2010, DR values are now published in the CELT report. Because DR was modeled at the low-side of the distribution bus in the power-flow model, all DR values were increased to account for the reduction in losses on the local distribution network. Passive demand resources were modeled by load zone and active demand resources were modeled by dispatch zone. Since active demand resources are only reported by load zone, the following methodology was used to represent active DR by dispatch zone:

$$\mathit{Active\ DR\ in\ Dispatch\ Zone} = \frac{\mathit{CELT\ Load\ in\ Dispatch\ Zone}}{\mathit{CELT\ Load\ in\ Load\ Zone}} \times \mathit{Active\ DR\ in\ Load\ Zone}$$

The 3,023 MW of DR that were modeled in the cases are listed in Table 3-1 and Table 3-2 by load zone and detailed reports can be found in Appendix A: 2010 CELT Load Forecast.

Table 3-1
Assumed FCA-4 Passive DR Values

Load Zone	CELT DRV[24] (MW)
Maine	152
New Hampshire	72
Vermont	97
Northeast Massachusetts & Boston	263
Southeast Massachusetts	140
West Central Massachusetts	150
Rhode Island	85
Connecticut	424
TOTAL	1383

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[24] DRV = Demand Reduction Value: the actual amount of load reduced measured at the customer meter.

[redacted]

Table 3-2
Assumed FCA-4 Active DR Values

Dispatch Zone	CELT DRV (MW)	Dispatch Zone	CELT DRV (MW)
Bangor Hydro	76	**Springfield, MA**	36
Maine	203	**Western Massachusetts**	45
Portland, ME	135	**Lower Southeast Massachusetts**	64
New Hampshire	64	**Southeast Massachusetts**	106
New Hampshire Seacoast	10	**Rhode Island**	77
Northwest Vermont	35	**Eastern Connecticut**	48
Vermont	19	**Northern Connecticut**	63
Boston, MA	212	**Norwalk-Stamford, Connecticut**	70
North Shore Massachusetts	83	**Western Connecticut**	208
Central Massachusetts	86	TOTAL	1640

The results of Forward Capacity Auction #5[25] (FCA-5) for the commitment period of June 1, 2014 to May 31, 2015 became available when this report was being finalized. As per Attachment K, a review was performed to determine if the new auction results would impact the results of the analysis. During this review it was discovered that the level of DR modeled for FCA-4 in the study cases was overstated due to two modeling errors. The first error was a result of using new, qualified DR as opposed to the amount that actually cleared in the auction. The second error was accounting for the losses twice when performing the loss compensation calculation for DR. Both of these errors resulted in lower loads in the case than what should have been used. To assess their impact on the analysis, the new FCA-5 values should be compared to the incorrect lower values used in the cases.

The net impact of the overstated FCA-4 DR when compared to the FCA-5 numbers is provided in Table 3-3. A negative number indicates that FCA-5 DR is higher than the DR modeled in the power flow cases. The fact that the majority of these numbers are positive, and some substantially positive, demonstrate that the needs as originally identified were somewhat understated.

Table 3-3
Comparison of FCA-5 DR and Modeled DR in Power Flow Cases

Study Area	Additional Passive DR Modeled compared to FCA-5 DR (MW)	Additional Active DR Modeled compared to FCA-5 DR (MW)
Eastern New England	-19	197
Western New England	6	46
Connecticut	25	53
Rhode Island	0	-2

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[25] http://www.iso-ne.com/markets/othrmkts_data/fcm/cal_results/ccp15/fca15/fca5_monthly_ob.xlsx

The understated needs would translate to an even earlier year of need for eastern New England import, western New England import and Connecticut import than described in the needs assessment.

[redacted]

Figure 3-1 : Eastern NE, Western NE and Greater RI Subareas

3.2.6 Load Levels Studied

In accordance with ISO planning practices, transmission planning studies utilize the ISO 90/10 forecast assumptions for modeling summer peak load profiles in New England. A summary of the state loads for the two CELT reports in 2010 and 2011 is shown in Table 3-4. For this analysis the 2010 CELT loads were used.

Table 3-4
CELT Load Comparison

State	2020 Load (MW)		Percent Change in Forecasted load
	2010 CELT	2011 CELT	
Maine	2,500	2,515	0.6
New Hampshire	3,080	3,035	-1.5
Vermont	1,255	1,235	-1.6
Massachusetts	15,575	15,740	1.1
Rhode Island	2,300	2,350	2.2
Connecticut	8,840	8,825	-0.2

3.2.7 Load Power Factor

Load power factors consistent with the local transmission owner's planning practices were applied uniformly at each substation and consistent with the MW load level assumed at each substation bus in the power flow model. Power factors for the demand resources were set to match the power factors of the load at each bus in the model.

[redacted]

3.2.8 Transfer Levels

In accordance with the reliability criteria of NERC, NPCC, and the ISO, the regional transmission power grid must be designed for reliable operation during stressed system conditions. Even though a multitude of stressed conditions were tested as a part of the steady state analysis, there were two overall biases modeled: East-West bias and West-East bias. The following external transfer levels were utilized for each of the biases.

- N-1 Analysis
    - New York to New England (AC ties)
        - 0 MW export for East-West bias
        - 0-1,200 MW import for West-East bias
    - Cross Sound Cable
        - 346 MW export to Long Island for East-West bias
        - 0 MW export to Long Island for West-East bias
    - Norwalk-Northport Cable
        - 100 MW export to Long Island for East-West bias
        - 0 MW export to Long Island for West-East bias
    - Highgate HVDC
        - 200 MW import to New England for all cases
    - Phase II HVDC
        - 2,000 MW import to New England for East-West bias
        - 0 MW import to New England for West-East bias
    - New Brunswick to New England
        - 0 MW import for East-West bias
        - 0 MW import for West-East bias
        - 700 MW import for West-East bias with Salem Harbor OOS

- N-1-1 Analysis
    - New York to New England (AC Ties)
        - 0 MW export for East-West bias
        - 0-1,200 MW import for West-East bias
    - Cross Sound Cable
        - 0 MW export to Long Island for all cases
    - Norwalk-Northport Cable
        - 0 MW export to Long Island for all cases
    - Highgate HVDC
        - 200 MW import to New England for all cases
    - Phase II HVDC
        - 2,000 MW import to New England for East-West bias
        - 0 MW import to New England for West-East bias
    - New Brunswick to New England
        - 0 MW import for East-West bias
        - 0 MW import for West-East bias
        - 700 MW import for West-East bias with Salem Harbor OOS

3.2.9 Generation Dispatch Scenarios

The power-flow models used in these analyses were adjusted to incorporate the capacity levels for existing[26] generators that were qualified and new generators that cleared FCA-4. Figure 3-2 identifies the resource additions by New England load zones between FCA-1 and FCA-4. The figure shows that a significant amount of new resources (both new generation and demand resources) have been added to the Connecticut load zone.

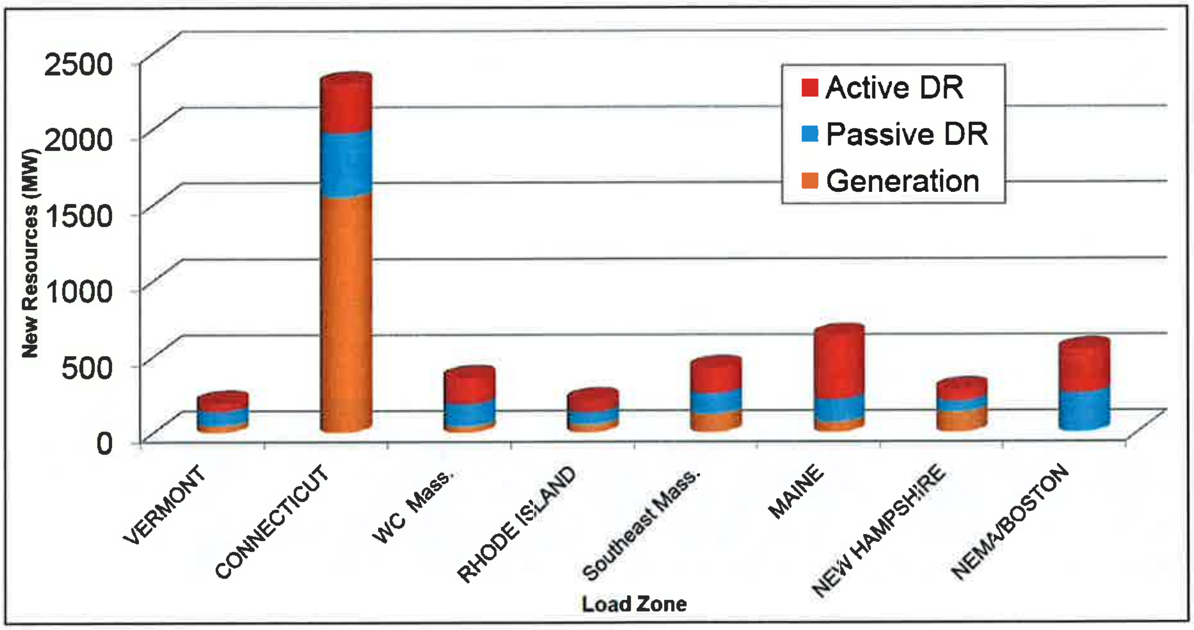

Figure 3-2: Resource Additions between FCA-1 and FCA-4

The outputs used in the study for generating units in New England are listed in the power flow case summary files in Appendix B: Power Flow Base cases. In constructing dispatch conditions for the subarea analyses, the working group considered a number of dispatch scenarios in New England that would have the greatest impact on power flows in the area of study.

Vermont Yankee is a 604 MW nuclear power generating station placed in service in 1972 located along the Connecticut River in Vernon, Vermont. There is significant uncertainty surrounding the continued operation of the plant after March 2012. To ensure that the New England transmission system is sufficiently robust to operate reliably in the event of a permanent shutdown at the station, this unit was considered offline in these analyses.

New England has two major pumped-storage hydroelectric stations, both located in western Massachusetts. Northfield generating station is a four unit 1,110 MW station on the Connecticut River in Northfield, Massachusetts. Bear Swamp generating station is a two unit 580 MW station on the Deerfield River in Rowe, Massachusetts. The base case assumes a reduction of power output of approximately 50% for these two stations. Derating these stations [redacted]

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[26] Existing refers to any generator that has cleared in the previous auction, FCA-4, held in August 2010.

[redacted]

[redacted]

In the case of the eastern New England stressed dispatches both Bear Swamp units were assumed to be available and were turned on. This was done to meet New England load while not over stressing the NY import lines.

Under normal operating conditions, if a large resource were offline, the quick-start resources within the subarea would be dispatched to compensate for lost generation. Due to the infrequent use of the units, they do not always respond when dispatched so an unavailability rate of 20% is assumed for all quick-start resources in the subarea of concern, consistent with current ISO operating practices. For each study area described below where large units are assumed unavailable, approximately 80% of the quick start resources were assumed to be available. The available quick starts were dispatched to their maximum output.

A description of the dispatches for each subarea is detailed in the following sections.

3.2.9.1 Eastern New England

[redacted]

A summary table of resources for the eastern New England analysis is shown in Table 3-5.

Table 3-5
Eastern New England Reliability Analysis Dispatch Assumptions

Resource	Capacity (MW)	Dispatch
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

The interface transfer levels for this dispatch on key interfaces in southern New England are provided in Table 3-6.

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[27] Phase II has a maximum output of 2000 MW. Phase II does not have a qualified capacity since it is not a generating resource.

[28] All other resources in eastern New England were modeled at 100% of their Qualified Capacity. To meet load balance requirements and external transfer levels, some excess generation in western New England was turned off to not violate this requirement.

[redacted]

Table 3-6
Interface Transfer Levels for Eastern New England Reliability Analysis Dispatch

Interface	All-Lines-In Level in 2020 (MW)	Line-out Level in 2020 (MW)
Eastern New England Import	3,009	3,009
New England West-East	1,510	1,510
Connecticut Export	1,343	1,343
North – South	719	719
SEMA/RI Export	2,425	2,425
Boston Import	2,784	2,784

3.2.9.2 Western New England and Connecticut

[redacted]

A summary table of resources for the western New England and Connecticut analysis is shown in Table 3-7.

[redacted]

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[29] Equivalent Demand Forced Outage Rate represents the portion of time a unit is in demand, but is unavailable due to forced outages.

[30] [redacted]

[redacted]

Table 3-7
Western NE and Connecticut Reliability Analysis Dispatch Assumptions

Resource	Capacity (MW)	Dispatch
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

The interface transfer levels for this dispatch on key interfaces in southern New England are provided in Table 3-8.

Table 3-8
Interface Transfer Levels for Western NE and CT Reliability Analysis Dispatch

Interface	All-Lines-In Level in 2020 (MW)	Line-out Level in 2020 (MW)
Western New England Import (New England East-West)	3,308	2,850
Connecticut Import	2,436	1,987
North – South	2,729	2,286
SEMA/RI Export	2,292	2,292
Boston Import	2,678	2,678

3.2.9.3 Rhode Island

[redacted]

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[31] [redacted]

[redacted]

[redacted]

A summary table of resources for the Rhode Island analysis is shown in Table 3-9.

Table 3-9
Rhode Island Reliability Analysis Dispatch Assumptions

Resource	Capacity (MW)	Dispatch
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

The interface transfer levels for this dispatch on key interfaces in southern New England are provided in Table 3-10.

Table 3-10
Interface Transfer Levels for Rhode Island Reliability Analysis Dispatch

Interface	All-Lines-In Level in 2020 (MW)	Line-out Level in 2020 (MW)
Western New England Import (New England East-West)	2,380	2,380
Connecticut Import	1,560	1,560
North – South	2,464	2,464
SEMA/RI Export	2,351	2,351
Boston Import	3,383	3,383

3.2.9.4 Salem Harbor Retirement Scenario

[redacted]

New Brunswick imports were increased to an allowable level which respected the current internal transfer limit from Maine to New Hampshire. A summary table of resources for the eastern New England analysis is shown in Table 3-11.

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[32] [redacted]

Table 3-11
Salem Harbor Retirement Analysis Dispatch Assumptions

Resource	Capacity (MW)	Dispatch
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

The interface transfer levels for this dispatch on key interfaces in southern New England are provided in Table 3-12.

Table 3-12
Interface Transfer Levels for Salem Harbor Retirement Dispatch

Interface	All-Lines-In Level in 2020 (MW)	Line-out Level in 2020 (MW)
Eastern New England Import	3,104	3,104
New England West-East	1,606	1,606
Connecticut Export	1,343	1,343
North – South	1,387	1,387
SEMA/RI Export	2,423	2,423
Boston Import	3,537	3,537

Real-time-emergency-generation (RTEG) cleared in the ISO Forward Capacity Market is typically not included in long-term reliability analyses due to their emissions restrictions and use in only emergency situations.

3.2.10 Reactive Resource and Dispatch

All area shunt reactive resources were assumed available and dispatched when conditions warranted. Reactive output of generating units was modeled to reflect defined limits. A summary of the reactive output of units and shunt devices connected to the transmission system that play a significant role in the study area can be found in the power flow case summaries included in Appendix B: Power Flow Base cases.

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[33] New Brunswick imports were increased until the Maine – New Hampshire interface reached a level of 1700 MW.

[34] [redacted]

[redacted]

3.2.11 Market Solutions Consideration

In accordance with the Attachment K of the OATT, resources that have cleared in the markets were assumed in the model for future planning reliability studies. This included numerous new generating resources cleared in FCA-1 through 4 and demand resources as listed in Section 3.2.4 and Section 3.2.5 respectively.

3.2.12 Demand Resource Availability

Active and passive demand resources, as shown in Section 3.2.5, were modeled for this study. For all analyses, passive demand resources were assumed to be 100% available and are expected to perform to 100% of their cleared amount. For active demand resources, their performance was dependent on which subarea was being studied. The import area assumed that 75% of all active demand resources performed when dispatched and the export area assumed 100% of all active demand resources performed when dispatched, to reflect historical performance of Active DR in the import area. A summary of assumed DR performance is shown in Table 3-13.

Table 3-13
New England Demand Resource Performance Assumptions

Region	Passive DR	Active DR	RTEGs
Import Area	100%	75%	0%
Export Area	100%	100%	0%

3.2.13 Protection and Control System Devices Included in the Study

All existing New England special protection systems (SPSs) and other control schemes are included in these analyses. Some of the relevant devices are listed below:

- [redacted]

Since the Millstone 345 kV circuit separation project will be completed prior to the in-service date of the Interstate project, the [redacted] SPS is assumed retired in this study.

Since the delta P issues at Lake Road were identified in the needs analysis as being a concern [redacted] and each plan will add new transmission into Connecticut, the Lake Road SPS is assumed out of service for the analysis.

3.2.14 Operating Procedures and Other Modeling Assumptions

Not applicable to this study.

3.3 Thermal Transmission Transfer Capability Analysis

According to Section 4 of the ISO PP-3, "The New England bulk power supply system shall be designed with adequate inter-Area and intra-Area transmission transfer capability to minimize system reserve requirements, facilitate transfers, provide emergency backup of supply resources, permit economic interchange of power, and to assure [the system will remain reliable under contingency conditions]."

The transmission transfer capability analysis determines the ability of a region to serve load utilizing resources within the area, as well as imports from neighboring areas. As load grows and if no future resources are placed in service in the region or no additional transmission capability is built to import more power, load cannot be served reliably. The key inputs to this analysis are the load, area resources, and the import limits into an area from surrounding areas.

3.3.1 Study Assumptions

The regional steady state model was developed to be representative of the 5-year projection (2015) of the 90/10 summer peak system demand levels to assess transmission transfer capability under stressed system conditions.

3.3.2 Power Flow Model

The transmission topology and the generator assumptions used for the transfer analysis were consistent with the assumptions used in the steady-state analysis. More details can be found in Section 3.2.3 and Section 3.2.4.

The forecasted summer peak 90/10 demand forecast for the year 2015 is 31,810 MW for New England. Load power factors assumptions were consistent with the steady state analysis.

3.3.3 Demand Resources

Active and passive demand resources cleared as of the FCA-4 auction were modeled for this study. For all analyses, passive demand resources were assumed to be 100% available and are expected to perform to 100% of their cleared amount. For active demand resources, their performance was dependent on which subarea was being studied. The import area assumed that 75% of all active demand resources performed when dispatched and the export area assumed 100% of all active demand resources performed when dispatched, to reflect historical performance of Active DR in the import area. RTEGs were not used in the transfer analysis.

There were two general transfer analyses run: East-West analysis and West-East analysis. The East-West analysis was done to capture CT import and Western NE (subarea) import limits. The West-East analysis was done to capture Eastern NE (subarea) import limits. The active DR assumptions for each subarea are provided in Table 3-14.

Table 3-14
Active DR Assumptions for Transmission Transfer Capability Analysis

Region	Active DR in Western NE Subarea	Active DR in Greater RI Subarea	Active DR in Eastern NE Subarea
East-West Analysis	75%	100%	100%
West-East Analysis	100%	100%	75%

3.3.4 Generation Dispatch Scenarios

Four base case dispatch scenarios were developed, two for East-West interface transfer analyses and two for West-East interface transfer analyses.

[redacted]

To determine a transfer limit, the Siemens PTI program Managing and Utilizing System Transmission (MUST) was used to increase transfers in the network model until a transmission element becomes overloaded in the base case or after a contingency event. To increase transfer levels in a case, a set of generators in the sending region of the transfer (the source) are increased and at the same time a set of generators in the receiving region of the transfer (the sink) are decreased. Testing was performed under all-lines-in and line-out conditions. The transfer level at which an element becomes overloaded is determined to be the transfer limit. The generators in the sources and sinks were adjusted up or down based on their maximum machine capability.

A description of the base cases and source/sink compositions for each transfer is detailed in the following sections.

3.3.4.1 East-West Thermal Transfer Analysis

The East-West analysis was conducted to determine the East-West interface limits (N-1 and N-1-1) and the Connecticut import limits (N-1 and N-1-1) for each Interstate option. To simultaneously determine both limits the transfer was established so that the source would be to the east of the East-West interface and the sink would be inside the Connecticut import interface. Thus, a single MW flowing from source to sink would flow through both the East-West and CT import interfaces.

The same sink was used for all four transfers tested. The sink is comprised of the units described in Table 3-15. All these units are turned on in the base case. As East-West and Connecticut import transfer levels increase these units are ramped down in the ratio of their maximum outputs.

Table 3-15
Connecticut Sink Composition

Units in Sink	Ramp-down Capability (MW)	Units in Sink	Ramp-down Capability (MW)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		

Two different sources are used for this analysis: southeast Massachusetts (SEMA) / Boston generation and Maine / New Hampshire (ME/NH) generation. The units considered in each source are described in Table 3-16 and Table 3-17. For the base case used as the starting point to test the transfer from SEMA / Boston to Connecticut the SEMA / Boston source units are kept at low output levels. For the base case used as the starting point to test the transfer from Maine/New Hampshire to Connecticut the Maine/New Hampshire source units are kept at low output levels.

[redacted]

Table 3-16
SEMA / Boston Source Composition

Units in Source	Ramp-up Capability (MW)	Units in Source	Ramp-up Capability (MW)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table 3-17
ME / NH Source Composition

Units in Source	Ramp-up Capability (MW)	Units in Source	Ramp-up Capability (MW)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

For each directional stress, namely SEMA / Boston to Connecticut and ME / NH to Connecticut, two dispatch conditions were tested. One dispatch assumed Millstone 3 OOS and the other dispatch assumed the Lake Road generating station OOS. The detailed dispatches for each of the base cases, before adding any Interstate option, are provided in Appendix B: Power Flow Base cases.

In summary for the East-West analysis the following cases were run:

- Lake Road station OOS: SEMA / Boston to Connecticut
- Lake Road station OOS: ME /NH to Connecticut
- Millstone 3 OOS: SEMA / Boston to Connecticut
- Millstone 3 OOS: ME / NH to Connecticut

3.3.4.2 West-East Thermal Transfer Analysis

The West-East analysis was conducted to determine the eastern New England import limits (N-1 and N-1-1) for each Interstate option. To simultaneously determine both limits the transfer was established so that the source would be to the west of the West-East interface and the sink would be inside the eastern New England import interface. Thus, a single MW flowing from source to sink would flow through both the West-East and eastern New England import interface.

The pre-Interstate eastern New England import interface is defined by the transmission elements in Table 3-18.

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[35] Unit did not clear FCA 1-4, but was used since there was resource inadequacy to stress the East-West interface to its limit.

Table 3-18
Eastern NE Import Interface

Element	kV	From	To
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

The same sink was used for all four transfers tested. The sink was comprised of the units described in Table 3-19. All these units are turned on in the base case. As West-East and eastern New England import levels increase these units are ramped down in the ratio of their maximum outputs.

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[36] [redacted]

[redacted]

Table 3-19
Eastern New England Sink Composition

Units in Sink	Ramp-down Capability (MW)	Units in Sink	Ramp-down Capability (MW)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		

Two different sources were used for this analysis with the only distinction between the two sources being the inclusion of the Lake Road generating station. The Lake Road station was at low output level in all the base cases used as the starting point to test the transfer but was included in one of the sources and excluded from the other. The Lake Road generating station is a 750 MW plant located very close to the West-East interface and was seen to have a significant impact on West-East transfers in the updated needs analysis. The other generating units utilized as sources in this transfer analysis are provided in Table 3-20.

Table 3-20
Source Composition for Western New England Sources

Units in Source	Ramp-up Capability (MW)	Units in Source	Ramp-up Capability (MW)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

For each of the two source-sink combinations, two dispatch conditions were tested. One dispatch assumed Phase II HVDC facility OOS and the other dispatch assumed the Mystic generating station OOS. Both dispatches took approximately 2000 MW of resources OOS in eastern NE. The detailed dispatches for each of the base cases, before adding any Interstate option, are provided in Appendix B: Power Flow Base cases.

In summary for the West-East analysis the following cases were run:

- Phase II HVDC OOS: Western NE to Eastern NE – Lake Road participating in source
- Phase II HVDC OOS: Western NE to Eastern NE – Lake Road excluded from source
- Mystic station OOS: Western NE to Eastern NE – Lake Road participating in source
- Mystic station OOS: Western NE to Eastern NE – Lake Road excluded from source

[redacted]

3.4 Stability Analysis

The addition of new transmission elements as a part of the different Interstate options and the resultant increased regional transfer levels may cause some stability criteria violations. The stability analysis performed for each Interstate option was restricted to being a screening analysis to determine potential stability issues for a few major 345 kV system faults in the study area.

In addition to the screening analysis involving key 345 kV faults, once a preferred option was determined an assessment of the impact of extreme contingencies and limited testing of Bulk Power System (BPS) classification of stations in the vicinity of the proposed upgrades was conducted.

Stability requirements include the assessment of extreme contingencies, which are more severe than normal contingencies and have a lower probability of occurrence. The performance of the power system to these contingency events is intended to be a measure of the system's robustness and ability to withstand such severe events without grid collapse or propagation outside of the New England region. The extreme contingency testing included modeling a permanent 3-phase fault on a transmission circuit with delayed fault clearing which could be due to circuit breaker, relay system, or signal channel malfunction.

A more detailed stability analysis will be performed as part of the PPA analysis for the preferred solution. This analysis will include a detailed assessment of normal contingencies, extreme contingencies and BPS testing.

3.4.1 Study Assumptions

The stability models used as part of this analysis were developed to be representative of the near term projection of a light load system demand level to assess the dynamic performance of the power system under stressed system conditions. The model assumptions included consideration of surrounding area regional interface transfer levels. These study assumptions are consistent with PP-3.

The starting base case for the analysis was the 2015 light load case from the 2010 Multiregional Modeling Working Group (MMWG) Base Case library. The MMWG is a part of the Eastern Interconnection Reliability Assessment Group (ERAG).

3.4.2 Load Level Studied

This transient stability study was performed at light load levels. The normal contingency testing was performed at a 2015 light load (45% of 50/50 peak load) New England load and losses representation of approximately 13,700 MW.

The extreme contingency testing and BPS testing was performed at a 2016 light load level of approximately 14,200 MW.

3.4.3 Load Models

The load models used when performing dynamic simulations for New England include 100% constant conductance for the real component and 100% constant susceptance for the imaginary component of the admittance, consistent with New England practices for stability modeling.

[redacted]

3.4.4 Dynamic Models

The dynamic models are captured in the snapshot file from the MMWG Base Case libraries. The normal testing corresponds with the 2015 light load cases from the 2009 MMWG Base Case library.

The EC testing and BPS testing corresponds to the 2016 light load cases from the 2010 MMWG Base Case library.

3.4.5 Transfer Levels

In this analysis, two major interface transfer scenarios were analyzed:

- High New England East – West transfer scenario
- High New England West – East transfer scenario

For the screening analysis of all Interstate options with the 345 kV faults, New England East-West and West-East transfer levels were stressed based on the results of the higher limit of the range of transfer levels determined as a part of the thermal transmission transfer capability analysis described in Section 3.3.

Power flows on other key interfaces are listed in Section 3.4.5.1 and Section 3.4.5.2. Further details on dispatches and transfers are provided in the power flow case summary in Appendix B: Power Flow Base cases.

3.4.5.1 All-Lines-In Stability Testing

This testing was performed for all the Interstate options.
Key interface transfer levels under high East-West transfer scenario:

- New England East - West interface: High limit of the East-West all-lines-in limit obtained in the transmission transfer capability analysis.
- 1,200 MW transfer on NE-NY Interface from New England to New York.

Key interface transfer levels under high West- East transfer scenario:

- New England West - East interface: High limit of the West-East all-lines-in limit obtained in the transmission transfer capability analysis.
- 1,200 MW transfer on NY-NE Interface from New York to New England.

3.4.5.2 Line-out Stability Testing

This testing was performed for all the Interstate options. Some preliminary stability analysis was performed for the pre-Interstate at high East-West and West-East transfer levels. The results did not demonstrate any criteria violations at the higher transfers. Hence, for the stability testing of the Interstate alternatives, the line-out testing was performed at the same levels utilized for the all-lines-in testing. If criteria violations are found the interface levels may be backed down to the higher limit of the thermal line-out transfer analysis.

Key interface transfer levels under high East-West transfer scenario:

- New England East - West interface: High limit of the East-West all-lines-in limit obtained in the transmission transfer capability analysis.
- 1,200 MW transfer on New England to New York Interface.

Key interface transfer levels under high West- East transfer scenario:

- New England West - East interface: High limit of the West-East all-lines-in limit obtained in the transmission transfer capability analysis.
- 1,200 MW transfer on New York to New England Interface.
  A summary of the interface transfer levels used for the stability screening analysis is provided in Appendix B: Power Flow Base cases.
  The other transfer levels are provided in Table 3-21 below:

Table 3-21
Interface Transfer Levels for All-lines-In and Line-out Stability Testing

Interface	Levels for East-West Stress (MW)	Levels for West-East Stress (MW)
New England East-West	4,115	-2,037
Connecticut Import	497	-671
New England West-East	-3,201	2,925
North – South	2,518	1,406
Eastern New England Import	-861	4,092
SEMA/RI Export	4,223	671
Boston Import	2,021	2,619
Maine – NH	1,346	1,398
New York – New England	-1,205	1,195

3.4.5.3 Extreme Contingency Testing

This testing was only performed for the preferred Interstate option. The majority of the extreme contingency testing was restricted to 345 kV stations. Based on historic performance under extreme contingencies two scenarios were set up:

- High East-West Stress with high Northern transfers and high SEMA/RI export
- High West-East Stress

In the 2008 PPA analysis for the Interstate Reliability Project the Woonsocket substation in Rhode Island was identified to have criteria violations as a part of the 115 kV Extreme Contingency (EC) testing. Thus, in addition to the 345 kV testing the Woonsocket substation was tested for extreme contingencies. For this testing the high East-West stress dispatch was utilized with all local generation in Rhode Island turned on.

The transfer levels on the different interfaces for these dispatches are provided in Table 3-22.

Table 3-22
Interface Transfer Levels for Extreme Contingency Testing

Interface	Levels for East-West Stress with high SEMA/RI export (MW)	Levels for East-West Stress high SEMA/RI export and local RI Generation online (MW)	Levels for West-East Stress (MW)
New England East-West	3,511	3,537	-1,385
Connecticut Import	656	663	-1,326
New England West-East	-3,505	-3,531	2,283
North – South	2,968	2,968	778
Eastern NE Import	-660	453	4,178
SEMA/RI Export	2,798	3,627	1,555
Boston Import	2,111	2,421	2,670
Maine – NH	1,614	1,609	971
New York – New England	-1,196	-1,220	-29

3.4.5.4 BPS Testing

[redacted]

[redacted]

[redacted]

In summary, two dispatches were set up for the BPS testing, one for the substations in Rhode Island and one for the substations in Connecticut. The details of the two dispatches are provided in Table 3-23.

Table 3-23
Interface Transfer Levels for BPS Testing

Interface	Levels for RI BPS Testing (MW)	Levels for CT BPS Testing (MW)
New England East-West	3,537	1,683
Connecticut Import	663	-1,145
New England West-East	-3,531	-773
North – South	2,968	2,129
Eastern NE Import	453	1,322
SEMA/RI Export	3,627	2,135
Boston Import	2,421	2,103
Maine – NH	1,609	1,615
New York – New England	-1,220	-1,199

3.4.6 Generation Dispatch Scenarios

The generation dispatch scenarios incorporate the common practice of turning on a significant amount of local area generation to stress the specific interface transfer levels. The major transfer levels used in these analyses are listed in section 3.4.5, while details can be found in the power flow case summary contained in Appendix B: Power Flow Base cases.

For the BPS testing, the case for testing Rhode Island substations had all Rhode Island generation online and the case for testing the Connecticut substations had all local generation in Connecticut online.

3.4.7 Reactive Resources Dispatch

Load power factors consistent with the local transmission owner's planning practices were applied uniformly at each substation and consistent with the MW load level assumed at each power flow model substation bus. The base cases assume all reactive resources are available.

3.4.8 Explanation of Operating Procedures and Other Modeling Assumptions

Not applicable for this study.

3.5 Short Circuit Model

Short circuit tests are conducted at 345 kV stations within the study area to determine the changes in the magnitude of the fault current levels as a result of proposed transmission system modifications. System upgrades, modifications and configuration changes to the transmission system's topology can alter fault current levels by reducing system impedance within the area. Reductions in system impedance result in higher fault current levels that can reach or exceed the interrupting capability of a circuit breaker or exceed the withstand capabilities of substation equipment.

The short circuit assessment performed as a part of the solutions study serves as a screening tool to determine the relative impact of each alternative on the interrupting current levels at area 345 kV

[redacted]

stations in the study area. The analysis was done using PSS/E with only the positive sequence model for facilities.

3.5.1 Study Assumptions

This analysis was performed using the positive sequence model as established in the power flow. Since only a positive sequence model was utilized the testing was restricted to three-phase balanced faults. The testing of unbalanced faults will be carried out as a part of the Proposed Plan Application analysis for the preferred solution.

3.5.2 Short Circuit Model

The power flow study cases used in this part of the study are the same as that used for the transmission transfer capability analysis described above in Section 3.3.2. The power flow model was representative of the 5-year projection (2015) of the 90/10 summer peak system demand. Transmission projects with PPA approval were included in the study base case.

Since the power flow model is used for the analysis, the detailed breaker configurations and breaker interrupting capabilities are not modeled. The analysis is therefore restricted to determining bus fault currents for three-phase symmetrical faults.

In addition the PSS/E analysis computes the instantaneous current. This calculation does not take into consideration the effects of X/R (which decays the current) and excludes the DC offset (which increases the short circuit current). Therefore the short circuit currents obtained through this analysis may be different than the values obtained through a detailed short circuit analysis.

3.5.3 Contributing Generation Assumptions

Generation resources that represent either an existing generating unit or a project that has cleared FCA 1-4 were modeled and included in the study base case.

Consistent with ISO planning practices, all PPA approved generators should be included in the short circuit model but since the intent of this analysis was to determine relative impact of each alternative on area 345 kV substations in the study area, the PPA approved generators that have not cleared the forward capacity auctions were excluded. However, the short circuit analysis that will be conducted as a part of the PPA analysis for the preferred solution will include the PPA approved generators that have not cleared the FCAs.

3.5.4 Generation and Transmission System Configurations

The short circuit screening analysis was performed with all transmission facilities in service. Since the intent of this analysis was to determine the relative impact of each option at the various substations, and not necessarily determine the short circuit levels, not all generation resources in New England were turned online. However, all major area resources in Connecticut, Rhode Island, Central Massachusetts and Southeast Massachusetts that would have a significant impact on the 345 kV substations tested were dispatched. A summary of the generation dispatch scenario is contained in Appendix B: Power Flow Base cases.

3.5.5 Boundaries

The testing was restricted to area 345 kV transmission stations in the vicinity of the new lines proposed in each option tested. The West Medway substation was excluded from this analysis because the short circuit needs assessment done by the Greater Boston working group identified the West Medway station as close to being overdutied after the originally planned NEEWS projects. Since the West Medway substation is an integral substation for the SEMA/RI area, the needs and solutions for its short circuit issues will be addressed by the SEMA/RI working group.

3.5.6 Other Relevant Modeling Assumptions

Not applicable for this study.

3.6 Other System Studies

In addition to the analyses discussed in Section 3.2 through 3.5, this solution study includes delta P analyses on relevant generating stations in the local area. The objective of this analysis was to investigate the torsional impact, known as delta P, on the mechanical equipment associated with a generator's shaft. Delta P is a measure of the sudden change in electrical power output on a generator due to transmission switching which causes mechanical stresses on the generator shaft and associated equipment. The opening of an area 345 kV transmission circuit can initiate a significant redistribution of power flows on the transmission system near the point the generating station interconnects to the transmission grid. Re-closing of the 345 kV transmission line can initiate a large and sudden change in electrical power on the generator which can result in excessive torsional torque on the machine's shaft and associated equipment.

3.6.1 Data Sources and Assumptions

Delta P issues are aggravated by large flows across transmission lines. The delta P analyses were performed utilizing a peak load base case. The power flow case used in these analyses models the 90/10 2015 summer peak load levels. All the transmission and generation assumptions utilized in Section 3.2, for the steady state analysis, were used for this analysis.

Two dispatches were created for the delta P testing. [redacted] The power flow summaries for these cases are contained in Appendix B: Power Flow Base cases.

3.6.2 Assumptions Used in the Analysis

[redacted]

Regional transmission interface transfer levels were stressed based on the results of the import limits determined as a part of the transmission transfer capability analysis described in Section 3.3. New England East-West interface transfer levels and New England West-East interface transfer levels are set to the higher end limits of the ranges determined in Section 3.3.

[redacted]

[redacted]

- [redacted]
- [redacted]

The units tested and their different ratings are provided in Table 3-24. If a unit is turned on for the analysis it is always dispatched to its maximum rating.

Table 3-24
Qualified Capacities and Greater than 50 Degree Ratings of Units Tested

Unit	Qualified Capacity (MW)	Greater than 50 Degree Rating (MW)
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

3.6.3 Other Relevant Assumptions

Not applicable for this study.

3.7 Changes in Study Assumptions

Not applicable for this study.

Section 4
Analysis Methodology

4.1 Planning Standards and Criteria

The applicable NERC, NPCC and ISO standards and criteria were the basis of this evaluation. A description of each of the NERC, NPCC and ISO standard tests that were included in all studies used to assess system performance are discussed later in this section.

4.2 Performance Criteria

4.2.1 Steady State

The solutions study was performed in accordance with NERC TPL-001, TPL-002 and TPL-003 Transmission System Standards, NPCC Regional Reliability Reference Directory #1, *Design and Operation of Bulk Power System,* and ISO PP-3.

4.2.1.1 Steady State Thermal and Voltage Limits

Loadings on all transmission facilities rated at 69 kV and above in the study area were monitored. The thermal violation screening criteria defined in Table 4-1 were applied.

Table 4-1
Steady State Thermal Criteria

System Condition	Maximum Allowable Facility Loading
Normal (all lines-in) (Pre-Contingency)	Normal Rating
Emergency (Post-Contingency)	Long Time Emergency (LTE) Rating

Voltages were monitored at all buses with voltages of 69 kV and above in the study area. System bus voltages outside of limits identified in Table 4-2 were identified for all normal (pre-contingency) and emergency (post-contingency) conditions.

Table 4-2
Steady State Voltage Criteria

Transmission Owner	Voltage Level	Bus Voltage Limits (Per-Unit)	
		Normal Conditions (Pre-Contingency)	Emergency Conditions (Post-Contingency)
Northeast Utilities	230 kV and above	0.98 to 1.05	0.95 to 1.05
	115 kV and below	0.95 to 1.05	0.95 to 1.05
National Grid	230 kV and above	0.98 to 1.05	0.95 to 1.05
	115 kV and below	0.95 to 1.05	0.90[37] to 1.05
NSTAR	230 kV and above	0.95 to 1.05	0.95 to 1.05
	115 kV and below	0.95 to 1.05	0.95 to 1.05
United Illuminating	230 kV and above	0.95 to 1.05	0.95 to 1.05
	115 kV and below	0.95 to 1.05	0.95 to 1.05
Millstone / Seabrook[38]	[redacted]	[redacted]	[redacted]
Pilgrim[38]	[redacted]	[redacted]	[redacted]
Vermont Yankee[38]	[redacted]	[redacted]	[redacted]

4.2.1.2 Steady State Solution Parameters

The steady state analysis was performed with pre-contingency solution parameters that allow adjustment of load tap-changing transformers (LTCs), static VAR devices (SVDs) including automatically-switched capacitors and phase angle regulators (PARs). Post-contingency solution parameters only allow adjustment of LTCs and SVDs. Table 4-3 displays these solution parameters.

Table 4-3
Study Solution Parameters

Case	Area Interchange	Transformer LTCs	Phase Angle Regulators	SVDs & Switched Shunts
Base	Tie Lines Regulating	Stepping	Regulating or Statically Set	Regulating
Contingency	Disabled	Stepping	Disabled	Regulating

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[37] This applies to non-BPS (Bulk Power System) designated substations. BPS stations must be greater than or equal to 0.95 p.u. post contingency.

[38] This is in compliance with NUC-001-2, *"Nuclear Plant Interface Coordination Reliability Standard,"* adopted on August 5, 2009.

4.2.2 Thermal Transfer Capability

The analysis was performed using a DC power flow and hence the results were restricted to thermal transfer limits. For each transfer level between source and sink all the contingencies were applied to the system and the most restrictive contingency and line overload determined the transfer limit.

4.2.3 Stability Performance

All stability testing was in accordance with ISO PP-3.

The criteria for normal contingencies (NC's) are as follows:

- All generating units must remain transiently stable.
- Generating units are allowed to be tripped offline but only as part of the fault clearing.
- A 53% reduction in the magnitude of system oscillations observed over the last four periods of the oscillation.

NEPOOL has developed metrics that are used to determine if system performance to extreme contingency events are acceptable. The following criteria define stable system performance:

- A 53% reduction in the magnitude of system oscillations observed over the last four periods of the oscillation.
- Loss of generation resources not greater that 1,400 MW.
- A loss of generation resources between 1,400 and 2,200 MW may be acceptable depending upon the likelihood of occurrence among other technical factors.

The following system performance behaviors are considered unacceptable and must be addressed and corrected.

- Transient unstable with wide-spread system collapse.
- Transiently unstable with under-damped or sustained power system oscillations
- A loss of generation resources greater than 2,200 MW

The criteria for the BPS testing are consistent with NPCC Directory A-10[39]. The criteria for BPS determination are as follows:

- A 53% reduction in the magnitude of system oscillations within four oscillation periods, measuring from the point in the simulation where only one oscillation mode remains present.
- No tripping of any generator outside New England, except for tripped units local to the fault.
- No system separation.
- Loss of source no greater than 1,200 MW (note that loss of synchronism any New England unit is acceptable as long as the total source loss is no greater than 1,200 MW).

4.2.4 Short Circuit Performance

The bus fault current calculated for each station tested is compared to the lowest-rated 345 kV circuit breaker at that station. The percentage increase in fault currents with respect to the interrupting capability of this bus breaker is used to gauge the relative impact of each plan at that station.

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[39] https://www.npcc.org/Standards/Criteria/A-10.pdf

[redacted]

4.2.5 Delta P

The objective of this analysis is to investigate the torsional impact, known as delta P, on a generator. Delta P is a measure of the sudden change in the electrical power output of a generator due to transmission switching which can cause damaging mechanical stresses on the generator shaft and associated equipment. The maximum recommended value for delta P is 0.5[40].

4.3 System Testing

4.3.1 Steady State Contingencies

Each base case was subjected to single element contingencies such as the loss of a transmission circuit or an autotransformer and contingencies which may cause the loss of multiple transmission circuit facilities, such as those on a common set of tower line structures, circuit breaker failures and substation bus faults. A comprehensive set of contingency events, listed in Appendix C: Contingency List, were tested to monitor thermal and voltage performance of the New England transmission system for all the Interstate options. The contingencies listed in Appendix C: Contingency List, are common contingencies that were tested as a part of the updated needs analysis. With the addition of different plans some of these contingencies were eliminated and other new contingencies were added. These will be described when the different plans are introduced in Section 5.4.

Table 4-4 provides a summary of NERC, NPCC and ISO contingency events by category.

Table 4-4
Summary of NERC, NPCC and/or ISO Category Contingencies Tested

Contingency Type	NERC Type	NPCC D-1 Section	ISO PP-3 Section	Tested
All Facilities in Service	A	5.4.2.b	3.2.b	Yes
Generator (Single Unit)	B1	5.4.1.a	3.1.a	Yes
Transmission Circuit	B2	5.4.1.a	3.1.a	Yes
Transformers	B3	5.4.1.a	3.1.a	Yes
Loss of an Element Without a Fault	B	5.4.1.d	3.1.d	Yes
Bus Section	C1	5.4.1.a	3.1.a	Yes
Breaker Failure	C2	5.4.1.e	3.1.e	Yes
Double Circuit Tower	C5	5.4.1.b	3.1.b	Yes
Extreme Contingencies	D	5.6	6	No[41]

Additional analyses evaluated N-1-1 conditions with an initial outage of a key transmission circuit followed by another contingency event. The N-1-1 analyses examined the summer peak load case with stressed conditions. For these N-1-1 cases, regional reliability standards, including ISO PP3,

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[40] "IEEE Screening Guide for Planned Steady-State Switching Operations to Minimize Harmful Effects on Steam Turbine-Generators", IEEE Working Group, 1980.

[41] Limited extreme contingency analysis was conducted as a part of the needs assessment, but no criteria violations were found for these contingencies. As a part of the PPA analysis for the preferred solution further extreme contingency testing will be evaluated.

allow specific manual system adjustments, such as quick start generation re-dispatch, phase-angle regulator adjustment or HVDC adjustments prior to the next single contingency event. A listing of all contingency events tested is provided in Appendix C: Contingency List. A listing of the line-out scenarios that were tested are provided in Table 4-5.

Table 4-5
N-1-1 Line-Out Scenarios

Element Name	kV	Description	E→W	W→E	RI
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]			[redacted]
[redacted]	[redacted]	[redacted]			[redacted]
[redacted]	[redacted]	[redacted]			[redacted]
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]		[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]		[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]			[redacted]
[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]		[redacted]	

The above list of line-outs was tested for all options considered. In addition to these line-outs, the new lines being added in each Interstate option were also considered as initial elements out in the N-1-1 analysis. These new elements will be discussed when the different options are introduced in Section 5.4.

4.3.2 Thermal Transfer Capability

Testing was performed under all-lines-in and line-out conditions. For the purposes of this study, only critical lines affecting the East-West and West-East interface were considered in determining the line-out transfer limits.

The contingencies used for the steady-state analysis in Section 4.3.1 were used for this analysis For each source-sink combination, the line-out conditions described in Table 4-6 were analyzed.

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[42] [redacted]

[redacted]

Table 4-6
Initial Element out for Transfer Analysis

Element Name	kV	Description	E→W	W→E
[redacted]		[redacted]	[redacted]	[redacted]
[redacted]		[redacted]		[redacted]
[redacted]		[redacted]		[redacted]
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]		[redacted]
[redacted]		[redacted]	[redacted]	[redacted]
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]	[redacted]	[redacted]
[redacted]		[redacted]		[redacted]
[redacted]		[redacted]		[redacted]
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]	[redacted]	[redacted]
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]		
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]		[redacted]
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]	[redacted]	
[redacted]		[redacted]	[redacted]	[redacted]
[redacted]		[redacted]	[redacted]	[redacted]
[redacted]		[redacted]	[redacted]	[redacted]
[redacted]		[redacted]		[redacted]

The above list of line-outs was tested for all options considered. In addition to these line-outs, the new lines being added in each Interstate option were also considered as initial elements out in the N-1-1 analysis. These new elements will be discussed when the different options are introduced in Section 5.4.

The second level contingency events were the same contingencies that were used for the N-1 transfer analysis.

4.3.3 Stability Contingencies / Faults

Studies were performed for all-lines-in and critical line-out conditions for all the Interstate options. The initial elements considered out of service in the line-out stability analysis are provided in Table 4-7.

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[43] [redacted]

[redacted]

Table 4-7
Initial Elements out for Line-out Stability Analysis

Element Name	kV	Description	E→W	W→E
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The stability testing that was conducted on all the Interstate options consisted of only three-phase normally cleared faults. Some critical extreme contingency conditions were evaluated for the preferred Interstate option. The testing was restricted to major 345 kV stations in the study area. A list of the normal stability contingencies (CTGs) tested is provided in Table 4-8.

The normal contingency testing performed included only three-phase faults with normal clearing because on the 345 kV system these contingency events typically pose a more severe stress on the power system compared to single-phase to ground faults with delayed clearing.

Extreme contingencies (ECs) were tested at the following stations:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

The extreme contingencies tested are provided in Table 4-9. In addition to these ECs the testing was also performed for ECs at the [redacted] Extreme contingencies at [redacted] were seen to have an issue in the 2008 NEEWS PPA analysis and hence were reevaluated for the preferred solution as a part of the 2011 analysis.

In addition to the normal and extreme contingency testing, BPS testing was conducted for the preferred alternatives at select substations in Connecticut and Rhode Island. The substations in CT and RI at which the BPS testing was conducted are provided in Table 4-10.

Table 4-8
Summary of 345 kV NC Stability Contingencies

Fault #	Fault Location	ID	Fault Type	NERC CTG Type	Stuck Breaker	Fault Description	Fault Clearing Time # cycles @ Substn
1	[redacted]	NC1	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
2	[redacted]	NC2	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
3	[redacted]	NC3	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
4	[redacted]	NC4	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
5	[redacted]	NC5	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
6	[redacted]	NC6	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
7	[redacted]	NC7	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
8	[redacted]	NC8[44]	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
9	[redacted]	NC9	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
10	[redacted]	NC10	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
11	[redacted]	NC11	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
12	[redacted]	NC12	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
13	[redacted]	NC13	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
14	[redacted]	NC14	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
15	[redacted]	NC15	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
16	[redacted]	NC16	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
17	[redacted]	NC17	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
18	[redacted]	NC18	Close in 3ØG	B	[redacted]	[redacted]	[redacted]
19	[redacted]	NC19	Close in 3ØG	B	[redacted]	[redacted]	[redacted]

---

[44] [redacted]

[redacted]

The testing of the extreme contingencies provided in Table 4-9 was done for the preferred Interstate option.

Table 4-9
Summary of 345 kV EC Stability Contingencies

Fault #	Fault Location	ID	Fault Type	NERC CTG Type	Stuck Breaker	Fault Description	Fault Clearing Time # cycles @ Substn
1	[redacted]	EC1	Close in 3ØG[45]	D	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	EC2	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
3	[redacted]	EC3	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
4	[redacted]	EC4	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
5	[redacted]	EC5	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
6	[redacted]	EC6	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
7	[redacted]	EC7	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
8	[redacted]	EC8	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
9	[redacted]	EC9	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
10	[redacted]	EC10	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
11	[redacted]	EC11	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
12	[redacted]	EC12	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
13	[redacted]	EC13	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
14	[redacted]	EC14	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
15	[redacted]	EC15	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
16	[redacted]	EC16	Close in 3ØG	D	[redacted]	[redacted]	[redacted]

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[45] [redacted]

[46] [redacted]

[47] [redacted]

[48] [redacted]

[redacted]

Fault #	Fault Location	ID	Fault Type	NERC CTG Type	Stuck Breaker	Fault Description	Fault Clearing Time # cycles @ Substn
17	[redacted]	EC17	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
18	[redacted]	EC18	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
19	[redacted]	EC19	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
20	[redacted]	EC20	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
21	[redacted]	EC21	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
22	[redacted]	EC22	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
23	[redacted]	EC23	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
24	[redacted]	EC24	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
25	[redacted]	EC25	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
26	[redacted]	EC26	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
27	[redacted]	EC27	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
28	[redacted]	EC28	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
29	[redacted]	EC29	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
30	[redacted]	EC30	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
31	[redacted]	EC31	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
32	[redacted]	EC32	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
33	[redacted]	EC33	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
34	[redacted]	EC34	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
35	[redacted]	EC35	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
36	[redacted]	EC36	Close in 3ØG	D	[redacted]	[redacted]	[redacted]
37	[redacted]	EC37	Close in 3ØG	D	[redacted]	[redacted]	[redacted]

[redacted]

Table 4-10
Substations Included for BPS Testing

115 kV Substation	State	115 kV Substation	State
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		

4.3.4 Bus Faults for Short Circuit Analysis

Table 4-11 contains a listing of the 345 kV stations where short circuit testing was performed.

Table 4-11
Summary of Stations for Short Circuit Testing

345 kV Substation	State	345 kV Substation	State
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

4.3.5 Delta P Analysis

This analysis is primarily concerned with the [redacted] Generating stations because of their electrical interconnection locations on the transmission system. [redacted]

4.3.5.1 [redacted]

The analysis performed evaluated the delta P for two sets of regional interface transfer levels. Three contingency events listed below were tested for all cases:

1. [redacted]
2.
3.

4.3.5.2 [redacted]

Two contingency events listed below were tested for all cases:

1. [redacted]
2.

Section 5
Development of Alternative Solutions

5.1 Preliminary Screen of Alternative Solutions

The 2008 Options Analysis identified five options as meeting the basic performance requirements that had been identified in the 2008 Needs Analysis for the Interstate component of NEEWS – which strengthens the ties between the southern New England states and increases the ability to move power between eastern and western New England. The original five options were designed to address the following needs:

- Improve the capability to transfer power into and within the following load centers in southern New England:
    - Connecticut
    - Rhode Island
    - Western New England
- Increase East – West and Connecticut import interface transfer capability
- Eliminate projected transmission line overloads under contingency conditions

As designed the alternatives were then evaluated for their potential to improve the reliability and performance of the New England transmission system, using the following performance comparison factors:

- Improve system voltages and decrease system losses
- Expand the 345 kV transmission network to increase transfer capability across Southern New England.
- Enhance generator operating flexibility (limit use of special protection systems)
- Maximize New England transmission system operating flexibility
- Ensure consistency with the long term plan for future system expandability and flexibility of the New England power grid

The 2011 Updated Needs Assessment, once again identified the same system requirements in the planning horizon as the 2008 Needs Analysis. In addition, the previously unrecognized need for additional transfer capability to reliably move power from west to east across the New England West-East interface into eastern New England was identified.

Accordingly, the working group considered whether the previously rejected Interstate alternatives could be adapted to serve the updated needs identified. The working group accordingly revisited the five options that had been identified in the 2008 Options Analysis in order to identify the best candidates for meeting the enhanced need identified in the updated needs analysis.

5.2 Coordination of Solutions with Other Area Studies

The working group coordinated the updated needs analysis with the analyses being performed at the same time by the Greater Boston working group, New Hampshire / Vermont working group and Greater Hartford and Central Connecticut working group. This coordination was to ensure that any reliability standards or criteria violations identified in the needs analysis were being addressed either by one of these other study groups or by the southern New England regional working group. For example, overloaded 115 kV circuits in the Hartford area will be addressed by the Greater Hartford and Central Connecticut (GHCC) working group. Accordingly, these violations will not be addressed by this working group and, in particular, were not a factor in evaluating the comparative performance of the options analyzed.

5.3 Description of Original Interstate Solutions

This section describes each of the original Interstate Reliability Project options in further detail. The 2008 Options Analysis identified five options as meeting the basic performance requirements that had been identified in the 2008 Needs Analysis for the Interstate component of NEEWS - strengthening the ties between the southern New England states, and increasing the ability to move power between eastern and western New England and into the state of Connecticut. These five options were briefly described as follows:

Interstate Option A: This plan included a new 345 kV transmission line from the Millbury switching station in Millbury, Massachusetts to the West Farnum substation in North Smithfield, Rhode Island, a new 345 kV transmission line from the West Farnum substation to the Lake Road switching station in Killingly, Connecticut, and a new 345 kV transmission line from the Lake Road switching station to the terminating Card Street substation in Lebanon, Connecticut.

Interstate Option B: This plan included a new 345 kV transmission line from the West Farnum substation to the Kent County substation in Warwick, Rhode Island and a new 345 kV transmission line from the Kent County substation to the Montville substation in Montville, Connecticut. (The 345 kV transmission line from the West Farnum substation to the Kent County substation is part of the Rhode Island Reliability Project)

Interstate Option C: This plan included a new 345 kV transmission line from the Millbury switching station to the Carpenter Hill substation in Charlton, Massachusetts and a new 345 kV transmission line from the Carpenter Hill substation to the Manchester substation in Manchester, Connecticut. This plan also required a new 345 kV transmission line from the Sherman Road switching station to the West Farnum substation.

Interstate Option D: This plan included a new 345 kV transmission line from the Millbury switching station to the Carpenter Hill substation and a new 345 kV transmission line from the Carpenter Hill substation to the Ludlow substation in Ludlow, Massachusetts. The plan also included a new 345 kV transmission line from the Ludlow substation to the Agawam substation in Agawam, Massachusetts and a new 345 kV line from the Agawam substation to the North Bloomfield substation in Bloomfield, Connecticut. (The 345 kV transmission lines from the Ludlow substation to the North Bloomfield substation are part of the Greater Springfield Reliability Project). As a part of this plan the existing 345 kV line between Ludlow and Manchester would be reconductored. This plan also required a new 345 kV transmission line from the Sherman Road switching station to the West Farnum substation.

Interstate Option E: This plan included a new 1,200 MW high-voltage direct-current (HVDC) transmission line from the Millbury switching station to the Southington substation in Southington, Connecticut. This plan also required a new 345 kV transmission line from the Sherman Road switching station to the West Farnum substation.

The above description of the five options just includes the major new facilities with each option. One-line diagrams of the 345 kV transmission upgrades for each option are included in the 2008 Options Report[49]. To make each option complete other existing facilities were upgraded and the description of these upgrades is also included in the 2008 Options report. The 2008 Options Analysis recognized that each of these five Interstate Reliability Project options would have to meet a set of threshold system objectives, but also noted that each option "offer[ed] different advantages and disadvantages compared with the other options in terms of system performance." In addition, the 2008 Options Analysis did not consider the cost, constructability, or routing aspects of each option.

The transmission owner's further analyzed these initial five options in detail as described in a report titled "*Solution Report for the Interstate Reliability Project,*" August, 2008[50] (Initial Solution Report). In this analysis, the ability of each alternative solution to meet threshold planning and operating objectives as well as their projected capital cost falling within a predetermined range were evaluated first, and then their potential environmental and social impacts were evaluated. Evaluating the options in this manner did not require the development of equally detailed routing and environmental information for each potential alternative solution. Where technical and/or cost analyses were sufficient to eliminate an option, a full environmental analysis was not performed.

Option E, the HVDC alternative, was the first option to be eliminated on grounds of system disadvantages and cost. This HVDC alternative provided very little flexibility in terms of expandability since any expansion of an HVDC system would involve an additional converter station. Also, in terms of thermal and voltage problems this solution was ranked fourth amongst the five options indicating that this alternative had lesser longevity.

Option B, which includes the 345 kV transmission line from Kent County to Montville along the coast, was eliminated based on inferior system benefits and a higher projected cost. This option had the greatest number of highly loaded lines and low system voltages post contingency amongst the five options analyzed. This option also had the lowest increase in N-1 transfer capability into Connecticut and across the East-West interface. All these factors led to this option being eliminated from consideration.

After this initial elimination of options B and E, the remaining three options were analyzed. The remaining options were amongst the top 3 in terms of thermal and voltage performance and ability to transfer more power into Connecticut and western New England.

Option A was recognized as a likely preferred solution because of the following factors[51].

- The electrical connection between Massachusetts and Rhode Island and between Connecticut and Rhode Island were enhanced to provide greater access to competitive power.
- A 345 kV loop was created around several large generators in central Massachusetts, by connecting National Grid's Millbury switching station with its West Farnum substation and NSTAR's West Medway substation, thereby improving the reliability of the supply from those sources.

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[49] http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/reports/2008/index.html

[50] http://www.transmission-nu.com/residential/projects/IRP/IRP%20MCF%20Vol.%204%20%202%20of%202/SD.25%20Solution%20Report%20for%20the%20Interstate%20Reliability%20Project%20August%202008.pdf

[51] It must be noted that some of these factors (e.g. construction on existing ROWs) are not unique to option A.

- Option A could be constructed for almost its entire length within existing transmission line ROWs.
- Option A was the least costly of all of the options.
- Option A had the least environmental impact of all the options.

Option C, which would have been in large part on a new ROW adjacent to an interstate highway corridor, for the section between Carpenter Hill and Manchester, was found to be impractical and more costly. To make this alternative constructible the existing ROW from Carpenter Hill to Ludlow to Manchester had to be used. This alternative was called option C-2.

Option D was determined to be impractical in the form envisioned in the 2008 Options Analysis. It was more practical to add a new circuit between Ludlow and Manchester and with this modification option D was virtually indistinguishable from option C-2 except for the new line's connection to the Ludlow substation.

Option C-2 was evaluated in detail, because its performance and cost were close to those of option A. Ultimately, a comparative analysis of option A and option C-2 demonstrated that, although both potential solutions had merit, option A performed better, costs less, and would have fewer environmental and social impacts. Accordingly, option A was selected as the preferred transmission solution.

5.4 Redesign of Selected Original Options to Address the Updated Need

To identify options that would fulfill the enhanced need identified by the updated needs analysis, the working group first considered which of the original five options appeared, by inspection, to be likely to be adaptable to meet the enhanced need in a cost effective manner. The working group re-evaluated the options in the original options analysis.

Option B did not add a line into Massachusetts and the updated needs analysis indicated a need to bolster the transmission system into eastern New England. Thus, to make option B a viable alternative more transmission upgrades would have to be added to option B described in Section 5.3. Since option B was already more expensive alternative, adding more upgrades to that plan would make that option a less desirable alternative.

Similarly, the cost and relative inflexibility of the HVDC solution (option E) still made it an inferior choice to options A and C-2. Also, the constructability issues with options C and D as originally planned have not changed and the combined system benefits of these two options are captured in option C-2.

Thus, the working group came to the conclusion that there was nothing in the updated needs analysis that altered the previous analysis that had eliminated options B, D, and E from consideration. The decisive differences in cost and/or system performance between these options and the original options A and C-2 were significant. The additional cost and impacts of the relatively modest modifications needed to meet the enhanced system need would not offset the difference that existed: therefore options B, C-1, D, and E were not analyzed further. However, because the system performance and cost of option C-2 had been close to those of option A, both option A and option C-2 were reconsidered in detail.

[redacted]

Both option A and C-2 were redesigned to meet the requirements of the updated needs analysis. In an iterative process, the original configurations were modified by the additions or changes that the study group anticipated would improve the capability of the southern New England transmission system to move power from west to east across the New England East-West interface. In addition, some of the original components of each plan were reviewed to see if they were still required in light of the updated needs. System performance with those modifications in place was then analyzed by power flow simulations in accordance with applicable reliability standards and criteria.

The modification of original option C-2, was designated option C-2.1, and four distinct variants of the original option A were designated options A-1 through A-4. All five options were found to provide an acceptable level of system performance to address the updated need.

The four A-series options all contain the same 345 kV construction plans within Connecticut. However, these variations have a slightly different configuration in Massachusetts and Rhode Island. These options all contain three primary components:

1. A new 345 kV line from the Card substation to the Lake Road switching station in eastern Connecticut.
2. A new 345 kV line from the Lake Road switching station in eastern Connecticut to the West Farnum substation in northern Rhode Island; in one A-series option this line loops in and out of the Sherman Road switching station enroute.
3. A new 345 kV line from the West Farnum substation (or the Sherman Road switching station) in Rhode Island to the Millbury switching station in central Massachusetts.

The differences between the four A-series options are described later in this section.

The original option C-2 consisted of a new 345 kV transmission line from Millbury switching station to the Manchester substation, with a tap at the Carpenter Hill substation. This new line would have no connection with the existing 301-302 line at the Carpenter Hill substation. As redesigned to meet the updated needs, this option (redesignated as option C-2.1) includes the construction of a new 345 kV switchyard at the Carpenter Hill substation, whereas the original option C-2 contemplated only the installation of a second 345/115 kV autotransformer at the Carpenter Hill substation.

The following upgrades[52] were common to all plans and involved certain NSTAR, NU, and Connecticut Municipal Electric Energy Cooperative (CMEEC) facilities:

- NSTAR – Reconductor a 1.2-mile section of the 345 kV 336 line (ANP Blackstone to NEA Bellingham Tap) and upgrade terminal equipment at the West Medway substation to [redacted]-rated equipment.
- NU/CMEEC – Eliminate the sag limit on the thermal rating of the 115 kV 1410 line (Montville to Buddington) in Connecticut.

Both upgrades address overloads seen on each facility under high West-East conditions.

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[52] These two upgrade projects already have PPA approval and are being advanced independently of the Interstate Reliability project. Accordingly, they are not further considered in comparisons of the Interstate solution options.

5.4.1 The A-series Options

The new 345 kV lines being constructed as a part of the Connecticut segment of the Interstate project are the same in each of the four A-series options, and remain unchanged from the initial option A solution. The differences among the four A-series options occur on National Grid facilities in Rhode Island and Massachusetts. The location of the Connecticut facilities, which is common to all four A-series options, and the area within which the differences in the A-series options would be located are illustrated in Figure 5-1.

[redacted]

Figure 5-1: New 345 kV Construction in the A Options

In addition to the 345 kV components of each A-series option described below, a series 115 kV circuit breaker will be inserted along with the 1713 circuit breaker at the 115 kV West Farnum switchyard for all the A-series options. This additional circuit breaker will eliminate a critical circuit breaker failure contingency event at the West Farnum substation that causes thermal overloads on the 115 kV line from West Farnum to Woonsocket (T-172N) under the 345 kV 336 line-out scenario.

[redacted]

5.4.1.1 Option A-1

In option A-1, a new 345 kV transmission line emanates from the Card substation in Lebanon, Connecticut and follows the existing transmission corridor (330 line) to the Lake Road switching station in Killingly, Connecticut. From the Lake Road switching station, a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) northeasterly to the vicinity of the Sherman Road switching station in Burrillville, Rhode Island. In option A-1, this new 345 kV transmission line does not connect to the Sherman Road switching station but goes by it and continues in a southeasterly direction on an existing transmission corridor (328 line) to terminate at the West Farnum substation in North Smithfield, Rhode Island. A new 345 kV transmission line would also be constructed on the existing transmission corridor (Q-143 and R-144 lines) between the West Farnum substation and the Millbury switching station in Millbury, Massachusetts. The existing 345 kV 328 line (Sherman Road to West Farnum) must also be rebuilt with higher capacity conductors under this plan. Figure 5-2 is a geographic representation of option A-1.

[redacted]

Figure 5-2: Option A-1 Geographic Layout

[redacted]

The new 345 kV lines being added as a part of this project are:

- Card to Lake Road
- Lake Road to West Farnum
- West Farnum to Millbury

These three lines were added to the initial element out set for the thermal and transfer analysis, for option A-1. In addition to these new line-outs some other 345 kV breaker failure contingencies were also modified based on the one-line description of the option A-1 in Figure 5-3. The West Farnum 1713 circuit breaker failure, a 115 kV breaker failure contingency was eliminated due to the addition of a series breaker for the option A-1 analysis.

[redacted]

Figure 5-3: Option A-1 One-Line Diagram

[redacted]

5.4.1.2 Option A-2

In option A-2, a new 345 kV transmission line emanates from the Card substation and follows the existing transmission corridor (330 line) to the Lake Road switching station. From the Lake Road switching station a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) northeasterly to the Sherman Road switching station. Another new 345 kV transmission line emanates from the Sherman Road switching station and follows the existing transmission corridor (328 line) in a southeasterly direction to the West Farnum substation. In addition, a second new 345 kV line emanates from the Sherman Road switching station and follows the existing NSTAR transmission corridor (3361 line) in a northeasterly direction until it intersects with the existing National Grid transmission corridor (Q-143 and R-144 lines) between the Millbury switching station and the West Farnum substation. At this intersection, this new 345 kV transmission line turns and follows the existing National Grid transmission corridor in a northwesterly direction to the Millbury switching station. Figure 5-4 is a geographic representation of option A-2.

[redacted]

Figure 5-4: Option A-2 Geographic Layout

[redacted]

The new 345 kV lines being added as a part of this project are:

- Card to Lake Road
- Lake Road to Sherman Road
- Sherman Road to West Farnum
- Sherman Road to Millbury

These four lines were added to the initial element out set for the thermal and transfer analysis, for option A-2. In addition to these new line-outs some other 345 kV breaker failure contingencies were also modified based on the one-line description of the option A-2 in Figure 5-5. The West Farnum 1713 circuit breaker failure, a 115 kV breaker failure contingency was eliminated due to the addition of a series breaker for the option A-2 analysis.

[redacted]

Figure 5-5: Option A-2 One-Line Diagram

[redacted]

5.4.1.3 Option A-3

In option A-3, a new 345 kV transmission line emanates from the Card substation and follows the existing transmission corridor (330 line) to the Lake Road switching station. From the Lake Road switching station a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) northeasterly to the vicinity of the Sherman Road switching station. However under this plan, the new 345 kV line does not connect to the Sherman Road switching station but goes by it and continues in a southeasterly direction on an existing transmission corridor (328 line) to the West Farnum substation. A new 345 kV line would be constructed on the existing transmission corridor (Q-143 and R-144 lines) between the West Farnum substation and the Millbury switching station. At the location where the new 345 kV West Farnum – Millbury line intersects with the existing 345 kV 3361 line (ANP Blackstone to Sherman Road) in Uxbridge, Massachusetts, a new 345 kV breaker-and-a-half switching station would be constructed. Both the new West Farnum to Millbury line and the existing 3361 line would be interconnected at the new switching station. As a part of this plan, the segment of the existing 3361 line between Sherman Road and the new switching station at Uxbridge will need to be upgraded by replacing terminal equipment at Sherman Road and eliminating sag limits to the 3361 line ratings. Figure 5-6 is a geographic representation of option A-3.

[redacted]

Figure 5-6: Option A-3 Geographic Layout

[redacted]

The new 345 kV lines being added as a part of this project are:

- Card to Lake Road
- Lake Road to West Farnum
- Uxbridge to West Farnum
- Uxbridge to Millbury

These four lines were added to the initial element out set for the thermal and transfer analysis, for option A-3. In addition to these new line-outs some other 345 kV breaker failure contingencies were also modified based on the one-line description of the option A-3 in Figure 5-7. The West Farnum 1713 circuit breaker failure, a 115 kV breaker failure contingency was eliminated due to the addition of a series breaker for the option A-3 analysis.

[redacted]

Figure 5-7: Option A-3 One-Line Diagram

[redacted]

5.4.1.4 Option A-4

In option A-4, a new 345 kV transmission line emanates from the Card substation and follows the existing transmission corridor (330 line) to the Lake Road switching station. From the Lake Road switching station a new 345 kV transmission line follows the existing transmission corridor (3348 and 347 lines) in a northeasterly direction to the vicinity of the Sherman Road switching station. In option A-4, the new 345 kV line does not connect to the Sherman Road switching station but goes by it and extends in a southeasterly direction on an existing transmission corridor (328 line) to the West Farnum substation. Another new 345 kV line would be constructed on the existing transmission corridor (Q-143 and R-144 lines) between the West Farnum substation and the Millbury switching station. In addition, a new 345 kV transmission line would be constructed between the Sherman Road switching station and the West Farnum substation within the same transmission corridor as the 328 line and the new 345 kV Lake Road – West Farnum transmission line. Figure 5-8 is a geographic representation of option A-4.

[redacted]

Figure 5-8: Option A-4 Geographic Layout

[redacted]

The new 345 kV lines being added as a part of this project are:

- Card to Lake Road
- Lake Road to West Farnum
- Sherman Road to West Farnum
- West Farnum to Millbury

These four lines were added to the initial element out set for the thermal and transfer analysis, for option A-4. In addition to these new line-outs some other 345 kV breaker failure contingencies were also modified based on the one-line description of the option A-4 in Figure 5-8. The West Farnum 1713 circuit breaker failure, a 115 kV breaker failure contingency was eliminated due to the addition of a series breaker for the option A-4 analysis.

[redacted]

Figure 5-9: Option A-4 One-Line Diagram

5.4.2 The C-2.1 Option

Option C-2.1 would involve the construction of a new 345 kV transmission line in a westerly direction within the existing transmission corridor (302 line) from the Millbury switching station to the Carpenter Hill substation in Charlton, Massachusetts. From the expanded 345 kV switchyard at the Carpenter Hill substation, a new 345 kV transmission line would be constructed in a westerly direction within the existing transmission corridor (301 line) to the vicinity of the Ludlow substation. This line would not connect to the Ludlow substation, rather it would turn south within the existing transmission corridor (3419 line and then 395 line) to the Manchester substation in Manchester, Connecticut. In addition, a new 345 kV transmission line would be constructed between the Sherman Road switching station and the West Farnum substation. This new 345 kV transmission line would be located within the existing transmission corridor with the existing 328 line. Figure 5-10 is a geographic representation of option C-2.1.

[redacted]

Figure 5-10: Option C-2.1 Geographic Layout

[redacted]

The new 345 kV lines being added as a part of this project are:

- Sherman Road to West Farnum
- Manchester to Carpenter Hill
- Carpenter Hill to Millbury

These three lines were added to the initial element out set for the thermal and transfer analysis, for option C-2.1. In addition to these new line-outs some other 345 kV breaker failure contingencies were also modified based on the one-line description of the option C-2.1 in Figure 5-11. The West Farnum 1713 circuit breaker failure, a 115 kV breaker failure contingency was eliminated due to the addition of a series breaker for the option C-2.1 analysis.

[redacted]

Figure 5-11: Option C-2.1 One-Line Diagram

[redacted]

5.5 Sherman Road Switching Station

Sherman Road is a major 345 kV switching station that interconnects four key transmission elements (as defined in Planning Procedure 9): a significant tie line between Rhode Island and Connecticut; a key switching station on the transmission path for supplying power to Rhode Island; a switching station that terminates another significant tie line which picks up two generating stations on the path to interconnecting with the NSTAR system at West Medway; and the radial supply line to the Ocean State (~540 MW summer) plant site. This station, which has experienced a number of updates through the years, originated as an air-insulated station (AIS) in a straight bus configuration back in 1968, and was later updated to a ring bus configuration. A section of gas insulated station (GIS) was installed to interconnect the Ocean State plant in 1989.

The current Sherman Road 345 kV ring-bus configuration, as it was improved over the years, consists of a variety of different vintage equipment. The six existing 345 kV circuit breakers are rated as follows:

- [redacted]
- [redacted]
- [redacted]

Additionally, there exists both [redacted] disconnect switches, relay equipment of various ratings, and numerous sections of rigid aluminum bus with diameters [redacted]

Figure 5-12 is a one-line of the existing configuration. As stated above, the switching station has a combination of GIS and AIS equipment. The elements in the dashed box, including the [redacted], are part of the GIS equipment. [redacted]

[redacted]

Figure 5-12: Existing Layout at Sherman Road Switching Station

5.5.1 Need to Improve Station

Each Interstate Reliability Project option required station work at Sherman Road to make the overall plan complete and to satisfy the needs analysis. As noted in Section 5.4 above, at least one new or upgraded 345 kV transmission line terminates at the Sherman Road switching station for options A-1, A-2, A-4 and C-2.1. The work ranges from adding new lines into the switching station in plans A-2, A-4 and C-2.1 to reconductoring of the 328 line from Sherman Road to West Farnum in option A-1. In addition, several plans including A-1and A-3 involve the addition of a series breaker along with the [redacted] at Sherman Road. This would eliminate [redacted] contingency that results in several thermal overloads that restrict power transfers from western New England and Greater Rhode Island to eastern New England.

In options A-2, A-4 and C-2.1, at least one new line terminates at the Sherman Road switching station. Each of the new lines terminating at Sherman Road [redacted] Sherman Road's existing ring-bus configuration, according to ISO Planning Procedure 9, should be changed to a breaker-and-a-half bus arrangement (with space provisions for a series-tie breaker in each bay) [redacted] Based on this guideline, the Sherman Road switching station would need to be expanded to a 3-bay breaker-and-a-half arrangement to accommodate the one new terminating line for options A-4 and C-2.1. Sherman Road would need to be expanded to a 4-bay breaker-and-a-half arrangement to accommodate the three new terminating lines for option A-2. The different alternatives that were evaluated for options A-2, A-4 and C-2.1 are detailed in the following section.

Since major upgrades at Sherman Road were determined to be needed for option A-2, A-4 and C-2.1, it was important to analyze if major upgrades were required at the switching station for the remaining two Interstate options. All of the Interstate options that were considered would increase the fault duty at the Sherman Road switching station due to new transmission lines being added in the surrounding

[redacted]

area (each option introduces at least one new 345 kV transmission line into the West Farnum substation). The working group performed a short-circuit screening assessment[53], as described in Section 3.5, to determine the relative impact of each option on the interrupting current levels at key 345 kV stations in the study area. In this screening analysis, option A-1 resulted in the smallest increase in short circuit current among the A-series options at the Sherman Road switching station. Furthermore, the bus fault current levels with option A-1 exceeded the smallest breaker at Sherman Road, indicating that at least one breaker would need to be upgraded for option A-1. Since both option A-1 and A-3 have the same bus configuration at Sherman Road and A-3 had higher bus fault currents than A-1, it can be reasonably concluded that at least one circuit breaker would be overdutied for option A-3.

Subsequently, the working group performed a more detailed analysis of Sherman Road using the ASPEN Breaker Rating module[54]. The detailed analysis was performed first for the system before applying any Interstate option and then again with the Interstate option A-1 in place. The results of this testing for Sherman Road switching station from a breaker perspective pre and post-Interstate option A-1 are listed in Table 5-1. (The reason that the available fault currents decrease in some cases is due to large system configuration changes and differing breaker arrangements at this and other substations.)

Table 5-1
Pre-Interstate and Post-Interstate Fault Currents at Sherman Road

Breaker	Breaker Interrupting Capability (A)	Pre-Interstate Duty (A)	Post-Interstate A-1 Duty (A)	Post-Interstate % of Rating
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The substation bus and bus structures, insulators, and ground grid must also be rated to withstand the maximum fault currents and their associated forces. Under option A-1, as stated above, the maximum fault current would be [redacted] Table 5-2 shows fault duty values for typical bus / bus

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[53] This screening analysis was performed using PSS/E's positive sequence impedance model which restricts the results to only symmetrical, three-phase balanced faults, but does provide a good relative comparison of resultant short circuit levels between alternatives.

[54] The Breaking Rating module of the ASPEN short-circuit software requires extensive modeling of the characteristics of each circuit breaker and how it interconnects to the system, and performs a full fault analysis that also captures the asymmetrical, unbalanced nature of the various type faults that can occur on the system. This is a more comprehensive short-circuit approach.

[redacted]

support configurations at Sherman Road switching station. [redacted]

Table 5-2
Typical Short Circuit Ratings for 4", 5" and 6" Rigid Bus Installations

Bus Diameter (in)	Symmetrical Short Circuit Duty (kA)	Bus Span (ft)	Phase Spacing (ft)
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

The increased regional power flows, under contingency conditions, result in additional thermal stresses on the station's older equipment. Table 5-3 provides the worst-case, thermal overloads of station equipment that occur under 2020 peak conditions with [redacted] for the A-1 alternative. This condition results in the Sherman Road to West Farnum 345 kV (328) line being loaded to 1,839 MVA.

Table 5-3
Worst Case Thermal Overloads of Station Equipment

Equipment	Nameplate (A)	LTE Rating (MVA)	% LTE
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]		[redacted]	[redacted]
[redacted]		[redacted]	[redacted]

Due to the post-Interstate increase in steady state currents (under contingency conditions) and the available fault currents, major work is required at this station. To eliminate these equipment concerns and also to provide margin for the future, any bus section identified as [redacted] should be replaced with [redacted], and all 345 kV circuit breakers and switches upgraded to [redacted] capabilities, matching new 345 kV substation construction. [redacted] One of the alternatives pursued for options A-1 and A-3 will be rebuilding the existing Sherman Road with the existing configuration.

5.5.2 Sherman Road Alternatives

Given the extent of changes required at the switching station, alternatives were developed and evaluated to determine the cost effective solution that would meet the reliability needs identified. The alternatives will be grouped based on the number of new elements being added into Sherman Road. Other factors included in the evaluation were construction time, outage requirements, construction sequencing, expansion capabilities, and environmental factors.

Examination of the existing Sherman Road property identified several factors that limit the extent to which the existing switching station could be expanded, including:

- [redacted]
- Significant wetland areas to the north, west and east of the existing station
- Known cultural resource areas to the south of the existing station.

After evaluating these existing constraints, it was determined that the existing station yard could be expanded to the northwest by an area of approximately 180-feet in width and 540-feet in length without causing significant environmental impacts. Expanding the existing station yard by any greater amount would cause unacceptable impacts to wetlands and cultural resource areas. This allowable 180-foot by 540-foot expansion area is sufficient space to construct up to 2 new bays of 345 kV breaker-and-a-half AIS equipment, or up to 4 new bays of 345 kV breaker-and-a-half GIS equipment.

The following sections detail the specific requirements and associated cost estimates for the Sherman Road switching station for each of the Interstate options, taking into account the aforementioned information.

5.5.2.1 Sherman Road Alternative for Interstate Options A-1 and A-3

The following alternatives were examined for the two options that do not add any new elements into Sherman Road. The final configuration required would be 2-bay switching station with a breaker-and-a-half bus arrangement.

Alternative 1: Rebuild the existing air-insulated station (AIS)

- This work entails systematic equipment upgrades in each 345 kV ring position including circuit breakers, disconnect switches, structures, insulators and bus. [redacted] The alternative of rebuilding the existing station in place has significant disadvantages :
    - [redacted]
    - [redacted]
    - [redacted]
    - Extended construction durations
    - Increased construction costs.

[redacted]

- This alternative was also determined to have the added disadvantage of incurring significant project costs but maintaining the existing ring bus configuration. As a result, the future addition of any fifth transmission element would require the station to be changed to a breaker-and-a-half configuration to meet the guidelines described in ISO Planning Procedure 9, which would again involve significant station changes and investment. However, for purposes of comparing alternatives, a conceptual grade estimate for Alternative 1 was developed, and the cost of rebuilding the existing switching station in place was determined to be $38.0M.

Alternative 2: Build a new gas-insulated station (GIS)

- The electrical configuration would be arranged as a modified breaker and a half scheme using 345 kV GIS equipment including 345 kV breakers, disconnect switches, instrument transformers, structures, bus and other required accessories. The electrical work entails adding a new GIS/Control building, associated yard equipment and transmission line termination structures to complete the new GIS station. [redacted] For options A-1 and A-3 a two-bay switchyard would be required and could be built in the expansion area to the northwest of the existing yard. All the work could then be performed unimpeded until the element cutovers were made. Alternative 2 was estimated to cost $44.9M.

Alternative 3: Build a new air-insulated station (AIS)

- The work entails building a completely new 345 kV AIS station in a breaker and a half configuration consisting of 345 kV breakers, disconnect switches, instrument transformers, structures, bus and other required accessories. [redacted] For options A-1 and A-3 a two-bay switchyard would be required, and could be built in the expansion area to the northwest of the existing yard. All the work could be performed unimpeded until the final element cutovers were made. Upon completion of all the cutovers, the existing yard equipment would be removed and the ground restored to the final elevation. Alternative 3 was estimated to cost $36.6M.

Table 5-4 summarizes the evaluation of the three alternatives.

[redacted]

Table 5-4
Sherman Road Alternatives for Options A-1 and A-3

Comparison Factor	Alternative 1 Rebuild Existing Station	Alternative 2 New GIS Station	Alternative 3 New AIS Station
Cost (Conceptual Grade[55] Estimate)	Medium Ring Bus – $38.0M	High 2-bays - $44.9M	Low 2-bays – $36.6M
Construction Time	Long - 24-36 Months	Standard - 18-24 Months	Standard - 18-24 Months
Outage Requirements	[redacted]	[redacted]	[redacted]
Construction Sequencing	Construction will conflict with other components at West Farnum and Millbury	Minimal conflicts	Minimal Conflicts
Expansion Capabilities	Difficult to Expand : Expansion requires reconfiguring from ring bus to breaker-and-a-half	Easy to expand: Up to 4 bays	Easy to expand: Up to 4 bays (after initial 2-bay build-out and removal of existing station)
Environmental Factors	Low Impact	GIS may not be considered carbon neutral	Medium Impact

Alternative 3, constructing a new 2-bay AIS Station, was determined to be the cost-effective solution for the Sherman Road station for Interstate Reliability options A-1 and A-3, based on low cost, low equipment outage requirements, minimal construction sequencing difficulties, opportunity for future expansion, and acceptable environmental impacts.

5.5.2.2 Sherman Road Alternative for Interstate Options A-4 and C-2.1

With the addition of one new transmission element, the Sherman Road station would need to be converted to a 3-bay breaker-and-a-half configuration for Interstate Reliability options A-4 and C-2.1. In addition, options A-4 and C-2.1 each would require upgrades of all existing equipment at the station,

Because of the significant disadvantages associated with upgrading the existing equipment at Sherman Road in its present location, and because sufficient area exists to expand the station to the northwest with up to 2 new AIS bays or up to 4 new GIS bays, two alternatives for the Sherman Road station were evaluated in connection with Interstate Reliability options A-4 and C-2.1:

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[55] Estimates have a -25% / +50% degree of accuracy.

Alternative 1: Build a New 3-Bay Air-Insulated Station (AIS) Using a 2-Stage Process

- This alternative would involve constructing two new AIS bays at Sherman Road in the expansion area to the northwest, while leaving the existing switching station operational and uninterrupted. Once the two new AIS bays were completed, the four existing 345 kV elements at the existing station would be systematically cutover and energized into the 2 new AIS bays. The old ring bus at Sherman Road could then be demolished, and the third new AIS bay could be built in its place. The new 345 kV element required under options A-4 and C-2.1 could then be connected into the third new AIS bay. Although Alternative 1 would involve a 2-Stage construction process, it was determined to be feasible because it involves the addition of only one new 345 kV element which would enter the station site from the southeast in the area where the third AIS bay would be constructed. As such, the need for temporary arrangements and 345 kV transmission line crossings in connection with Alternative 1 would be limited. This alternative was estimated to cost $43.4M.

Alternative 2: Build a New 3-Bay Gas-Insulated Station (GIS)

- This alternative would involve constructing three new GIS bays at Sherman Road in the expansion area to the northwest, while leaving the existing switching station operational and uninterrupted. Once the three new GIS bays were completed, the four existing 345 kV elements and the new 345 kV element at the station would be systematically cutover and energized into the 3 new GIS bays. The old ring bus at Sherman Road could then be demolished. This alternative was determined to be feasible and was estimated to cost $58.9 M.

Alternative 1 and Alternative 2 would have similar environmental impacts, due to the use of the northwest expansion area. Alternative 1 and 2 would also have similar equipment outage requirements, associated with the cutover of the existing 345 kV elements at the site.

Although Alternative 1 would have longer construction duration due to the 2-stage construction process than Alternative 2, its significant lower cost makes it the cost-effective alternative for the Sherman Road station for Interstate Reliability options A-4 and C-2.1.

5.5.2.3 Sherman Road Alternative for Interstate Option A-2

With the addition of the three new 345 kV transmission elements, the Sherman Road station would need to be converted to a 4-bay breaker-and-a-half configuration. In addition, option A-2 would require the upgrade of all existing equipment at the station as previously described.

Because of the significant disadvantages associated with upgrading the existing equipment at Sherman Road in its present location and because sufficient area exists to expand the station to the northwest with up to 2 new AIS bays or up to 4 new GIS bays, two alternatives for the Sherman Road station were evaluated in connection with Interstate Reliability option A-2:

[redacted]

Alternative 1: Build a New 4-Bay Air-Insulated Station (AIS) Using a Multi-Stage Process

- This alternative would involve constructing two new AIS bays at Sherman Road in the expansion area to the northwest, while leaving the existing switching station operational and uninterrupted. Once the two new AIS bays were completed, the existing 345 kV elements at the existing station could then be cutover and energized into the 2 new AIS bays. The old ring bus at Sherman Road could then be demolished, and the third and fourth new AIS bays could then be built in its place. The three new 345 kV transmission lines each enter the Sherman Road site from different directions, and in order to achieve the appropriate electrical arrangement and topology for the station, various 345 kV elements of all four bays would need to be relocated to different positions following construction of the third and fourth new AIS bays. When more closely evaluated, this alternative of building a new 4-bay AIS station in a multi-stage process to accommodate three new 345 kV elements was found to be infeasible, for the following reasons:
    - This alternative would introduce several 345 kV transmission line crossings into the network. 345 kV transmission line crossings are avoided where possible [redacted]
    - This alternative would require numerous "temporary arrangements" of lines, devices and protection schemes, increasing engineering costs and construction complexities
    - [redacted]
    - [redacted]
    - [redacted]
    - This alternative would add a year or more to the construction duration, and as such would significantly lengthen the overall delivery timeframe for the Interstate Reliability Project
    - [redacted]

Alternative 2: Build a New 4-Bay Gas-Insulated Station (GIS)

- This alternative would involve constructing four new GIS bays at Sherman Road in the expansion area to the northwest, while leaving the existing switching station operational and uninterrupted. Once the four new GIS bays were completed, the existing 345 kV elements and the new 345 kV elements at the station would be systematically cutover and energized into their final positions in the 4 new GIS bays. The physical layout of the new proposed GIS requires changes to the line coming into Sherman Road from Ocean State (0.2 miles) for crossings, outages, etc. This requires structures and other devices to be modified and changed out, and hence this alternative will include rebuilding the 0.2 mile 345 kV transmission line (333 line) from Sherman Road switching station to Ocean State Power. The old ring bus at Sherman Road could then be demolished. By using Gas-Insulated Line (GIL) extensions to the required transmission line termination points, this alternative could be built in a manner which:
    - Minimizes 345 kV transmission line crossings
    - Achieves the appropriate electrical arrangement with the initial build-out
    - Eliminates the need for temporary electrical arrangements

- Minimizes the equipment outages required for construction
- [redacted]
- [redacted]

For these reasons, Alternative 2 is the only feasible and practical alternative for the upgrades and additions required at the Sherman Road station for Interstate Reliability option A-2. The estimated cost of the improvements at Sherman Road station for option A-2 is $81.1M.

5.5.3 Preferred Sherman Road Switching Station Alternatives

Evaluation of the three alternatives for options A-1 and A-3 showed that alternative 3, a new air-insulated switching station, proved to be cost effective, minimized construction time and outage difficulties, and could be expanded to meet future needs. This configuration of Sherman Road is shown in Figure 5-13.

[redacted]

Figure 5-13: Proposed Sherman Road Switching Station Layout for Option A-1 and A-3

Evaluation of the two alternatives at Sherman Road switching station for Interstate Reliability options A-4 and C-2.1 showed that Alternative 1, building a new 3-bay air-insulated switching station was the preferred solution. The estimated cost for the Sherman Road improvements associated with Interstate Reliability options A-4 and C-2.1 is $43.4M

Evaluation of the two alternatives at Sherman Road switching station for Interstate Reliability option A-2 showed that Alternative 2, a new 4-bay gas-insulated switching station was the only feasible and practical alternative. The estimated cost for the Sherman Road improvements associated with Interstate Reliability options A-2 is $81.1M

Section 6
Alternative Solution Performance and Results

6.1 Steady State Performance Results

This section summarizes the steady-state analysis performed on each of the five Interstate alternatives. The five options were tested against the three regional stresses described in Section 3.2.9, at the 90/10 summer peak load levels in 2020, for thermal and voltage violations. All five options eliminated the criteria violations that the project is designed to address. The results of the analysis are documented in Appendix F: Thermal and Voltage Analysis Results.

The following sections include a summary of the thermal and voltage violations for each stress. For each stress the number of highly loaded transmission lines was also recorded. A line was deemed to be highly-loaded when the flow on it was over 90% of its LTE rating after a contingency.

6.1.1 N-0 Thermal and Voltage Performance Summary

6.1.1.1 Eastern New England

No N-0 thermal or voltage violations were found in 2020 for the eastern New England import stress for any of the five Interstate options.

There were no highly loaded lines under N-0 conditions.

6.1.1.2 Western New England and Connecticut

No N-0 thermal or voltage violations were found in 2020 for the western New England and Connecticut import stress for any of the five Interstate options.

There were no highly loaded lines under N-0 conditions.

6.1.1.3 Rhode Island

No N-0 thermal or voltage violations were found in 2020 for the Rhode Island import stress for any of the five Interstate options.

There were no highly loaded lines under N-0 conditions.

6.1.2 N-1 Thermal and Voltage Performance Summary

6.1.2.1 Eastern New England

No N-1 thermal or voltage violations were found in 2020 for the eastern New England import stress for any of the five Interstate options.

There were no highly loaded lines under N-1 conditions.

6.1.2.2 Western New England and Connecticut

No N-1 thermal or voltage violations were found in 2020 for the western New England and Connecticut import stress for any of the five Interstate options.

There were no highly loaded lines under N-1 conditions.

6.1.2.3 Rhode Island

No N-1 thermal or voltage violations were found in 2020 for the Rhode Island import stress for any of the five Interstate options.

There were no highly loaded lines under N-1 conditions.

6.1.3 N-1-1 Thermal and Voltage Performance Summary

6.1.3.1 Eastern New England

No N-1-1 thermal or voltage violations were found in 2020 for the eastern New England import stress for any of the five Interstate options.

There were 18 highly loaded lines under N-1-1 conditions. The maximum loadings on these lines for each of the five options are provided in Table 6-1 as a percentage of the LTE ratings.

Table 6-1
Eastern NE Analysis: Maximum N-1-1 Element Loadings

Element ID	kV	Element Description	% LTE A-1	% LTE A-2	% LTE A-3	% LTE A-4	% LTE C-2.1
308	345	Millbury – Wachusett	95.75	96.78	97.79	95.91	94.38
327	345	Brayton Point – Berry Street	< 90	< 90	< 90	< 90	92.36
328	345	Sherman Road – W. Farnum	< 90	< 90	93.42	92.83	98.12
336	345	NEA Bellingham – W. Medway	90.10	< 90	< 90	< 90	< 90
3520	345	ANP Bellingham – W Medway	92.22	91.66	92.43	93.02	95.64
Mont18X		Montville 345/115 kV Auto	90.23	90.53	90.42	90.09	< 90
E205E	230	Bearswamp – Pratts Jct	91.07	90.95	91.12	91.28	91.19
O215	230	N. Litchfield – Tewksbury	94.14	93.94	94.03	94.09	93.92
1280	115	Whipple Jct – Mystic, CT	98.40	97.40	98.57	98.13	90.71
1870S	115	Shunock – Wood River	< 90	< 90	< 90	< 90	95.81
B-128	115	Cabot Tap – Montague	94.45	93.64	93.99	94.21	93.95
C-181S	115	Brayton Point – Chartley Pond	< 90	< 90	< 90	< 90	92.07
E131	115	Bearswamp – Harriman	93.72	93.68	93.92	93.92	93.58
F-184	115	Mink Street – Read Street	91.38	91.74	91.51	91.57	93.75
H-17	115	Farnum – Riverside	< 90	< 90	< 90	< 90	90.33
Q-143S	115	Woonsocket – Uxbridge	< 90	< 90	< 90	< 90	98.60
S-171N	115	W. Farnum – Woonsocket	91.72	90.30	< 90	92.48	96.63
T-172N	115	W. Farnum – Woonsocket	90.03	< 90	< 90	90.80	94.77

[redacted]

6.1.3.2 Western New England and Connecticut

No N-1-1 thermal or voltage violations were found in 2020 for the western New England and Connecticut import stress for any of the five Interstate options.

There were five highly loaded lines under N-1-1 conditions. The maximum loadings on these lines for each of the five options are provided in Table 6-2 as a percentage of the LTE ratings.

Table 6-2
Western NE Analysis: Maximum N-1-1 Element Loadings

Element ID	kV	Element Description	% LTE A-1	% LTE A-2	% LTE A-3	% LTE A-4	% LTE C-2.1
302	345	Millbury – Carpenter Hill	< 90	< 90	< 90	< 90	92.37
F-162	115	Greggs – Weare	91.53	91.41	91.49	< 90	91.19
O-141W	115	Wachusett – Greendale	90.54	90.77	90.61	90.51	< 90
W-175	115	Little Rest Rd – Palmer	< 90	< 90	< 90	< 90	92.91
W-175	115	West Charlton – Little Rest Rd	< 90	< 90	< 90	< 90	98.55

6.1.3.3 Rhode Island

No N-1-1 thermal or voltage violations were found in 2020 for the Rhode Island import stress for any of the five Interstate options.

There were three highly loaded lines under N-1-1 conditions. The maximum loadings on these lines for each of the five options are provided in Table 6-3 as a percentage of the LTE ratings.

Table 6-3
RI Analysis: Maximum N-1-1 Element Loadings

Element ID	kV	Element Description	% LTE A-1	% LTE A-2	% LTE A-3	% LTE A-4	% LTE C-2.1
E-183E	115	Brayton Point – Warren	93.13	93.98	92.79	92.44	93.44
F-184	115	Mink Street – Read Street	94.39	95.87	93.92	93.75	96.05
G-185N	115	Kent County – Drumrock	< 90	< 90	< 90	90.03	< 90

6.1.4 Results of Extreme Contingency Testing

No extreme contingency testing was performed with these analyses.

6.1.5 Summary of Steady State Performance

The thermal analysis indicates that in addition to resolving all the criteria violations in the study area, all five alternatives reduced the loadings on the transmission elements in the study area to below 90% of their LTE rating under N-1 conditions. Under N-1-1 conditions, there were a few elements that were over 90% of their LTE rating for all 5 alternatives. These elements were almost identical for the four A-series options. The option C-2.1 did have different elements loading over 90% of LTE rating when compared to the A-series options. Further, option C-2.1 had generally more lines loaded over 90% compared to the A-series options and also had higher loadings on the common lines that were loaded above 90% of LTE for all 5 options.

6.2 Transmission Transfer Analysis

As a part of the updated needs analysis, transfer analyses were performed to first determine the range of transfer limits on the western NE import interface, the eastern NE import interface and the Connecticut Import interfaces following the addition of the Greater Springfield Reliability Project and the Rhode Island Reliability Project. As a part of the solutions study the transfer analyses were repeated for each Interstate Reliability Project option solution to determine the range of interface transfer levels on the western NE import capability, eastern New England import capability and Connecticut import capability. These analyses were based on DC power flow methodology and hence the limits obtained are restricted to thermal limits. Thermal transfer limits are variable and dependent upon the following system parameters:

- System load levels
- Load distribution
- Generation dispatch
- Generation source and sink combinations[56]
- Transmission facility outages
- Transmission facility equipment ratings
- Phase-angle regulator settings
- Power flow solution techniques
- Neighboring Control Area transfers

Varying any of the parameters produce a range of transfer limit levels across an interface; therefore, at any given time system conditions may exist that could result in restricting transfer limit levels below the limits stated. Conversely, system conditions may also exist that could allow for even higher transfers. For the comparison of the five Interstate options all thermal transfer limit variables were held constant.

In performing the needs analysis, some transfer constraints that could be considered more local in nature and were expected to be resolved by future projects (developed by other ongoing studies) other than the Interstate project were disregarded. These disregarded constraints were again reviewed as part of the solutions study's transfer analysis to determine if they could be directly attributed to the transfer level being studied rather than being classified as local issues or issues being analyzed by other working groups. The constraints that were a result of the transfers were resolved as a part of the solution.

Those constraints that could not be directly attributed to the transfers under study have not been taken into account in the transfer limit analyses. These are not used for the determination of the new limits. These constraints are however recorded in the report and the associated study area that will look at this issue is identified. As such, some of the post-project limits documented in this report may be higher than the future determined limits based on comprehensive thermal, voltage and stability analysis.

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[56] A *source* point is a point on the transmission system where electric energy is injected, such as an increase in generation. A *sink* point is a point on the transmission system where electric energy is withdrawn, such as a decrease in generation or an increase in load. By increasing the source and decreasing the sink increasing transfers occur on the system.

[redacted]

6.2.1 Pre-Interstate Transfer Analysis

Table 6-4 summarizes the results of the N-1 interface transfer capability simulations following the construction of the Greater Springfield Reliability Project and the Rhode Island Reliability Project. The details of the analysis are available in the 2011 Updated Needs Analysis report.

Table 6-4
New England Interface N-1 Transfer Levels

Interface	Post GSRP & RIRP
Western NE Import	3400-3950
Eastern NE Import	2600-2700
Connecticut Import	3050-3750

Table 6-5 summarizes the results of the (N-1-1) interface transfer capability simulations following the construction of the Greater Springfield Reliability Project and the Rhode Island Reliability Project. The details of the analysis are available in the 2011 Updated Needs Analysis report.

Table 6-5
New England Interface N-1-1 Transfer Levels

Interface	Post GSRP & RIRP
Western NE Import	2250-3000
Eastern NE Import	1250-1350
Connecticut Import	1750-2400

6.2.2 Post-Interstate Transfer Analysis

The following sections cover each of the individual interfaces that were studied and detail the results of the transfer analysis performed for each option.

For the eastern New England import analysis the following stresses were included:

- Phase II HVDC OOS: Western NE to Eastern NE – Lake Road participating in source
- Phase II HVDC OOS: Western NE to Eastern NE – Lake Road excluded from source
- Mystic station OOS: Western NE to Eastern NE – Lake Road participating in source
- Mystic station OOS: Western NE to Eastern NE – Lake Road excluded from source

As a part of the eastern New England import analysis the sink used in eastern New England consisted of units across eastern New England. These units included units in Southeastern Massachusetts and Boston that were not turned off in the needs cases for eastern New England used for the thermal and voltage analysis in section 3.2.9.1. The eastern New England needs case was based on Phase II and Seabrook OOS.

When a diversified eastern New England sink was utilized for the import analysis into eastern New England, [redacted] showed up as a limiting contingency. The contingency showed up at eastern NE import values that were lower than the required eastern New England import based on the Needs Assessment and were attributable to high eastern NE import conditions rather than being local issues or issues being analyzed by other working groups. The contingency showed up as limiting in both the N-1 and N-1-1 import analysis and were seen for all

[redacted]

the Interstate options. A summary of the most restrictive transfer levels that showed up for options A-1 through A-4 is provided in Table 6-6 and Table 6-7. The contingency also showed up at similar values for option C-2.1.

Table 6-6
Impact of [redacted] on Eastern NE N-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	Contingency	Min ENE Import Level
323	345	Millbury – West Medway	[redacted]	2,866

Table 6-7
Impact of [redacted] on Eastern NE N-1-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	L/O	Contingency	Min ENE Import Level
345B		West Medway 345/230 kV Auto	[redacted]	[redacted]	1,533
C-129N	115	Depot Street – Milford Power	[redacted]	[redacted]	2,219
323	345	Millbury – West Medway	[redacted]	[redacted]	2,230
111	115	High Hill – Industrial Park	[redacted]	[redacted]	2,352
D-130	115	Milford Power – Depot Street	[redacted]	[redacted]	2,369
337	345	Sandy Pond – Tewksbury	[redacted]	[redacted]	2,993

Since the [redacted] was showing up as a limiting contingency for a number of different transmission elements, and other contingencies at [redacted] did not show up for the required eastern New England import levels, the addition of a new breaker in series with the [redacted] substation was considered a preferred solution to attain the required eastern New England import levels. Therefore a project[57] to add a new breaker in series with [redacted] is required for all Interstate options. The cost for this project is $3 million.

For the western New England import and Connecticut import analysis the following stresses were included:

- Lake Road station OOS : SEMA/ Boston to Connecticut
- Lake Road station OOS : Maine/NH to Connecticut
- Millstone 3 OOS: SEMA/ Boston to Connecticut
- Millstone 3 OOS: Maine/NH to Connecticut

During the transfer analysis certain element/contingency pairs were disregarded in determining the transfer limits. These issues are either more local in nature or are being addressed by on-going studies. The Interstate Reliability Project is not intended to address these issues.

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[57] This project will seek a separate PPA approval and will be advanced independently of the Interstate Reliability project. Accordingly, it is not further considered in comparisons of the Interstate solution options.

The issues disregarded for each scenario are identified along with the transfer analysis results in the following sections.

6.2.2.1 N-1 Eastern New England Import Analysis

The element/contingency pairs that were disregarded in the N-1 eastern NE import analysis are provided in Table 6-8 and Table 6-9.

Since all the A-series options have similar topology, the elements that are disregarded for the transfer analysis occur at approximately the same level of transfer across A-1 through A-4. The elements disregarded for A-1 through A-4 are recorded in Table 6-8. The elements disregarded and their respective eastern NE import levels for the C-2.1 option are provided in Table 6-9.

For each option the four stresses were analyzed and the most limiting element/contingency pair for each stress is recorded. These values are then used to determine the range of eastern New England import that is attained with each option.

Table 6-8
Elements Disregarded in Eastern NE N-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	Contingency	Min ENE Import Level	Issue
3161	345	West Walpole – Stoughton	[redacted]	3,495	See note 1
1443	115	Middletown – Portland	[redacted]	3,653	See note 2
325	345	West Medway – West Walpole	[redacted]	3,741	See note 3

Table 6-9
Elements Disregarded in Eastern NE N-1 Import Analysis – Option C-2.1

Elem ID	kV	Element Description	Contingency	Min ENE Import Level	Issue
1443	115	Middletown - Portland	[redacted]	3,291	See note 2
3161	345	West Walpole - Stoughton	[redacted]	3,446	See note 1
325	345	West Medway - West Walpole	[redacted]	3,677	See note 3

Table 6-8 and Table 6-9 Notes:

1. Greater Boston Study Issue: [redacted] It is likely that the preferred solution coming out of the Greater Boston working group will eliminate this overload.
2. Greater Hartford Central Connecticut Study Issue: Local Issue in Central Connecticut - GHCC Area.
3. SEMA / RI Study Issue: [redacted]

Table 6-10 provides the most restrictive N-1 eastern NE import values for option A-1.

Table 6-10
Eastern New England N-1 Transfer Limits for Option A-1

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	Contingency	ENE Import (MW)
Mystic	Yes	**381**	345	Northfield – Vernon	[redacted]	4,408
Mystic	No	**381**	345	Northfield – Vernon	[redacted]	3,956
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	4,462
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	4,000

Based on the results in Table 6-10, the range of eastern New England N-1 import capability with option A-1 is 3,950 to 4,450 MW.

Table 6-11 provides the most restrictive N-1 eastern NE import values for option A-2.

Table 6-11
Eastern New England N-1 Transfer Limits for Option A-2

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	Contingency	ENE Import (MW)
Mystic	Yes	**381**	345	Northfield – Vernon	[redacted]	4,419
Mystic	No	**381**	345	Northfield – Vernon	[redacted]	3,965
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	4,475
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	4,009

Based on the results in Table 6-11, the range of eastern New England N-1 import capability with option A-2 is 3,950 to 4,450 MW.

Table 6-12 provides the most restrictive N-1 eastern NE import values for option A-3.

Table 6-12
Eastern New England N-1 Transfer Limits for Option A-3

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	Contingency	ENE Import (MW)
Mystic	Yes	**381**	345	Northfield – Vernon	[redacted]	4,411
Mystic	No	**381**	345	Northfield – Vernon	[redacted]	3,960
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	4,468
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	4,006

Based on the results in Table 6-12, the range of eastern New England N-1 import capability with option A-3 is 3,950 to 4,450 MW.

Table 6-13 provides the most restrictive N-1 eastern NE import values for option A-4.

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[58] [redacted]

Table 6-13
Eastern New England N-1 Transfer Limits for Option A-4

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	Contingency	ENE Import (MW)
Mystic	Yes	**381**	345	Northfield – Vernon	[redacted]	4,406
Mystic	No	**381**	345	Northfield – Vernon	[redacted]	3,957
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	4,461
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	4,001

Based on the results in Table 6-13, the range of eastern New England N-1 import capability with option A-4 is 3,950 to 4,450 MW.

Table 6-14 provides the most restrictive N-1 eastern NE import values for option C-2.1.

Table 6-14
Eastern New England N-1 Transfer Limits for Option C-2.1

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	Contingency	ENE Import (MW)
Mystic	Yes	**381**	345	Northfield – Vernon	[redacted]	4,004
Mystic	No	**381**	345	Northfield – Vernon	[redacted]	3,958
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	4,462
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	4,405

Based on the results in Table 6-14, the range of eastern New England N-1 import capability with option C-2.1 is 3,950 to 4,450 MW.

6.2.2.2 N-1-1 Eastern New England Import Analysis

The element/contingency pairs that were disregarded in the N-1-1 eastern NE import analysis are provided in Table 6-15 and Table 6-16.

Similar to the N-1 analysis, all the A series options have similar topology, and the elements that are disregarded for the transfer analysis occur at approximately the same level of transfer across A1 through A4. The elements disregarded for A1-A4 are recorded in Table 6-15. The elements disregarded and their respective eastern NE import levels for the C-2.1 option are provided in Table 6-16.

[redacted]

Table 6-15
Elements Disregarded in Eastern NE N-1-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	L/O	Contingency	Min ENE Import Level	Issue
1443	115	Middletown – Portland	3520	[redacted]	2,352	See note 1
B-128	115	Cabot Jct. – Montague	381	[redacted]	2,401	See note 2
381	345	Northfield – Vernon	354	[redacted]	2,725	See note 3
3161	345	West Walpole – Stoughton	381	[redacted]	2,893	See note 4
312	345	Berkshire – Northfield	3520	[redacted]	2,894	See note 3
E205-E	230	Bearswamp – Pratts Jct.	381	[redacted]	2,980	See note 3
302	345	Carpenter Hill – Millbury	381	[redacted]	3,104	See note 3
282-520	115	Watertown 115 – Brighton 115	381	[redacted]	3,105	See note 5

Table 6-15 Notes:

1. Greater Hartford Central Connecticut Study Issue: Local Issue in Central Connecticut - GHCC Area.
2. Pittsfield Greenfield MA Issue: Line overload seen in the Pittsfield/Greenfield Needs analysis – Addressed by the preferred solution for that area.
3. New York Import Issue: [redacted]
4. Boston Import Issue: [redacted]
5. Greater Boston Study Issue: Overload seen in GBWG – It is likely that the preferred solution coming out of the GBWG will eliminate this overload.

Table 6-16
Elements Disregarded in Eastern NE N-1-1 Import Analysis – Options C-2.1

Element ID	kV	Element Description	L/O	Contingency	Min ENE Import Level	Issue
1443	115	Middletown – Portland	[redacted]	[redacted]	2,083	See note 1
B-128	115	Cabot Jct. – Montague	[redacted]	[redacted]	2,405	See note 2
381	345	Northfield – Vernon	[redacted]	[redacted]	2,726	See note 3
312	345	Berkshire – Northfield	[redacted]	[redacted]	2,788	See note 3

Table 6-16 Notes:

1. Greater Hartford Central Connecticut Study Issue: Local Issue in Central Connecticut - GHCC Area.
2. Pittsfield Greenfield MA Issue: Line overload seen in the Pittsfield/Greenfield Needs analysis – Addressed by the preferred solution for that area.
3. New York Import Issue: [redacted]

Table 6-17 provides the most restrictive N-1-1 eastern NE import values for option A-1.

Table 6-17
Eastern New England N-1-1 Transfer Limits for Option A-1

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	L/O	Contingency	ENE Import (MW)
Mystic	Yes	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,559
Mystic	No	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,165
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,490
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,161

Based on the results in Table 6-17, the range of eastern New England N-1-1 import capability with option A-1 is 3,150 to 3,550 MW.

Table 6-18 provides the most restrictive N-1-1 eastern NE import values for option A-2.

Table 6-18
Eastern New England N-1 Transfer Limits for Option A-2

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	L/O	Contingency	ENE Import (MW)
Mystic	Yes	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,582
Mystic	No	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,179
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,504
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,171

Based on the results in Table 6-18, the range of eastern New England N-1-1 import capability with option A-2 is 3,150 to 3,550 MW.

Table 6-19 provides the most restrictive N-1-1 eastern NE import values for option A-3.

Table 6-19
Eastern New England N-1 Transfer Limits for Option A-3

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	L/O	Contingency	ENE Import (MW)
Mystic	Yes	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,566
Mystic	No	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,169
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,498
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,167

Based on the results in Table 6-19, the range of eastern New England N-1-1 import capability with option A-3 is 3,150 to 3,550 MW.

Table 6-20 provides the most restrictive N-1 eastern NE import values for option A-4.

Table 6-20
Eastern New England N-1-1 Transfer Limits for Option A-4

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	L/O	Contingency	ENE Import (MW)
Mystic	Yes	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,566
Mystic	No	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,169
Phase II	Yes	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,492
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,162

Based on the results in Table 6-20, the range of eastern New England N-1-1 import capability with option A-4 is 3,150 to 3,550 MW.

Table 6-21 provides the most restrictive N-1-1 eastern NE import values for option C-2.1.

Table 6-21
Eastern New England N-1-1 Transfer Limits for Option C-2.1

Unit(s) Out in Base case	Lake Road Participating	Elem ID	kV	Element Description	L/O	Contingency	ENE Import (MW)
Mystic	Yes	**D130**	115	Depot St – Milford Pwr	[redacted]	[redacted]	2,877
Mystic	No	**B128**	115	Tower 510 – Webster	[redacted]	[redacted]	3,184
Phase II	Yes	**D130**	115	Depot St – Milford Pwr	[redacted]	[redacted]	3,248
Phase II	No	**381**	345	Northfield – Vernon	[redacted]	[redacted]	3,169

Based on the results in Table 6-21, the range of eastern New England N-1-1 import capability with option C-2.1 is 2,850 to 3,200 MW.

6.2.2.3 N-1 Western New England Import Analysis

The element/contingency pairs that were disregarded in the N-1 western NE import analysis are provided in Table 6-22 and Table 6-23.

Since all the A series options have similar topology, the elements that are disregarded for the transfer analysis occur at approximately the same level of transfer across A1 through A4. The elements disregarded for A1-A4 are recorded in Table 6-22. The elements disregarded and their respective western NE import levels for the C-2.1 option are provided in Table 6-23.

For each option the four stresses were analyzed and the most element/contingency pair for each stress is recorded. These values are then used to determine the range of western New England import that is attained with each option.

Table 6-22
Elements Disregarded in Western NE N-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	Contingency	Min WNE Import Level	Issue
1207	115	Manchester – East Hartford	[redacted]	3,045	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	3,507	See note 2
1443	115	Manchester – South Meadow	[redacted]	3,678	See note 1
1783	115	Farmington – Newington	[redacted]	3,842	See note 2
1784	115	N Bloomfield – NE Simsbury	[redacted]	3,911	See note 1
343	345	Sandy Pond – Wachusett	[redacted]	4,379	See note 3
1726	115	N Bloomfield – Farmington	[redacted]	4,437	See note 2
1773	115	South Meadow – Rocky Hill	[redacted]	4,471	See note 2

Table 6-23
Elements Disregarded in Western NE N-1 Import Analysis – Option C-2.1

Elem ID	kV	Element Description	Contingency	Min WNE Import Level	Issue
1207	115	Manchester – East Hartford	[redacted]	2,732	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	3,185	See note 2
1443	115	Manchester – South Meadow	[redacted]	3,290	See note 1
1783	115	Farmington – Newington	[redacted]	3,657	See note 2
1784	115	N Bloomfield – NE Simsbury	[redacted]	3,715	See note 1
1773	345	South Meadow – Rocky Hill	[redacted]	4,229	See note 2
343	115	Sandy Pond – Wachusett	[redacted]	4,289	See note 3

Table 6-22 and Table 6-23 Notes:

1. Greater Hartford Central Connecticut Study Area: All Interstate options along with GSRP would have a similar impact on the Hartford area and hence these overloads could not be used to diffentiate between Interstate options.
2. Greater Hartford Central Connecticut Study Issue: GHCC Issue – [redacted] The GHCC Study will evaluate whether the [redacted] import levels at which these violations are seen are needed for reliability in that area. The sinks defined for the Connecticut area may have exceeded reasonable unit unavailability in western Connecticut, as the intent of this analysis was to determine binding transmission limits in moving power into Connecticut and not necessarily determining constraints in moving power within Connecticut.
3. North South Issue: [redacted]

Table 6-24 provides the most restrictive N-1 western NE import values for option A-1.

Table 6-24
Western New England N-1 Transfer Limits for Option A-1

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	4,169
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	4,167
Millstone 3	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	5,061
Millstone 3	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	5,035

Based on the results in Table 6-24, the range of western New England N-1 import capability with option A-1 is 4,150 to 5,050 MW.

Table 6-25 provides the most restrictive N-1 western NE import values for option A-2.

Table 6-25
Western New England N-1 Transfer Limits for Option A-2

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	4,145
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	4,140
Millstone 3	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	5,028
Millstone 3	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	4,996

Based on the results in Table 6-25, the range of western New England N-1 import capability with option A-2 is 4,100 to 5,000 MW.
Table 6-26 provides the most restrictive N-1 western NE import values for option A-3.

Table 6-26
Western New England N-1 Transfer Limits for Option A-3

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	4,159
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	4,160
Millstone 3	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	5,027
Millstone 3	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	5,055

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[59] [redacted]

[60] [redacted]

[61] [redacted]

[redacted]

Based on the results in Table 6-26, the range of western New England N-1 import capability with option A-3 is 4,150 to 5,050 MW.

Table 6-27 provides the most restrictive N-1 western NE import values for option A-4.

Table 6-27
Western New England N-1 Transfer Limits for Option A-4

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	4,156
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	4,152
Millstone 3	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	5,049
Millstone 3	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	5,021

Based on the results in Table 6-27, the range of western New England N-1 import capability with option A-4 is 4,150 to 5,000 MW.

Table 6-28 provides the most restrictive N-1 western NE import values for option C-2.1.

Table 6-28
Western New England N-1 Transfer Limits for Option C-2.1

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	**N/A**	345	N/A	[redacted]	> 4,250[62]
Lake Road	Maine/NH	**302**	345	Millbury – Carpenter Hill	[redacted]	4,431
Millstone 3	SEMA/BOS	**302**	345	Millbury – Carpenter Hill	[redacted]	4,805
Millstone 3	Maine/NH	**302**	345	Millbury – Carpenter Hill	[redacted]	4,758

Based on the results in Table 6-28, the range of western New England N-1 import capability with option C-2.1 is 4,250 to 4,800 MW.

6.2.2.4 N-1-1 Western New England Import Analysis

The element/contingency pairs that were disregarded in the N-1-1 western NE import analysis are provided in Table 6-29 and Table 6-30.

Similar to the N-1 analysis, all the A series options have similar topology, and the elements that are disregarded for the transfer analysis occur at approximately the same level of transfer across A1 through A4. The elements disregarded for A1-A4 are recorded in Table 6-29. The elements disregarded and their respective western NE import levels for the C-2.1 option are provided in Table 6-30.

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[62] Source reached the maximum limit before any western New England import violations were seen.

[63] [redacted]

[redacted]

Table 6-29
Elements Disregarded in Western NE N-1-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	L/O	Contingency	Min WNE Import Level	Issue
1704	115	South Meadow – SW Hartford	[redacted]	[redacted]	< 0	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	[redacted]	1,801	See note 2
1207	115	Manchester – East Hartford	[redacted]	[redacted]	1,825	See note 1
1773	115	South Meadow – Rocky Hill	[redacted]	[redacted]	2,123	See note 2
1783	115	Farmington – Newington	[redacted]	[redacted]	2,283	See note 2
1775	115	Manchester – South Meadow	[redacted]	[redacted]	2,348	See note 1
1722	115	Capitol Dist Tap – NW Hrtford	[redacted]	[redacted]	2,439	See note 1
1784	115	N Bloomfield – NE Simsbury	[redacted]	[redacted]	2,475	See note 2
1726	115	N Bloomfield – Farmington	[redacted]	[redacted]	2,794	See note 1
364	345	Montville – Haddam Neck	[redacted]	[redacted]	3,051	See note 2
343	345	Sandy Pond - Wachusett	[redacted]	[redacted]	3,200	See note 3

Table 6-30
Elements Disregarded in Western NE N-1-1 Import Analysis – Options C-2.1

Elem ID	kV	Element Description	L/O	Contingency	Min WNE Import Level	Issue
1704	115	South Meadow – SW Hartford	[redacted]	[redacted]	< 0	See note 1
1722	115	Capitol Dist Tap – NW Hartford	[redacted]	[redacted]	376	See note 1
1207	115	Manchester – East Hartford	[redacted]	[redacted]	555	See note 1
1775	115	Manchester – South Meadow	[redacted]	[redacted]	1,296	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	[redacted]	1,685	See note 2
1773	115	South Meadow – Rocky Hill	[redacted]	[redacted]	2,077	See note 2
1786	115	East Hartford – South Meadow	[redacted]	[redacted]	2,229	See note 1
1783	115	Farmington – Newington	[redacted]	[redacted]	2,296	See note 2
1784	115	N Bloomfield – NE Simsbury	[redacted]	[redacted]	2,315	See note 2
1726	115	N Bloomfield – Farmington	[redacted]	[redacted]	2,776	See note 2
343	345	Sandy Pond – Wachusett	[redacted]	[redacted]	2,990	See note 3
364	345	Montville – Haddam Neck	[redacted]	[redacted]	3,124	See note 2

Table 6-29 and Table 6-30 Notes:

1. Greater Hartford Central Connecticut Study Area: All Interstate options along with GSRP would have a similar impact on the Hartford area and hence these overloads could not be used to differentiate between Interstate options.
2. Greater Hartford Central Connecticut Study Issue: [redacted] The GHCC Study will evaluate whether the [redacted] import levels at which these violations are seen are needed for reliability in that area. The sinks defined for the Connecticut area may have exceeded reasonable unit unavailability in western Connecticut, as the intent of this analysis was to determine binding transmission limits in moving power

into Connecticut and not necessarily determining constraints in moving power within Connecticut.

3. North – South Issue: Driven by high North – South flows.

Table 6-31 provides the most restrictive N-1-1 western NE import values for option A-1.

Table 6-31
Western New England N-1-1 Transfer Limits for Option A-1

Unit(s) Out in Base case	Source	Elem ID	Element Description	L/O	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	347	Sherman Road – Killingly	[redacted]	[redacted]	3,284
Lake Road	Maine/NH	347	Sherman Road – Killingly	[redacted]	[redacted]	3,126
Millstone 3	SEMA/BOS	302	Carpenter Hill – Millbury	[redacted]	[redacted]	3,942
Millstone 3	Maine/NH	302	Carpenter Hill – Millbury	[redacted]	[redacted]	3,668

Based on the results in Table 6-31, the range of western New England N-1-1 import capability with option A-1 is 3,100 to 3,900 MW.

Table 6-32 provides the most restrictive N-1-1 western NE import values for option A-2.

Table 6-32
Western New England N-1-1 Transfer Limits for Option A-2

Unit(s) Out in Base case	Source	Elem ID	Element Description	L/O	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	347	Sherman Road – Killingly	[redacted]	[redacted]	3,258
Lake Road	Maine/NH	347	Sherman Road – Killingly	[redacted]	[redacted]	3,101
Millstone 3	SEMA/BOS	302	Carpenter Hill – Millbury	[redacted]	[redacted]	3,930
Millstone 3	Maine/NH	302	Carpenter Hill – Millbury	[redacted]	[redacted]	3,654

Based on the results in Table 6-32, the range of western New England N-1-1 import capability with option A-2 is 3,100 to 3,900 MW.

Table 6-33 provides the most restrictive N-1-1 western NE import values for option A-3.

Table 6-33
Western New England N-1-1 Transfer Limits for Option A-3

Unit(s) Out in Base case	Source	Elem ID	Element Description	L/O	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	347	Sherman Road – Killingly	[redacted]	[redacted]	3,269
Lake Road	Maine/NH	347	Sherman Road – Killingly	[redacted]	[redacted]	3,118
Millstone 3	SEMA/BOS	302	Carpenter Hill – Millbury	[redacted]	[redacted]	3,922
Millstone 3	Maine/NH	302	Carpenter Hill – Millbury	[redacted]	[redacted]	3,637

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[64] [redacted]

[redacted]

Based on the results in Table 6-33, the range of western New England N-1-1 import capability with option A-3 is 3,100 to 3,900 MW.

Table 6-34 provides the most restrictive N-1-1 western NE import values for option A-4.

Table 6-34
Western New England N-1-1 Transfer Limits for Option A-4

Unit(s) Out in Base case	Source	Elem ID	Element Description	L/O	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	**347**	Sherman Road – Killingly	[redacted]	[redacted]	3,276
Lake Road	Maine/NH	**347**	Sherman Road – Killingly	[redacted]	[redacted]	3,118
Millstone 3	SEMA/BOS	**302**	Carpenter Hill – Millbury	[redacted]	[redacted]	3,941
Millstone 3	Maine/NH	**302**	Carpenter Hill – Millbury	[redacted]	[redacted]	3,667

Based on the results in Table 6-34, the range of western New England N-1-1 import capability with option A-4 is 3,100 to 3,900 MW.

Table 6-35 provides the most restrictive N-1-1 western NE import values for option C-2.1.

Table 6-35
Western New England N-1-1 Transfer Limits for Option C-2.1

Unit(s) Out in Base case	Source	Elem ID	Element Description	L/O	Contingency	WNE Import (MW)
Lake Road	SEMA/BOS	**302**	Millbury – Carpenter Hill	[redacted]	[redacted]	3,062
Lake Road	Maine/NH	**L190**	Davisville Tap – Tower Hill	[redacted]	[redacted]	2,846
Millstone 3	SEMA/BOS	**302**	Millbury – Carpenter Hill	[redacted]	[redacted]	3,478
Millstone 3	Maine/NH	**302**	Millbury – Carpenter Hill	[redacted]	[redacted]	3,169

Based on the results in Table 6-35, the range of western New England N-1-1 import capability with option C-2.1 is 2,800 to 3,450 MW.

6.2.2.5 N-1 Connecticut Import Analysis

The element/contingency pairs that were disregarded in the N-1 Connecticut import analysis are provided in Table 6-36 and Table 6-37.

Since all the A series options have similar topology, the elements that are disregarded for the transfer analysis occur at approximately the same level of transfer across A1 through A4. The elements disregarded for A1-A4 are recorded in Table 6-36. The elements disregarded and their respective Connecticut import levels for the C-2.1 option are provided in Table 6-37.

For each option the four stresses were analyzed and the most limiting element/contingency pair for each stress is recorded. These values are then used to determine the range of Connecticut import that is attained with each option.

Table 6-36
Elements Disregarded in Connecticut N-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	Contingency	Min CT Import Level	Issue
1207	115	Manchester – East Hartford	[redacted]	2,516	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	2,978	See note 2
1443	115	Manchester – South Meadow	[redacted]	3,155	See note 1
1783	115	Farmington – Newington	[redacted]	3,389	See note 2
1784	115	N Bloomfield – NE Simsbury	[redacted]	3,717	See note 1
343	345	Sandy Pond – Wachusett	[redacted]	3,850	See note 3
1726	115	N Bloomfield – Farmington	[redacted]	3,908	See note 2
1773	115	South Meadow – Rocky Hill	[redacted]	3,907	See note 2

Table 6-37
Elements Disregarded in Connecticut N-1 Import Analysis – Option C-2.1

Elem ID	kV	Element Description	Contingency	Min CT Import Level	Issue
1207	115	Manchester – East Hartford	[redacted]	2,205	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	2,658	See note 2
1443	115	Manchester – South Meadow	[redacted]	2,768	See note 1
1783	115	Farmington – Newington	[redacted]	3,135	See note 2
1784	115	N Bloomfield – NE Simsbury	[redacted]	3,192	See note 1
1773	115	South Meadow – Rocky Hill	[redacted]	3,667	See note 2
343	345	Sandy Pond – Wachusett	[redacted]	3,762	See note 3

Table 6-36 and Table 6-37 Notes:

1. Greater Hartford Central Connecticut Study Area: All Interstate options along with GSRP would have a similar impact on the Hartford area and hence these overloads could not be used to differentiate between Interstate options.
2. Greater Hartford Central Connecticut Study Issue: [redacted] The GHCC Study will evaluate whether the [redacted] import levels at which these violations are seen are needed for reliability in that area. The sinks defined for the Connecticut area may have exceeded reasonable unit unavailability in western Connecticut, as the intent of this analysis was to determine binding transmission limits in moving power into Connecticut and not necessarily determining constraints in moving power within Connecticut.
3. North South Issue: [redacted]

Table 6-38 provides the most restrictive N-1 Connecticut import values for option A-1.

Table 6-38
Connecticut N-1 Transfer Limits for Option A-1

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	CT Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	3,647
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	3,640
Millstone 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	4,121
Millstone 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	4,048

Based on the results in Table 6-38, the range of Connecticut N-1 import capability with option A-1 is 3,600 to 4,100 MW.

Table 6-39 provides the most restrictive N-1 Connecticut import values for option A-2.

Table 6-39
Connecticut N-1 Transfer Limits for Option A-2

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	CT Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	3,622
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	3,611
Millstone 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	4,079
Millstone 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	3,999

Based on the results in Table 6-39, the range of Connecticut N-1 import capability with option A-2 is 3,600 to 4,050 MW.
Table 6-40 provides the most restrictive N-1 Connecticut import values for option A-3.

Table 6-40
Connecticut N-1 Transfer Limits for Option A-3

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	CT Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	3,638
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	3,630
Millstone 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	4,145
Millstone 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	4,083

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[65] [redacted]

[66] [redacted]

[67] [redacted]

Based on the results in Table 6-40, the range of Connecticut N-1 import capability with option A-3 is 3,600 to 4,100 MW.

Table 6-41 provides the most restrictive N-1 Connecticut import values for option A-4.

Table 6-41
Connecticut N-1 Transfer Limits for Option A-4

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	CT Import (MW)
Lake Road	SEMA/BOS	**347**	345	Sherman Road – Killingly	[redacted]	3,634
Lake Road	Maine/NH	**347**	345	Sherman Road – Killingly	[redacted]	3,624
Millstone 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	4,130
Millstone 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	4,060

Based on the results in Table 6-41, the range of Connecticut N-1 import capability with option A-4 is 3,600 to 4,100 MW.

Table 6-42 provides the most restrictive N-1 Connecticut import values for option C-2.1.

Table 6-42
Connecticut N-1 Transfer Limits for Option C-2.1

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	Contingency	CT Import (MW)
Lake Road	SEMA/BOS	N/A	345	N/A	[redacted]	> 3,750[68]
Lake Road	Maine/NH	**302**	345	Millbury – Carpenter Hill	[redacted]	3,904
Millstone 3	SEMA/BOS	**302**	345	Millbury – Carpenter Hill	[redacted]	4,243
Millstone 3	Maine/NH	**302**	345	Millbury – Carpenter Hill	[redacted]	4,246

Based on the results in Table 6-42, the range of Connecticut N-1 import capability with option C-2.1 is 3,750 to 4,200 MW.

6.2.2.6 N-1-1 Connecticut Import Analysis

The element/contingency pairs that were disregarded in the N-1-1 Connecticut import analysis are provided in Table 6-43 and Table 6-44.

Similar to the N-1 analysis, all the A series options have similar topology, and the elements that are disregarded for the transfer analysis occur at approximately the same level of transfer across A1 through A4. The elements disregarded for A1-A4 are recorded in Table 6-43. The elements disregarded and their respective Connecticut import levels for the C-2.1 option are provided in Table 6-44.

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[68] Source hit maximum limit before any Connecticut import violations were seen.

Table 6-43
Elements Disregarded in Connecticut N-1-1 Import Analysis – Options A-1 to A-4

Elem ID	kV	Element Description	L/O	Contingency	Min CT Import Level	Issue
1704	115	South Meadow – SW Hartford	[redacted]	[redacted]	< 0	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	[redacted]	1,264	See note 2
1207	115	Manchester – East Hartford	[redacted]	[redacted]	1,287	See note 1
1773	115	South Meadow – Rocky Hill	[redacted]	[redacted]	1,585	See note 3
1783	115	Farmington – Newington	[redacted]	[redacted]	1,745	See note 3
1775	115	Manchester – South Meadow	[redacted]	[redacted]	1,811	See note 1
1722	115	Capitol Dist Tap – NW Hartford	[redacted]	[redacted]	1,867	See note 1
1784	115	N Bloomfield – NE Simsbury	[redacted]	[redacted]	1,937	See note 2
1726	115	N Bloomfield – Farmington	[redacted]	[redacted]	2,256	See note 2
364	345	Montville – Haddam Neck	[redacted]	[redacted]	2,513	See note 2
343	345	Sandy Pond – Wachusett	[redacted]	[redacted]	2,616	See note 3

Table 6-44
Elements Disregarded in Connecticut N-1-1 Import Analysis – Options C-2.1

Elem ID	kV	Element Description	L/O	Contingency	Min CT Import Level	Issue
1704	115	South Meadow – SW Hartford	[redacted]	[redacted]	< 0	See note 1
1722	115	Capitol Dist Tap – NW Hartford	[redacted]	[redacted]	< 0	See note 1
1207	115	Manchester – East Hartford	[redacted]	[redacted]	23	See note 1
1775	115	Manchester – South Meadow	[redacted]	[redacted]	765	See note 1
4X		Manchester 345/115 kV Auto	[redacted]	[redacted]	1,150	See note 2
1773	115	South Meadow – Rocky Hill	[redacted]	[redacted]	1,543	See note 2
1786	115	East Hartford – South Meadow	[redacted]	[redacted]	1,702	See note 1
1783	115	Farmington – Newington	[redacted]	[redacted]	1,766	See note 2
1784	115	N Bloomfield – NE Simsbury	[redacted]	[redacted]	1,780	See note 2
1726	115	N Bloomfield – Farmington	[redacted]	[redacted]	2,241	See note 2
343	345	Sandy Pond – Wachusett	[redacted]	[redacted]	2,406	See note 3
364	345	Montville – Haddam Neck	[redacted]	[redacted]	2,589	See note 2

Table 6-43and Table 6-44 Notes:

1. Greater Hartford Central Connecticut Study Area: All Interstate options along with GSRP would have a similar impact on the Hartford area and hence these overloads could not be used to differentiate between Interstate options.
2. Greater Hartford Central Connecticut Study Issue: [redacted] The GHCC Study will evaluate whether the [redacted] import levels at which these violations are seen are needed for reliability in that area. The sinks defined for the Connecticut area may have exceeded reasonable unit unavailability in western Connecticut, as the intent of this analysis was to determine binding transmission limits in moving power

into Connecticut and not necessarily determining constraints in moving power within Connecticut.

3. North – South Issue: [redacted]

Table 6-45 provides the most restrictive N-1-1 Connecticut import values for option A-1.

Table 6-45
Connecticut N-1-1 Transfer Limits for Option A-1

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	L/O	Contingency	CT Imp (MW)
Lake Rd	SEMA/BOS	**7X**		N. Bloomfld 345/115 kV Auto	[redacted]	[redacted]	2,723
Lake Rd	Maine/NH	**347**	345	Sherman Rd – Killingly	[redacted]	[redacted]	2,599
Millstne 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	[redacted]	3,134
Millstne 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	[redacted]	2,839

Based on the results in Table 6-45, the range of Connecticut N-1-1 import capability with option A-1 is 2,550 to 3,100 MW.

Table 6-46 provides the most restrictive N-1-1 Connecticut import values for option A-2.

Table 6-46
Connecticut N-1-1 Transfer Limits for Option A-2

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	L/O	Contingency	CT Imp (MW)
Lake Rd	SEMA/BOS	**347**	345	Sherman Rd – Killingly	[redacted]	[redacted]	2,736
Lake Rd	Maine/NH	**347**	345	Sherman Rd – Killingly	[redacted]	[redacted]	2,571
Millstne 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	[redacted]	3,109
Millstne 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	[redacted]	2,812

Based on the results in Table 6-46, the range of Connecticut N-1-1 import capability with option A-2 is 2,550 to 3,100 MW. Table 6-47 provides the most restrictive N-1-1 Connecticut import values for option A-3.

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[69] [redacted]

[70] [redacted]

Table 6-47
Connecticut N-1-1 Transfer Limits for Option A-3

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	L/O	Contingency	CT Imp (MW)
Lake Rd	SEMA/BOS	**7X**	N. Bloomfld 345/115 kV Auto		[redacted]	[redacted]	2,726
Lake Rd	Maine/NH	**347**	345	Sherman Rd – Killingly	[redacted]	[redacted]	2,588
Millstne 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	[redacted]	3,137
Millstne 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	[redacted]	2,850

Based on the results in Table 6-47, the range of Connecticut N-1-1 import capability with option A-3 is 2,550 to 3,100 MW.

Table 6-48 provides the most restrictive N-1-1 Connecticut import values for option A-4.

Table 6-48
Connecticut N-1-1 Transfer Limits for Option A-4

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	L/O	Contingency	CT Imp (MW)
Lake Rd	SEMA/BOS	**7X**	N. Bloomfld 345/115 kV Auto		[redacted]	[redacted]	2,726
Lake Rd	Maine/NH	**347**	345	Sherman Rd – Killingly	[redacted]	[redacted]	2,589
Millstne 3	SEMA/BOS	**310**	345	Card – Manchester	[redacted]	[redacted]	3,139
Millstne 3	Maine/NH	**310**	345	Card – Manchester	[redacted]	[redacted]	2,845

Based on the results in Table 6-48, the range of Connecticut N-1-1 import capability with option A-4 is 2,550 to 3,100 MW.

Table 6-49 provides the most restrictive N-1-1 Connecticut values for option C-2.1.

Table 6-49
Connecticut N-1-1 Transfer Limits for Option C-2.1

Unit(s) Out in Base case	Source	Elem ID	kV	Element Description	L/O	Contingency	CT Imp (MW)
Lake Rd	SEMA/BOS	**302**	345	Millbury – Carpenter Hill	[redacted]	[redacted]	2,540
Lake Rd	Maine/NH	**L190**	345	Davisville Tap - Tower Hill	[redacted]	[redacted]	2,314
Millstne 3	SEMA/BOS	**302**	345	Millbury – Carpenter Hill	[redacted]	[redacted]	2,908
Millstne 3	Maine/NH	**302**	345	Millbury – Carpenter Hill	[redacted]	[redacted]	2,653

Based on the results in Table 6-49, the range of Connecticut N-1-1 import capability with option C-2.1 is 2,300 to 2,900 MW.

[redacted]

6.2.3 Summary of Transfer Analysis Results

Table 6-50 summarizes the results of the (N-1) interface transfer capability simulations for each of the Interstate Reliability Project options.

Table 6-50
New England Interface N-1 Transfer Levels

Interface	Option A-1	Option A-2	Option A-3	Option A-4	Option C-2.1
WNE Import	4,150-5,050	4,100-5,000	4,150-5,050	4,150-5,000	4,250-4,750
ENE Import	3,950-4,450	3,950-4,450	3,950-4,450	3,950-4,450	3,950-4,450
CT Import	3,600-4,100	3,600-4,050	3,600-4,100	3,600-4,100	3,750-4,200

Table 6-51 summarizes the results of the (N-1-1) interface transfer capability simulations for each of the Interstate Reliability Project options.

Table 6-51
New England Interface N-1-1 Transfer Levels

Interface	Option A-1	Option A-2	Option A-3	Option A-4	Option C-2.1
WNE Import	3,100-3,900	3,100-3,900	3,100-3,900	3,100-3,900	2,800-3,450
ENE Import	3,150-3,550	3,150-3,550	3,150-3,550	3,150-3,550	2,850-3,200
CT Import	2,550-3,100	2,550-3,100	2,550-3,100	2,550-3,100	2,300-2,900

6.2.4 Transfer Levels Used for Further Analysis

For ease of testing and comparability in the stability screening analysis and the delta P analysis, a single value of eastern New England import and western New England import was assumed for all 5 alternatives. The single values selected (4,000 MW) were significantly higher than the required transfer capability for reliability in eastern New England (3,009 for N-1 and N-1-1) and western New England (3,308 for N-1 and 2,850 for N-1-1) in the year 2020 as shown in section 3.2.9.In summary, the single values used for testing were as follows:

- East-West stress cases were tested at 4,000 MW of western NE import
- West-East stress cases were tested at 4,000 MW of eastern NE import
- It is important to note that both the line-out stability and delta P testing were done at values which were higher than the all-lines-in need to insure adequate stress conditions since a minimum number of cases were being tested. Although the all-lines-in thermal import capabilities were in the 4,000 MW range, the line-out thermal limits were in the 2,800 MW range.

[redacted]

6.3 Stability Performance Results

This section contains the results of transient stability simulations performed at selected substations and switching stations in southern New England. The stations selected were in the vicinity of the Interstate options in order to compare the dynamic performance of the transmission system with the infrastructure associated with each option in-place. The scope of this analysis was to accurately and sufficiently compare electric system performance metrics such as rotor angle, frequency and voltage.

The working group concluded that it was unnecessary to perform stability simulations for options A-4 because it is very similar to option A-1. The significant difference is that option A-4 adds an additional 345 kV line from West Farnum to Sherman Road. The addition of a transmission line will bring the power system electrically closer together and is expected to result in improved stability performance.

The stability analyses studied system performance during and immediately following a 3-phase fault condition with normal clearing at six key 345 kV substations and switching stations: Manchester, Carpenter Hill (for option C-2.1 only), Millbury, West Medway (line-out conditions only), Sherman Road, and West Farnum. The dynamic stability screening results are located in Appendix H: Stability Analysis Results.

The extreme contingency testing and BPS testing were performed for the preferred solution and the results of those analyses are detailed in sections 7.7and 7.8.

6.3.1 All-Lines-In Stability Performance Results

All three phase faults with normal clearing passed the acceptability criteria defined in Section 3.3 of ISO PP-3. Based on bulk power system (BPS) requirements, the protective relaying systems associated with each 345 kV transmission element include two independent protection schemes. Based on information provided by the transmission owners the stations that were tested as a part of this analysis were modeled to have maximum primary and backup clearing times of [redacted]

6.3.2 Line-Out-of-Service Stability Performance Results

N-1-1 testing was also performed for all system condition models described in Section 6.3.1 above. The results of the contingency event analyses which remove a second critical 345 kV circuit in the southern New England area are found in Appendix H: Stability Analysis Results. The line-out stability study results did not violate NERC, NPCC and ISO reliability standards and criteria. The line-out stability analysis was performed at the same levels as the all-lines-in analysis. The dynamic simulations of the system for all the faults tested in these analyses resulted in stable and well damped responses at all tested New England interface transfer levels.

6.4 Short Circuit Screening Performance Results

Short circuit screening analysis was conducted at 345 kV stations within the study area to determine the change in the magnitude of the fault current levels as a result of proposed transmission system modifications. The results are presented in two tables. The analysis included 3-phase balanced faults and was conducted using PSS/E.

Table 6-52 shows the fault current levels as a percentage of the lowest short circuit interrupting capability of a circuit breaker at that substation or switching station. The stations with the short circuit current over 80% of its lowest rated breaker's rating are indicated in red. Table 6-53shows the percentage change in short circuit current at various area substations associated with each option.

Table 6-52
Short Circuit Currents (SCC) at Area 345 kV Stations

345 kV Substation	Small Brkr @ Statn	Pre-IRP SCC (A)	Pre-IRP Duty (%)	A-1 SCC (A)	A-1 Duty (%)	A-2 SCC (A)	A-2 Duty (%)	A-3 SCC (A)	A-3 Duty (%)	A-4 SCC (A)	A-4 Duty (%)	C-2.1 SCC (A)	C-2.1 Duty (%)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The short circuit screening study results demonstrate that some of the Millbury switching station 345 kV circuit breakers must be replaced for all options. Option C-2.1 had the least impact on the Millbury breakers.

[redacted]

Table 6-53
Percent Increase in SCC at Area 345 kV Stations

345 kV Substation	Pre-IRP Duty (A)	A-1 % change	A-2 % change	A-3 % change	A-4 % change	C-2.1 % change
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The [redacted] at the Millbury switching station were also identified in the earlier NEEWS short circuit studies, performed as part of the PPA process, as being overdutied. They were proposed to be replaced with circuit breakers having a [redacted] interrupting duty. The existing layout at the Millbury switching station is shown in Figure 6-1.

[redacted]

Figure 6-1: Existing Millbury 345 kV Switchyard Layout

The results also indicate that the fault currents with option A-2 would exceed the duty of the lowest rated breaker at Sherman Road. But as a part of the A-2 plan the Sherman Road switching station has to be rebuilt to a GIS station to accommodate the three new lines, and hence the breakers would be upgraded as a part of the plan.

The short circuit screening study results indicate that there is very little difference among the options A-1 through A-4 with respect to short circuit currents. Option C-2.1 affects the short circuit currents at different stations compared to options A-1 through A-4, since C-2.1 has a different route.

6.5 Delta P Performance Results

The following sections describe the results of analyses that determined the delta P on the generating units at [redacted]

6.5.1 Delta P Analysis at [redacted]

The initially all lines in-service study results of the delta P analysis performed in this study are provided in Table 6-54. The table also contains the voltage angle differences across the 345 kV circuit breakers following the contingency event and before the transmission line is reclosed. Results of the analysis illustrate that prior to any of the Interstate options, the delta P on [redacted] is 0.75 per unit of machine MVA (the [redacted] contingency event). This value exceeds the recommended limit of 0.5 per unit. The [redacted] experience approximately the same per unit of machine MVA level. The maximum angle difference across the 345 kV circuit breakers at the local and remote ends (the [redacted] contingency event) for this scenario was 38.5 degrees. There is an SPS at the [redacted] that would trip the [redacted] generating units under this condition. Also, the testing in Table 6-54 was conducted at the higher transfer limits attained with the Interstate options that are described in Section 6.2.4.

The worst delta P results were seen for the contingency involving the loss of the [redacted] This contingency was then repeated with two sensitivities. The first was increasing unit outputs to their greater than 50 degree rating. This did not significantly change results such that conclusions would be altered.

The second sensitivity was having [redacted] out of service and thus causing more power to flow on the [redacted] This sensitivity did demonstrate higher delta P values than with the [redacted] in-service. The results show that for options A-1, A-2, A-3 and A-4 the delta P is below 0.5. However, for option C-2.1 the delta P was at 0.92 which is well over the recommended 0.5 value.

Table 6-54
[redacted] Delta P – All Lines In-Service

		Pre-Interstate[71]		A1		A2		A3		A4		C-2.1	
Base case	**CTG**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**
High E→W	[redacted]	38.5	**0.44**	11.1	**0.08**	11.2	**0.08**	11	**0.08**	11.1	**0.08**	28.6	**0.34**
High E→W	[redacted]	27.5	**0.75**	9.5	**0.18**	5.3	**0.09**	8.9	**0.17**	8.7	**0.17**	17.6	**0.47**
High E→W	[redacted]	25.8	**0.72**	9	**0.17**	5	**0.09**	8.4	**0.16**	8.2	**0.16**	15.5	**0.43**
High W→E	[redacted]	6	**0.09**	3	**0.02**	3	**0.02**	3	**0.02**	3	**0.02**	7	**0.04**
High W→E	[redacted]	29	**0.66**	7	**0.12**	5	**0.08**	7	**0.13**	7	**0.12**	22	**0.53**
High W→E	[redacted]	30	**0.71**	7	**0.12**	5	**0.08**	8	**0.13**	7	**0.13**	24	**0.57**
Sensitivity Test													
High E→W 50° rating	[redacted]	27.3	**0.74**	9.4	**0.18**	5.2	**0.09**	8.6	**0.17**	8.6	**0.17**	17.5	**0.47**
High E→W 50° rating [redacted]	[redacted]	40.5	**1.3**	12.5	**0.26**	6.3	**0.24**	11.6	**0.25**	11.6	**0.25**	27.8	**0.92**

🟥	**ΔP > 0.5**
🟧	**0.4 < ΔP < 0.5**

In summary, the results of the analysis show that, except for option C-2.1, no post Interstate delta P value greater than 0.26 per unit of machine MVA was found. The tests with option C-2.1 show unacceptable values above 0.5 per unit of machine MVA. Further, the largest angle difference obtained for the cases with the Interstate Reliability Project with option A-1 through A-4 installed was 11.2 degrees, which is significantly less than the largest angle difference obtained for the pre-Interstate study case.

6.5.2 Delta P Analysis at [redacted]

The results of the initially all lines in-service delta P analysis performed in this study are provided in the Table 6-55. The table also contains the bus voltage angle differences across the 345 kV circuit breakers after a contingency event has occurred and before the transmission line is reclosed. Results of the analysis illustrate that prior to the installation of one of the Interstate Reliability Project options, the delta P on [redacted] is 0.6 per unit of machine MVA (the [redacted] contingency event). This value exceeds the recommended limit (0.5 per unit). The [redacted] experiences approximately the same level. The maximum angle difference

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[71] Testing for Pre-Interstate Project carried out at post-Interstate interface transfer levels.

across the 345 kV circuit breakers at the local and remote end (the [redacted] contingency event) for this scenario was 21 degrees. It is to be noted that the testing in Table 6-55 was conducted at the higher transfer limits attained with the Interstate options that are described in Section 6.2.4.

Table 6-55
[redacted] Delta P – All-Lines-In-Service

		Pre-Interstate[72]		A1		A2		A3		A4		C-2.1	
Base case	**CTG**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**	**Ang. Diff**	**ΔP**
High E→W	[redacted]	8.8	**0.14**	5.9	**0.1**	5.6	**0.11**	3.2	**0.02**	5.7	**0.1**	5.7	**0.1**
High E→W	[redacted]	0.07	**0.02**	0.2	**0.01**	0.3	**0.01**	0.1	**0**	0	**0**	1.7	**0.05**
High W→E	[redacted]	15	**0.26**	8	**0.14**	5.9	**0.12**	6.2	**0.06**	7	**0.13**	11.5	**0.2**
High W→E	[redacted]	21	🟥	13	**0.36**	10	**0.28**	7	**0.16**	12	**0.32**	17	**0.5**

🟥	ΔP > 0.5
🟧	0.4 < ΔP < 0.5

The results of the analysis with the Interstate options also show that, except for option C-2.1, no post-Interstate delta P value greater than 0.36 as a per unit of machine MVA was found. The tests with option C-2.1 still show a borderline unacceptable value of 0.5 per unit of machine MVA. This testing indicates that if option C-2.1 is selected as the preferred alternative further analysis will be required to determine if an SPS is required at [redacted] to attain the west-east transfer levels needed to meet the load serving requirements in eastern New England.

Further, the largest angle difference obtained for the cases with option A-1 through A-4 in service was 13 degrees, which is considerably less than the largest angle difference obtained for the pre-Interstate study case.

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[72] Testing for Pre-Interstate Project carried out at post-Interstate interface transfer levels. A sensitivity test was performed for the [redacted] with the West-East interface at the current transfer limit of 1000 MW. For that case the delta P a[redacted] was 0.47, which is below the recommended 0.5 value.

Section 7
Comparison of Alternative Solutions

7.1 Factors Used to Compare Alternatives

The objective of this section is to determine the preferred option by comparing them in the following three categories:

- Electrical Performance
- Costs
- Impact on Natural and Human Environments

The following sections discuss the comparison of the five Interstate options based on each of the above categories.

7.2 Comparison of Electrical Performance of Alternatives

Electrical performance factors are used to compare the overall system benefits provided by each of the five options. The system upgrades associated with each option were designed to resolve the reliability concerns in the 2011 updated needs assessment analysis for the southern New England transmission system over the 2015 to 2020 planning horizon. Each option was next evaluated for its ability to improve the reliability and performance of the transmission system in the following areas:

- Improve the capability of the transmission system to move power into and within the load centers of southern New England, specifically increasing the transfer capability across the following interfaces:
    - New England East-West Interface
    - New England West-East interface
    - Connecticut import interface.
- Eliminate projected line overloads and voltage violations following a contingency event.
- Minimize short circuit impact at area 345 kV switchyards.
- Prevent degradation in stability performance to faults at major 345 kV switchyards in southern New England.
- Minimize delta P values along [redacted] corridor.
- Maximize ability for future expansion.

This section compares the improvements that each of the five Interstate Reliability Project options contributes to the performance of the southern New England system. It includes comparison tables for the electrical performance factors tested in Section 6. Some introductory detail on a few of these performance areas listed above follows below.

For each option, the study evaluated a number of contingency events under which the power flow on a transmission element exceeded its emergency rating under the modeled contingency and dispatch conditions. Similarly, voltage levels at various substations and switching stations following the contingency event were compared. A comparison of these performance measures conveys the relative system strength of each option.

Each option's potential for enhancing system expandability and flexibility was reviewed. This is an important consideration given that transmission assets typically have long lifetimes that must allow for changing system requirements. The 345 kV network is the standard high voltage backbone of the New England transmission system that can more easily be connected to new generation facilities and transmission substations.

7.2.1 Eastern New England Import Capability

The improvement offered by each Interstate option on the eastern New England import capability under all-lines-in (N-1) and line-out (N-1-1) conditions is provided in Table 7-1. The table also includes the incremental increase in import capability provided by each option.

The improvement offered by all five Interstate options was comparable on N-1 eastern New England import capability. However, under line-out conditions the A-series options performed better than the C-2.1 option. The N-1-1 eastern New England import capability was about 300-350 MW higher with the A-series options than with option C-2.1.

The needs assessment identified a need to increase the N-1-1 eastern New England import limit by about 1750 MW. All Interstate options meet this objective.

Table 7-1
Eastern New England Import Capability Improvement

Interstate Option	Eastern NE N-1 Import Capability (MW)	Incremental Increase in Eastern NE N-1 Import Capability (MW)	Eastern NE N-1-1 Import Capability (MW)	Incremental Increase in Eastern NE N-1-1 Import Capability (MW)
Base case	2,600-2,700	N/A	1,250-1,350	N/A
A-1	3,950-4,450	1,350-1,850	3,150-3,550	1,900-2,300
A-2	3,950-4,450	1,350-1,850	3,150-3,550	1,900-2,300
A-3	3,950-4,450	1,350-1,850	3,150-3,550	1,900-2,300
A-4	3,950-4,450	1,350-1,850	3,150-3,550	1,900-2,300
C-2.1	3,950-4,450	1,350-1,850	2,850-3,200	1,600-1,950

7.2.2 Western New England Import Capability

The improvement offered by each Interstate option on the western New England import capability under all-lines-in (N-1) and line-out (N-1-1) conditions is provided in Table 7-2. The table also includes the incremental increase in import capability provided by each option.

The improvement offered by all five Interstate options was comparable on N-1 western New England import capability. However, under line-out conditions the A-series options performed better than the C-2.1 option. The N-1-1 western New England import capability with the A-series options was about 350-400 MW higher than C-2.1. The needs assessment identified a need to increase the N-1-1 western New England import limit by about 300 MW. All Interstate options exceed this objective.

Table 7-2
Western New England Import Capability Improvement

Interstate Option	Western NE N-1 Import Capability (MW)	Incremental Increase in Western NE N-1 Import Capability (MW)	Western NE N-1-1 Import Capability (MW)	Incremental Increase in Western NE N-1-1 Import Capability (MW)
Base case	3,400-3,950	N/A	2,250-3,000	N/A
A-1	4,150-5,050	750-1,650	3,100-3,900	850-1,650
A-2	4,100-5,050	700-1,650	3,100-3,900	850-1,650
A-3	4,150-5,050	750-1,650	3,100-3,900	850-1,650
A-4	4,150-5,050	750-1,650	3,100-3,900	850-1,650
C-2.1	4,250-4,750	850-1,350	2,800-3,450	550-1,200

7.2.3 Connecticut Import Capability

The improvement offered by each Interstate option on the Connecticut import capability under all-lines-in (N-1) and line-out (N-1-1) conditions is provided in Table 7-3. The table also includes the incremental increase in import capability provided by each option.

The improvement offered by all five Interstate options was comparable on N-1 Connecticut import capability. However, under line-out conditions the A-series options performed better than the C-2.1 option. The N-1-1 Connecticut import capability was about 200-250 MW higher with the A-series options than with option C-2.1. The needs assessment identified a need to increase the N-1-1 Connecticut import limit by about 400 MW. All Interstate options exceed this objective.

Table 7-3
Connecticut Import Capability Improvement

Interstate Option	Connecticut N-1 Import Capability (MW)	Incremental Increase in Connecticut N-1 Import Capability (MW)	Connecticut N-1-1 Import Capability (MW)	Incremental Increase in Connecticut N-1-1 Import Capability (MW)
Base case	3,050-3,750	N/A	1,750-2,400	N/A
A-1	3,600-4,100	550-1,050	2,550-3,100	800-1,350
A-2	3,600-4,050	550-1,000	2,550-3,100	800-1,350
A-3	3,600-4,100	550-1,050	2,550-3,100	800-1,350
A-4	3,600-4,100	550-1,050	2,550-3,100	800-1,350
C-2.1	3,750-4,200	700-1,150	2,300-2,900	550-1,150

7.2.4 Line Loading Following Contingencies

All five Interstate options mitigate all relevant thermal overloads on transmission elements that would occur in the planned transmission system (with GSRP and RIRP in-service) at projected 2020 load levels following an N-1 or N-1-1 contingency event. A comparison of the number of transmission line loadings above 90%-of-rating following each contingency event provides a basic understanding of the magnitude of additional transmission capacity margin that each option can provide. The option with the lowest number of transmission lines loaded at or above 90% of rating would be viewed as providing the most robust system solution.

These results are displayed in Table 7-4, where "high" means loadings over 90% of rating. The A-series options have substantially fewer transmission elements loaded over 90% of its LTE than option C-2.1. Among the A-series options, A-2 and A-3 had the least number of elements with loadings over 90% of LTE.

Table 7-4
Comparison of Line Loadings in 2020

Interstate Option	Number of High "All-Lines-In" Loadings	Number of High "Line-Out" Loadings	Total Number of Line Loadings
A-1	0	55	55
A-2	0	44	44
A-3	0	44	44
A-4	0	53	53
C-2.1	0	139	139

7.2.5 Stability Screening Analysis

A stability screening analysis was performed to determine if any options exhibited undesirable transient behavior following a fault condition. All options exhibited stable system performance and no stability criteria violations were seen for the all-lines-in and line-out analysis.

7.2.6 Short Circuit Screening Analysis

Table 7-5 provides a comparison of the maximum percent increases in short circuit duties at 3 substations/switching stations in the study area. Based on maximum short-circuit currents at a particular substation or switching station, option C-2.1 offers the lowest increase in fault duty at a given substation. Option A-4 showed the highest percentage increase in short circuit current at a 345 kV switchyard. The relatively small differences in these results, which are displayed in Table 7-5, do not appear to be significant and so are not considered a material factor in selecting a preferred option. However, the testing did serve as an effective screening tool for determining whether any option was fatally flawed.

Table 7-5
Comparison of Short-Circuit Impacts

Interstate Option	Substation with Maximum Short Circuit Impact	Short Circuit Impact at [redacted] (% increase)	Short Circuit Impact at [redacted] (% increase)	Short Circuit Impact at [redacted] (% increase)
A-1	[redacted]	**41**	38	4
A-2	[redacted]	28	**45**	4
A-3	[redacted]	**43**	39	5
A-4	[redacted]	**48**	39	4
C-2.1	[redacted]	10	1	**40**

Checks on whether the potential three-phase bus fault current exceeded the interrupting capability of the lowest rated circuit breaker at a particular substation or switching station found this to occur only at the Millbury 345 kV switching station. The results demonstrated that all options would require 345 kV circuit breaker replacements at this facility.

7.2.7 Delta P Analysis

For reducing the need for Special Protection Schemes (SPSs) to minimize shaft torque concerns, option A-2 appears to be best. Options A-1, A-3 and A-4 provide similar performance under the delta P analysis. Option C-2.1 does not reduce the delta P to below 0.5 pu under all lines in-service scenarios. Table 7-6 contains a comparison of the impact on delta P at [redacted]

[redacted]

Table 7-6
Comparison of Delta P Impact of Interstate Options

Interstate Option	Reduces the Delta P at [redacted] below 0.5 p.u with all lines in-service	Reduces the Delta P at [redacted] with all lines in-service
A-1	Yes	Yes
A-2	Yes	Yes
A-3	Yes	Yes
A-4	Yes	Yes
C-2.1	No	No

7.2.8 System Flexibility and Expandability

A preferred system solution should best permit further system expansion and change, beyond the current planning horizon, without incurring excessive costs to meet future reliability needs.

The following factors were used to evaluate the future expansion capabilities of the options:

- Ability to accommodate increased fault duties.
- Ability to expand the terminating stations and ability to add future transmission facilities.
- Flexibility to adapt based on future needs.

7.2.8.1 Short Circuit Margins

As evidenced in Table 6-53 in Section 6.4, a screening analysis was performed to determine the increase in short circuit currents at 17 area 345 kV substations and switching stations in southern New England. Based on these results option C-2.1 offers the lowest increase in fault currents at 11 of the 17 stations. Hence in terms of available room for future short circuit duty increases, option C-2.1 is the best alternative.

Among the four A-series options, option A-1 had the least impact at 5 substations and had a lower percentage increase in short circuit currents at almost all stations. Thus in terms of available short circuit duty margin, A-1 is the best of the A-series options. Furthermore, in comparison to C-2.1 at 4 of the 11 stations where C-2.1 had the lowest impact on short circuit current, the A-1 impact was within 4% of the impact of C-2.1.

7.2.8.2 Station Expandability

Next, the five options were reviewed for future expandability at the terminating substations and switching stations. The comparison is made based on 5 existing facilities in the area with 345 kV switchyards.

West Farnum Substation

- Options C-2.1 and A-2 each add one new line into West Farnum and leave the most room for expandability at this substation.
- Options A-1 and A-3 each add two new lines into the West Farnum substation and leave less room for expansion compared to A-2 and C-2.1.
- Option A-4 adds 3 new lines into the West Farnum substation and leaves the least amount of room for expansion at West Farnum.

[redacted]

Sherman Road Switching Station

- Option A-1 and A-3 do not add any new lines into Sherman Road, and with the construction of a new 2-Bay AIS, these options would leave the most room for future expansion at this switching station site.
- Options A-4 and C-2.1 each add one new line into the Sherman Road switching station, and with the construction of a new 3-Bay AIS, these options would leave less room for future expansion at this switching station site when compared to options A-1 and A-3.
- Option A-2 adds three new lines into Sherman Road, and with the construction of a new 4-Bay GIS this option would leave room for future expansion at this switching station site similar to options A-1 and A-3.

Millbury Switching Station

- All five options add one line into Millbury and hence no option provides a clear benefit in terms of future expansion capabilities at Millbury.

Manchester (CT) and Carpenter Hill (MA) Substations

- The only option that affects these substations is option C-2.1. All the A-series options leave room for future expandability at these substations. Option C-2.1 would leave Manchester substation interconnecting six 345 kV transmission lines.

In summary, options A-1 and A-3 provide maximum benefit in terms of available room for expansion at area 345 kV substations and switchyards in southern New England. However A-3 requires the construction of a new switching station at Uxbridge, and the construction of this switching station consumes a potential site for a future substation. Thus, A-1 is the preferred alternative in terms of future expandability.

7.2.8.3 System Flexibility

The next and final comparison of the options is based on the flexibility of the option to adapt to future needs.

Option A-1: Option A-1 can easily be adapted to resemble option A-3 and option A-4. Thus, if future needs indicate a need for an A-3 or A-4 system configuration, A-1 provides the flexibility to attain these configurations.

Option A-2: Option A-2 cannot be easily adapted to resemble any of the other options. It also adds 3 new lines into Sherman Road for a total of 6 transmission circuits at Sherman Road. This large number of circuits at Sherman Road adds system security risk in terms of potential extreme contingency events at Sherman Road.

Option A-3: Option A-3 cannot be easily adapted to resemble the other options. But the addition of a new switching station at Uxbridge, which can be expanded to include more lines in the future, provides a level of expandability that options A-2 and C-2.1 do not provide.

Option A-4: Option A-4 requires an additional switchyard bay at West Farnum compared to all other options, hence constricting flexibility at West Farnum. Also, it cannot be easily adapted to resemble the other options. Again, option A-4 also provides the capability of building a new substation or switching station at Uxbridge in the future, but the resultant configuration would still be a combination of A-3 and A-4.

Option C-2.1: Option C-2.1 is fundamentally different from the A-series options and hence does not resemble the A-series options. This option also does not add a line from the generation rich corridor from Lake Road to NEA Bellingham into Millbury and thereby constricts the addition of new generators along that corridor as compared to the A-series options.

Thus, option A-1 provides the most flexibility to be modified to resemble the other A-series options, a distinct advantage in future system expandability to adapt to changing needs.

In summary based on the short circuit impact, expandability at area 345 kV substations and switching stations, and flexibility, option A-1 is the preferred alternative.

7.2.9 Summary of Electrical Performance

Table 7-7 is a summary comparison table that includes all the electrical performance factors.

Table 7-7
Comparison of Options

Interstate Options and Needs	Option A-1	Option A-2	Option A-3	Option A-4	Option C-2.1
Improve Eastern NE Import Capability	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: Medium
Improve Western NE Import Capability	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: Medium
Improve Connecticut Import Capability	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: High	N-1: High N-1-1: Medium
Number of highly-loaded lines (>90% of LTE)	Moderate	Low	Low	Moderate	High
Increased SC Duty at 345 kV substations	Moderate	High	High	High	Low
Impact on [redacted] SPSs (all lines in)	May eliminate the SPS	May eliminate the SPS	May eliminate the SPS	May eliminate the SPS	Does not Eliminate the need for the SPS
System Flexibility and Expandability	High	Low	Moderate	Moderate	Low

The four A-series options provide comparable results on all the electrical performance metrics tested. However, the A-series options are superior to the C-2.1 option on increased transfer capabilities and number of highly-loaded lines. The C-2.1 option has a lesser impact than the A-series options in terms of increased fault currents at key 345 kV substations and switching stations in southern New England. Option A-1 was a close second.

The stability performance met the criteria requirement for all 5 options.

[redacted]

The A-series options reduce the delta P levels at [redacted] under all-lines-in conditions. Option C-2.1 does not provide this benefit. Furthermore, option C-2.1 may necessitate a new delta P SPS at [redacted] to attain the high post project transfers across the West-East interface.

In terms of system expandability and flexibility A-1 was the most favorable of the five options.

Overall, the A-series options performed better than the C-2.1 option on most of the electrical performance metrics. Within the A-series options there is no clear option that performs substantially better than the others. However, future system expandability and flexibility considerations favor option A-1 over the other A-series options.

7.3 Comparison of Costs of Alternatives

For each of the five options, cost estimates were prepared using a process consistent with ISO-NE procedures as defined in Attachment D of the ISO Planning Procedure 4[73], "*Procedure for Pool-Supported PTF Cost Review*". Table 7-8 summarizes these cost estimates for each option. The detailed cost estimates for each option is provided in Appendix I: Detailed Cost Estimates for Interstate Alternatives.

Table 7-8
Summary of Cost Estimates[74] of Interstate Options ($M)

	A-1	A-2	A-3	A-4	C-2.1
NU					
Substation Upgrades	$30	$30	$30	$30	$14
Transmission Lines	$221	$221	$221	$221	$295
NU Total	$251	$251	$251	$251	$309
National Grid					
Substations	$101	$138	$145	$118	$150
Transmission Lines	$190	$139	$154	$201	$255
Grid Total	$291	$277	$299	$319	$405
NSTAR					
Substations	$0	$0	$0	$0	$0
Transmission Lines	$0	$15	$3	$0	$0
NSTAR Total	$0	$15	$3	$0	$0
Interstate Total					
Substations	$131	$168	$175	$148	$164
Transmission Lines	$411	$375	$378	$422	$550
Total[75]	**$542**	**$543**	**$553**	**$570**	**$714**

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[73] http://www.iso-ne.com/rules_proceds/isone_plan/pp4_0_attachment_d.pdf

[74] Estimates have a -25% / +50% degree of accuracy.

[75] The above estimates reflect capitalized Allowance for Funds Used during Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

While all the A-series options were close in cost, the estimate for option A-1 was the lowest. The estimates for all the A-series options were substantially less than the estimate for option C-1.2. The difference between the highest estimated cost for option C-2.1 ($714 million) and the highest estimated cost amongst the A-series options, option A-4 ($570 million) was $144 million. Thus, the estimated cost for C-2.1 is over 25% higher than the highest estimate amongst the A-series options.

The above cost estimates do not include the three advanced projects:

- NSTAR – Reconductor 1.2 mile section of the 345 kV line 336 from ANP Blackstone to NEA Bellingham Tap and upgrade terminal equipment at the W. Medway substation to 3,000 A rated equipment.
  - NSTAR Substation Costs - $700,000
  - NSTAR Transmission Costs - $1,000,000
- NSTAR – Add a new breaker in series with the 106 breaker at West Medway 345 kV substation.
  - NSTAR Substation Costs - $3,000,000
- NU/CMEEC – Eliminate the sag limit on the 115 kV Montville - Buddington 1410 line in Connecticut.
  - NU Transmission Costs - $3,500,000
  - CMEEC Transmission Costs - $60,000

7.4 Comparison of Natural and Human Environments Impact of Alternatives

Natural and human environment information related to the currently proposed options was initially compiled commencing in 2006 as part of an analyses of the five original Interstate options. In 2011, additional data was compiled focusing on the variations to option C-2 and option A as the options that would best meet the defined need and performance requirements. Information sources used in the comparative analyses of natural and human environment resource features included:

- U.S. Geological Survey topographic maps
- Aerial photography-based maps
- Geographical Information System (GIS) environmental and land-use data bases
- Transmission line ROW and existing line characteristics from NU and National Grid
- General field reconnaissance of the 345 kV transmission line routes for each option
- Review of natural and human environment data compiled by NU and National Grid in conjunction with other NEEWS projects[76]

Using this information, the following factors were applied to evaluate and compare the various options:

- Miles of new 345 kV transmission line
- ROW Length (miles)
- New ROW Easement Acquisition Required

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[76] For example, the Manchester Substation to Meekville Junction segment of Option C-2.1 is the same ROW along which the Connecticut Siting Council recently approved NU's MMP-V Project, involving a new 345 kV line. This ROW segment was studied extensively as part of the MMP-V Project. Similarly, the Ludlow Substation to Hampden Junction portion of Option C-2.1 was part of the GSRP's Noticed-Alternative route for proceedings before the Massachusetts Energy Facilities Siting Board and thus was investigated thoroughly as part of that siting process. In addition the original A Option in Massachusetts and Rhode Island was studied extensively in anticipation of EFSB filings in those states. The data resulting from these studies was used as appropriate in the analyses of Option C-2.1 and the A-series options.

- Widening of previously undisturbed ROW (acres)
- New Land Acquisition Required for substation development or expansion
- Forest Vegetation Traversed
    - Forested Upland
    - Forested Wetland
- Wetlands traversed within ROW.
- Wetlands altered for substation development or expansion (acres)
- Watercourse crossings
- Habitat for state- or federally-designated species of concern encompassed by ROW and substation sites
- Designated public lands traversed by ROW (federal, state, local parks, forests, trails, recreational areas)
- Residences located within 500 feet of the new 345 kV centerline along the ROW

Table 7-9 summarizes the primary elements of options A-1, A-2, A-3, A-4 and C-2.1.

Table 7-9
Summary of Primary Elements in CT, RI and MA: A-series Options and C-2.1

Primary Feature	Option A Series				Option
	A-1	A-2	A-3	A-4	C-2.1
New 345 kV Lines (Miles)	74.7	72.2	74.7	83.7	84.1
Record. / Rebuild Existing 345 kV Lines (mi.)	9	0.2	8.7	0	0
Record. / Rebuild /Uprate Existing 115 kV Lines (mi.)	0	0	0	0	15.4
New Substations / Switching Stations	New AIS at Sherman Rd	New GIS at Sherman Rd	New AIS at Sherman Rd New 345 kV AIS at Uxbridge, MA	New AIS at Sherman Rd	New AIS at Sherman Rd New 345 kV switchyard at Carpenter Hill
Modified Substations/ Switching Stations	Upgrade Millbury switching station Mods to CT Stations (Card Street, Lake Road, Killingly) Mods at West Farnum substation	Upgrade Millbury switching station Mods to CT Stations (Card Street, Lake Road, Killingly) Mods at West Farnum substation	Upgrade Millbury switching station Mods to CT Stations (Card Street., Lake Road, Killingly) Mods at West Farnum substation	Upgrade Millbury switching station Mods to CT Stations (Card Street, Lake Road, Killingly) New bay at West Farnum substation	Upgrade Millbury switching station Expand Manchester Substation Mods at West Farnum substation

Section 7.4.1 compares the A-series options as a group with option C-2.1 using a range of natural and human environment features. Section 7.4.2 then compares the natural and human environmental

characteristics of the A-series options. Since the A-series options are identical within Connecticut, this analysis focuses on the states of Massachusetts and Rhode Island.

The comparisons provided in the following sections exclude the impact of the reconductoring of the 336 line and sag elimination on the 1410 line. These common projects are relatively low environmental impact projects since they are on existing ROWs.

7.4.1 Comparison of Option C-2.1 to Options A series

The A-series options are all very similar with respect to ROW's as compared to C-2.1. Therefore it was decided to group the four A-series options in a comparison to C-2.1. For purposes of evaluating potential environmental impacts, option C-2.1 was compared to all of the A-series options, based on a range of natural and human environment characteristics. The comparison focuses on the length of new 345 kV lines in relation to various natural and human environmental resources along the ROW in the three states affected by the project: Connecticut, Rhode Island, and Massachusetts. It also considers ROW expansion required and land converted to utility use for substations or switching stations in the three states. Table 7-10 compares the natural and human environment features of option C-2.1 to the range of these same features for options A-1, A-2, A-3 and A-4.

Table 7-10
Comparison[77] of Impact of A-Series Options and C-2.1: CT, RI, and MA

Feature	A-series Options (Range for Options A-1 to A-4)	Option C-2.1
New 345 kV Transmission Line Len. (Miles[78])	74.7-83.7	84.3
Length through wetlands (Miles)	5.2-7.0	11.9
Watercourse Crossings (Number)	118-129	177
Upland Forest Traversed (Miles)	36.5-39.1	54.0
Wetland Forest Traversed (Miles)	2.5-3.3	3.3
Parkland Traversed (Miles)	2.7	2.9
Length through Rare, Threatened or Endangered (Listed) Species Habitat (Miles)	14.8-15.2	18.1
Residences within 500 feet of new 345 kV transmission line centerline (Number)	478-536	942
ROW Expansion Required (Estimated Acres)	0-11 (Mansfield Hollow area , CT[79])	< 1 (Manchester, CT)
Total Additional Land Development[80] (Estimated acres)	4-15 (4 acres: Sherman Rd station, RI) (11 acres: Uxbridge station, MA)	3.5 (Carpenter Hill, MA, Manchester, CT)

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[77] Table compares new 345 kV transmission lines and related substation and switching station modifications that would be required for the A-series options and option C-2.1.

[78] All linear miles across features are calculated based on the presumed centerline of the new 345 kV transmission line.

[79] Additional easement acquisition is proposed for the new 345 kV line (all A-series options) in Mansfield Hollow (CT); however, NU has also identified design options that would either not require any additional easement or would minimize the amount of easement required.

[80] Land to be converted to utility use for Substations or Switching Stations (Estimated Acres) (*Includes NU / NGRID property outside existing station fence lines and private property)*

Specifically, compared to the four A-series options, option C-2.1 would involve:

- **Greater impacts in terms of overall vegetation clearing and habitat alteration**. The new 345 kV transmission lines required for option C-2.1 would traverse more miles than any of the new 345 kV lines for the four A-series options.

- **Close to full-width ROW vegetation clearing along some segments.** Between the Barbour Hill substation and Meekville Junction in Connecticut, all vegetation would be cleared to the eastern edge of the ROW in order to safely construct and operate the new line. Between the Ludlow substation and Hampden Junction in Massachusetts (approximately 11 miles), the ROW for option C-2.1 is not wide enough to accommodate a new 345 kV H-frame line. This line would require the use of vertical conductor configurations within the available easement width. Vegetation clearing to within 20 feet of the limits of the easement would be required in this section. The construction of and vegetation management along new 345 kV lines would result in limited areas of remaining on-ROW vegetation that is available to act as screening for adjacent land uses. In contrast, the majority of the route along options A1-A4 would allow typically between 55 feet and 75 feet of vegetation to remain in the ROW to act as visual screening.

- **Alignment through or near more areas of known habitat for state- or federally-listed protected species** (i.e., threatened, endangered, or special concern species). Option C-2.1 would traverse or be located within 500 feet of approximately 18.1 miles of such mapped habitat, compared to 14.8-15.2 miles along the A-series options.

- **Alignment across more watercourses**. Option C-2.1 would cross 177 streams, compared to 118-129 streams for the four A-series options.

- **Alignment in proximity to substantially more residences**. Portions of option C-2.1 would traverse through populated areas, resulting in an estimated 942 homes within 500 feet of the centerline of the new 345 kV transmission line. In comparison, the centerline of the new 345 kV line along the four A-series options would be within 500 feet of 478 to 536 homes (in MA, RI and CT).

- **Requirement of additional transmission line easements**. Both option C-2.1 and the A-series options would involve the development of the new 345 kV transmission lines principally within existing transmission line easements. However, any of the A-series options would potentially require 11 acres of additional easement (i.e., ROW expansion) through 1.4 miles of federally-owned lands in Mansfield Hollow State Park and the Mansfield Wildlife Management Area in the Connecticut towns of Mansfield and Chaplin[81]. Likewise, option C-2.1 would require ROW expansion along the Manchester to Meekville Junction segment in Connecticut. Option C-2.1 also would extend across Wells State Park in Sturbridge, Massachusetts.

Overall, option C-2.1 would involve greater potential environmental effects than the A-series options and thus is not preferred on the basis of the natural and human environmental impacts.

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[81] NU has identified three design options for traversing these federally-owned properties, one of which would not require any additional easement acquisition.

[redacted]

7.4.2 Comparison of Option A-1, A-2, A-3 and A-4

Due to the similarities of the four A-series options, a more detailed analysis was necessary to evaluate these options. Each option has common facilities in Connecticut[82] and thus, all four of the A-series options would have the same natural and human environment impacts within Connecticut. Therefore, the analysis concentrated only on the Massachusetts and Rhode Island portions of these options.

Table 7-11summarizes the anticipated natural and human environment characteristics of the four A-series options within Rhode Island and Massachusetts.

Table 7-11
Environmental Impact of A-series Options: RI and MA only

Feature	Option A-1	Option A-2	Option A-3	Option A-4
New 345 kV Transmission Lines				
New 345 kV Line Length (mi.)	37.9	35.6	37.9	46.9[83]
Est. Upland Forest Cleared (Acres)	149.5	165.9	149.5	149.5
Est. Wetland Forest Cleared (Acres)	19.2	7.25	19.2	19.2
Est. Tree Clearing within Mapped Rare, Threatened or Endangered (Listed) Species Habitat (Acres)	1.4 – Upland Forest 2.1 – Forested Wetland	12.4 – Upland Forest 0.6 – Forested Wetland	1.4 – Upland Forest 2.1 – Forested Wetland	1.4 – Upland Forest 2.1 – Forested Wetland
Watercourse Crossings (Number)	53	50	53	61
Parkland Traversed (mi.)	2.1	2.1	2.1	3.2
Residences within 500 ft of route centerline	319	265	319	319
Substations and Switching Stations				
New Switching Station (Sherman Road)	Yes	Yes	Yes	Yes
New AIS Station (Uxbridge, MA)[84]	No	No	Yes	No
Wetlands[85] (acres permanently affected)	0.3	0.3	2.4	0.3
Upland forest[85] (acres permanently. affected)	2.7	2.7	16.6	2.7

In order to accurately assess the relative merits of the A-series options, which have similar characteristics even within these two states, estimates are provided of impacts to resources along the ROW and at substation sites. These estimates take into account the extent of forest clearing along the ROW required for each of the A-series options, as well as the miles of resources traversed.

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[82] In Connecticut, Options A-1, A-2, A-3, and A-4 all would include a new 345 kV transmission line that would emanate from the Card substation in Lebanon, CT, follow NU's existing 345 kV transmission corridor (330 Line), and terminate at the Lake Road switching station in Killingly, CT. Further, each of the four options would include a second 345 kV transmission line that would extend east from the Lake Road switching station along the existing transmission corridor to the Connecticut/Rhode Island border. In addition, all of the A-series options would involve the same modifications to the Card substation, Lake Road switching station, and Killingly substation in Connecticut.

[83] Second 345 kV line to be constructed between Sherman Road switching station and the West Farnum substation

[84] Includes impacts at substation site and for transmission line interconnections

[85] Includes impacts of both the Sherman Road switching station and the Uxbridge (option A-3) switching station.

7.4.2.1 Option A-1

Within Massachusetts and Rhode Island, the key elements of option A-1 include:

- A new 17.7-mile 345 kV transmission line from the Connecticut border to the West Farnum substation, located within existing transmission ROWs (347 line and 328 line).
- A new 20.2-mile 345 kV transmission line from the West Farnum substation to the Millbury switching station within an existing transmission ROW (Q-143 and R-144 lines).
- Rebuilding the existing 9.0-mile 345 kV line on the ROW between Sherman Road and West Farnum (328 line).
- A new 345 kV AIS switchyard at Sherman Road, and retirement of the existing Sherman Road switching station.

Overall, option A-1 would involve relatively minimal human and natural environment impacts. For the segment of option A-1 between Millbury switching station and West Farnum substation in Massachusetts and Rhode Island, the majority of the new 345 kV line would be aligned in the existing ROW in a location that was previously occupied by a decommissioned 69 kV line. The use of this alignment for the new 345 kV line would minimize forested upland and forested wetland clearing and the potential environmental impacts associated with tree clearing wetlands and rare species habitat. In addition limited tree clearing would minimize the commonly described human impact of project visibility. While all A-series options require tree clearing for the segment between the West Farnum substation and the Rhode Island / Connecticut border, option A-1 calls for the rebuilding of the existing 328 345 kV line between West Farnum substation and the Sherman Road switching station which would occur within the existing maintained ROW, and hence result in mostly temporary environmental impacts. In both Massachusetts and Rhode Island, there is minimal residential development, with an average of less than 9 residences within 500 feet of the right of way centerline per mile of ROW. The development of the new AIS switchyard at Sherman Road would result in approximately 0.3 acres of permanent impacts to wetlands; this impact would be shared by all the A-series options.

7.4.2.2 Option A-2

Within Massachusetts and Rhode Island, the key elements of option A-2 include:

- A new 8.7-mile 345 kV transmission line from the Connecticut border to the Sherman Road switching station, located within an existing transmission ROW (347 line).
- A new 9.0-mile 345 kV line on the ROW between the Sherman Road switching station and the West Farnum substation, located within an existing transmission ROW (328 line).
- A new 17.7-mile 345 kV transmission line from the Sherman Road switching station to the Millbury switching station, located partially within a ROW occupied by NSTAR's 345 kV 3361 Line, and partially within National Grid's existing transmission ROW (Q-143 and R-144 lines).
- A new 345 kV GIS switchyard at Sherman Road, and retirement of the existing Sherman Road switching station.
- Rebuilding the 0.2-mile 333 345 kV transmission line from Sherman Road switching station to Ocean State Power in Burrillville, Rhode Island.

Option A-2 is unique among the A-series options in that it involves the development of a 345 kV line segment along 3.4 miles of NSTAR's 3361 line ROW between Sherman Road and Uxbridge, instead of along the 6.7 mile segment of National Grid's ROW between West Farnum and Uxbridge.

[redacted]

Presently, the 3361 line ROW is not cleared to its full width; as a result, to accommodate the new 345 kV line, an additional 75-foot-wide area would have to be cleared along this 3.4-mile ROW segment. The majority of the vegetation that would have to be cleared would be forested upland or forested wetland, much of it within mapped rare, threatened or endangered species habitat. The removal of forest vegetation along this ROW segment and the subsequent management of the wider area as scrub-shrub vegetation would represent a long-term habitat impact.

Along the option A-2 ROW in both Massachusetts and Rhode Island, there is minimal residential development, with an average of less than 8 residences within 500 feet of the 345 kV centerline in each mile of the ROW.

Option A-2 is also unique in that it requires a new GIS switchyard, rather than an AIS switchyard, at Sherman Road. The impacts to wetlands and upland forest are similar; however, the GIS substation would use more SF_6, which is considered a greenhouse gas. The other A-series options use less SF_6.

7.4.2.3 Option A-3

Within Massachusetts and Rhode Island, the key elements of option A-3 include:

- A new 17.7-mile 345 kV transmission line from the Connecticut border to the West Farnum substation, located within existing transmission ROWs (347 line and 328 line).
- A new 20.2-mile 345 kV transmission line from the West Farnum substation to the Millbury switching station within an existing transmission ROW (Q-143 and R-144 lines).
- A new 345 kV switching station in Uxbridge, Massachusetts.
- Increases in conductor height on 8.7 miles of NSTAR's existing 345 kV line (3361 line) between Sherman Road, the new Uxbridge switching station, and the ANP Blackstone power plant.
- A new 345 kV AIS switchyard at Sherman Road and retirement of the existing Sherman Road switching station.

The temporary and permanent impacts of transmission line construction for option A-3 are very similar to those described above for option A-1, as they use the same existing ROWs for the development of the new 345 kV lines. In both Massachusetts and Rhode Island, there is minimal residential development, with an average of less than 9 residences within 500 feet of the right of way centerline in each mile of the ROW.

However, the requirement for a new switching station in Uxbridge under option A-3 would involve additional environmental impacts not associated with option A-1. A potential site has been identified at the junction of the lines the study group proposes to interconnect. At this site, approximately 11 acres of privately owned property would be purchased and converted permanently to utility use. The site is near the Blackstone River and within the Blackstone Valley National Heritage Corridor, a federally designated scenic area. Vegetation clearing (including forest removal) on part of this site and the associated line interconnections between the switch station and existing transmission lines would change the visual environment, which could be inconsistent with the location of this facility within the Blackstone Valley National Heritage Corridor. In addition, the switching station site would be within mapped rare and endangered species habitat. Construction of the new switching station would impact approximately two acres of wetlands and vernal pool habitat. That in combination with work within the potential habitat of listed threatened or endangered species greatly increases potential for permanent environmental impacts.

7.4.2.4 Option A- 4

Within Massachusetts and Rhode Island, the key elements of option A-4 include:

- A new 17.7-mile 345 kV transmission line from the Connecticut border to the West Farnum substation, located within existing transmission ROWs (347 line and 328 line).
- A second new 9.0-mile 345 kV transmission line on the ROW between Sherman Road and West Farnum (328 line).
- A new 20.2-mile 345 kV transmission line from the West Farnum substation to the Millbury switching station within an existing transmission ROW (Q-143 and R-144 lines).
- A new 345 kV AIS switchyard at Sherman Road, and retirement of the existing Sherman Road switching station.

The use of the abandoned 69 kV line portion of the existing ROW in Massachusetts would minimize tree clearing. In both Massachusetts and Rhode Island, there is minimal residential development, with an average of less than 9 residences within 500 feet of the right of way centerline in each mile of ROW. However, construction of two new 345 kV lines between the Sherman Road switching station and the West Farnum substation, for a total of three 345 kV lines along this 9-mile stretch of ROW, would result in additional unavoidable permanent impacts to wetlands and watercourses from new structure foundations and access roads, forest clearing to almost the full width of the ROW. In order to create space within the corridor, the use of taller "delta" structures along approximately 3 miles of the route is necessary. The taller structures and the additional tree clearing increase potential visual impacts.

7.4.2.5 Summary of A-series Options

As can be seen from Table 7-11, the natural and human environment impacts associated with the new 345 kV transmission line are identical for options A-1 and A-3. However, the addition of a new 345 kV switching station at Uxbridge creates additional environmental impacts. Option A-1 is therefore superior to option A-3 from the standpoint of natural and human environment impacts.

Table 7-11 also demonstrates that the natural and human environment impacts associated with the new 345 kV transmission line are substantially greater for option A-4 than for option A-1, due in large part to the placement of two new 345 kV transmission lines along a 9-mile ROW segment between Sherman Road and West Farnum. There are no off-setting environmental advantages to option A-4. Option A-1 is therefore superior to option A-4 from the standpoint of natural and human environment impacts.

Finally, Table 7-11 demonstrates that impacts of options A-1 and A-2 at the Sherman Road and West Farnum station sites are very similar, although the option A-2 GIS station requires larger quantities of SF_6 than option A-1's AIS station.

The relative metrics associated with the development of the new 345 kV transmission lines along these two options are mixed. Option A-2 would require 2.5 fewer miles of new 345 kV line than option A-1. However, option A-1 traverses 2.5 fewer miles of forested ROW, reducing the need for tree clearing and its associated natural and human environment impacts.

Along the option A-2 route, vegetation within an approximately 75-foot-wide presently unused area along 3.4 miles of NSTAR (3361 line) ROW between Sherman Road and Uxbridge would have to be cleared of trees to accommodate a new 345 kV line. Much of this area is also within estimated habitat

[redacted]

of rare and endangered species. In comparison, National Grid's ROW between West Farnum and Uxbridge would not require as much clearing in estimated habitat. In Massachusetts, the Natural Heritage and Endangered Species Program takes a critical view of projects within estimated habitat. The 12.4 acres of upland forest land clearing required by A-2 within designated rare species habitat (as compared to 1.4 acres of upland forest along option A-1) has the potential for taking of habitat and represents a serious disadvantage for option A-2.

Overall compared to option A-2, option A-1 would require 11 fewer acres of upland forest clearing within listed species habitat. Preservation of such forest land within areas of known species habitat is a key concern of state regulatory agencies. Therefore while options A-1 and A-2 may appear very similar, option A-1 is preferred as having the least natural and human environment impacts.

7.5 Selection of the Preferred Alternative

The electrical performance testing in Section 7.2 demonstrated that the A-series options performed better than option C-2.1. Further the cost estimates in Section 7.3 indicated the A-series options to be less expensive than option C-2.1. The estimated cost of option C-2.1 is over 25% more than the estimated cost of the most expensive A-series option.

Based on these factors the A-series options were found to be more cost effective than option C-2.1 for resolving the projected criteria violations. However the results from Section 7.2 and Section 7.3 do not provide a preferred alternative amongst the A-series options. The estimated costs of the four A-series options are within 5% of each other. All the A-series options performed well electrically and essentially equally, however, future system expandability and flexibility considerations favor option A-1 over the other A-series options.

An analysis of the natural and human environmental impacts of the four A-series options concluded that option A-1 also represents the best of the four A-series options. Hence, the A-1 option is selected as the preferred alternative by the working group based on the comparisons in Sections 7.2 through 7.4.

7.6 Sensitivity Testing for Salem Harbor Retirement

After determining A-1 to be the preferred solution, sensitivity testing was performed to determine the impact of the Salem Harbor retirement on the needs in eastern New England. The dispatch details and assumptions are provided in Section 3.2. The results of the analysis are provided in Appendix F: Thermal and Voltage Analysis Results.

No thermal or voltage criteria violations were seen for this case in the study area. The results indicate that the option A-1 would not need any modifications or enhancements to accommodate the Salem Harbor retirement[86].

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[86] Results are based on the assumption that New Brunswick imports are increased from 0 to 700 MW for the Salem Harbor retirement case.

7.7 Extreme Contingency Testing for Preferred Solution

The extreme contingency (EC) testing was performed for option A-1. The 345 kV faults identified in Section 4.3.3 were tested for the two stresses – East-West and West-East.

In addition the EC testing at the Woonsocket substation was done with the East-West stress case with high RI generation to set up local stresses in Rhode Island.

7.7.1 Results of Extreme Contingency Testing

The testing of the 345 kV extreme contingency faults for the West-East stress cases was done with eastern New England import above 4,000 MW. At these transfer levels all the contingencies exhibited well damped system oscillations and stable performance.

The East-West stress cases were initially tested at a western New England import level of 4000 MW. Some of the extreme contingency events at Millbury and West Medway resulted in loss of generation resources (within New England) and severe voltage depressions and large oscillations in central and northern Maine, causing generation in Maine to trip offline potentially resulting in transmission system separation in northern Maine. The total loss of source under this condition was unacceptable.

Since the need for western New England import in 2020 was 3,308 MW under all-lines-in conditions, the western New England import levels were backed off to 3,500 MW. At this reduced level the 345 kV extreme contingencies were simulated. Even at these lower levels, the extreme contingencies at West Medway and Millbury resulted in loss of generation resources and voltage depressions, but the loss of source was acceptable. The amount of generation tripping off line is identified in the summaries in Appendix H: Stability Analysis Results.

Some of the extreme contingencies at [redacted] cause the Orrington South interface to split, thereby cutting off 1,280 MW of flow into rest of Maine and the New England system. This loss of interface flow coupled with other generation that trips south of the Orrington South interface constitutes the total loss of source. The amount of lost generation resources south of Orrington South ranges up to 199 MW. This results in a maximum loss of source of 1,479 MW.

Similar results had also been previously identified in the original Proposed Plan Application studies done in 2008. Other ISO planning studies in New England have also encountered the same system performance phenomenon.

This magnitude is between 1,400 and 2,200 MW and may be considered acceptable depending upon the likelihood of occurrence among other technical factors. On doing preliminary investigation of transmission or protection fixes that would reduce the source loss below 1400, it was determined that the source loss could not be lowered below 1,400 MW with minor fixes. Since the source loss was marginally over 1,400 MW and the 3,500 MW transfer level would resolve the needs in western New England, all further testing on the western New England import interface was be performed at 3,500 MW. This includes the BPS testing of substations in Connecticut and Rhode Island.

A summary of the generation that was tripped south of the Orrington-South interface is provided in Appendix H: Stability Analysis Results.

Therefore, the study results for the Interstate Reliability Project, with the new transfer capabilities it provides, does not pose an adverse impact to already known and existing system performance conditions in Maine and throughout the rest of New England for the extreme contingencies tested.

Testing of [redacted] extreme contingencies resulted in loss of generation in addition to system separation in northern New England for several of the [redacted] EC's. The loss of source was in excess of 1,400 MW. The circuit breakers at [redacted] are non-IPT. Several options were considered in order to mitigate the effect of these EC's. The easiest fix would be to reduce clearing times associated with the EC's. Investigation was done, and it was found that all of the [redacted] EC's that caused system separation and total loss of source greater than 1,400 MW could be addressed by reducing the clearing times associated with these EC's. The reduction of the clearing times will become a part of the NEEWS Interstate Project.
Simulation plots are included in Appendix H: Stability Analysis Results.

7.7.2 Conclusions of Extreme Contingency Testing

- Unacceptable system performance was seen at western New England import level of 4,000 MW. The post-Interstate transfer levels were reduced to 3,500 MW on the western New England import interface.

- With the new interface levels, all 345 kV extreme contingency events exhibited well damped system oscillations and stable performance except fault simulations at [redacted] as noted above. They are acceptable under New England performance criteria.

- Extreme contingency events at [redacted] result in loss of generation resources (within New England) and may also result in transmission system separation in northern Maine. However, these results are consistent with system response to ECs in this area and do not indicate an adverse impact of the Interstate Reliability Project.

- The [redacted] extreme contingencies that result in system separation and total loss of source greater than 1,400 MW will be addressed by reducing the clearing times associated with these EC's.

7.8 BPS Testing for Preferred Solution

Three non-BPS Rhode Island stations that have shown in the past that they are close to becoming BPS were tested as a part of the stability analyses. The three stations are [redacted] A few Connecticut substations were also tested in the vicinity of the new 345 kV line as a part of option A-1 into Connecticut, around the [redacted] substations.

7.8.1 Results of BPS Testing

The results of the testing showed tha[redacted] did not show BPS positive results but [redacted] did. An investigation was done to see if the zone 2 clearing from [redacted] could be reduced from [redacted] cycles to [redacted] cycles. It was found that this reduction is possible. With this reduced zone 2 clearing time, the [redacted] substation no longer showed a need to be upgraded to BPS requirements.

The testing performed at the Connecticut substations did not demonstrate a need to upgrade any of the tested stations to BPS standards.

7.8.2 Conclusions of BPS Testing

- None of the Rhode Island stations that were tested will become BPS as a result of the option A-1. The reduction of the zone 2 clearing time at [redacted] will become a part of the Interstate Reliability Project.

- The Connecticut 115 kV stations that were tested are not required to be classified as part of the BPS.

Section 8
Conclusion

8.1 Recommended Solution Description

The five Interstate Reliability Project options considered in this study provide a level of electrical system performance that meets design requirements for satisfying the NERC, NPCC and ISO reliability standards and criteria. The A-series options do provide a slightly better electrical performance over the C-2.1 option. Within the A-series options A-1 provides benefit in terms of system expandability and flexibility. The A-series options also have significantly lower estimated costs than option C-2.1. Option A-1 also has the least environmental impact. Based on all these factors, option A-1 was selected as the recommended solution for the needs identified in the updated needs analysis.

The major 345 kV components of the A-1 plan are:

- A new 345 kV line from Card substation to the Lake Road switching station
- A new 345 kV line from the Lake Road switching station in Connecticut to the West Farnum substation in Rhode Island
- A new 345 kV line from the West Farnum substation in Rhode Island to the Millbury switching station in Massachusetts.

The other components of the plan are detailed in Appendix D: Description of Interstate Alternatives.

The new line into Millbury from West Farnum provides a new import line into eastern New England and allows for the movement of power from western New England and Greater Rhode Island to reliably serve load in eastern New England during capacity deficiency conditions in eastern New England. Option A-1 provides an increase in the eastern New England import capability by 1350-1850 MW under N-1 conditions and 1900-2300 MW under N-1-1 conditions.

Similarly the line into Card substation via Lake Road and West Farnum provides a new import path into Connecticut and western New England and allows for the movement of power from eastern New England and Greater Rhode Island to reliably serve load in Connecticut and western New England during capacity deficiency conditions in the west. The option A-1 provides an increase in the western New England import capability by 750-1650 MW under N-1 conditions and 850-1650 MW under N-1-1 conditions. It also provides an increase in the Connecticut import capability by 550-1050 MW under N-1 conditions and 850-1350 MW under N-1-1 conditions.

The project also provides two new 345 kV lines into West Farnum which resolve the criteria violations in Rhode Island seen for the loss of the two existing 345 kV lines into West Farnum from Sherman Road and Brayton Point.

Thus, the preferred solution A-1 resolves all the needs identified in the updated needs analysis.

8.2 Solution Component Year of Need

The updated needs assessment provides approximate timeframes[87] when criteria violations were seen for the different needs described above.

- Violations related to the loss of the two 345 kV supplies into West Farnum are seen in today's system. On linear extrapolation based on the 2015 and 2020 loadings seen in the updated needs analysis, the first violations would be in 2003-2004[88].
- The need for additional transmission transfer capability from western New England and Greater Rhode Island to eastern New England was forecasted to occur in 2011. With generation retirements, the need for additional eastern New England transmission transfer capability would be greater.
- The need for additional transmission transfer capability from eastern New England and Greater Rhode Island to western New England was forecasted to occur between 2017 and 2018.
- The need for additional transmission transfer capability into the state of Connecticut was reasonably forecasted to occur between 2014 and 2015.

The projected in-service date of all the components of A-1 is December 2015. This is based on the siting and permitting required in three states (MA, CT and RI) for the new 345 kV construction.

With respect to the three import areas that require additional import capability, the most urgent need is the need for additional eastern New England import capability. As a part of the eastern New England import analysis the two binding 115 kV and 345 kV elements were the 1410 line and the 336 line respectively. Furthermore, the 336 line was the highest loaded 345 kV element in 2015 and 2020, for the eastern New England analysis. Hence the following two projects will be advanced and are being pursued independent of the Interstate Reliability Project.

- Reconductor a 1.2-mile section of the 345 kV line 336 from ANP Blackstone to NEA Bellingham Tap and upgrade terminal equipment at the W. Medway substation to [redacted] rated equipment.
- Add a new breaker in series with the [redacted] at West Medway 345 kV substation.
- Eliminate the sag limit on the 115 kV Montville - Buddington 1410 line in Connecticut.

The projected in-service date for the 336 upgrade is June 2013 and the 1410 sag elimination is expected to be completed by December 2012. With these components in-service there should be an increase in eastern New England import capability and this would help prevent system concerns in the period preceding the complete Interstate Reliability Project going into service.

8.3 Schedule for Implementation and Lead Times

In accordance with NERC TPL Standards, this assessment provides:

- A written summary of plans to address the system performance issues described in the New England East-West Solution (NEEWS): Interstate Reliability Project Component Updated Needs Assessment, dated April 2011
- A schedule for implementation as described below

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[87] The year of need beyond 2010 is based on the 2010 CELT report.

[88] The year of need, if at load levels less than the 2010 forecast is calculated based on historic forecasted 90/10 peaks.

[redacted]

- A discussion of expected required in-service dates of facilities and associated load level when required as described in Section 8.2 above.
- A discussion of lead times necessary to implement plans described below

The following two projects will be advanced and separate PPA approvals will be pursued for these projects.

- Reconductor a 1.2-mile section of the 345 kV line 336 from ANP Blackstone to NEA Bellingham Tap and upgrade terminal equipment at the W. Medway substation to [redacted] rated equipment.
- Add a new breaker in series with the [redacted] at West Medway 345 kV substation
- Eliminate the sag limit on the 115 kV Montville - Buddington 1410 line in Connecticut.

The project involving the reconductoring of the 336 line and the upgrade of terminal equipment at West Medway already has PPA approval and has a projected in-service date of June, 2013. The project for the 1410 line sag elimination has also received PPA approval and has a projected in-service date of December, 2012. The project that adds a breaker in series with the 106 breaker at West Medway will receive PPA approval in 1st quarter of 2012 and has a projected in-service date of December, 2013.The advancement of these three projects should provide some relief to potential system concerns under capacity deficient conditions in eastern New England.

The other components of plan A-1 include a significant amount of new 345 kV construction and have a 3-4 year lead time before they will be in-service.

NU and National Grid shall pursue the Proposed Plan Application, in accordance with section I.3.9 of the ISO tariff in late 2011. NU and National Grid shall also pursue all required state (MA, CT and RI) siting approvals with the applications being filed in late 2011.

Construction of the project is tentatively scheduled (based on receipt of all approvals of applications) in late 2013/early 2014, with a projected in-service date of all components of option A-1 of December 2015.

The planned completion date of the preferred solution as described in Section 8.1 is December 2015.

Section 9
Appendix A: 2010 CELT Load Forecast

Table 9-1
2010 CELT Seasonal Peak Load Forecast Distributions

		Peak Load Forecast at Milder Than Expected Weather				Reference Forecast at Expected Weather	Peak Load Forecast at More Extreme Than Expected Weather				
Summer (MW)	2010	25925	26150	26455	26805	27190	27600	28020	28620	29310	29915
	2011	26365	26595	26910	27265	27660	28080	28510	29125	29835	30455
	2012	26845	27080	27400	27765	28165	28595	29030	29655	30390	31025
	2013	27230	27470	27795	28160	28570	29005	29450	30085	30840	31490
	2014	27665	27905	28240	28610	29025	29465	29915	30560	31340	32000
	2015	28070	28315	28650	29030	29450	29895	30355	31010	31810	32480
	2016	28390	28640	28975	29360	29785	30235	30700	31365	32180	32865
	2017	28700	28950	29295	29680	30110	30565	31035	31705	32545	33240
	2018	29005	29260	29605	29995	30430	30890	31365	32040	32895	33600
	2019	29290	29545	29895	30290	30730	31195	31675	32360	33225	33940
WTHI (1)		78.49	78.73	79.00	79.39	79.88	80.30	80.72	81.14	81.96	82.33
Dry-Bulb Temperature (2)		88.50	88.90	89.20	89.90	90.20	91.20	92.20	92.90	94.20	95.40
Probability of Forecast Being Exceeded		90%	80%	70%	60%	50%	40%	30%	20%	10%	5%
Winter (MW)	2010/11	21655	21775	21870	21935	22085	22240	22405	22510	22765	23140
	2011/12	21790	21915	22010	22075	22225	22380	22545	22655	22905	23280
	2012/13	21845	21965	22065	22130	22280	22435	22605	22710	22960	23335
	2013/14	21965	22085	22180	22250	22400	22555	22725	22830	23080	23455
	2014/15	22065	22190	22285	22350	22505	22665	22830	22940	23185	23560
	2015/16	22170	22295	22390	22455	22610	22770	22940	23045	23290	23660
	2016/17	22280	22400	22500	22565	22720	22880	23050	23155	23400	23775
	2017/18	22390	22515	22615	22680	22835	22995	23165	23275	23520	23890
	2018/19	22505	22630	22725	22795	22950	23110	23285	23390	23635	24005
	2019/20	22620	22745	22845	22915	23070	23230	23405	23515	23750	24120
Dry-Bulb Temperature (3)		10.72	9.66	8.84	8.30	7.03	5.77	4.40	3.58	1.61	(1.15)

FOOTNOTES:

(1) WTHI - a three-day weighted temperature-humidity index for eight New England weather stations. It is the weather variable used in producing the summer peak load forecast. For more information on the weather variables see http://www.iso-ne.com/trans/celt/fsct_detail/.

(2) Dry-bulb temperature (in degrees Fahrenheit) shown in the summer season is for informational purposes only.

(3) Dry-bulb temperature (in degrees Fahrenheit) shown in the winter season is a weighted value from eight New England weather stations.

Table 9-2
2015 Detailed Load Distributions by State and Company

Study Date : 8/1/2015 **CELT Forecast :** 2010 **Forecast Year :** 2015

Season : Summer Peak **Weather :** 90/10 **Load Distribution :** N+6_SUM

CELT Load : 31810 MW **% of Peak :** 100.00% **Tx Losses :** 4.00%

Maine **State Load = 2370 MW - 4.00% Losses = 2275.2 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CMP	85.33%	1941.46	767.46	0.930	704.56
BHE	14.67%	333.76	116.59	0.944	91.57

New Hampshire **State Load = 2865 MW - 4.00% Losses = 2750.4 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
PSNH	79.00%	2172.81	309.49	0.990	
UNITIL	11.99%	329.76	47.00	0.990	
GSE	9.01%	247.82	9.18	0.999	1.60

Vermont **State Load = 1185 MW - 4.00% Losses = 1137.6 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
VELCO	100.00%	1137.58	290.15	0.969	104.80

Massachusetts **State Load = 14750 MW - 4.00% Losses = 14160 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
BECO	27.97%	3960.55	1080.97	0.965	38.13
COMEL	11.37%	1610.00	282.09	0.985	
MA-NGRID	40.32%	5701.85	347.08	0.998	38.79
WMECO	6.55%	927.46	132.18	0.990	
MUNI:BOST	4.21%	596.12	86.17	0.990	
MUNI:CNEMA	2.07%	293.08	60.26	0.980	
MUNI:RI	0.88%	124.60	23.80	0.982	
MUNI:SEMA	3.56%	504.09	86.26	0.986	
MUNI:WMA	3.06%	433.31	62.88	0.990	

Rhode Island **State Load = 2185 MW - 4.00% Losses = 2097.6 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
RI-NGRID	100.00%	2097.62	204.12	0.995	34.60

Connecticut **State Load = 8450 MW - 4.00% Losses = 8112 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CLP	75.72%	6142.45	875.28	0.990	75.10
CMEEC	5.34%	433.19	61.73	0.990	
UI	18.95%	1537.22	153.80	0.995	

Table 9-3
2020 Detailed Load Distributions by State and Company

Study Date :	8/1/2020	**CELT Forecast :**	2010	**Forecast Year :**	2020
Season :	Summer Peak	**Weather :**	90/10	**Load Distribution :**	N+11_SUM
CELT Load :	33555 MW	**% of Peak :**	100.00%	**Tx Losses :**	4.00%

Maine **State Load = 2500 MW - 4.00% Losses = 2400 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CMP	85.33%	2047.99	799.64	0.932	704.56
BHE	14.67%	352.09	122.84	0.944	91.57

New Hampshire **State Load = 3080 MW - 4.00% Losses = 2956.8 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
PSNH	79.00%	2335.87	332.74	0.990	
UNITIL	11.99%	354.53	50.52	0.990	
GSE	9.01%	266.40	9.80	0.999	1.60

Vermont **State Load = 1255 MW - 4.00% Losses = 1204.8 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
VELCO	100.00%	1204.82	306.34	0.969	104.80

Massachusetts **State Load = 15575 MW - 4.00% Losses = 14952 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
BECO	27.97%	4182.06	1135.77	0.965	38.13
COMEL	11.37%	1700.04	298.03	0.985	
MA-NGRID	40.32%	6021.18	366.25	0.998	38.79
WMECO	6.55%	979.34	139.58	0.990	
MUNI:BOST	4.21%	629.49	91.63	0.990	
MUNI:CNEMA	2.07%	309.51	63.68	0.979	
MUNI:RI	0.88%	131.56	24.70	0.983	
MUNI:SEMA	3.56%	532.28	90.33	0.986	
MUNI:WMA	3.06%	457.52	66.43	0.990	

Rhode Island **State Load = 2300 MW - 4.00% Losses = 2208 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
RI-NGRID	100.00%	2207.96	216.09	0.995	34.60

Connecticut **State Load = 8840 MW - 4.00% Losses = 8486.4 MW**

Company	State Share	Total P (MW)	Total Q (MVAR)	Overall PF	Non-Scaling (MW)
CLP	75.72%	6425.84	915.72	0.990	75.10
CMEEC	5.34%	453.18	64.58	0.990	
UI	18.95%	1608.18	160.91	0.995	

[redacted]

Table 9-4
Detailed Demand Response Distributions by Zone

Study Date : 7/17/2020 **CCP :** 2013/2014 **Load Season :** Summer Peak

Load Distrb : N+11_SUM **Distrb Losses :** 4.00% **DR Season :** SUM

Passive DR Availability : 100.00% **Active DR Availability :** 100.00%

Passive DR Performance : 100.00% **Active DR Performance :** 75.00%

Passive Demand Resources - (On-Peak and Seasonal Peak Demand Responses)

DR Modeled = (DRV_SUM * 100.00% Availability * 100.00% Performance) + 4.00% Losses Gross-Up

Zone	ID	Description	CELT DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_P_ME	20	Maine	152.21	-158.33	-58.34
DR_P_NH	21	New Hampshire	71.53	-74.39	-10.36
DR_P_VT	22	Vermont	96.80	-100.65	-25.71
DR_P_NEMABOS	23	Northeast Massachusetts & Boston	263.32	-273.81	-60.80
DR_P_SEMA	24	Southeast Massachusetts	139.56	-145.21	-15.60
DR_P_WCMA	25	West Central Massachusetts	150.39	-156.45	-15.04
DR_P_RI	26	Rhode Island	85.29	-88.71	-8.66
DR_P_CT	27	Connecticut	423.97	-440.98	-59.30

Active Demand Resources - (Real Time Demand Response (RTDR), Excludes RTEG)

DR Modeled = (DRV_SUM * 100.00% Availability * 75.00% Performance) + 4.00% Losses Gross-Up

Zone	ID	Description	CELT DRV (MW)	Total P (MW)	Total Q (MVAR)
DR_A_ME_BHE	30	ME - Bangor Hydro	75.84	-59.15	-23.90
DR_A_ME_MAIN	31	ME - Maine	202.72	-158.14	-55.68
DR_A_ME_PORT	32	ME - Portland Maine	135.26	-105.51	-39.53
DR_A_NH_NEWH	33	NH - New Hampshire	64.21	-50.08	-7.01
DR_A_NH_SEAC	34	NH - Seacoast	9.75	-7.61	-1.10
DR_A_VT_NWVT	35	VT - Northwest Vermont	34.77	-27.10	-6.79
DR_A_VT_VERM	36	VT - Vermont	19.43	-15.17	-4.03
DR_A_MA_BOST	37	MA - Boston	211.96	-165.34	-44.49
DR_A_MA_NSHR	38	MA - North Shore	82.82	-64.61	-7.04
DR_A_MA_CMA	39	MA - Central Massachusetts	85.56	-66.76	-4.64
DR_A_MA_SPFD	40	MA - Springfield	36.23	-28.25	-4.02
DR_A_MA_WMA	41	MA - Western Massachusetts	45.17	-35.21	-3.53
DR_A_MA_LSM	42	MA - Lower Southeast Massachusetts	64.42	-50.23	-8.27
DR_A_MA_SEMA	43	MA - Southeast Massachusetts	106.41	-82.97	-6.78
DR_A_RI_RHOD	44	RI - Rhode Island	77.17	-60.23	-5.86
DR_A_CT_EAST	45	CT - Eastern Connecticut	47.87	-37.34	-5.30
DR_A_CT_NRTH	46	CT - Northern Connecticut	63.36	-49.43	-7.03
DR_A_CT_NRST	47	CT - Norwalk-Stamford	69.72	-54.41	-7.37
DR_A_CT_WEST	48	CT - Western Connecticut	207.54	-161.89	-20.96

Section 10
Appendix B: Power Flow Base cases

[redacted]

[redacted]

Section 11
Appendix C: Contingency List

[redacted]

[redacted]

Section 12

Appendix D: Description of Interstate Alternatives

Appendix D1 - Description of Interstate Option A-1 Components.pdf

Appendix D2 - Description of Interstate Option A-2 Components.pdf

Appendix D3 - Description of Interstate Option A-3 Components.pdf

Appendix D4 - Description of Interstate Option A-4 Components.pdf

Appendix D5 - Description of Interstate Option C-2.1 Components.pdf

[redacted]

Interstate Option A-1 Components

345 kV Transmission line facilities:

1. **Card – Lake Road (NU):** Build a 29.3 mile 345 kV transmission line (#3271) from the Card Substation in Lebanon, Connecticut to the Lake Road Switching Station in Killingly, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

2. **Lake Road – CT/RI Border (NU):** Build a 7.5 mile 345 kV transmission line (#341) from the Lake Road Switching Station in Killingly, Connecticut to the Rhode Island border in Thompson, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

3. **CT/RI Border – West Farnum (National Grid):** Build a 17.7 mile 345 kV transmission line (#341) from the Connecticut border in Burrillville, Rhode Island to the West Farnum Substation in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

4. **West Farnum – MA/RI Border (National Grid):** Build a 4.8 mile 345 kV transmission line (#366) from the West Farnum Substation in North Smithfield, Rhode Island to the Massachusetts border in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

5. **MA/RI Border – Millbury (National Grid):** Build a 15.4 mile 345 kV transmission line (#366) from the Rhode Island border in Millville, Massachusetts to the Millbury Switching Station in Millbury, Massachusetts. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

6. **Sherman Road – West Farnum (National Grid):** Reconductor and rebuild the existing 9.0 mile 345 kV 328 transmission line from the Sherman Road Switching Station in Burrillville, Rhode Island to the West Farnum Substation in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

345 kV Substation or Switching Station facilities:

1. **Card Substation (NU):** Expand the existing 345 kV ring-bus configuration by installing three new 345 kV circuit breakers. [redacted]

2. **Lake Road Switching Station (NU):** Expand the existing three bay 345 kV breaker-and-a-half scheme bus configuration by installing three new 345 kV breakers and associated bus work. [redacted] Also, add a new fourth 345 kV bay [redacted]

[redacted]

3. **West Farnum Substation (National Grid):** Install two additional 345 kV circuit breakers [redacted]

4. **Millbury Switching Station (National Grid):** Expand the existing two bay 345 kV breaker-and-a-half scheme bus configuration by installing four new 345 kV circuit breakers and associated bus work and upgrading three existing 345 kV circuit breakers. [redacted]

5. **Sherman Road Switching Station (National Grid):** Replace the existing ring bus with a new two bay breaker and a half open air switching station [redacted]

6. **Carpenter Hill Substation National Grid):** Upgrade the 345 kV protection system.

7. **Killingly Substation (NU):** Install two terminal structures to support the new 345-kV line conductors that traverse the existing Killingly 345-kV bus work.

115 kV Substation or Switching Station facilities:

1. **West Farnum (National Grid):** [redacted]

2. **Riverside (National Grid):** Upgrade protection system for the 115 kV H-17 transmission line.

3. **Woonsocket (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

4. **Hartford Avenue (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

[redacted]

Interstate Option A-2 Components

345 kV Transmission line facilities:

1. **Card – Lake Road (NU):** Build a 29.3 mile 345 kV transmission line (#3271) from the Card Substation in Lebanon, Connecticut to the Lake Road Switching Station in Killingly, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

2. **Lake Road – CT/RI Border (NU):** Build a 7.5 mile 345 kV transmission line (#341) from the Lake Road Switching Station in Killingly, Connecticut to the Rhode Island border in Thompson, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

3. **CT/RI Border – Sherman Road (National Grid):**Build a 8.7 mile 345 kV transmission line from the Connecticut border in Burrillville, Rhode Island to the Sherman Road Switching Station in Burrillville, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

4. **Sherman Road – West Farnum (National Grid):** Build a 9.0 mile 345 kV transmission line from the Sherman Road Switching Station in Burrillville, Rhode Island to the West Farnum Substation in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

5. **Sherman Road – MA/RI Border (National Grid):** Build a 0.2 mile 345 kV transmission line from the Sherman Road Switching Station in Burriville, Rhode Island to the Massachusetts border in Burriville, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

6. **MA /RI Border – Millbury (National Grid):** Build a 17.5 mile 345 kV transmission line from the Rhode Island border in Uxbridge, Massachusetts to the Millbury Switching Station in Millbury, Massachusetts. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

7. **Sherman Road – Ocean State Power:** Rebuild the 0.2 mile 333 345 kV transmission line from Sherman Road Switching Station in Burriville, Rhode Island to Ocean State Power in Burriville, Rhode Island.

345 kV Substation or Switching Station facilities:

1. **Card Substation (NU):** Expand the existing 345 kV ring-bus configuration by installing three new 345 kV circuit breakers. [redacted]

2. **Lake Road Switching Station (NU):** Expand the existing three bay 345 kV breaker-and-a-half scheme bus configuration by installing three new 345 kV breakers and associated bus work. [redacted] Also, add a new fourth 345 kV bay [redacted]

3. **Sherman Road Switching Substation (National Grid):** Replace the existing ring bus with a new four bay breaker and a half open air switching station [redacted]

4. **West Farnum Substation (National Grid):** Install an additional 345 kV circuit breaker [redacted]

5. **Millbury Switching Station (National Grid):** Expand the existing two bay 345 kV breaker-and-a-half scheme bus configuration by installing four new 345 kV circuit breakers and associated bus work and upgrading three existing 345 kV circuit breakers. [redacted]

6. **Carpenter Hill Substation (National Grid):** Upgrade the 345 kV protection system.

7. **Killingly Substation (NU):** Install two terminal structures to support the new 345-kV line conductors that traverse the existing Killingly 345 kV bus work.

115 kV Substation or Switching Station facilities:

1. **West Farnum (National Grid):** [redacted]

2. **Riverside (National Grid):** Upgrade protection system for the 115 kV H-17 transmission line.

3. **Woonsocket (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

4. **Hartford Avenue National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

Interstate Option A-3 Components

345 kV Transmission line facilities:

1. **Card – Lake Road (NU):** Build a 29.3 mile 345 kV transmission line (#3271) from the Card Substation in Lebanon, Connecticut to the Lake Road Switching Station in Killingly, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

2. **Lake Road – CT/RI Border (NU):** Build a 7.5 mile 345 kV transmission line (#341) from the Lake Road Switching Station in Killingly, Connecticut to the Rhode Island border in Thompson, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

3. **CT/RI Border – West Farnum (National Grid):** Build a 17.7 mile 345 kV transmission line (#341) from the Connecticut border in Burrillville, Rhode Island to the West Farnum Substation in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

4. **West Farnum – MA/RI Border (National Grid):** Build a 4.8 mile 345 kV transmission line from the West Farnum Substation in North Smithfield, Rhode Island to the MA border in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

5. **MA/RI Border – Uxbridge (National Grid):** Build a 1.9 mile 345 kV transmission line from the MA border in Uxbridge, Massachusetts to a new Uxbridge Switching Station in Uxbridge Massachusetts. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

6. **Uxbridge – Millbury (National Grid):** Build a 13.5 mile 345 kV transmission line from the Uxbridge Switching Station in Uxbridge Massachusetts to the Millbury Switching Station Millbury Massachusetts. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

7. **Sherman Road – Uxbridge (National Grid/NSTAR):** Increase conductor height on 4.1 mile 345 kV line, from Sherman Road Switching Station in Burrillville, Rhode Island to Uxbridge Switching Station in Uxbridge, Massachusetts.

8. **Uxbridge – ANP Blackstone (NSTAR):** Increase conductor height on the 4.6 mile 345 kV line, from Uxbridge Switching Station in Uxbridge Massachusetts to ANP Blackstone Station in Blackstone, Massachusetts.

345 kV Substation or Switching Station facilities:

1. **Card Substation (NU):** Expand the existing 345 kV ring-bus configuration by installing three new 345 kV circuit breakers. [redacted]
2. **Lake Road Switching Station (NU):** Expand the existing three bay 345 kV breaker-and-a-half scheme bus configuration by installing three new 345 kV breakers and associated bus work. [redacted] Also, add a new fourth 345 kV bay [redacted]
3. **West Farnum Substation (National Grid):** Install two additional 345 kV circuit breakers [redacted]
4. **Uxbridge Switching Station (National Grid):** Build a new 345 kV switching station in a breaker-and-a-half configuration by installing six new 345 kV circuit breakers in two new bays. [redacted]
5. **Millbury Switching Station (National Grid):** Expand the existing two bay 345 kV breaker-and-a-half scheme bus configuration by installing four new 345 kV circuit breakers and associated bus work and upgrading three existing 345 kV circuit breakers. [redacted]
6. **Sherman Road Switching Station (National Grid):** Replace the existing ring bus with a new two bay breaker and a half open air switching station [redacted]
7. **Carpenter Hill Substation (National Grid):** Upgrade the 345 kV protection system.
8. **Killingly Substation (NU)** : Install two terminal structures to support the new 345-kV line conductors that traverse the existing Killingly 345 kV bus work.

115 kV Substation or Switching Station facilities:

1. **West Farnum (National Grid):** [redacted]
2. **Riverside (National Grid):** Upgrade protection system for the 115 kV H-17 transmission line.
3. **Woonsocket (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

4. **Hartford Avenue (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

Interstate Option A-4 Components

345 kV Transmission line facilities:

1. **Card – Lake Road (NU):** Build a 29.3 mile 345 kV transmission line (#3271) from the Card Substation in Lebanon, Connecticut to the Lake Road Switching Station in Killingly, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

2. **Lake Road – CT/RI Border (NU):** Build a 7.5 mile 345 kV transmission line (#341) from the Lake Road Switching Station in Killingly, Connecticut to the Rhode Island border in Thompson, Connecticut. The line will be constructed using steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase. In some places the line will be built in a delta steel pole configuration.

3. **CT/RI Border – West Farnum (National Grid):** Build a 17.7 mile 345 kV transmission line (#341) from the Connecticut border in Burrillville, Rhode Island to the West Farnum Substation in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

4. **West Farnum – MA/RI Border (National Grid):** Build a 4.8 mile 345 kV transmission line from the West Farnum Substation in North Smithfield, Rhode Island to the MA border in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

5. **MA/RI Border – Millbury (National Grid):** Build a 15.4 mile 345 kV transmission line from the Rhode Island border in Millville, Massachusetts to the Millbury Switching Station in Millbury, Massachusetts. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase

6. **Sherman Road – West Farnum (National Grid):** Build a 9.0 mile 345 kV transmission line from the Sherman Road Switching Station in Burrillville, Rhode Island to the West Farnum Substation in North Smithfield, Rhode Island. The line will be constructed using steel H-frames structures with two (bundled) 1590 kcmil ACSR conductors per phase.

345 kV Substation or Switching Station facilities:

1. **Card Substation (NU):** Expand the existing 345 kV ring-bus configuration by installing three new 345 kV circuit breakers. [redacted]

2. **Lake Road Switching Station (NU):** Expand the existing three bay 345 kV breaker-and-a-half scheme bus configuration by installing three new 345 kV breakers and associated bus work. [redacted] Also, add a new fourth 345 kV bay [redacted]

[redacted]

3. **West Farnum Substation (National Grid):** Expand the existing four bay 345 kV breaker-and-a-half scheme bus configuration to five bays. [redacted]

4. **Millbury Switching Station (National Grid):** Expand the existing two bay 345 kV breaker-and-a-half scheme bus configuration by installing four new 345 kV circuit breakers and associated bus work and upgrading three existing 345 kV circuit breakers. [redacted]

5. **Sherman Road Switching Station (National Grid):** Replace the existing ring bus with a new three bay open air breaker and a half switching station [redacted]

6. **Carpenter Hill Substation (National Grid):** Upgrade the 345 kV protection system.

7. **Killingly Substation (NU)** : Install two terminal structures to support the new 345-kV line conductors that traverse the existing Killingly 345 kV bus work.

115 kV Substation or Switching Station facilities:

1. **West Farnum (National Grid):** [redacted]

2. **Riverside (National Grid):** Upgrade protection system for the 115 kV H-17 transmission line.

3. **Woonsocket (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

4. **Hartford Avenue (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

Interstate Option C-2.1 Components

345kV Transmission line facilities:

1. **Manchester – CT/MA Border (NU):** Build a 33.4 mile 345 kV transmission line from the Manchester Substation in Manchester, Connecticut to the CT/MA border in Somers, Connecticut. The line will be constructed using vertical steel monopole and steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase.
2. **CT/MA Border –Belchertown/Ludlow Town Line (NU/National Grid (NU):** Build a 14.3 mile 345 kV transmission line from the CT/MA border in Hampden, Massachusetts to the Belchertown/Ludlow town line in Massachusetts. The line will be constructed using vertical steel monopole and steel (or wood) H-frame structures with two (bundled) 1590 kcmil ACSS conductors per phase

3. **Belchertown/Ludlow Town Line (NU/National Grid) – Carpenter Hill (National Grid):** Build a 23.1 mile 345 kV transmission line from the Belchertown/Ludlow town line to the Carpenter Hill substation in Charlton, Massachusetts. The line will be constructed using steel H-frame structures with two (bundled) 1590 kcmil ACSR conductors per phase. Note: National Grid also to relocate 2.6 miles of the 345kV 301 in the ROW, in Massachusetts.

4. **Carpenter Hill – Millbury (National Grid):** Build a 16.0 mile 345 kV transmission line from the Carpenter Hill Substation in Charlton, Massachusetts to the Millbury Switching Station in Millbury, Massachusetts. The line will be constructed using steel H-frame structures with two (bundled) 1590 kcmil ACSR conductors per phase.

5. **Sherman Road – West Farnum (National Grid):** Build a 9.0 mile 345 kV transmission line from the Sherman Road Switching Station in Burrillville, Rhode Island to the West Farnum Substation in North Smithfield, Rhode Island. The line will be constructed using steel H-frame structures with two (bundled) 1590 kcmil ACSR conductors per phase.

345 kV Substation or Switching Station facilities:

1. **Manchester Substation (NU):** Expand the existing 345 kV three bay 345 kV breaker-and-a-half scheme bus configuration by adding a new bay and installing two new 345 kV circuit breakers. [redacted] Upgrade substation equipment.

2. **Carpenter Hill Substation (National Grid):** Expand the existing 345 kV substation by adding two new 345 kV bays and installing six new 345 kV circuit breakers and a 345/115 kV autotransformer. [redacted] The project also involves the upgrade of the 345 kV protection system.

3. **Millbury Switching Station (National Grid):** Expand the existing two bay 345 kV breaker-and-a-half scheme bus configuration by installing four new 345 kV circuit breakers and associated buswork and upgrading three existing 345 kV circuit breakers. [redacted]

[redacted]

4. **West Farnum Substation (National Grid):** Install an additional 345 kV circuit breaker [redacted]

5. **Sherman Road Switching Station (National Grid):** Replace the existing ring bus with a new three bay open air breaker and a half switching station [redacted]

115 kV Transmission line facilities:

1. **Wood River – CT/MA Border (National Grid):** Uprate [redacted] the 7.2 mile 115 kV 1870S transmission line from the Wood River Substation in Charleston, Rhode Island to the CT/MA border in Westerly, Rhode Island.

2. **West Farnum Tap – Woonsocket (National Grid):** Reconductor the 1.1 mile 115 kV S-171N transmission line from the West Farnum Substation in North Smithfield, Rhode Island to the Woonsocket Substation in Smithfield, Rhode Island with 1590 ACSS.

3. **West Farnum Tap – Woonsocket (National Grid):** Reconductor the 1.1 mile 115 kV T-172N transmission line from the West Farnum Substation in North Smithfield, Rhode Island to the Woonsocket Substation in Smithfield, Rhode Island with 1590 ACSS.

4. **South Wrentham – Union Street (National Grid):** Uprate [redacted] the 3.3 mile 115 kV C-129S transmission line from the South Wrentham Substation in Wrentham, Massachusetts to the Union Street Substation in Franklin, Massachusetts.

5. **Depot Street Tap – Milford Power and Light Plant Tap (National Grid):** Reconductor the 2.65 mile 115 kV C-129N transmission line from the Depot Street Tap in Milford, Massachusetts to the Milford Power and Light Plant Tap in Milford, Massachusetts with 795 ACSR.

115 kV Substation or Switching Station facilities:

1. **West Farnum (National Grid):** [redacted]

2. **Riverside (National Grid):** Upgrade protection system for the 115 kV H-17 transmission line.

3. **Woonsocket (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines and upgrade 115 kV terminal equipment.

4. **Hartford Avenue (National Grid):** Upgrade protection systems for the 115 kV S-171N and T-172N transmission lines.

Section 13
Appendix E: Sherman Road Short Circuit Results

[redacted]

[redacted]

Section 14
Appendix F: Thermal and Voltage Analysis Results

[redacted]

Section 15
Appendix G: Thermal Transfer Capability Results

[redacted]

Section 16
Appendix H: Stability Analysis Results

[redacted]

[redacted]

Section 17
Appendix I: Detailed Cost Estimates for Interstate Alternatives

Appendix I - Detailed Cost Estimates.pdf

Option A-1 Cost Estimate Detail

345 kV Transmission Line Facilities

Description	Company	Cost ($ Millions)
New Line – Card to Lake Road	NU	$176.0
New Line – Lake Road to RI/CT Border	NU	$44.6
New Line – RI/CT Border to West Farnum	National Grid	$71.7
New Line – West Farnum to MA/RI Border	National Grid	$81.8
New Line – MA/RI Border to Millbury	National Grid	
Reconductor 328 Line – Sherman Road to West Farnum	National Grid	$36.5
Transmission Lines Total		$410.6

345 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
Card Substation- Ring bus expansion	NU	$20.0
Lake Road Switching Station - 4th bay	NU	$8.0
West Farnum Substation 345 kV Additions	National Grid	$18.6
Millbury 345 kV Substation Expansion	National Grid	$30.7
New Sherman Road 345 kV AIS Substation	National Grid	$36.6
Carpenter Hill Substation Relay Upgrades	National Grid	$1.9
Killingly Substation - Terminal structures	NU	$2.4
345 kV Substations Total		$118.2

115 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
West Farnum Substation 115 kV Upgrades	National Grid	$8.0
Riverside Substation Relay Upgrades	National Grid	$1.0
Woonsocket Substation Relay Upgrades	National Grid	$2.5
Hartford Avenue Substation Relay Upgrades	National Grid	$1.5
115 kV Substations Total		$13.0

Option A-1 Total	**$541.8**

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1) Estimates have a -25% / +50% degree of accuracy

2) The above estimates reflect capitalized Allowance for Funds Used During Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

Option A-2 Cost Estimate Detail

345 kV Transmission Line Facilities

Description	Company	Cost ($ Millions)
New Line – Card to Lake Road	NU	$176.0
New Line – Lake Road to RI/CT Border	NU	$44.6
New Line – RI/CT Border to Sherman Road	National Grid	$35.2
New Line – Sherman Road to West Farnum	National Grid	$47.1
New Line – Sherman Road to MA/RI Border	National Grid	$55.1
New Line – Millbury to Intersection of NSTAR/NGRID ROWs	National Grid	
New Line – Sherman Road to Intersection of NSTAR/NGRID ROWs	NSTAR	$15.1
New Line – Sherman Road to Ocean State Power	National Grid	$1.0
Transmission Lines Total		$375.1

345 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
Card Substation- Ring bus expansion	NU	$20.0
Lake Road Switching Station - 4th bay	NU	$8.0
New Sherman Road 345 kV GIS Substation	National Grid	$81.1
West Farnum Substation 345 kV Additions	National Grid	$10.6
Millbury 345 kV Substation Expansion	National Grid	$30.7
Carpenter Hill Substation Relay Upgrades	National Grid	$1.9
Killingly Substation - Terminal structures	NU	$2.4
345 kV Substations Total		$154.7

115 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
West Farnum Substation 115 kV Upgrades	National Grid	$8.0
Riverside Substation Relay Upgrades	National Grid	$1.0
Woonsocket Substation Relay Upgrades	National Grid	$2.5
Hartford Avenue Substation Relay Upgrades	National Grid	$1.5
115 kV Substations Total		$13.0

Option A-2 Total	**$542.8**

1) Estimates have a -25% / +50% degree of accuracy

2) The above estimates reflect capitalized Allowance for Funds Used During Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

Option A-3 Cost Estimate Detail

345 kV Transmission Line Facilities

Description	Company	Cost ($ Millions)
New Line – Card to Lake Road	NU	$176.0
New Line – Lake Road to RI/CT Border	NU	$44.6
New Line – RI/CT Border to West Farnum	National Grid	$71.7
New Line – West Farnum to MA/RI Border	National Grid	$81.8
New Line – MA/RI Border to New Uxbridge Substation	National Grid	
New Line – Millbury to New Uxbridge Substation	National Grid	
Fix Sag – Sherman Road to Uxbridge	NSTAR	$3.0
Fix Sag – ANP Blackstone to Uxbridge		
Transmission Lines Total		$377.1

345 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
Card Substation- Ring bus expansion	NU	$20.0
Lake Road Switching Station - 4th bay	NU	$8.0
West Farnum Substation 345 kV Additions	National Grid	$18.6
New Uxbridge Switching Station	National Grid	$44.6
Millbury 345 kV Substation Expansion	National Grid	$30.7
New Sherman Road 345 kV AIS Substation	National Grid	$36.6
Carpenter Hill Substation Relay Upgrades	National Grid	$1.9
Killingly Substation - Terminal structures	NU	$2.4
345 kV Substations Total		$162.8

115 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
West Farnum Substation 115 kV Upgrades	National Grid	$8.0
Riverside Substation Relay Upgrades	National Grid	$1.0
Woonsocket Substation Relay Upgrades	National Grid	$2.5
Hartford Avenue Substation Relay Upgrades	National Grid	$1.5
115 kV Substations Total		$13.0

Option A-3 Total	**$552.9**

1) Estimates have a -25% / +50% degree of accuracy

2) The above estimates reflect capitalized Allowance for Funds Used During Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

Option A-4 Cost Estimate Detail

345 kV Transmission Line Facilities

Description	Company	Cost ($ Millions)
New Line – Card to Lake Road	NU	$176.0
New Line – Lake Road to RI/CT Border	NU	$44.6
New Line – RI/CT Border to West Farnum	National Grid	$71.7
New Line – West Farnum to MA/RI Border	National Grid	$81.8
New Line – MA/RI Border to Millbury	National Grid	
New Line – Sherman Road to West Farnum	National Grid	$47.7
Transmission Lines Total		$421.8

345 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
Card Substation- Ring bus expansion	NU	$20.0
Lake Road Switching Station - 4th bay	NU	$8.0
West Farnum Substation 345 kV Additions	National Grid	$29.3
Millbury 345 kV Substation Expansion	National Grid	$30.7
New Sherman Road 345 kV AIS Substation	National Grid	$43.4
Carpenter Hill Substation Relay Upgrades	National Grid	$1.9
Killingly Substation - Terminal structures	NU	$2.4
345 kV Substations Total		$135.7

115 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
West Farnum Substation	National Grid	$8.0
Riverside Substation Relay Upgrades	National Grid	$1.0
Woonsocket Substation Relay Upgrades	National Grid	$2.5
Hartford Avenue Substation Relay Upgrades	National Grid	$1.5
115 kV Substations Total		$13.0

Option A-4 Total	**$570.5**

1) Estimates have a -25% / +50% degree of accuracy

2) The above estimates reflect capitalized Allowance for Funds Used During Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

Option C-2.1 Cost Estimate Detail

345 kV Transmission Line Facilities

Description	Company	Cost ($ Millions)
New Line – Manchester to CT/MA Border	NU	$295.0
New Line – CT/MA Border to NU/NGRID Service territory Border		
New Line – Carpenter Hill to NU/NGRID Service territory Border	National Grid	$114.4
New Line – Carpenter Hill to Millbury	National Grid	$71.2
New Line – Sherman Road to West Farnum	National Grid	$47.7
345 kV Transmission Lines Total		$528.3

345 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
Manchester Substation Upgrades	NU	$14.1
Carpenter Hill Substation Expansion	National Grid	$46.3
Millbury 345-kV Substation Expansion	National Grid	$30.7
West Farnum Substation 345 kV Additions	National Grid	$14.6
New Sherman Road 345 kV AIS Substation	National Grid	$43.4
345 kV Substations Total		$149.1

115 kV Transmission Line Facilities

Description	Company	Cost ($ Millions)
Uprate 1870S Line – Wood River to RI/CT Border	National Grid	$8.6
Reconductor S171N Line – West Farnum to Woonsocket	National Grid	$3.4
Reconductor T172N Line – West Farnum to Woonsocket	National Grid	$3.4
Uprate C129S Line – South Wrentham to Union Street	National Grid	$2.5
Reconductor C129N Line – Depot Street Tap to Milford Power Tap	National Grid	$4.0
115 kV Transmission Lines Total		$21.9

1) Estimates have a -25% / +50% degree of accuracy

2) The above estimates reflect capitalized Allowance for Funds Used During Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

Option C-2.1 Cost Estimate Detail (continued)

115 kV Substation or Switching Station Facilities

Description	Company	Cost ($ Millions)
West Farnum Substation	National Grid	$8.0
Riverside Substation Relay Upgrades	National Grid	$1.0
Woonsocket Substation 115 kV Terminal and Relay Upgrades	National Grid	$4.4
Hartford Avenue Substation Relay Upgrades	National Grid	$1.5
115 kV Substations Total		**$14.9**

Option C-2.1 Total	**$714.2**

1) Estimates have a -25% / +50% degree of accuracy

2) The above estimates reflect capitalized Allowance for Funds Used During Construction (AFUDC) accrual for the duration of the project, which was used consistently for cost comparisons of the various options. On May 27, 2011, the Federal Energy Regulatory Commission issued an Order authorizing recovery in rate base by CL&P and the New England Power Company (collectively the "Companies") of 100% of transmission construction work in progress (CWIP) costs for the New England East-West Solution (NEEWS) projects, including the Interstate Reliability Project in current year regional rates. Recalculation of the cost estimates for all options, using the revised accounting treatment has not been undertaken for this report, since it would not change the relative costs of the options.

Section 18

Appendix J: Comparison of Modeled DR and FCA-5 DR

Table 18-1:
Comparison of Passive DR

Load Zone	Modeled DR (MW)	FCA-5 DR (MW)
Maine	152	134
NH	72	72
Vermont	97	102
NEMA_BOSTON	263	273
SEMA	140	153
WCMA	150	177
RI	85	85
CT	424	399

Table 18-2:
Comparison of Active DR

Load Zone	Modeled DR (MW)	FCA-5 DR (MW)
BHE ME	76	45
ME	203	127
PORT ME	135	120
NEW Hamp	64	49
Seacoast NH	10	7
NW VT	35	35
Vermont	19	20
Boston	212	196
North Shore	83	69
CMA	86	75
SPFD	96	34
WMA	45	54
LSM	64	47
SEMA	106	107
RI	77	79
Eastern Ct	48	40
Northern Ct	63	[illegible]
Western CT	208	183
Nor/Stamford	70	60