New England East–West Solutions

(Formerly Southern New England Transmission Reliability)

Report 2
Options Analysis

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Southern New England Regional Working Group

ISO New England

National Grid

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Executive Summary

National Grid, Northeast Utilities, and ISO New England (ISO) formed a working group to conduct the studies necessary to develop a 10-year plan for transmission system improvements for the southern New England (SNE) region. The 10-year plan specifically addresses western and central Massachusetts (particularly the Springfield area), Rhode Island, and eastern and central Connecticut.

The objective of this 10-year plan is to ensure that the SNE region continues to comply with criteria and reliability standards established by the North American Electric Reliability Corporation (NERC), the Northeast Power Coordinating Council (NPCC), and the ISO.[1] These criteria and standards define regional transmission requirements and transmission-transfer capabilities with respect to stability, steady state, and fault-current conditions. They are in place to ensure, for the long term, that the regional transmission system serving New England is robust and flexible, reliably delivers power to customers under a wide range of projected future system conditions, and is able to address reasonably foreseeable contingencies.

The working group developed the transmission system improvements described in this analysis in conjunction with the ISO's 10-year regional system planning process, which showed the likelihood of portions of the SNE region not meeting the criteria and standards by 2009.[2] A full explanation and review of the criteria, the results of the analysis, and the statement of need for the SNE transmission system are contained in the January, 2008, report, *Southern New England Transmission Reliability (SNETR) Report 1—Need Analysis* (Needs Analysis).[3]

This report, *Report 2—Options Analysis*, describes the results of the working group's analysis of the options that address the needs identified in the Needs Analysis. The Options Analysis explains how the options were developed to meet the identified needs, describes the main features of the solutions, and compares the solutions in terms of system performance characteristics. As shown in this report, a number of the potential solutions would ensure reliable system performance for the SNE region for the time periods under study.

[1]The ISO system must comply with NERC and NPCC criteria and standards and ISO planning and operating procedures. As certified by the Federal Energy Regulatory Commission in 2006, NERC is the "electric reliability organization" (ERO) whose mission is to improve the reliability and security of the bulk power system in North America. Information on NERC requirements is available online at http://www.nerc.com (Princeton, NJ: NERC, 2007). NPCC is the cross-border regional entity and criteria services corporation for northeastern North America. NPCC's mission is to promote and enhance the reliable and efficient operation of the international, interconnected bulk power system in the geographic area that includes New York State, the six New England states, and the Ontario, Québec, and the Maritime provinces of Canada. Additional information on NPCC is available online at http://www.npcc-cbre.org/default.aspx (New York: NPCC Inc., 2007). Information about ISO New England Planning Procedure No. 3 (PP 3), *Reliability Standards for the New England Area Bulk Power Supply System*, is available online at http://www.iso-ne.com/rules_proceds/isone_plan/PP3_R3.doc (Holyoke, MA: ISO New England, 2006).

[2] Summaries of the ISO's projections for the southern New England transmission system have appeared in the 2005, 2006, and 2007 Regional System Plans (RSPs) as well as previous years' Regional Transmission Expansion Plans. These reports are available online at http://www.iso-ne.com/trans/rsp/index.html.

[3] The *Southern New England Transmission Reliability (SNETR) Report 1—Needs Analysis* can be obtained by contacting ISO Customer Service at 413-540-4220 or custserv@iso-ne.com.

Development and Assessment of Plan Components and Options

The first step for this study was to establish the design objectives for the future southern New England transmission system based on the reliability deficiencies identified in the Needs Analysis. Using these design objectives, the working group developed and evaluated a combination of complementary options for upgrading the system to meet the identified performance objectives during the long-term planning horizon.

In formulating each option, the working group considered more than just the performance of the option under specific conditions. It also considered the relationship that each option could have with other components of the comprehensive solution for the SNE region, with other elements of the transmission system, and with the regional transmission system as a whole. Consideration of these relationships ensured that the development of a "solution" was comprehensive and did not have an adverse impact on other parts of the bulk transmission system. These relationships led the working group to develop an approach to solving the SNE region's needs with these four components:

- **Interstate Component**—This component provides an additional link between Massachusetts, Rhode Island and Connecticut or, in one case, just between Rhode Island and Connecticut, and improves regional transfer capabilities. Initial brainstorming sessions among working group members resulted in 17 options for the Interstate component, of which five viable options remain.
- **Rhode Island Component—**This component increases Rhode Island's access to New England's 345 kV bulk transmission system and eliminates both thermal overloads and voltage violations. Three options (two Interstate options plus one independent option) were developed to better connect Rhode Island to the rest of the system, three options were developed to extend these new facilities farther into the major load center in southwest Rhode Island, and two options were developed to bring an additional source into the 115 kV load center from the east.
- **Connecticut East–West Component**—This component provides an additional link between western and eastern Connecticut and improves system transfer capabilities between these areas. Initially, four options were developed for this component. One option was eliminated as a result of poor performance, which left three options for further study.
- **Springfield Component—**This component eliminates both thermal and voltage violations in the Springfield area while increasing the area's access to the 345 kV bulk transmission system. The number of 345 kV options for the Springfield component was limited; however, 35 options were initially developed because a number of possible 115 kV solutions would work well with any of the 345 kV options, which created a multiplicative effect. Three 345 kV options remain, each having four 115 kV variations, for a total of 12 potential solutions.

Developing the options for each of these four components has been an iterative process for the working group. Options that appeared to be capable of mitigating reliability concerns were formulated and then analyzed for compliance with design criteria and objectives. Additional modifications were formulated as necessary and then the option was reevaluated. This step was repeated until either the option was clearly workable or was determined to be not viable or not practical because it would require too many modifications.

Component Options that Exhibited Superior Performance

In each of the four components, most of the options that were found to meet or exceed the system criteria and objectives involve adding new 345 kV transmission lines, although all the upgrades associated with the four components also include 115 kV facilities and autotransformers.

Interstate Component Options

The Interstate component serves to strengthen the ties between the southern New England states and increase the ability to move power between eastern New England and western New England. For the five Interstate options that exhibited superior performance in meeting system criteria and objectives, the new 345 kV lines that would act as the 'backbone' for the options are listed below.

- **Interstate Option A**—a new 345 kV line from the Millbury, MA, substation to the West Farnum, RI, substation and then to the Lake Road, CT, substation and terminate at the Card, CT, substation
- **Interstate Option B**—a new 345 kV line from the West Farnum substation to the Kent County, RI, substation and then to the Montville, CT, substation. (The line from the West Farnum substation to the Kent County substation is part of the Rhode Island component.)
- **Interstate Option C**—a new 345 kV line from the Millbury substation to the Carpenter Hill, MA, substation and terminate at the Manchester, CT, substation
- **Interstate Option D**—a new 345 kV line from the Millbury substation to the Carpenter Hill substation to the Ludlow, MA, substation to the Agawam, MA, substation to the North Bloomfield, CT, substation. (The line from the Ludlow substation to the Agawam substation to the North Bloomfield substation is part of the Springfield component.)
- **Interstate Option E**—a new 1,200 MW high-voltage direct-current (HVDC) tie between the Millbury substation and the Southington, CT, substation

Rhode Island Component Options

The Rhode Island component upgrades would serve three basic functions: (1) bring an additional source (in the form of a new transmission line) into Rhode Island, (2) extend a second source (transmission line) to the southwest area of Rhode Island, and (3) add a new source (345/115 kV autotransformer) from the east into the 115 kV load center.

Bringing an additional source into Rhode Island is handled as part of Interstate Options A and B or by installing a second Sherman Road, RI–West Farnum 345 kV line as part of Interstate Options C, D, and E.

The addition of a second West Farnum–Kent County 345 kV line proved to be the most cost-effective option for extending a second source to the southwest area. Adding 115 kV lines and upgrades proved unable to support the loss of the existing West Farnum–Kent County 345 kV line.

Similarly, adding a new 345/115 kV substation into the 115 kV system from the east side proved to be the most effective option for eliminating the 115 kV voltage concerns that had been identified and forecast. This new substation would be looped into the existing 345 kV line (the 303 line) that extends from Brayton Point to ANP–Bellingham. The 115 kV lines that currently tie the South Wrentham substation to the Brayton Point substation (the 181 and 182 lines) also would be looped into this new substation under this option.

Connecticut East–West Component Options

The Connecticut East–West component increases the ability to move power between eastern and western Connecticut. It can be thought of as an extension to the Interstate component by helping to move power from eastern to western New England, and vice versa, depending on the dispatch of existing generation and on the location of future generators. The three options for the Connecticut East–West component that exhibited superior performance are as follows:

- **Option A**—a new 345 kV line from Manchester to Southington
- **Option B**—a new 345 kV line from Manchester to Scovill Rock and from Berlin to Hans Brook Junction
- **Option C**—a new 345 kV line from North Bloomfield to Frost Bridge

Springfield Component Options

The Springfield component reduces Springfield's dependence on internal generation by increasing the area's access to the 345 kV bulk transmission system and eliminates the thermal and voltage criteria violations of the area. The three options for the Springfield component that exhibited superior performance in meeting these objectives are as follows:

- **Option A**—a new 345 kV line from Ludlow to Agawam to North Bloomfield
- **Option B**—a new 345 kV line from Ludlow to North Bloomfield
- **Option C**—a new 345 kV line from Ludlow to Manchester

Relationships among Components and Options

The relationships among the four components and options are as follows:

- **Interstate Component—**The preferred Interstate option can be selected without respect to other component selections; however, this selection will dictate some of the Rhode Island component selections. Interstate Option E, which adds a HVDC line from the Millbury substation to the Southington substation, obviates the need for a separate 345 kV line to mitigate Connecticut East–West constraints.
- **Rhode Island Component—**As stated, some of the system improvements that make up the Rhode Island options depend on which Interstate option is selected (as shown in Appendix A, Table A-2). Therefore, the Interstate option selected will directly affect which Rhode Island option is selected. Some of the improvements of the Rhode Island component options are independent of the selections for any of the other components of the plan.
- **Connecticut East–West Component—**The improvements for the Connecticut East–West component options are independent of the selections for any of the other component options. However, as stated, the selection of Interstate Option E would obviate the need for a Connecticut East–West 345 kV option, since it would satisfy the reliability need for both the Interstate and the Connecticut East–West components.
- **Springfield Component—**The improvements for the Springfield component are independent of the preferred Interstate option unless Option D is selected. In this case, additional Springfield area upgrade(s) would be required. This component is independent of the Rhode Island and Connecticut East–West Component options.

Next Steps

The next part of the process is for the participating transmission owners to analyze the environmental impacts, cost, constructability, and routing for each option of each component. Once this information is gathered and analyzed, preferred options for each of the four plan components can be identified.

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Section 1
Introduction

National Grid, Northeast Utilities, and ISO New England (ISO) formed a working group to conduct the studies necessary to develop a 10-year plan for transmission system improvements for the southern New England (SNE) region. The plan specifically addresses western and central Massachusetts (particularly the Springfield area), Rhode Island, and eastern and central Connecticut (see Figure 1-1).

Figure 1-1: Key substations in southern New England.

The objective of the 10-year integrated SNE transmission enhancement plan is to ensure that the region complies with a number of design, operation, and reliability criteria and standards, as follows, to improve the long-term reliability and performance of the southern New England transmission system:

- North American Electric Reliability Corporation's (NERC) Reliability Standards for the Bulk Power Systems of North America[4]
- Northeast Power Coordinating Council's (NPCC) Basic Criteria for the Design and Operation of Interconnected Power Systems[5]
- The ISO's Planning Procedure No. 3 (PP 3), Reliability Standards for the New England Area Bulk Power Supply System[6]

These criteria and standards are in place to ensure that the regional transmission system serving New England can reliably deliver power to customers under a wide range of system conditions, such as anticipated facility outage events and system contingencies (i.e., the sudden and unplanned outage of a generating unit or transmission facility). The standards and criteria also ensure the adequate transfer of power among the New England Control Area and the surrounding control areas and account for possible future system configurations (i.e., load and generation scenarios). To comply with PP 3, the system meets the minimum acceptable level of reliable service if it passes the test conditions under simulation, as specified in this procedure.

A full explanation and review of the criteria, the statement of need for the SNE regional transmission system, and the results of an analysis of the needs are contained in *Southern New England Transmission Reliability (SNETR) Report 1—Needs Analysis* (Needs Analysis).[7] This report, *Report 2—Options Analysis*, summarizes the needs identified in the first report and describes each of the solutions and how they were developed for addressing the identified needs. This report also discusses the results of the analysis for developing options for solutions and compares them in terms of system performance characteristics.

A number of the transmission upgrades that were developed were found to meet the stated requirements for ensuring reliable and adequate system performance for the areas and time periods under study.

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[4] As certified by the Federal Energy Regulatory Commission in 2006, NERC is the "electric reliability organization" (ERO) whose mission is to improve the reliability and security of the bulk power system in North America. Information on NERC requirements is available online at http://www.nerc.com (Princeton, NJ: NERC, 2007).

[5] NPCC is the cross-border regional entity and criteria services corporation for northeastern North America. NPCC's mission is to promote and enhance the reliable and efficient operation of the international, interconnected bulk power system in the geographic area that includes New York State, the six New England states, and the Ontario, Québec, and the Maritime provinces of Canada. Additional information on NPCC is available online at http://www.npcc-cbre.org/default.aspx (New York: NPCC Inc., 2007).

[6] ISO New England Planning Procedure No. 3, *Reliability Standards for the New England Area Bulk Power Supply System*, is available online at http://www.iso-ne.com/rules_proceds/isone_plan/PP3_R3.doc (Holyoke, MA: ISO New England, 2006).

[7] The *Southern New England Transmission Reliability (SNETR) Report 1—Needs Analysis* (August 7, 2006) can be obtained by contacting ISO Customer Service at 413-540-4220 or custserv@iso-ne.com.

Section 2
Overview of Transmission System Problems and Needs

Through its analyses of the 10-year planning period, the working group identified a number of deficiencies in transmission system security that could lead to violations of the planning criteria and standards the system must meet. These deficiencies—many of which are a result of the significant degree of load growth in the SNE region—form the justification for the needed transmission system improvements. Although discussed in detail in the Needs Analysis, the specific reliability needs are summarized as follows for quick reference:

- The amount of power that can be delivered between eastern New England and western New England must be increased. The east–west power flows across southern New England could be limited because of potential thermal and voltage violations of area transmission facilities under contingency conditions.
- The amount of power that can be moved between Connecticut, Massachusetts, and Rhode Island must be increased to eliminate transmission security criteria violations.
- The reliability of the transmission supply to the Springfield, Massachusetts, area must be improved by eliminating thermal overloads and voltage problems under numerous contingencies. The severity of these problems increases as the system attempts to move power into Connecticut from the rest of New England. In the Springfield area, local double-circuit tower outages (DCT), stuck-breaker outages, and single-element outages all can result in severe thermal overloads and low-voltage conditions. **This sentence has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.**
- The ability to move power into and out of Connecticut must be enhanced. In the past, the limited ability to export power from Connecticut to the rest of New England was the more serious problem; however, this has reversed in recent years. The ability to import power presently is limited and could eventually result in the inability to serve load under many probable system conditions. Power-transfer capabilities in the Connecticut area are forecast to be insufficient for meeting the area's requirements as early as 2009.[8] If improvements are not made by 2016, the deficiency for this area under "generator unavailability conditions" (i.e., when the largest unit plus a historical average amount of other generation is out-of-service) and when a single power system element is lost (N-1 conditions) is expected to be greater than 1,500 MW, assuming a transfer limit of 2,500 MW and no new capacity additions. On the basis of planning assumptions of future generation additions of 500 MW and retirements of 204 MW within the Connecticut area, by 2016 a deficiency of approximately 1,100 MW will occur for N-1 conditions, and 1,200 MW for N-1-1 conditions (i.e., conditions under which a transmission element is unavailable and a single power system element is lost).
- The amount of power that can be delivered from eastern Connecticut to western Connecticut must be increased by eliminating transmission security criteria violations. These violations, which can cause thermal constraints, limit the Connecticut east–west power transfers across the central part of Connecticut. The movement of power from east to west, in conjunction

[8] RSP06, Table 9-3

with higher import levels to serve Connecticut, overloads transmission facilities within Connecticut.

- The reliability of the transmission supply to the Rhode Island area must be improved by eliminating thermal overloads and voltage problems. Rhode Island now is overly dependent on a limited number of transmission lines or autotransformers to serve its needs, which could result in thermal overloads and voltage problems during contingency conditions. Causal factors for these conditions include high load growth (especially in southern Rhode Island and the coastal communities), unit availability, and planned and unplanned transmission outages. The Rhode Island 115 kV system is constrained when a 345 kV line is out of service. Outage of any one of a number of 345 kV transmission lines limits the amount of power that can be transferred into Rhode Island. For line-out conditions, the next critical contingency involving the loss of a 345/115 kV autotransformer or a second 345 kV line results in numerous thermal and voltage violations.

Section 3
Development and Assessment of Options

Developing and assessing the options for addressing the identified reliability needs has been a highly complex effort. The first part of the process was to establish the objectives for the future performance of the SNE transmission system based upon the reliability deficiencies shown in the Regional System Plans (RSPs) and as discussed in the Needs Analysis report. Using these performance objectives, the working group developed and evaluated a combination of complementary options for transmission system upgrades for the long-term planning horizon. This section describes the design objectives for the options as well as the ability of each set of options to meet these objectives.

3.1 Developing the Four-Component Approach

In formulating each option, the working group considered not only the performance of the option but also the relationship that each option could have with other components of the comprehensive solution, with other elements of the transmission system, and with the regional transmission system as a whole. Consideration of these relationships ensured that the development of one "solution" was comprehensive and did not have an adverse impact on other parts of the system. These relationships led the working group to develop an approach to solving the SNE region's needs with these four components:

- **Interstate Component**—This component either provides an additional link between Massachusetts, Rhode Island, and Connecticut or, in one case, just between Rhode Island and Connecticut, and improves regional transfer capabilities. Initial brainstorming sessions identified 17 options for the Interstate component, of which five viable options remain.
- **Rhode Island Component**—This component increases Rhode Island's access to New England's 345 kV bulk transmission system and eliminates both thermal overloads and voltage violations. Three options (two Interstate options plus one independent option) were developed to better connect Rhode Island to the rest of the system, three options were developed to extend these new facilities farther into the major load center in southwest Rhode Island, and two options were developed to bring an additional source into the 115 kV load center from the east.
- **Connecticut East–West Component**—This component provides an additional link between western and eastern Connecticut and improves system transfer capabilities. Four options were initially developed for this component; one was eliminated as a result of poor performance, which left three options for further study.
- **Springfield Component**—This component eliminates both thermal and voltage violations in the Springfield area while increasing the area's access to the 345 kV bulk transmission system. The number of 345 kV options for the Springfield component was limited; however, 35 options were initially developed because a number of possible 115 kV solutions would work well with any of the 345 kV options. Three 345 kV options remain, each having four 115 kV variations, for a total of 12 potential solutions.

As shown in Figure 3-1, a number of factors were considered in formulating and evaluating the options within each component of the plan. These factors ranged from considering the impacts of an option on the New York–New England transfer capabilities to assessing the impact of adding a specific generating unit.

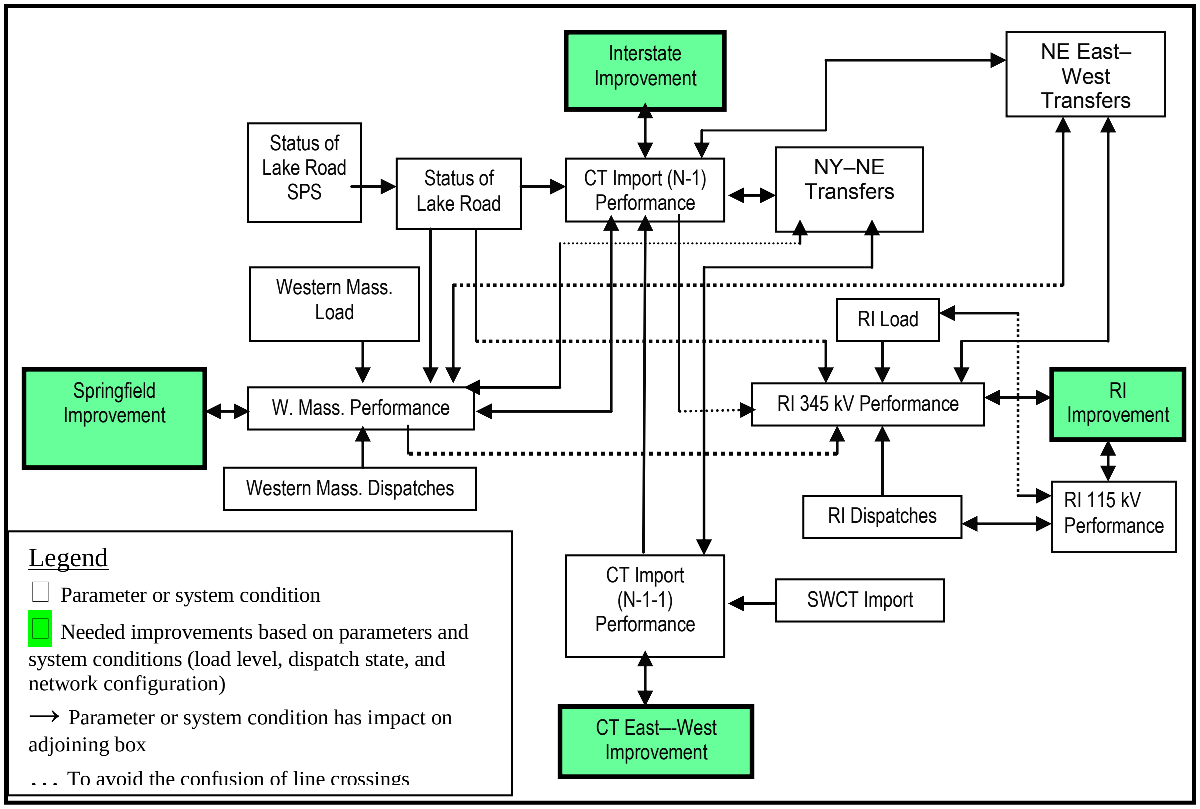

Figure 3-1: Diagram of relationships among southern New England components.

The lines interconnecting the boxes in Figure 3-1 show how the components can have an impact on one another. For example, the performance of the Rhode Island 345 kV system depends, to some extent, on all the following:

- RI Load (Rhode Island load levels)
- NE East-West Transfers (transfer level from eastern to western New England)
- CT Import (N-1) Performance (transfer level into Connecticut)
- RI Dispatches (generation dispatch in Rhode Island)
- Status of Lake Road (generation dispatch on the borders)
- W. Mass. Performance (performance of western Massachusetts system [i.e., Ludlow to Manchester loading])

To ensure the resiliency of the solutions, the design of the system upgrades accounted for the premature loss of generation concurrent with the ability of the system to maintain an acceptable level of performance under line-out-of-service conditions. This is an important planning consideration because implementing a transmission system upgrade to ensure system reliability in response to an unforeseen event can require from three to five years. To create solutions that are sufficient to meet minimum reliability requirements for both the foreseeable and the unforeseen circumstances, the following assumptions have been included as planning considerations:

- Connecticut generation—the unavailability of the following generation, alone or in combination, plus no new major generation additions:
  - Millstone #3 (1,260 MW)
  - Other major area generation (Equivalent demand forced-outage rates are calculated at over 500 MW.[9])
- Rhode Island generation—the unavailability of any of the following units or stations, alone or in combination, plus no new major generation additions:
  - Rhode Island State Energy combined-cycle unit (448 MW)
  - Manchester Street station (357 MW)
  - Brayton Point 115 kV generation (479 MW)
  - Milford Power and Tiverton generation (433 MW)
- Springfield generation—the unavailability of any of the following plants, alone or in combination:
  - Berkshire Power (280 MW)
  - Mount Tom (147 MW)
  - West Springfield station (194 MW)

All these assumptions enable the design of a system that would be responsive to potential events or conditions that limit the resources available to a supply area. The development and selection of options that contemplate such conditions allow for a more robust and flexible system and, ultimately, system upgrades with greater longevity.

Developing these options has been an iterative process. Options that seemed capable of mitigating reliability concerns were formulated and analyzed for compliance with the design criteria and objectives. Additional modifications were formulated as necessary and the options reevaluated. This step was repeated until either a workable option was identified or it became clear that the option was not viable because it would require too many system modifications.

3.2 Assessing the Options

All the system upgrades associated with the four plan components were designed to resolve the reliability concerns for the southern New England transmission system over the projected planning horizon, as identified in the Needs Analysis. The options for the four plan components were evaluated for their potential to improve the reliability and performance of the transmission system, including the following factors:

- Improving the capability to transfer power into and within the load centers in southern New England
- Improving east-to-west and west-to-east transfer capability across New England and within Connecticut
- Eliminating projected line overloads under contingency conditions

[9] An e*quivalent demand forced-outage rate* is the portion of time a unit is in demand but is unavailable because of a forced outage.

- Improving system voltages under contingency conditions
- Decreasing system losses
- Improving system expandability and flexibility

The options also were compared on the basis of the thermal transfer limits across key New England interfaces that would be affected by these improvements. These included the New England–New York interface, the New England East–West interface, the Connecticut Import interface, and the Connecticut East–West interface. Thermal transfer limits are a function of a number of variables, as follows:

- Load levels
- Load distribution
- Generation availability assumptions
- Generation source and sink combinations[10]
- Transmission facility outage assumptions
- Transmission facility equipment ratings
- Phase-angle regulator settings
- Solution techniques

Varying any of these factors produces a range of values for any interface transfer limit. System conditions could exist that restrict transfers below the limits stated. Conversely, system conditions also could allow for even higher transfers. For comparing the transfer-capability improvements resulting from the various options of each component, all thermal transfer limit variables were held constant in this analysis.

The study evaluated the number of times an element is highly loaded (above 90%) under various contingency and dispatch conditions for each of the options within the Interstate component. Similarly, the study compared contingency voltage levels. These performance measures convey the relative strength of each option. The likelihood of each option reducing system losses, which provides both economic and efficiency improvements, also was evaluated.

Limiting the increase in short-circuit duty for areas of the transmission system that may experience future short-circuit constraints is important for developing future generation. Areas that presently contain existing equipment that is close to the short-circuit limit are less likely to attract new generation because of the potential cost for system upgrades that would be required for the generation to interconnect. Therefore, comparing options on the basis of their impact on the short-circuit duty of an area's existing equipment is useful. This analysis did not consider the number of locations where increases may occur but rather only the highest increase at any single location observed on the system.

[10] 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.

The working group also evaluated each option's potential for enhancing system expandability and flexibility. This is a key consideration given that transmission assets typically have lifetimes that exceed 40 years.

Section 4
Interstate Component Options

System studies have extensively examined the existing key transmission paths that interconnect Connecticut, Massachusetts, and Rhode Island. These studies have determined that reinforcing or otherwise modifying existing facilities alone will not bring the system into compliance with applicable reliability criteria and planning standards for the future. The most practical options to meet reliability criteria and simultaneously improve interstate transfer capability and load-serving ability were determined to be adding new 345 kV lines coupled with other reinforcements, as described elsewhere in this report.

Accordingly, all five options for the Interstate component include the addition of new 345 kV lines, together with additional modifications and reinforcements. In general, each of the proposed Interstate options, coupled with the solutions of the three other components, will improve the ability of the SNE bulk transmission system to move power between eastern New England and western New England and enhance transmission security in Connecticut. They also will mitigate area transmission supply concerns for the Springfield and the Rhode Island supply areas and relieve transmission constraints for the transfer of power between eastern Connecticut and western Connecticut.

Each option has been designed such that its general performance meets the design criteria established for the reliability of the SNE system. However, some salient characteristics related to such areas of concern as transfer capabilities, line loadings, voltage levels, and expandability are unique to each solution.

This section summarizes the five options of the Interstate component and each option's potential to improve system performance and reliability. The factors used in evaluating each option are discussed and their individual characteristics compared in terms of their impact on other system characteristics. Detailed listings of the upgrades associated with each option are included in Appendix A.

4.1 Process to Develop and Eliminate Interstate Options

During an initial study session, 17 Interstate options were developed for discussion. The options identified as impractical, infeasible, or likely poor performers were eliminated over time, and new options were added to the mix. One of three original HVDC options was modified and reconsidered. Fourteen options were retained for further testing, which eventually were reduced to the five remaining options. The review process is depicted in Table 4-1, which also summarizes the 14 options and the reasoning used to either eliminate or retain them.

Table 4-1
The Process to Develop and Eliminate the Interstate Options

Original 345 kV Interstate Options	Disposition	Final Top 5 Options
1 Card–Lake Road 2 Card–Lake Road–Sherman Road	This option was eliminated because it proved to be only a partial solution without adequate increases in interstate transfer capability.	
3 Card–Lake Road–Sherman Road–Millbury	This option was eliminated because of performance issues compared with option 4.	
4 Card–Lake Road–West Farnum–Millbury		4. Card–Lake Road–West Farnum–Millbury (designated Option A)
5 Card–Lake Road–Sherman Road–West Farnum–Millbury	This option was eliminated because of performance issues compared with option 4.	
6 Millbury–Sherman Road–West Farnum–Kent County–Montville		6. Millbury–Sherman Road–West Farnum–Kent County–Montville (designated Option B)
7 Card–Lake Road–Carpenter Hill	This option was eliminated because it proved to be only a partial solution without adequate increases in interstate transfer capability.	
8 Montville–Brayton Point	This option was eliminated because of performance issues. (Constructability issues also were raised.)	
9 Manchester–Carpenter Hill	This option was eliminated because it proved to be only a partial solution without adequate increases in interstate transfer capability.	
10 Manchester–Carpenter Hill–Millbury		10. Manchester–Carpenter Hill–Millbury (designated Option C)
12 North Bloomfield–Agawam–Ludlow–Carpenter Hill–Millbury 12a North Bloomfield–Agawam–Ludlow–Carpenter Hill–Millbury, plus separation of existing 395 line (Ludlow–Manchester–North Bloomfield)	Options 12 and 12a were combined into one option: option 12.	12 Ludlow–Carpenter Hill–Millbury, plus separation of existing 395 line (designated Option D)
13 Montville–Kent County–Manchester–Brayton Point	This option was eliminated because of performance issues. (Constructability issues also were raised.)	
14 Ludlow–Agawam–North Bloomfield	This option became part of the Springfield Component analysis.	
	DC–Millbury–Southington (added)	DC–Millbury–Southington (designated Option E)

The five final Interstate options are as follows:

- **Interstate Option A**—a new 345 kV line from the Millbury, MA, substation to the West Farnum, RI, substation and then to the Lake Road, CT, substation, terminating at the Card, CT, substation
- **Interstate Option B**—a new 345 kV line from the West Farnum substation to the Kent County, RI, substation and then to the Montville, CT, substation. (The line from the West Farnum substation to the Kent County substation is part of the Rhode Island component.)
- **Interstate Option C**—a new 345 kV line from the Millbury substation to the Carpenter Hill, MA, substation, terminating at the Manchester, CT, substation
- **Interstate Option D**—a new 345 kV line from the Millbury substation to the Carpenter Hill substation to the Ludlow, MA, substation to the Agawam, MA, substation to the North Bloomfield, CT, substation. (The line from the Ludlow substation to the Agawam substation to the North Bloomfield substation is part of the Springfield component.)
- **Interstate Option E**—a new 1,200 MW high-voltage direct-current (HVDC) tie between the Millbury substation and the Southington, CT, substation

4.2 Description and Performance of the 345 kV Interstate Options

This section describes each of the interstate options in further detail. One-line diagrams of the 345 kV transmission upgrades for each option are included. These figures do not show associated 115 kV system improvements; however, Appendix A contains a detailed description of all the upgrades included in each option. For simplicity, these figures also do not show some intermediate 345 kV substations, such as Barbour Hill and Killingly.

Each section also contains a table summarizing how the option performed with respect to the assessment process as described in Section 3.2.

4.2.1 Interstate Option A—Millbury to West Farnum to Lake Road to Card 345 kV Major Upgrades

This option adds a new 345 kV line that connects Millbury to West Farnum and then continues on to connect West Farnum to Card, with an intermediate connection at Lake Road. The reconductoring of the portion of the Sherman Road to Lake Road 345 kV line that physically is in Rhode Island also is part of this option.

Figure 4-1 depicts the major upgrades that comprise Interstate Option A. Table 4-2 summarizes the assessment results for this option.

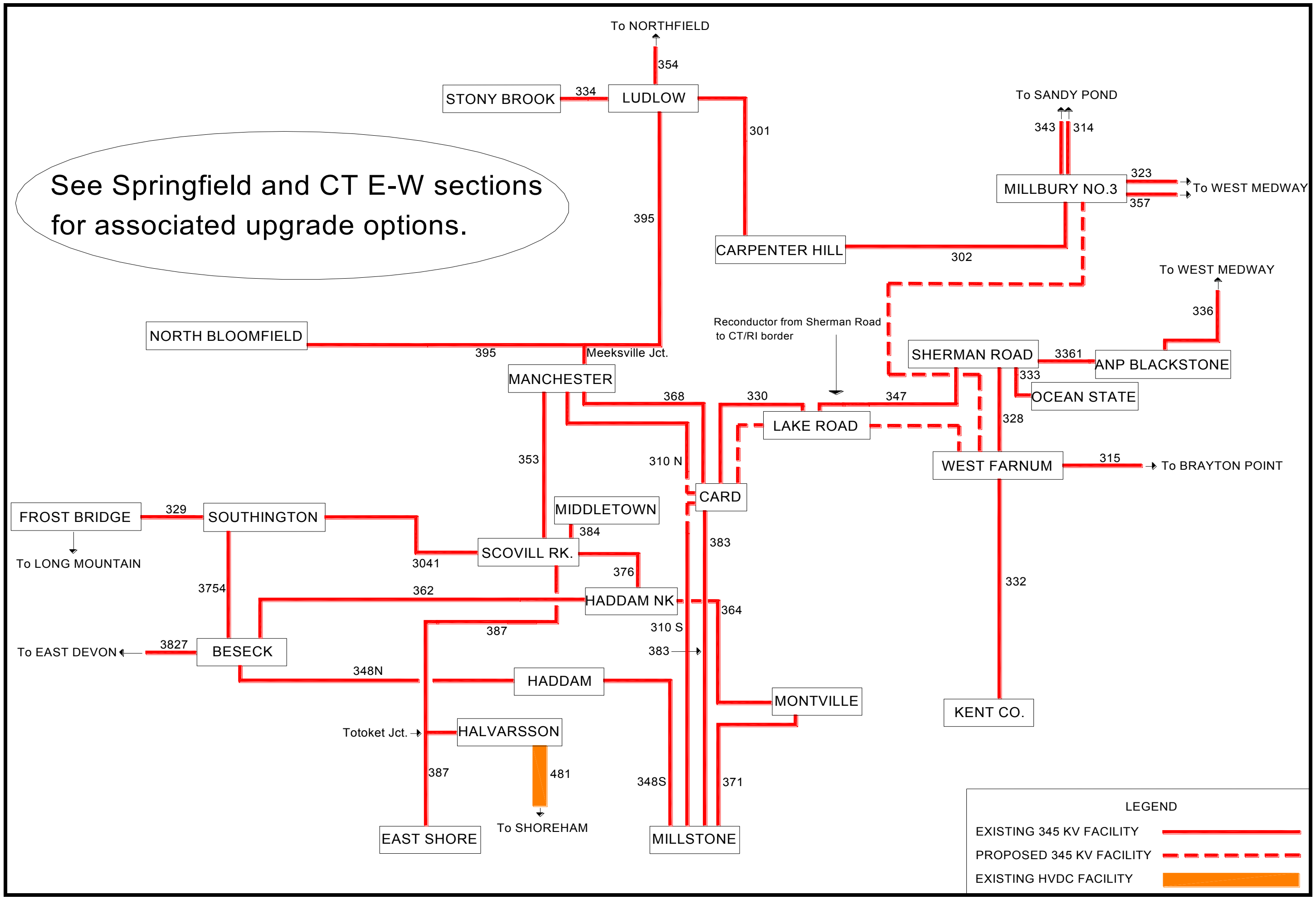

Figure 4-1: Interstate Option A—Millbury to West Farnum to Lake Road to Card 345 kV major upgrades.

Table 4-2
System Performance Factors of Interstate Option A

System Performance Factors	Results	Comments[(a)]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details.
Improving New England east–west transfer capability	Increases capability by 1,376 MW (to 4,174 MW total)	Ranked third
Improving Connecticut's import capability	N-1 import capability increases by 1,766 MW (to 4,443 total); N-1-1 import capability increases by 1,591 MW (to 2,783 MW)	N-1 limit tied for third among the options; N-1-1 ranked second
Eliminating high line loadings under contingencies (2016)	46 high line loadings total; 3 high all-lines-in loading; 43 high line-out loadings	Ranked first—lowest number of high loadings
Improving system voltages during contingencies (2016)	6 borderline voltage cases following N-1 contingencies	Ranked first—-lowest number of borderline voltage issues
Decreasing system losses	56 MW reduction in system losses compared with pre-project system	Ranked fourth
Decreasing short-circuit duty	8.9% increase on worst location	Ranked fourth
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.2 Interstate Option B—West Farnum to Kent County to Montville 345 kV Major Upgrades

Interstate Option B extends the existing 345 kV line from the West Farnum station to the Kent County station into Connecticut to Montville station, providing a common supply path for both Rhode Island and Connecticut. This option also includes the reconductoring of the 345 kV line from Millbury through Carpenter Hill to Ludlow and the 345 kV line from ANP Blackstone (MA) to Sherman Road.

Figure 4-2 depicts the major upgrades that comprise Interstate Option B. Table 4-3 summarizes the assessment results for this option.

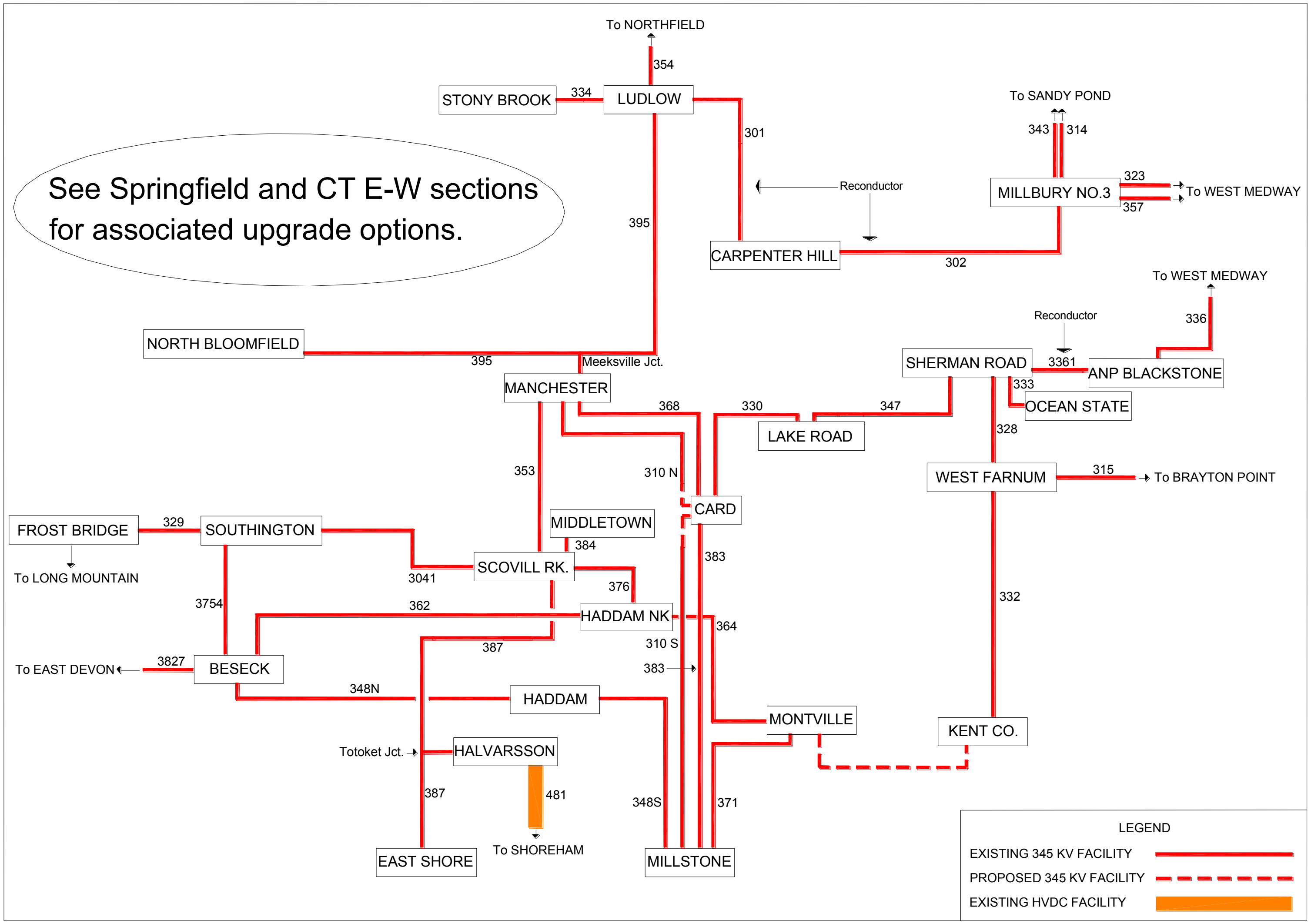

Figure 4-2: Interstate Option B—West Farnum to Kent County to Montville 345 kV major upgrades.

Table 4-3
System Performance Factors of Interstate Option B

System Performance Factors	Results	Comments[(a)]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,198 MW (to 3,996 MW total)	Ranked fifth
Improving Connecticut's import capability	N-1 import capability increases by 1,298 MW (to 3,975 total); N-1-1 import capability increases by 1,347 MW (to 2,539 MW)	N-1 limit ranked fifth among the options; N-1-1 ranked fourth
Eliminating high line loadings under contingencies (2016)	118 high line loadings total; 21 high all-lines-in loading; 97 high line-out loadings	Ranked fifth—highest number of high loadings
Improving system voltages during contingencies (2016)	29 borderline voltage cases following N-1 contingencies	Ranked fifth—highest number of borderline voltage issues
Decreasing system losses	55 MW reduction in system losses compared with pre-project system	Ranked fifth
Decreasing short-circuit duty	5.3% increase on worst location	Ranked second
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.3 Interstate Option C—Millbury to Carpenter Hill to Manchester 345 kV Major Upgrades

Interstate Option C provides a new 345 kV line from Millbury through Carpenter Hill to Manchester. In addition, a new 345 kV line from Sherman Road to West Farnum is required.

Figure 4-3 depicts the major upgrades that comprise Interstate Option C. Table 4-4 summarizes the assessment results for this option.

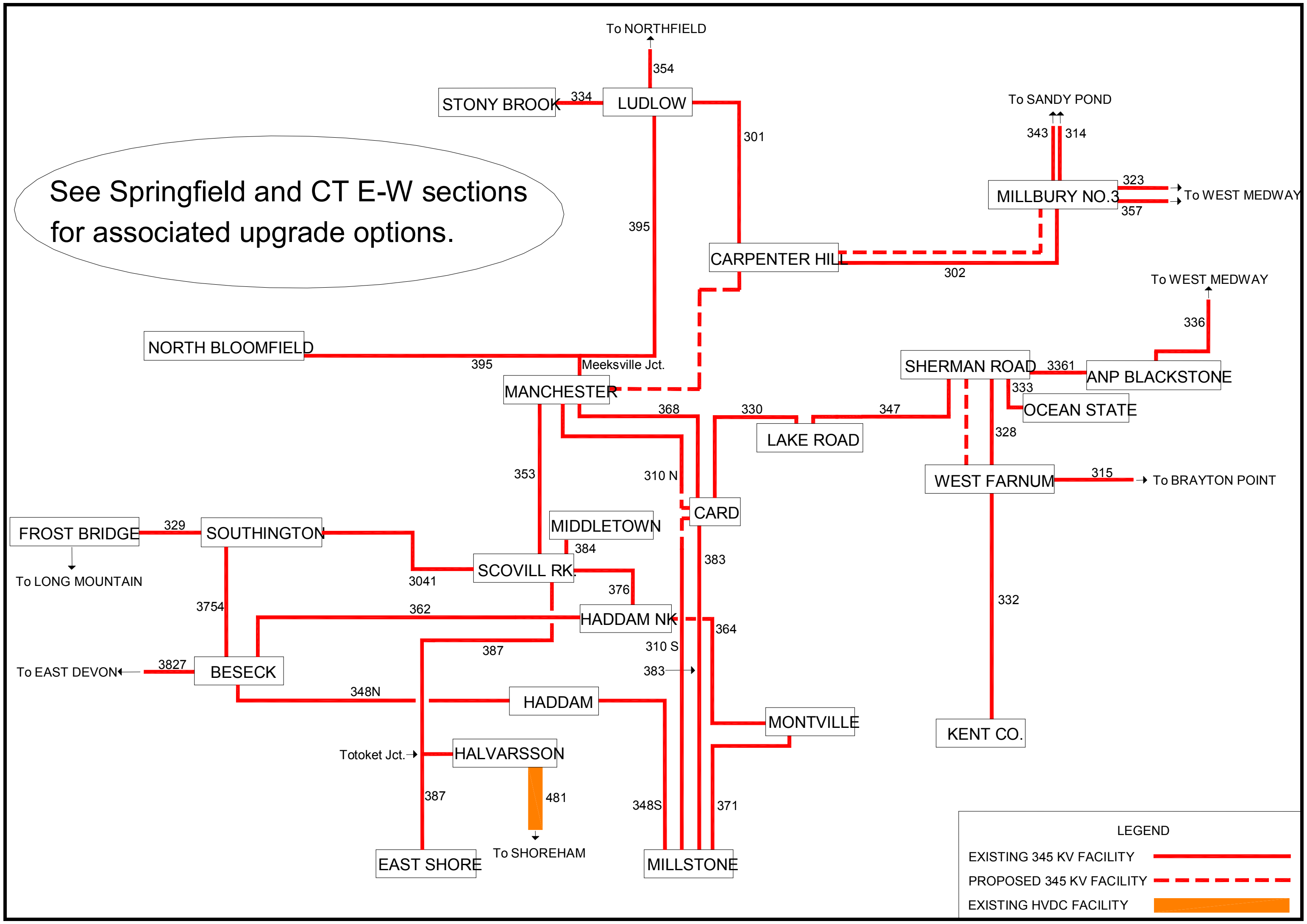

Figure 4-3: Interstate Option C—Millbury to Carpenter Hill to Manchester major 345 kV upgrades.

Table 4-4
System Performance Factors of Interstate Option C

System Performance Factors	Results	Comments[(a)]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,293 MW (to 4,091 MW total)	Ranked fourth
Improving Connecticut's import capability	N-1 import capability increases by 1,766 MW (to 4,443 total); N-1-1 import capability increases by 1,535 MW (to 2,727 MW)	N-1 limit tied for third among the options; N-1-1 ranked third
Eliminating high line loadings under contingencies (2016)	73 high line loadings total; 6 high all-lines-in loading; 67 high line-out loadings	Ranked second
Improving system voltages during contingencies (2016)	8 borderline voltage cases following N-1 contingencies	Ranked second
Decreasing system losses	69 MW reduction in system losses compared with pre-project system	Ranked first
Decreasing short-circuit duty	9.3% increase on worst location	Ranked fifth
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.4 Interstate Option D—Millbury to Carpenter Hill to Ludlow 345 kV Major Upgrades

Interstate Option D builds a new 345 kV line from Millbury to Carpenter Hill to Ludlow and takes advantage of the proposed Springfield area improvements to complete the interstate connection. It also requires uprating of the 345 kV lines from Ludlow to Manchester and from Sherman Road to the state border. A new line from Sherman Road to West Farnum also is required.

Figure 4-4 depicts the major upgrades that comprise Interstate Option D. Table 4-5 summarizes the assessment results for this option.

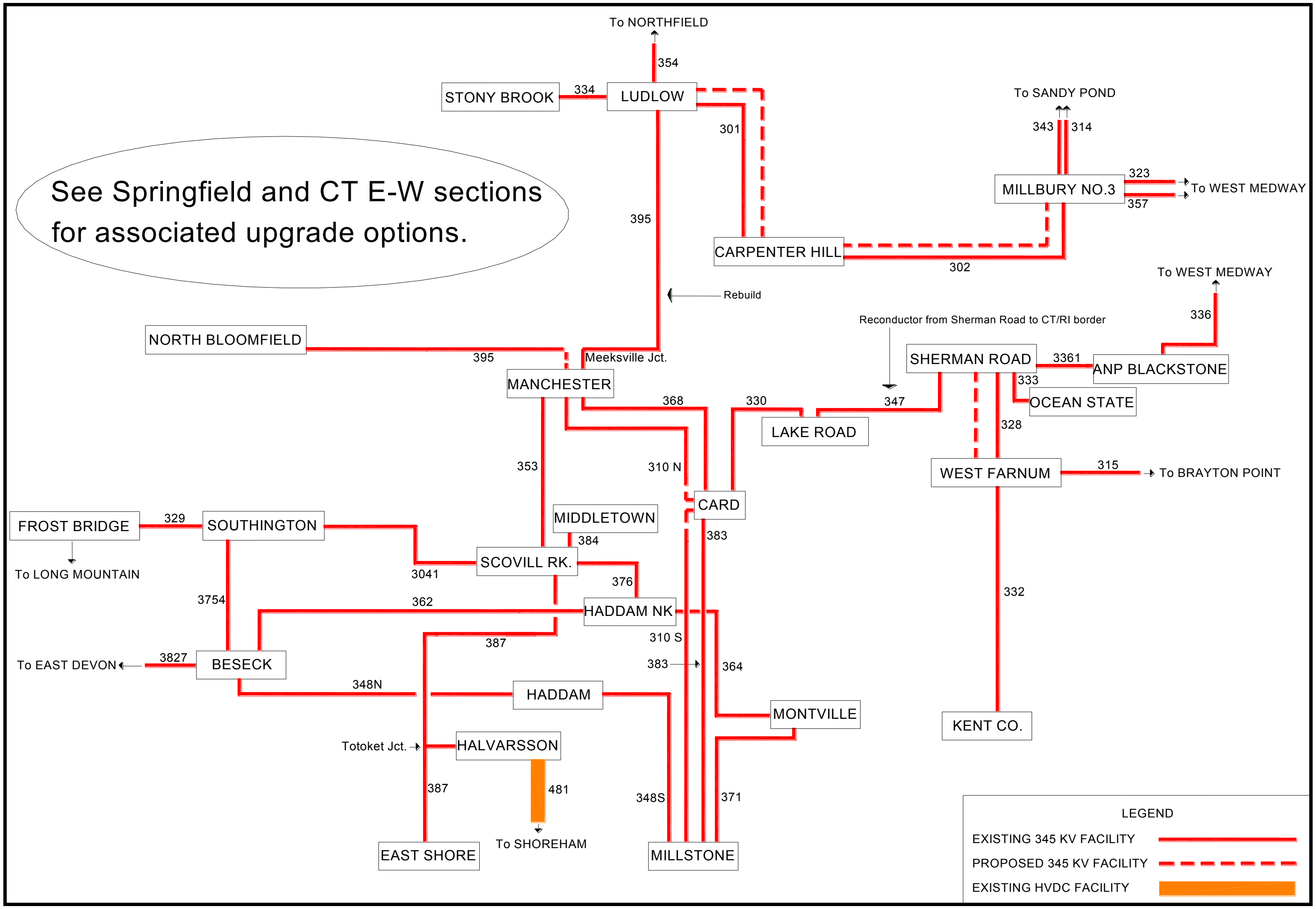

Figure 4-4: Interstate Option D—Millbury to Carpenter Hill to Ludlow major 345 kV upgrades.

Table 4-5
System Performance Factors of Interstate Option D

System Performance Factors	Results	Comments[(a)]
Effect on transfer capability between New York and New England	Positive effect	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,853 MW (to 4,651 MW total)	Ranked first
Improving Connecticut's import capability	N-1 import capability increases by 1,903 MW (to 4,580 total); N-1-1 import capability increases by 1,262 MW (to 2,454 MW)	N-1 limit tied for second among the options; N-1-1 ranked fifth
Eliminating high line loadings under contingencies (2016)	76 high line loadings total; 5 high all-lines-in loading; 71 high line-out loadings	Ranked third
Improving system voltages during contingencies (2016)	9 borderline voltage cases following N-1 contingencies	Ranked third
Decreasing system losses	57 MW reduction in system losses compared with pre-project system	Ranked third
Decreasing short-circuit duty	7.5% increase on worst location	Ranked second
Improving system expandability	Yes	AC lines can readily be tapped for future substations and generator interconnections.

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.2.5 Interstate Option E—Millbury to Southington High Voltage DC Major Upgrades

Interstate Option E involves the installation of HVDC facilities and provides an independent, controllable supply path through the addition of a bipole HVDC line from Millbury to Southington. A new 345 kV line from Sherman Road to West Farnum also is required in connection with Interstate Option E.

Figure 4-5 depicts the major upgrades that comprise Interstate Option E. Table 4-6 summarizes the assessment results for this option.

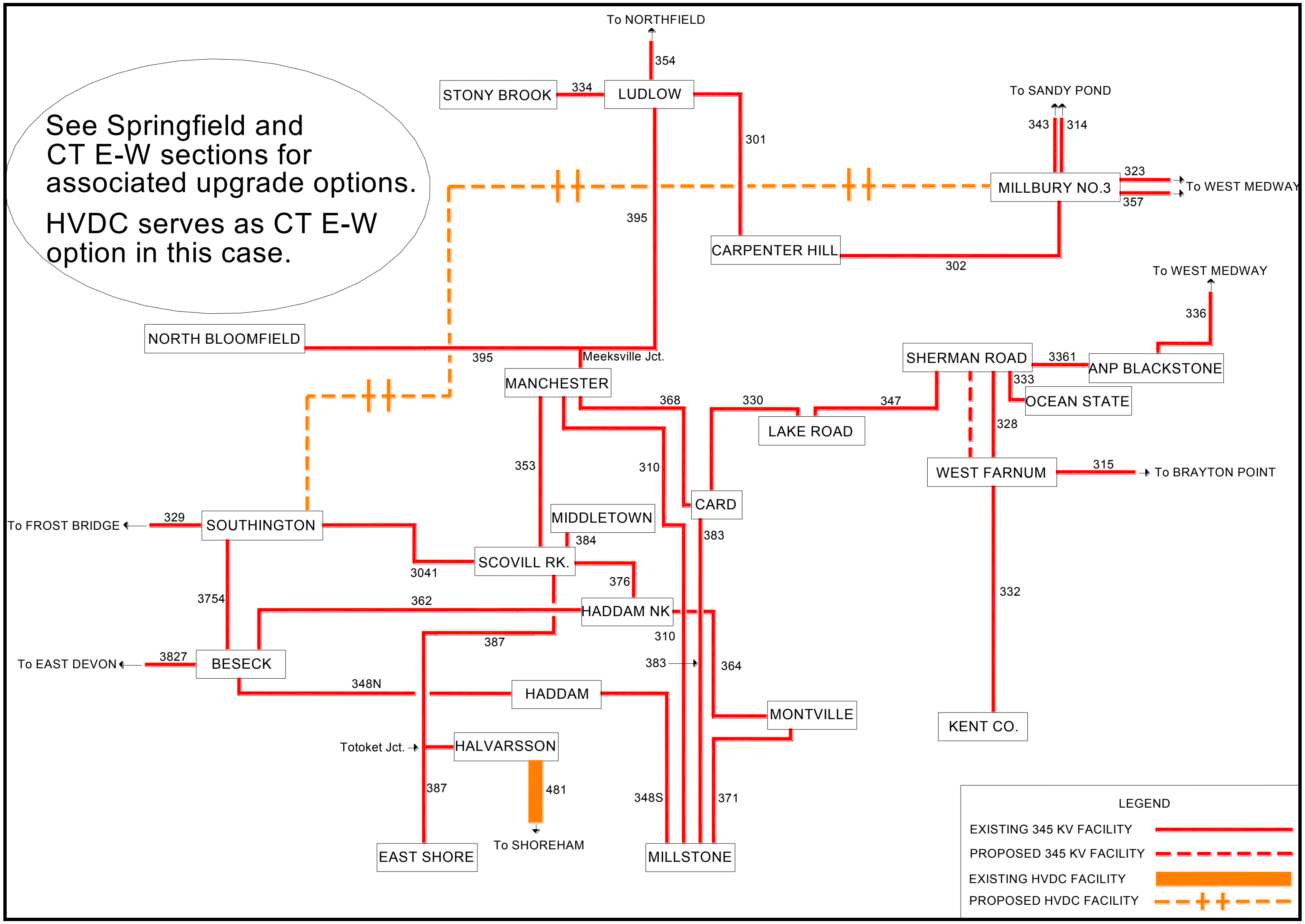

Figure 4-5: Interstate Option E—Millbury to Southington HVDC line.

Table 4-6
System Performance Factors of Interstate Option E

System Performance Factors	Results	Comments[(a)]
Effect on transfer capability between New York and New England	This option was originally more limiting on NY to NE. However, the 2010 western MA improvements eliminate that limiting condition.	See Section 4.3.8 for details
Improving New England east–west transfer capability	Increases capability by 1,580 MW (to 4,378 MW total)	Ranked second
Improving Connecticut's import capability	N-1 import capability increases by 1,974 MW (to 4,651 total); N-1-1 import capability increases by 1,621 MW (to 2,813 MW)	N-1 limit ranked first among the options; N-1-1 ranked first
Eliminating high line loadings under contingencies (2016)	100 high line loadings total; 18 high all-lines-in loading; 82 high line-out loadings	Ranked fourth
Improving system voltages during contingencies (2016)	23 borderline voltage cases following N-1 contingencies	Ranked fourth
Decreasing system losses	68/33 MW (conventional DC/DC light) reduction in system losses compared with pre-project system	Ranked second/fifth
Decreasing short-circuit duty	7.5% increase on worst location	Ranked first
Improving system expandability	No	DC system not easily expandable; an additional converter station would be needed for adding a generator or substation

(a) The performance rankings range from one to five, one being the best and five being the worst.

4.3 Comparison of Interstate Options

Each of the five options of the Interstate component fully addresses all the reliability concerns for the SNE bulk transmission system over the projected planning horizon, although each has its own set of characteristics with respect to system performance improvements. This section compares the improvements that each option could contribute to system performance for the reliability-based characteristics important for the southern New England system and includes comparison tables for several of the electrical performance factors.

Target values shown in these tables are based on either the project design objectives or the minimum requirements needed to satisfy the reliability requirements for the system.

Table 4-7 is a master comparison table that includes all the factors. Each factor is discussed in detail.

Table 4-7
Comparison of Interstate Options

Interstate Options and Needs	Pre-Project System	Option A	Option B	Option C	Option D	Option E
New England east–west transfer capability (MW)	2,798	4,174	3,996	4,091	4,651	4,378
CT import: N-1 (MW)	2,677	4,443	3,975	4,443	4,580	4,651
CT import: N-1-1 (MW)	1,192	2,783	2,539	2,727	2,454	2,813
Number of 'high' 'all-lines-in' loadings in 2016	NA	3	21	6	5	18
Number of 'high' 'line-out' loadings in 2016	NA	43	97	67	71	82
Total high loadings	NA	46	118	73	76	100
Number of borderline voltage cases	NA	6	29	8	9	23
Decrease in New England system losses (MW)	NA	56	55	69	57	68 (conv)/ 33 (light)
Short-circuit impact (percent increase)	NA	8.9	5.3	9.3	7.5	3.8

4.3.1 New England East–West Transfer Capability

The improvement in New England east–west transfer capability ranged from a low of about 1,200 MW for Interstate Option B to a high of about 1,900 MW for Option D. Table 4-8 shows the incremental improvement for each of the options for N-1 conditions.

Table 4-8
New England East–West 2012 N-1 Transfer Capability Improvement

Interstate Option	New England East–West Transfer Capability (MW)	Incremental Increase in New England East–West Transfer Capability (MW)
Base	2,798	
A	4,174	1,376
B	3,996	1,198
C	4,091	1,293
D	4,651	1,853
E	4,378	1,580

4.3.2 Connecticut Import Improvement

The results for improving the import capability into the Connecticut area show that each option more than satisfies the year 2012 planning horizon requirements for area supply, although each option differs in the amount of improvement it could provide to the system.

Table 4-9 and Table 4-10 show the target improvement level, the import level, and the incremental improvement for each of the options for both N-1 and N-1-1 conditions, respectively.

Table 4-9
Connecticut 2012 N-1 Import Comparison

Interstate Option	CT Import: N-1 (MW)	Incremental Improvement in CT Import: N-1 (MW)
Base	2,677	
Target[(a)]	3,574	923
A	4,443	1,766
B	3,975	1,298
C	4,443	1,766
D	4,580	1,903
E	4,651	1,974

(a) The target of 3,574 MW is the result of adding the year 2012 N-1 shortage of 1,074 MW (from Table 9-3 in RSP06) to the existing N-1 limit of 2,500 MW.

Table 4-10
Connecticut 2012 N-1-1 Import Comparison

Interstate Option	CT Import: N-1-1 (MW)	Incremental Improvement in CT Import: N-1-1 (MW)
Base	1,192	
Target[(a)]	2,374	1,308
A	2,783	1,591
B	2,539	1,347
C	2,727	1,535
D	2,454	1,262
E	2,813	1,621

(a) The target of 2,374 MW is the result of adding the year 2012 N-1-1 shortage of 1,154 MW (from table 9-3 in RSP06) to the existing N-1-1 limit of 1,220 MW.

The target is a 923 MW increase for N-1 and a 1,308 MW increase for N-1-1 Connecticut-import capability.

Interstate Option A provides an improvement of almost 1,800 MW over the existing N-1 Connecticut-import capability. The N-1-1 improvement under this option for the Connecticut-import capability is about 1,600 MW, one of the highest.

Interstate Option B provides the least improvement in Connecticut-import capability, increasing N-1 imports by about 1,300 MW, which is almost 700 MW less than the option with the greatest improvement. The N-1-1 import capability improvement for this option also is about 1,300 MW, one of the lowest.

Interstate Option C provides an improvement in N-1 and N-1-1 import capability similar to Option A.

Interstate Option D provides an improvement of N-1 import capability at about 1,900 MW, one of the highest. However, the N-1-1 import capability improvement for Option D of less than 1,300 MW is the lowest of all options.

Interstate Option E (HVDC) provides the greatest level of N-1 import improvement of all options studied at about 2,000 MW. The N-1-1 import capability improvement for this option is about 1,600 MW, also the highest among all options.

4.3.3 Line Loading during Contingencies

All five Interstate options eliminate transmission element overloads that occur for N-1 or N-1-1 contingency conditions. A comparison of the number of line loadings above 90%-of-rating following such events suggests the amount of additional transmission capacity margin each option could provide. Alternatives with fewer high loadings indicate more robust plans.

These results are displayed in Table 4-11. In total, Interstate Options A, C, and D performed somewhat better than the other two options.

Table 4-11
Comparison of Line Loadings in 2016

Interstate Option	Number of High "All-Lines-In" Loadings	Number of High "Line-Out" Loadings	Total Number of Line Loadings
A	3	43	46
B	21	97	118
C	6	67	73
D	5	71	76
E	18	82	100

4.3.4 System Voltages during Contingencies

Similar to the number of contingency high line loadings, the lower the number of borderline contingency voltage cases that occur in an option might also suggest that it is a more robust option. In general, Interstate Options A, C, and D performed somewhat better than the other options. The voltage results appear in Table 4-12 and reflect the number of cases of low or high equipment voltages during contingency events for each of the Interstate options.

Table 4-12
Comparison of Voltages during Disturbances in 2016

Interstate Option	Number of Borderline Voltage Cases
A	6
B	29
C	8
D	9
E	23

4.3.5 System Losses

The Interstate options varied in their ability to reduce system losses from about 55 MW to as high as 69 MW, as shown in Table 4-13.

Table 4-13
Comparison of System Loss Reductions

Interstate Option	Decrease in New England System Losses (MW)
A	56
B	55
C (assuming the Route I-84 path)	69
D	57
E	68 (conventional DC) 33 (DC light)

4.3.6 Stability Screening Analysis

A stability screening analysis was performed to determine if any options exhibited undesirable transient behavior following a fault condition. Generally, all the options improved system performance; however, some findings are worth noting.

If the West Medway South bus were out of service, only Option A would be able to mitigate system instability for a three-phase fault on West Medway bus B (stuck breaker 104). Similarly, only Option A would prevent a Lake Road trip if the 330 line (Lake Road–Card 345 kV) were out of service and the 347 line (Sherman Road–Killingly 345 kV) had a fault. This also would hold true if the fault were on the 330 line and the 347 line were out of service. Also under Option A, Lake Road would not trip if the 347 line were out of service and the 383 line (Millstone-Card 345 kV) at Card had a three-phase fault that resulted in a 3T stuck-breaker condition (the 383 line, the 330 line, and the autotransformer).

Option B is the only option that does not mitigate a Lake Road and Ocean States Power trip for the condition where the 330 line is out of service and Sherman Road has a subsequent stuck breaker (stuck breaker 142, which takes the 3361 line from Sherman Road to ANP Blackstone and the 328 line from Sherman Road to West Farnum out of service). This indicates the need to add a second Card–Lake Road 345 kV line or a second West Farnum–Sherman Road 345 kV line or to eliminate the possible stuck-breaker condition.

4.3.7 Short-Circuit Duty Impacts

Based on a high-level approximation of the percent increase in short-circuit duty at constrained locations, Interstate Option E showed the lowest increase in fault duty compared with the other options, and Option C showed the greatest increase. The differences in these results, which are displayed in Table 4-14, do not appear to be significant and may not be a material factor for selecting a preferred alternative. However, the testing did serve as an effective screening tool for determining whether any options were fatally flawed. Once the preferred selection is made and the associated short-circuit studies are completed, more clearly determining any significant impacts will be possible.

Table 4-14
Comparison of Short-Circuit Impacts

Interstate Option	Short Circuit Impact (percent increase)
A	8.9
B	5.3
C	9.3
D	7.5
E	3.8

4.3.8 System Expandability and Flexibility

In terms of future system expandability and system flexibility, all four AC options offer much more expandability than the DC option. DC systems historically have been used for relatively long, point-to-point type delivery and have not been integrated into the center of AC systems.

The only action required to increase the capacity of an AC line might be a simple reconductoring; increasing the capacity of a DC system would require, at a minimum, either major converter additions or converter change-outs at each end of the line. Adding a new generator midpoint to a DC line would most likely require a new converter station, possibly with two new converters. Similarly, the need to connect to a lower voltage system, either to provide voltage support or eliminate thermal overloads, would be equally difficult.

4.3.9 Impact of Improved Connecticut Transfer Capability on the New York–New England Interface

This section presents the results of a parallel transfer analysis conducted by the working group that evaluated the impact of each SNE transmission reinforcement upgrade option on the ability of the New England bulk transmission system to export to and import from New York. The intent was to determine whether any option particularly enhances or has an adverse impact on this capability.

In the simulation analysis performed by the working group, generation in New York was chosen to aggravate, as much as possible, a potential clockwise loop flow through New England. In this analysis, generation was scaled up at Gilboa (NY) (near the Berkshire–Alps 345 kV tie with New England) and scaled down at Bowline (NY) (south of Long Mountain to the Pleasant Valley 345 kV tie with New England). As most New York generation was on line in the base case, Roseton (NY) generation had to be scaled up to provide coverage for New York exports, despite its beneficial impact on countering any clockwise loop flow.

Generation in eastern New England was chosen to represent a homogeneous source or sink point across all three eastern regions: Maine, Boston, and Southeast Massachusetts. Because most existing generation was on line in the base case, some older retired units had to be scaled up to provide coverage for eastern New England exports.

The main transfer analysis was first performed as described in the preceding paragraph. The following sensitivity analyses were then performed:

- Replacing output from Millennium with Seabrook
- Replacing output from Mystic with West Springfield and Berkshire Power
- Changing the New York source and sink subsystems to represent a "best-case loop-flow scenario." Generation was scaled up at Bowline and scaled down at Bethlehem (Albany area) and Athens.

The results of the analysis show the following:

- Except for Option E, the HVDC option, all options either maintain the transfer capability with New York or improve it.
- Except for the Option E, the HVDC option, all options perform similarly.
- The HVDC option marginally limits imports from New York. However, the transfer-response factor on the limiting element is low (5.9%), and the limiting element (Bear Swamp autotransformer) is a known issue, which will be fixed as part of the central and western Massachusetts upgrades.
- In all instances, exports to New York are limited by the overload of the E131 line from Bear Swamp to the E131 tap. This limiting element also is a known issue, which will also be fixed as part of the central and western Massachusetts upgrades.
- None of the sensitivity runs identified any significant difference in performance among Options A, B, C, or D.

4.3.10 Input from Operations Personnel

The working group presented the details of the Interstate options to Operations personnel from ISO New England, CONVEX, and REMVEC at a joint Planning-Operations meeting. The operators, who were not presented with any information concerning cost, environmental, or routing impacts, preferred Option A for the following reasons:

- It best alleviates the angular difference between Rhode Island and Connecticut, thus removing all the operating complexities related to taking lines out of service in the area.
- Alleviating the angular differences will eliminate the need for the SPS that takes the Lake Road units out of service for certain contingencies to avoid possible shaft damage.
- The new Killingly substation serving eastern Connecticut can receive support from the rest of New England even with the 347 line out of service.

4.4 Interstate Component Conclusion

The comparison of the Interstate options indicates that all options meet the design objectives for satisfying the reliability criteria for the projected New England transmission system. Each option offers different advantages and disadvantages compared with the other options in terms of system performance. These differences will be combined with cost, siting, and construction-related factors to determine the optimal solution for the identified needs.

Section 5
Rhode Island Component Options

As discussed in Section 2, Rhode Island now is overly dependent on limited transmission lines or autotransformers to serve its needs, which could result in thermal overloads and voltage problems during contingency conditions. Causal factors include high load growth (especially in southern Rhode Island and the coastal communities), unit availability, and planned and unplanned transmission outages. The Rhode Island 115 kV system is constrained when a 345 kV line is out of service; an outage of any one of a number of 345 kV transmission lines results in limits to power transfer capability into Rhode Island. For line-out conditions, the next critical contingency involving the loss of a 345/115 kV autotransformer or a second 345 kV line would result in numerous thermal and voltage violations.

To address the identified reliability issues, three new 345 kV facilities were found to be necessary to support the Greater Rhode Island area and to better integrate it with the rest of the New England system. Generally, these improvements would bring a third source into Rhode Island. **This sentence has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.** The improvements also would extend a second source into the load center in southern Rhode Island and add a new source into a 115 kV load center located just east of the Rhode Island border. Several options were evaluated for each of these facilities, which are described in the following sections.

5.1 Rhode Island Recommendations

Figure 5-1 displays the recommended improvements for Rhode Island to increase the ability to move power into West Farnum, creating a stronger tie to the rest of New England; extend another 345 kV path to the southern part of the state; and add a new 345 kV injection point into the load center from the east.

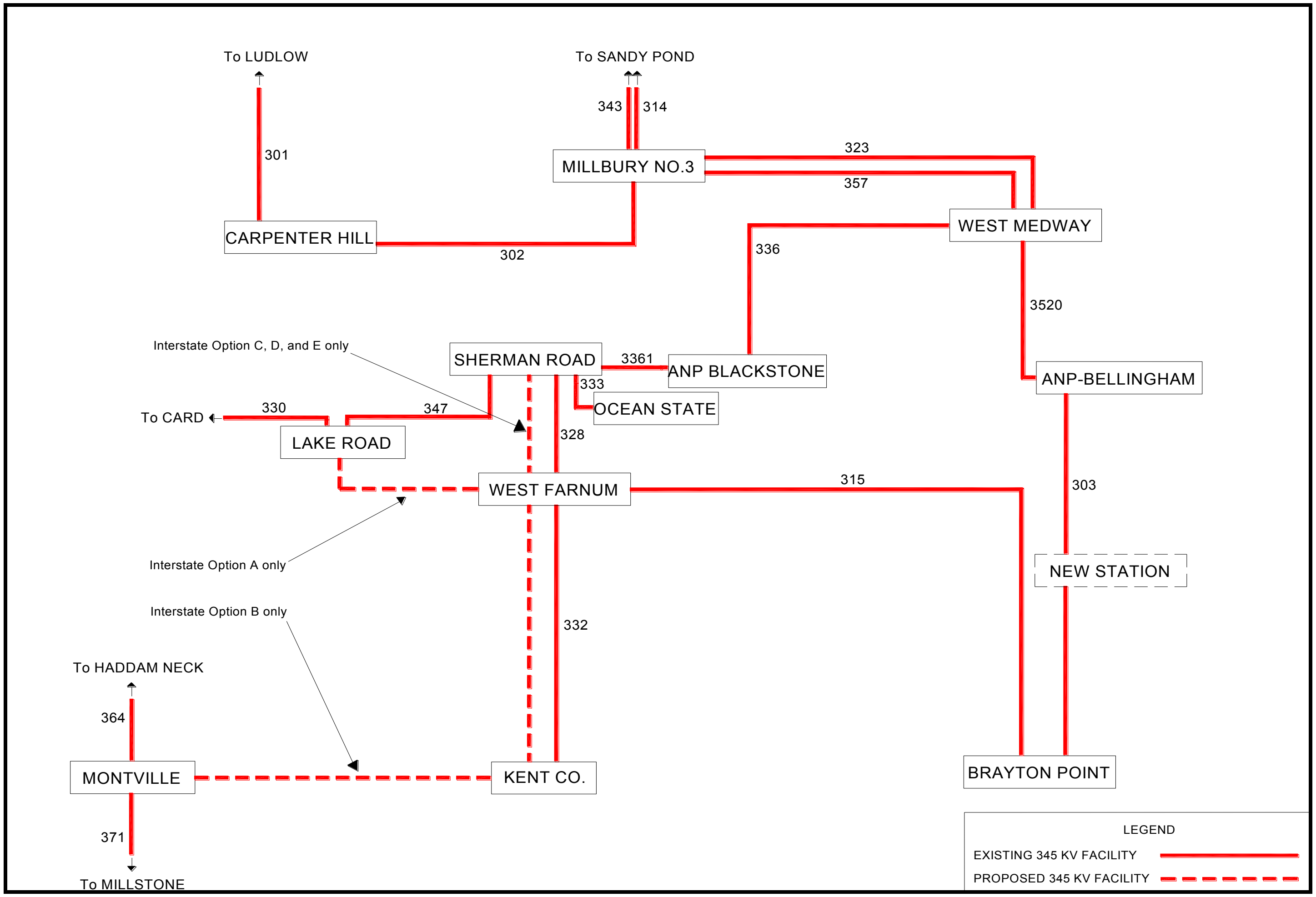

Figure 5-1: Rhode Island upgrades.

5.2 Overview of Rhode Island Options

This section further describes the three areas of Rhode Island needing improvement and the options that were considered for each. The solutions to these three problems are as follows:

- A new 345 kV line from West Farnum to Kent County (recommended with all Interstate options over two other options)
- A new 345 kV line from Sherman Road to West Farnum (recommended with Interstate Options C, D, and E but not needed for Interstate Option A and which brings new lines in from Lake Road, CT, and Millbury, MA) or Interstate Option B (which brings a new line in from Montville, CT)
- A new 345/115 kV substation and transformer (recommended with all Interstate options over one other option)

5.2.1 New 345 kV Line from West Farnum to Kent County (Recommended with All Interstate Options)

A new 345 kV line from West Farnum to Kent County is needed to support the southwestern Rhode Island area if the existing 345 kV line (line 332) is lost, especially if either the FPLE Rise or Manchester Street generation plant is out of service. This recommended line would be critical when line 332 is out of service and an additional key southwestern Rhode Island element is lost (an N-1-1 contingency condition).

Several alternatives to this recommendation were developed, analyzed, and subsequently eliminated. One option was to add a new 345 kV line from Brayton Point to Franklin Square to Kent County. This option was a part of an original Interstate option that the working group is no longer pursuing; the full 345 kV portion of this option was Montville–Kent County–Hartford Ave.–Franklin Square–Brayton Point. This option attempted to resolve some of the transmission bottlenecks by interconnecting the three Greater Rhode Island stations of Brayton Point, Hartford Avenue, and Kent County with a new 345 kV line. Other modifications associated with this option follow:

- Convert the E105 and F106 115 kV cables from Hartford Ave. to Franklin Square to a single 345 kV cable
- Remove the 115 kV W4/K15 and X3 lines and move the Swansea substation to the E-183E line (to make space available for the new 345kV line)
- Feed all of Phillipsdale from E183W (also to make space for the new 345 kV line)

The analysis showed that this option tended to push too much power from Brayton Point to West Farnum and Kent County and thus heavily overloaded transmission system elements in Rhode Island. For certain contingencies under some dispatch scenarios, very low voltages were observed on the Rhode Island 115 kV system that would be difficult to mitigate. Additional 345 kV lines and 345/115 kV transformers (along with significant 115 kV upgrades) would be required for second-contingency conditions. As a result, the working group concluded that these improvements do not provide a viable option compared with the recommended second 345 kV line between West Farnum and Kent County.

Another option developed and analyzed for the Rhode Island component was to add two new 115 kV cables from Franklin Square to Sockanosset. Although these cables strengthen the 115 kV transmission system that connects the Providence area to southwestern Rhode Island, this option does not perform as well under N-1-1 (line-out) system conditions. When the existing 345 kV line from West Farnum to Kent County (line 332) is out of service, various second contingencies cause significant 345/115 kV transformer and 115 kV line overloads, along with very low 115 kV voltages. The working group concluded that these two 115 kV cables do not provide a viable option compared with the second 345 kV line between West Farnum and Kent County.

5.2.2 New 345 kV Line from Sherman Road to West Farnum (Recommended with Interstate Options C, D, E)

A new 345 kV line into Rhode Island is needed to respond to the contingency condition when both line 328 (from West Farnum to Sherman Road) and line 315 (from Brayton Point to West Farnum) are out of service. In the case of Interstate Options C, D, and E, this second-contingency condition would leave all of Rhode Island without a 345 kV connection and could result in very low voltages or voltage collapse for certain dispatch scenarios.

For Interstate Option A (Lake Road to West Farnum and Millbury to West Farnum) and Interstate Option B (Montville to Kent County), this new 345 kV line segment from Sherman Road to West Farnum is not needed because Rhode Island second-contingency support is afforded by the Interstate options themselves.

5.2.3 New 345/115 kV Substation and Transformer (Recommended with All Interstate Options)

The working group also recommends that a new 345/115 kV substation and transformer be located about 1.5 miles south of the existing South Wrentham substation. This new substation will interconnect the 345 kV 303 line and the 115 kV C-181 and D-182 lines and provide transformation from 345 kV to 115 kV. This substation will off-load the existing Brayton Point 3A/3B transformer pair and also eliminate 115 kV contingency low-voltage conditions in the surrounding area of this new substation.

One option developed for this aspect of the Rhode Island component was to add a new 345/115 kV transformer at Brayton Point substation. This transformer would off-load the existing Brayton Point 3A/3B transformer pair, but it would not eliminate the 115 kV contingency low-voltage conditions in the area surrounding South Wrentham substation. The working group also found that the addition of a 345/115 kV transformer at Brayton Point would increase the 115 kV fault current to a value above the 63 kA rating of the existing Brayton Point 115 kV breakers. (The combination of the additional 345/115 kV transformer at Brayton Point and a proposed 115 kV line from Brayton Point substation to Somerset substation—proposed as a part of a separate study of the Somerset Area—would raise the 115 kV fault current above 63 kA.)

Appendix A contains a full list of all the recommended Greater Rhode Island area upgrades.

5.3 Rhode Island Component Conclusion

The recommended items for the Rhode Island component (along with the additional Rhode Island area upgrades listed in Appendix A) will fully address the Rhode Island area reliability issues and coordinate with the three other component upgrades.

Section 6
Connecticut East–West Component Options

This section presents the three final options for the Connecticut East–West component, as follows, and compares the transfer improvements for each option relative to each of the Interstate options:

- **Connecticut East–West Option A—**a 345 kV line from Manchester to Southington
- **Connecticut East–West Option B—**a 345 kV line from Manchester to Scovill Rock with a tap to the New Berlin 345 kV substation
- **Connecticut East–West Option C—**a 345 kV line from North Bloomfield to Frost Bridge

As discussed in Section 2, the ability to move power into Connecticut currently is limited and could eventually result in the bulk transmission system's inability to serve load under many probable system conditions. Connecticut-area power-transfer capabilities will not meet the area's requirements as early as 2009. If improvements are not made by 2016, the deficiency for this area under "generator unavailability conditions" (i.e., when the largest unit plus a historical average amount of other generation is out-of-service) and under N-1 conditions is expected to be greater than 1,500 MW, assuming a transfer limit of 2,500 MW and no new capacity additions. On the basis of planning assumptions that added 500 MW of generation and retired 204 MW within the Connecticut area, a deficiency of approximately 1,100 MW will occur by 2016 for N-1 conditions, and 1,200 MW for N- 1-1 conditions.

The amount of power that can be delivered from eastern Connecticut to western Connecticut is limited by transmission security criteria violations. These violations, which can cause thermal constraints, limit the Connecticut east–west power transfers across the central part of Connecticut. The movement of power from east to west in conjunction with higher import levels to serve Connecticut results in overloads of transmission facilities located within Connecticut.

The most practical solutions to eliminate the second-contingency transmission security violation when trying to move power from eastern to western Connecticut were found to be new 345 kV line additions. Of the four solutions initially selected, only one failed to be a viable option—a possible 345 kV line from Montville to Haddam Neck, which was eliminated because of poor system performance that could not easily be corrected. Accordingly, the three options previously described were retained for further consideration and analysis.

6.1 Description of Connecticut East–West Options

Figure 6-1 to Figure 6-3 are 345 kV one-line diagrams depicting each option of the final three Connecticut East-West components.

Figure 6-1 depicts Connecticut East–West Option A, adding a 345 kV line from Manchester to Southington. This option creates a link from the Manchester substation (which has ties to Massachusetts, to Rhode Island, and to the Millstone Plant) to the Southington substation, which serves as a source into the southwestern Connecticut load pocket.

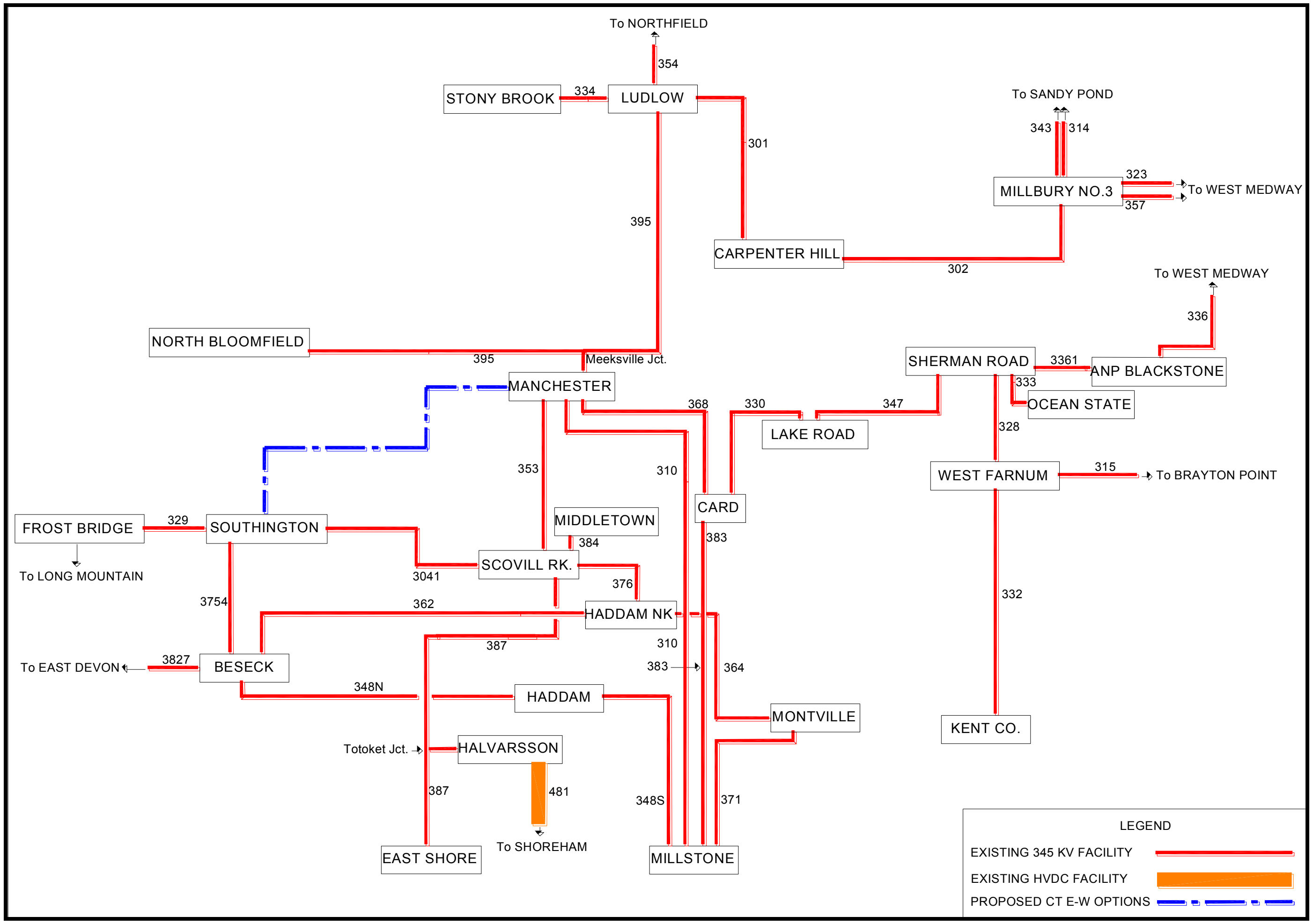

Figure 6-1: Connecticut East–West Option A—345 kV line from Manchester to Southington.

Figure 6-2 depicts Connecticut East–West Option B, adding a 345 kV line from Manchester to Scovill Rock with a tap to a new 345 kV substation in Berlin. This option also taps the Manchester substation but ties it into the Scovill Rock substation as opposed to the Southington substation. Because this line does not extend sufficiently far in a westerly direction, additional stress is placed on the 115 kV system through Hartford, and accordingly, the Berlin 345/115kV autotransformer must provide support to the area's 115 kV system.

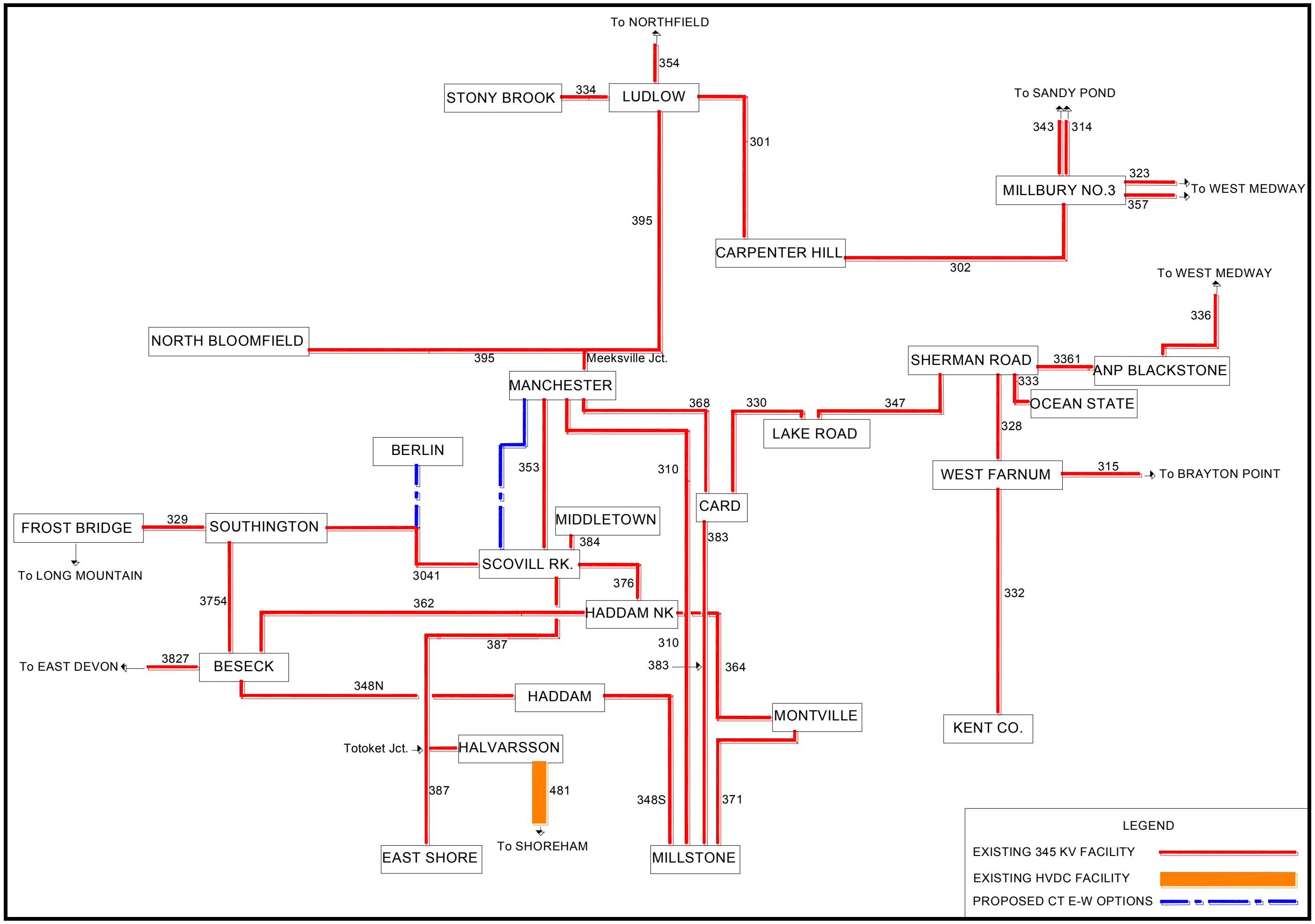

Figure 6-2: Connecticut East–West Option B—345 kV line from Manchester to Scovill Rock with a tap to a new 345 kV substation in Berlin.

Figure 6-3 depicts Connecticut East–West Option C, adding a 345 kV line from North Bloomfield to Frost Bridge. This option makes use of the new Springfield 345 kV supply into North Bloomfield by further extending the 345 kV line from North Bloomfield to the Frost Bridge substation. The Frost Bridge substation, similar to the Southington substation, serves as a source into the southwest Connecticut load pocket.

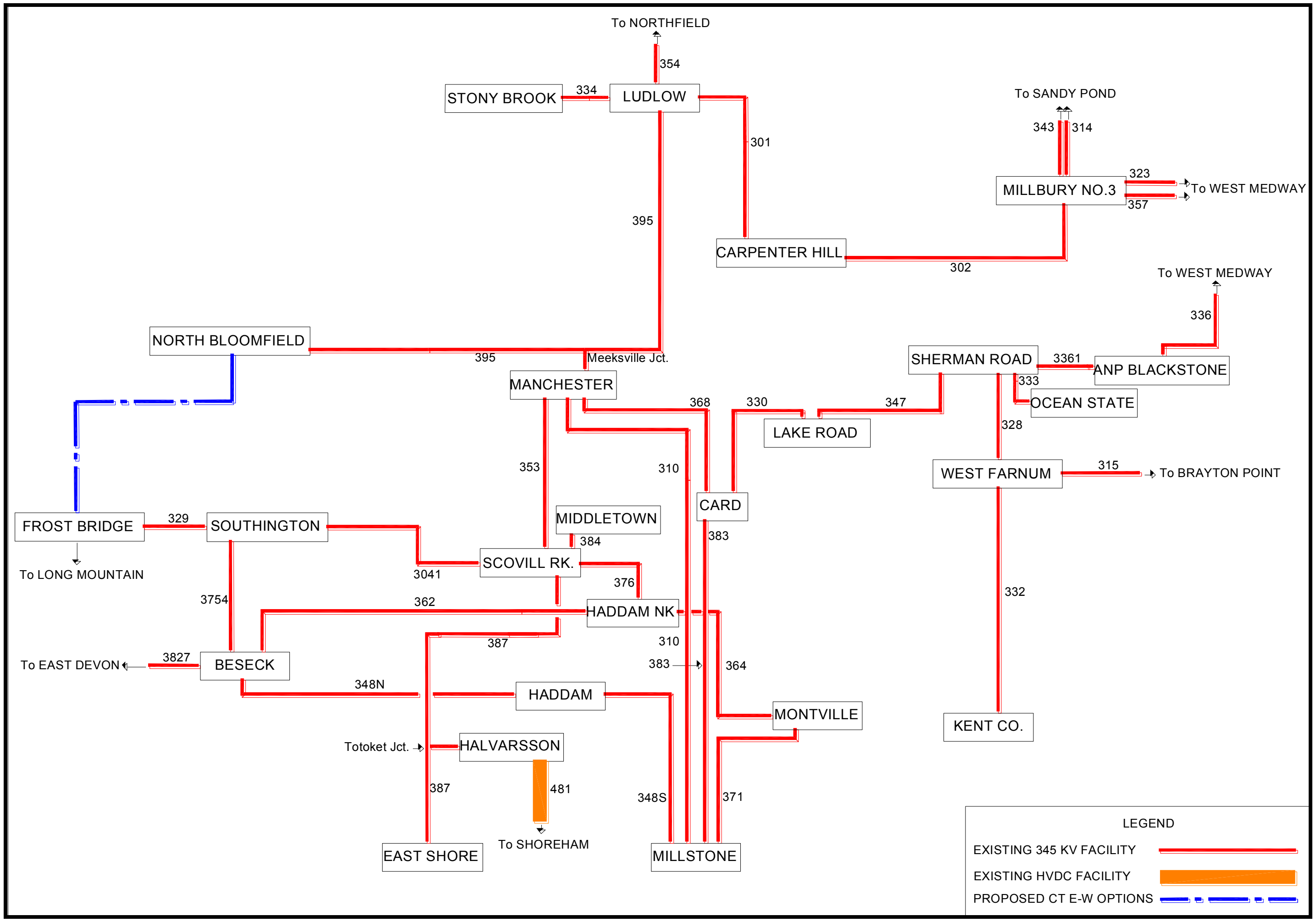

Figure 6-3: Connecticut East–West Option C—345 kV line from North Bloomfield to Frost Bridge.

6.2 Comparison of Connecticut East–West Options

Table 6-1 displays the results of the second-contingency transfer-capability analysis into western Connecticut. Estimating western Connecticut load at 18% to 20% of New England load results in a required transfer capability for 2012 of roughly 2,750 to 3,350 MW under second-contingency system conditions. These figures show that all three options selected with any of the four AC Interstate options will satisfy the 2012 needs. With load growing at about 100 MW per year in western Connecticut, however, Option C can result in a longer lifetime by seven years.

Table 6-1
Connecticut East–West 2012 N-1-1 Transfer Capability (MW)

Interstate Option	CT East–West Option A	CT East–West Option B	CT East–West Option C
A	3,493	3,560	4,117
B	3,744	3,576	3,947
C	3,781	3,461	3,834
D	3,928	3,586	4,291

The working group presented the details of the Connecticut east-west options to Operations personnel from ISO New England and CONVEX at a joint Planning-Operations meeting. The operators, who were not presented with any information concerning cost, environmental, or routing impacts, preferred Option C for the following reasons:

- It provides a solid 345 kV path into the Connecticut 345 kV grid west of the Southington substation. (This is considered beneficial because Southington is an old substation, and upgrades over the years have created some operating issues.) Operators would prefer that new facilities stay clear of the Southington substation
- Option B requires a fifth autotransformer installation at Southington, which is not considered advantageous.
- It allows a greater degree of flexibility in northwestern Connecticut for future development possibilities (e.g., transmission expansion, generator leads, etc.).

6.3 Connecticut East–West Component Conclusion

In summary, three of the four options to eliminate the second-contingency transmission security constraints in central Connecticut met reliability criteria standards for 2012 and beyond. Connecticut East–West Option C achieves higher transfer capabilities regardless of which Interstate option is selected. This option should therefore maintain reliability standards farther into the future. However, Connecticut East–West Options A and B also are viable.

Section 7
Springfield Component Options

As discussed in Section 2, the Springfield, Massachusetts, area has significant transmission reliability concerns, including thermal overloads and voltage problems under numerous contingency scenarios. The severity of these problems increases as the system attempts to move power into Connecticut from the rest of New England. In the Springfield area, local double-circuit tower outages (DCT), stuck-breaker outages, and single-element outages result in severe thermal overloads and low-voltage conditions. **This sentence has been redacted and may be accessed by calling ISO New England Customer Service at (413) 540-4220.**

A wide range of transmission reinforcement options were considered to alleviate thermal and voltage problems in the Springfield area. These options included extensive 115 kV reinforcements, additional 345/115 kV transformers, new 345 kV lines, new bulk power sources, and phase shifters. Some of the reinforcement options investigated did not fully meet the area reliability requirements or were not considered to be effective long-term solutions. Other options were not sufficiently compatible with the overall SNE transmission reinforcement plans.

The working group determined that three 345 kV expansion options would fully meet the reliability requirements of the Springfield area and be consistent with the long-term expansion plans for southern New England. Each of the 345 kV options has a number of 115 kV variations, resulting in 12 distinct options. A complete listing of the upgrades that are part of these 12 options can be found in Appendix A.

7.1 Description of the Springfield 345 kV Options

The Springfield area option expansion plans include three 345 kV transmission reinforcement options that are highly compatible with the overall southern New England bulk transmission reinforcement plans. These options are as follows:

- A new 345 kV line from Ludlow to Agawam and from Agawam to North Bloomfield
- A new 345 kV line from Ludlow to North Bloomfield
- A new 345 kV line from Ludlow to Manchester

Each of the above options reinforces the electrical connection between western Massachusetts and Connecticut, which provides benefits to both the Springfield and Connecticut areas. These 345 kV options along with their associated 115 kV reinforcements all meet the required reliability standards.

7.1.1 Springfield Option A—345 kV Line from Ludlow to Agawam to North Bloomfield

This option consists of building new 345 kV lines from Ludlow to Agawam and Agawam to North Bloomfield with 345/115 kV transformation at Agawam. Springfield Option A provides another bulk transmission supply point for the Springfield area. The Springfield area requires other 115 kV transmission reinforcements to meet reliability requirements. Figure 7-1 is a 345 kV one-line diagram of Springfield Option A.

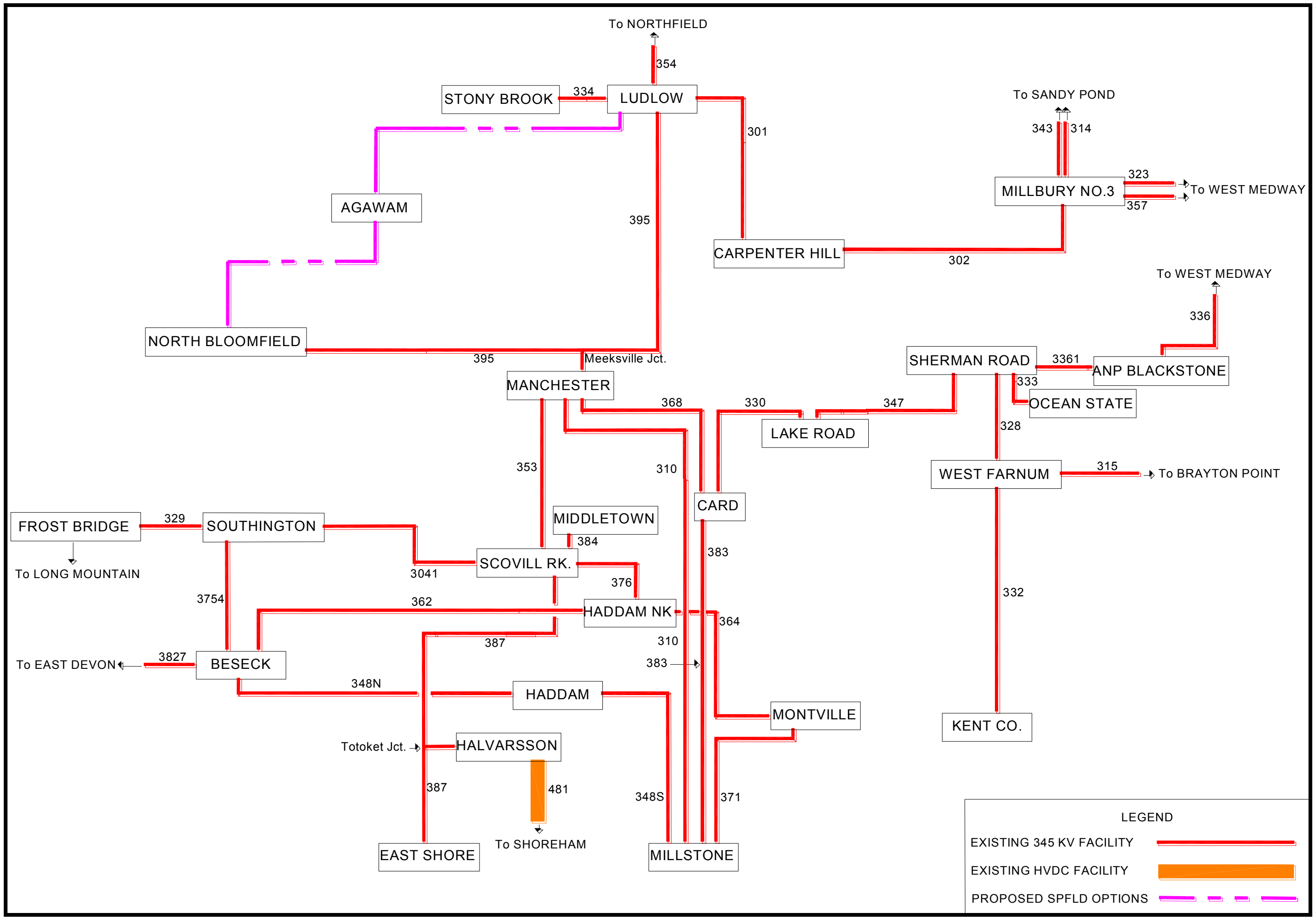

Figure 7-1: Springfield Option A—345 kV line from Ludlow to Agawam to North Bloomfield.

7.1.2 Springfield Option B—345 kV line from Ludlow to North Bloomfield

Springfield Option B includes building a new 345 kV line from Ludlow to North Bloomfield. It is primarily a backup to the existing 345 kV line 395, decreasing the amount of power being wheeled through the Springfield 115 kV system.[11] Springfield Option B requires phase shifters at North Bloomfield on the 115 kV ties between western Massachusetts and Connecticut to further restrain the power flow through the Springfield area. The Springfield area requires other 115 kV transmission reinforcements to meet reliability requirements. Figure 7-2 depicts the 345 kV portion of Springfield Option B.

[11] *Wheel through* refers to the transmission of power through an area to supply load in another area.

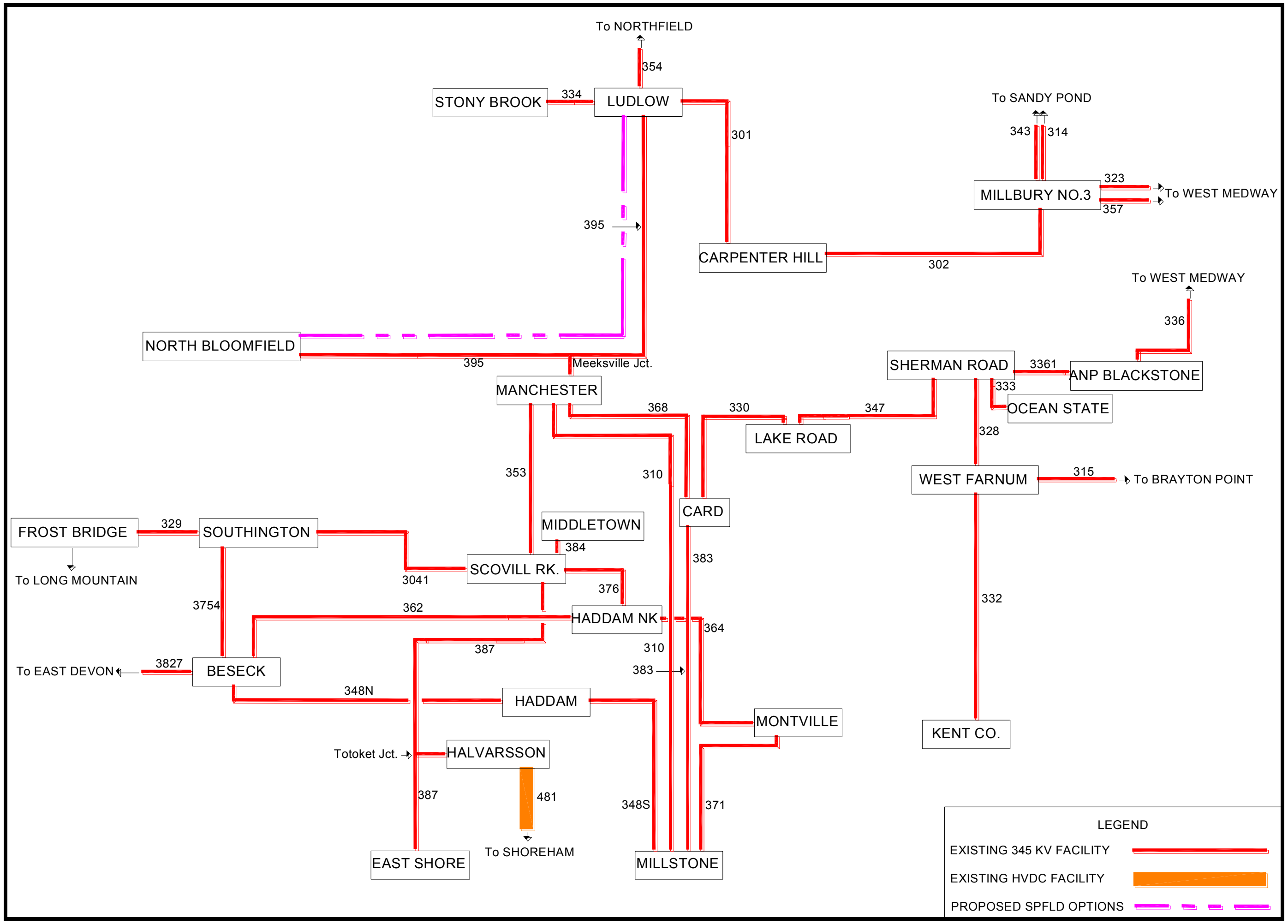

Figure 7-2: Springfield Option B—Ludlow to North Bloomfield 345 kV line.

7.1.3 Springfield Option C—Ludlow to Manchester 345 kV Line

Springfield Option C consists of building a new 345 kV line from Ludlow to Manchester. It also primarily is a backup to the existing 345 kV line 395, decreasing the amount of power being wheeled through the Springfield area. Springfield Option C requires the installation of phase shifters at North Bloomfield on the 115 kV ties between western Massachusetts and Connecticut to further restrain the power flow through the Springfield area. The Springfield area requires other 115 kV transmission reinforcements to meet reliability requirements. Figure 7-3 depicts Springfield Option C.

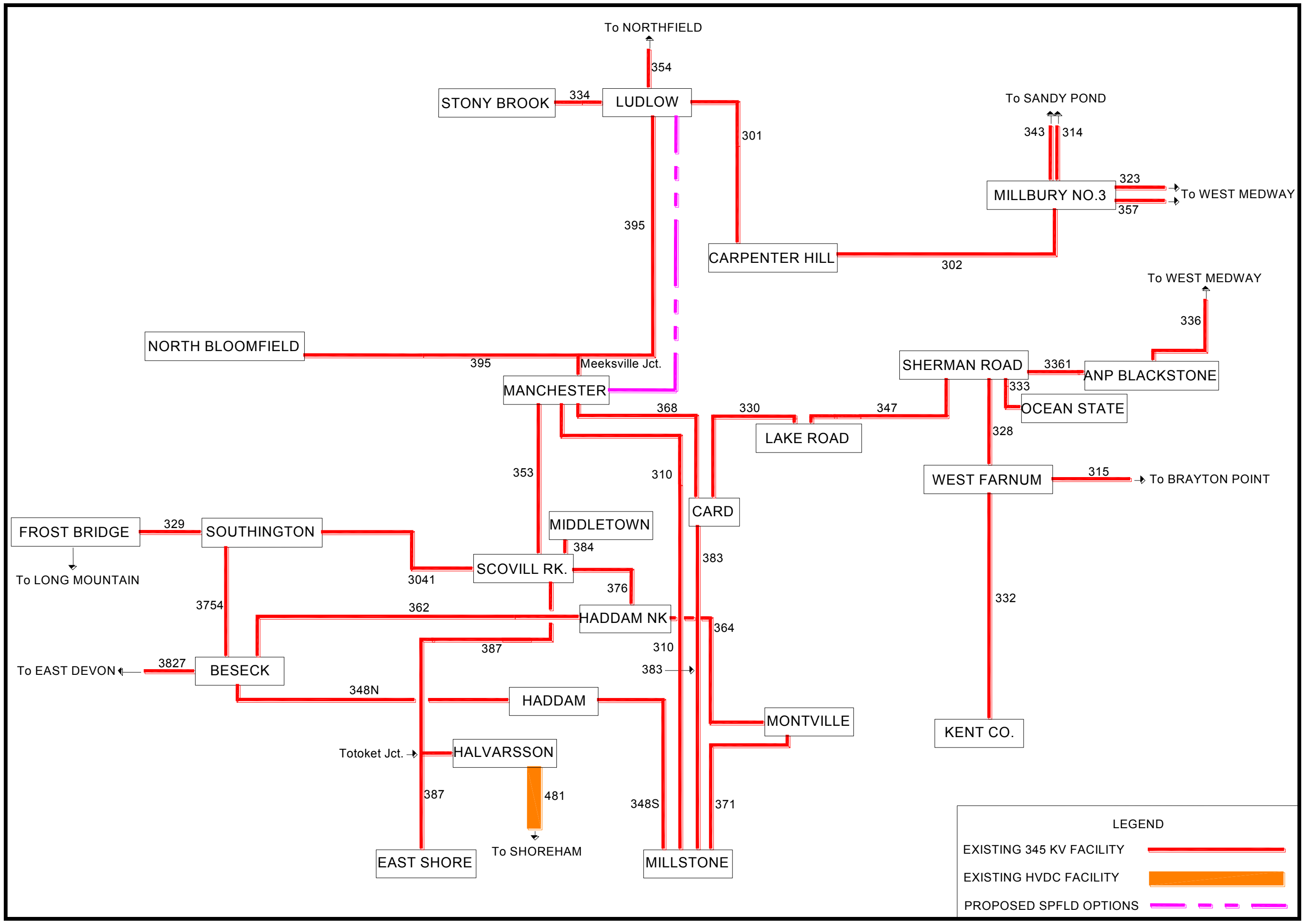

Figure 7-3: Springfield Option C—Ludlow to Manchester 345 kV line.

7.2 Comparison of Springfield Options

The three Springfield area 345 kV options (A, B, and C) and their various associated 115 kV reinforcement options were formulated into a total of 12 transmission reinforcement options. The following subsections discuss the features, benefits, and disadvantages of these options. Appendix A provides a complete list of reinforcements for each option.

The capital letter in each option name (A, B, or C) refers to the 345 kV solution that serves as the backbone of the option. The number and small letter following the capital letter signify the varying 115 kV improvements associated with each of the 345 kV options. Sequential numbers that appear to be missing were assigned to alternatives that were previously eliminated.

7.2.1 Springfield Option A Variations

Eight variations of Springfield Option A remained after the elimination process.

7.2.1.1 Springfield Option A Variation 3a

The major system improvements of this option, in addition to the new 345 kV lines from Ludlow to Agawam and Agawam to North Bloomfield, include three 345/115 kV autotransformers at Agawam, three 115 kV phase shifters in series with the Agawam autotransformers, and the replacement of both 115 kV cables from Breckwood to West Springfield and from Breckwood to East Springfield. This option also would separate the 115 kV ties between western Massachusetts and Connecticut in the South Agawam–North Bloomfield area.

The benefits of this option are as follows:

- Less 115 kV work would be required.
- Phase shifters would facilitate more power flow through the Agawam autotransformers, which would further limit power flow through the Springfield area system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield-area 115 kV system.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The North Bloomfield 2A substation would be more reliable.

One disadvantage of this option is the possibility that additional studies may need to be conducted periodically to optimize the phase-shifter settings.

7.2.1.2 Springfield Option A Variation 3b

This option is similar to the 3a variation except that it ties the Stonybrook 115 kV station into the Springfield 115 kV system. It also allows the output of the Stonybrook plant to be injected directly into the Springfield load pocket as opposed to passing it through the Ludlow 345 kV substation and down the autotransformers.

Variation 3b of Springfield Option A has the following additional benefits:

- The Stony Brook fast-start units would improve the area's non-spinning reserves.[12]
- The severity of extreme contingencies would be reduced or minimized because the Stony Brook–Fairmont lines are on a right-of-way separated from the other Springfield lines.

7.2.1.3 Springfield Option A Variation 6a

In addition to the new 345 kV lines from Ludlow to Agawam and Agawam to North Bloomfield, which is inherent to the Option A variations, this variation includes the following measures:

- Replacing the Breckwood–East Springfield 115 kV cable
- Adding a new 115 kV cable from East Springfield to Clinton
- Eliminating the three-terminal lines at East Springfield Junction (lines 1254 and 1723)
- Installing a breaker-and-one-half substation configuration at Fairmont
- Separating and rebuilding double-circuit lines from Ludlow to East Springfield
- Separating and rebuilding the double-circuit lines from East Springfield to Fairmont
- Separating the western Massachusetts/Connecticut 115 kV ties

No phase shifters would be installed with this variation, and one of the Agawam autotransformers would be replaced with a third autotransformer at Ludlow.

The benefits of this option are as follows:

- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield-area 115 kV system.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The North Bloomfield 2A substation would be more reliable.

One disadvantage of this option would be that the flexibility to restrain power flow through the Springfield area, which variable phase shifters provide, would not be available.

7.2.1.4 Springfield Option A Variation 6b

This option is similar to the 6a variation except that it ties the Stonybrook 115 kV station into the Springfield 115 kV system, as in the 3b variation (Section 7.2.1.2), instead of separating and rebuilding the double-circuit 115 kV lines from Ludlow to East Springfield to Fairmont.

This option has the following benefits:

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[12] *Non-spinning* (non-synchronized) operating reserves are off-line, fast-start resources that can be electrically synchronized to the system and quickly reach rated capability. *Spinning* (synchronized) operating reserve is generation that already is on line, is synchronized to the system, and can increase output.

- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield-area 115 kV system.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The Stony Brook fast-start units would improve the area's non-spinning reserves.
- The severity of extreme contingencies would be reduced or minimized because the lines from Stony Brook to Fairmont would be on a right-of-way separated from the other Springfield lines.
- The North Bloomfield 2A substation would be more reliable.

Similar to Option 6a, one disadvantage of Option 6b would be that the flexibility to restrain power flow through the Springfield area, which variable phase shifters provide, would not be available.

7.2.1.5 Springfield Option A Variation 6c

This option is similar to the 6b variation except that it installs a third 115 kV cable from West Springfield to Clinton and a new 115 kV line from Ludlow to Fairmont as opposed to tieing the Stonybrook 115 kV station into the Springfield 115 kV system.

The benefits of the 6c variation of Springfield Option A are as follows:

- The new 345 kV source at Agawam would provide an alternate path for power to flow into the Springfield area 115 kV system.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The weak 115 kV western Massachusetts/Connecticut ties would be replaced with a stronger 345 kV tie.
- The North Bloomfield 2A substation would be more reliable.

Similar to 6a and 6b, one disadvantage of this option would be that the flexibility to restrain power flow through the Springfield area, which variable phase shifters provide, would not be available.

7.2.1.6 Springfield Option A Variations 8a, 8b, and 8c

These options are very similar to the 6a, 6b, and 6c variations except that the third Ludlow 345/115 kV autotransformer and the Fairmont substation work is replaced with a 115 kV line from Stonybrook to Ludlow. Accordingly, the benefits and the disadvantage are similar also.

7.2.2 Springfield Option B Variations

Three variations of Springfield Option B remained after the elimination process.

7.2.2.1 Springfield Option B Variation 7a

In addition to adding the new 345 kV line from Ludlow to North Bloomfield, the major system improvements of this option include adding phase shifters at North Bloomfield on the western Massachusetts/Connecticut 115 kV tie lines, replacing the cable from Breckwood to East Springfield, adding a new cable from East Springfield to Clinton, eliminating the three-terminal lines at East Springfield Junction (lines 1254 and 1723), installing a breaker-and-one-half substation configuration at Fairmont, and separating and rebuilding the double-circuit lines that run from Ludlow to East Springfield and from East Springfield to Fairmont.

The benefits of the 7a variation of Springfield Option B are as follows:

- Phase shifters would help restrain the power flow through the Springfield-area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The North Bloomfield 2A substation would be more reliable.

The disadvantages of this option are that another 345 kV connection into the Springfield load center would not be provided. Additionally, to avoid future problems and system upgrades, operating studies may need to be conducted periodically for properly adjusting the phase-shifter setting of the variable phase shifter.

7.2.2.2 Springfield Option B Variation 7b

This option is similar to the 7a variation except that it ties the Stonybrook 115 kV station into the Springfield 115 kV system, as in the 3b and 6b variations of Option A, instead of separating and rebuilding the double-circuit 115 kV lines that run from Ludlow to East Springfield to Fairmont. This option also adds a third 115 kV cable from West Springfield to Clinton.

The option has the following benefits:

- Phase shifters would help restrain the power flow through the Springfield area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Fairmont substation would be more reliable and better able to provide voltage support in to the surrounding area.
- The North Bloomfield 2A substation would be more reliable.
- The Stony Brook fast-start units would improve the area's non-spinning reserves.
- The severity of extreme contingencies would be reduced or minimized because the lines from Stony Brook to Fairmont would be on a right-of-way separated from the other Springfield lines.

The disadvantages of the 7b variation of Springfield Option B are the same as those for the 7a variation.

7.2.2.3 Springfield Option B Variation 7c

This option is similar to the 7b variation except that it installs a new 115 kV line from Ludlow to Fairmont as opposed to tieing the Stonybrook 115 kV station into the Springfield 115 kV system.

The benefits of this variation of Springfield Option B are as follows:

- Phase shifters would help restrain the power flow through the Springfield-area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Fairmont substation would be more reliable and better able to provide voltage support to the surrounding area.
- The North Bloomfield 2A substation would be more reliable.

The disadvantages of this option are the same as for the 7a and 7b variations of Option B.

7.2.3 Springfield Option C Variation

Only variation 5b of Springfield Option C was deemed to be viable.

In addition to the new 345 kV line from Ludlow to Manchester, the major system improvements of this option include adding 115 kV phase shifters at North Bloomfield in series with each of the three western Massachusetts/Connecticut tie lines, replacing the 115 kV cable from Breckwood to East Springfield, and adding a new 115 kV cable from East Springfield to Clinton and a third 115 kV cable from West Springfield to Clinton. The three-terminal lines at East Springfield Junction (lines 1254 and 1723) would be eliminated, and a breaker-and-one-half substation configuration would be installed at Fairmont. This option ties the Stonybrook 115 kV station into the Springfield 115 kV system.

The benefits of this variation are as follows:

- The phase shifters would help restrain the power flow through the Springfield-area 115 kV system.
- The phase shift could be modified in the future to accommodate system configurations and conditions that are not presently foreseen.
- The Stony Brook fast-start units would improve the area’s non-spinning reserves.
- The severity of extreme contingencies would be reduced or minimized because the lines from Stony Brook to Fairmont would be on a right-of-way separated from the other Springfield lines.

The disadvantages of the 5b variation of Springfield Option C are that the Hartford area would require additional 115 kV reinforcements, including underground cable circuits; the North Bloomfield 2A substation would not be more reliable; and another 345 kV connection into the Springfield load center would not be provided. Additionally, to avoid future problems and system upgrades, operating studies may need to be conducted periodically for properly adjusting the phase-shifter setting of the variable phase shifter.

7.2.4 Input from Operations Personnel

The working group presented the details of the Springfield options to Operations personnel from ISO New England and CONVEX at a joint Planning Operations meeting. The operators, who were not presented with any information concerning cost, environmental, or routing impacts, preferred Option A, variation 6b (installing a Ludlow–Agawam–North Bloomfield 345 kV line and a 115 kV tie to the Stony Brook generating station with no phase shifters at either Agawam or North Bloomfield) for the following reasons:

- It relies less on the smaller-conductor 115 kV lines heading north out of North Bloomfield.
- The operation of phase-shifters would be burdensome (i.e., they would require daily adjustments) and add an unknown degree of operating complexity.
- It offers a 345 kV source to Agawam and provides an injection point more centrally located in the Springfield load pocket.
- It reduces reliance on the Ludlow autotransformers, which are roughly 40 years old and have a known design deficiency.
- Separating the Connecticut and Massachusetts 115 kV feeds at North Bloomfield is desired as a result of all the operating problems experienced with this through the years.
- A tie to Stony Brook allows power from Stony Brook to flow to the Springfield load center directly, even with the Ludlow substation out of service. (Currently, Stony Brook ties radially into Ludlow.)
- A tie to Stony Brook provides a redundant path for power flowing on the 345 kV to enter the Springfield 115 kV system.
- Currently, all power to the 115 kV system in this area comes through the Ludlow substation. The tie to Stony Brook will allow some power to flow directly to the 115 kV system from the generator, reducing reliance on the Ludlow autotransformers, which are roughly 40 years old and have a known design deficiency.
- Stony Brook autotransformers are single-phase banks, which can be replaced more quickly than three-phase banks at Ludlow providing greater reliability.

7.3 Springfield Component Conclusion

A wide range of transmission reinforcement options were considered to remedy problems in the Springfield area. The 12 options developed were selected for their ability to meet area reliability requirements. They all provide reliability and supply benefits to both Springfield and Connecticut and are compatible with the long-term expansion of the southern New England electric transmission system.

All the Springfield area reinforcement options include a new 345 kV connection between western Massachusetts and Connecticut as well as other associated 115 kV reinforcements to bring the Springfield area electric system into compliance with reliability standards. The main differences among these options are whether they provide another area bulk supply point, eliminate the weak western Massachusetts/Connecticut 115 kV ties, or use phase shifters to restrain power being wheeled through the area.

Section 8
Option Relationships and the Selection of the Preferred Options

Selecting a long-term option to upgrade a complex, integrated transmission grid extending over three states is a difficult and complicated process. Various relationships and points of distinction exist due to the behavior of the transmission grid over a wide range of system conditions. For example, system conditions in one area might affect the performance in an adjacent area, and solving this area's criteria violations may actually eliminate its dependence on the adjacent area. The following list explains these relationships and points of distinction among the options of the four components of the NEEWS plan.

- **Interstate Component—**The selection of the preferred Interstate option of the five available options is totally independent of which of the other components' improvements are selected. Because the Interstate option can be selected independent of any of the other components' improvements, it can be selected during the first stage of the NEEWS selection process.

- **Rhode Island Component—**Because some improvements in the Rhode Island component depend on the Interstate option selected, the Rhode Island component improvements will be selected and eliminated as a result of the Interstate option selected. The remaining improvements of the Rhode Island component are independent of any other component's selection process and can be selected during the first stage of the selection process.

- **Connecticut East–West Component—**The improvements in this component are independent of the preferred selections for any of the other components. However, some 115 kV improvements are needed in the Hartford area, which depend on the preferred options for the Springfield and Connecticut East–West components.

- **Springfield Component—**Although a number of the improvements for this component are primarily needed to address existing system conditions, they have been designed to consider the other components. These improvements are independent of the preferred Interstate component and can be selected during the first stage of the selection process. One exception is that if Interstate Option D is selected, additional Springfield upgrade(s) will be required.

Section 9
Next Steps

The next part of the overall process is for the participating transmission owners to analyze the environmental, cost, constructability, and routing aspects of each option within each component. After this information is gathered and formulated, selections can be made on the basis of all pertinent information.

Appendix A
Listing of Reinforcements by Components

Table A-1
Interstate Component Reinforcements

Interstate Reinforcements	Interstate Option Designation				
	A	B	C	D	E
Build 345 kV circuit, Card–Lake Road	X				
Build 345 kV circuit, Lake Road–W. Farnum	X				
Build 345 kV circuit, W. Farnum–Millbury	X				
Build 345 kV circuit, Montville–Kent County		X			
Build 345 kV circuit, Manchester–Carpenter Hill			X		
Build 345 kV circuit, Carpenter Hill–Millbury			X	X	
Build 345 kV circuit, Ludlow–Carpenter Hill				X	
Build 345 kV circuit, Manchester–Meekville Junction; Split 395 to attach new line				X	
Reconductor line 395, Ludlow–Manchester with bundled 1272 ACSR				X	
Build a HVDC bipole, Millbury–Southington					X
Build a Connecticut East–West solution, see alternate table	X	X	X	X	
Separate line 310, Card–Manchester, and line 368, Card–Millstone	X	X	X	X	X
Replace terminal equipment on line 368 at Manchester	X	X	X	X	X
Replace terminal equipment on line 1272 at Bunker Hill	X	X	X	X	X
Place 14.4 MVAR capacitor at Killingly 115 kV substation	X	X	X	X	X
Loop line 310 from Millstone to Manchester into Card	X	X	X	X	
Replace terminal equipment on line 353 at Manchester	X	X	X	X	
Replace terminal equipment at both terminals on line 376, Haddam Neck–Scovill Rock	X	X	X	X	
Reconductor 345 kV line 3361, Sherman Rd. to ANP Blackstone		X			
Upgrade terminal equipment on Sherman Rd.–ANP Blackstone line 3361	X		X	X	
Upgrade terminal equipment on Sherman Rd.–W. Farnum line 328		X			
Reconductor 345 kV line 347, Sherman Rd. to CTX Border	X			X	
Upgrade terminal at W. Farnum and reconductor line T-172N on W. Farnum–W. Farnum tap	X	X	X	X	X
Reconductor Carpenter Hill–Belchertown 301 line		X			

Interstate Reinforcements	Interstate Option Designation				
Reconductor Millbury–Carpenter Hill 302 line		X			
Reconductor W. Charlton–Little Rest W-175		X			X
Reconductor Little Rest–Palmer W-175		X	X		

Table A-2
Rhode Island Component Reinforcements

Rhode Island Reinforcements	Interstate Option Designation				
	A	B	C	D	E
Build 345 kV circuit, Kent County to W. Farnum	X	X	X	X	X
Install one additional 345/115 kV autotransformer at Kent County	X	X	X	X	X
Install one additional 345/115 kV autotransformer at Kent County	X	X	X	X	X
Build 345/115 kV substation that connects line 303 with lines C-181 and D-182 (including a 345/115 transformer and a 115 kV capacitor bank)	X	X	X	X	X
Build 345 kV circuit, Sherman Rd. to W. Farnum (2nd line)			X	X	X
Uprate Drumrock terminals on Drumrock to Amtrak I-187 line	X	X	X	X	X
Uprate Drumrock terminals on Drumrock–Kilvert line J-188	X	X	X	X	X
Uprate Brayton terminal on line E-183E from Brayton to Merxman Jct.	X	X	X	X	X
Uprate Chartley Pond terminal on line C-181S from Brayton to Chartley Pond	X	X	X	X	X
Uprate breakers and switch on Kent County T3 345/115kV autotransformer	X	X	X	X	X
Uprate Hartford Ave. terminal on Johnston–Hartford Ave. S-171S		X			
Uprate Hartford Ave. terminal on Johnston–-Hartford Ave. T-172S		X	X		X
Reconductor Johnston–Hartford Ave. S-171S; uprate Hart Ave. terminal	X		X	X	X
Reconductor Johnston–Hartford Ave. T-172S; uprate Hart Ave. terminal	X			X	
Upgrade Kent County terminal on G-185N line from KentT1 to Kent County	X	X	X	X	X
Upgrade Kent County terminal on K-189 line, KentT7–Kent County	X	X	X	X	X
Upgrade both terminals and reconductor Pawtucket–Somerset T7 line	X	X	X	X	X
Upgrade bus work disconnects and breakers on W. Farnum T174 345/115kV autotransformer	X	X	X	X	X
Upgrade breakers on W. Farnum T175 345/115kV autotransformer	X	X	X	X	X
Upgrade terminal at W. Farnum on the S-171N W. Farnum–W. Farnum tap	X	X	X	X	X
Reconductor Drumrock–Kent County G-185N	X	X	X	X	X
Reconductor MPLP–Depot St. C-129		X		X	
Reconductor Medway–Depot St. D-130		X	X	X	X
Upgrade terminal equipment Brayton Pt.–Warren E-183		X			

Rhode Island Reinforcements	Interstate Option Designation				
	A	B	C	D	E
Upgrade terminal equipment Mink St.–Wampanoag E-183		X			
Upgrade terminal equipment Wampanoag–Phillipsdale E-183		X			
Upgrade terminal equipment Phillipsdale–Franklin Sq. E-183	X	X	X	X	X
Upgrade Franklin Sq. 115 kV breakers Phillipsdale–Fr. Sq. E-183		X			
Upgrade terminal equipment at South Wrentham	X	X	X	X	X
Reconductor Somerset–Swansea W4		X	X	X	X
Install two 63 MVAR 115 kV capacitors at Kent County	X		X	X	X

Table A-3
Connecticut East–West Component Reinforcements

Connecticut East–West Reinforcements	Connecticut East–West Option Designation		
	A	B	C
Build 345 kV circuit, Manchester–Southington	X		
Build 345 kV circuit, Manchester–Scovill Rock		X	
Tap 362 line at Has Brook Junction; build 3-breaker ring bus		X	
Build 345 kV circuit, Hans Brook Junction–Berlin		X	
Add three 200 MVA single-phase transformers at Berlin		X	
Build 345 kV circuit, North Bloomfield–Frost Bridge			X
Add three 200 MVA single-phase transformers at Southington	X	X	
Increase reactor size from 4 to 6.67 ohms on line 1910, Southington–Todd	X		
Increase reactor size from 4 to 6.67 ohms on line 1950 line, Southington–Canal	X		
Reconductor line 1810 from Southington to Chippen Hill with 795 ACSR	X	X	
Replace terminal equipment at Chippen Hill on line 1810	X	X	
Reconductor line 1783 from North Bloomfield to Northeast Simsbury with 954 ACSR		X	
Replace terminal equipment on line 362 at Haddam Neck		X	
Add three 200 MVA single-phase transformers at Frost Bridge			X
Reconductor line 1777 from North Bloomfield to Bloomfield with 795 ACSR	X	X	
Reconductor line 1786 from East Hartford to the tap with 1590 ACSR			X
Reconductor line 353 from Kleen Energy to Scovill Rock with bundled 954 ACSR			X

Table A-4
Springfield Component Reinforcements

	Springfield Option Designation											
Springfield Reinforcements	**3a**	**3b**	**5b**	**6a**	**6b**	**6c**	**7a**	**7b**	**7c**	**8a**	**8b**	**8c**
Associated 345 kV Option:	**A**	**A**	**C**	**A**	**A**	**A**	**B**	**B**	**B**	**A**	**A**	**A**
345 kV												
Build Ludlow–Agawam 345 kV circuit #1	X	X		X	X	X				X	X	X
Build Agawam–N. Bloomfield 345 kV circuit #1	X	X		X	X	X				X	X	X
Build Ludlow–Manchester 345 kV circuit #1			X									
Build Ludlow–North Bloomfield 345 kV circuit							X	X	X			
Transformers												
Install Agawam 345/115 kV transformer #1	X	X		X	X	X				X	X	X
Install Agawam 345/115 kV transformer #2	X	X		X	X	X				X	X	X
Install Agawam 115 kV phase shifters circuit #s 1–2 (in series with transformer)	X	X										
One spare 115 kV phase shifter	X	X	X				X	X	X			
Replace N. Bloomfield 345/115 kV transformer #1 (CT)	X	X		X	X	X	X	X	X	X	X	X
Install N. Bloomfield 345/115 kV transformer #2 (CT)	X	X		X	X	X	X	X	X	X	X	X
Install N. Bloomfield–S. Agawam phase shifters #s 1–2			X				X	X	X			
Add N. Bloomfield–Southwick phase shifter			X				X	X	X			
Reconnect Ludlow 345/115 kV transformer #1 into bay	X	X	X	X	X	X	X	X	X	X	X	X
Reconnect Ludlow 345/115 kV transformer #2 into bay	X	X	X	X	X	X	X	X	X	X	X	X
Install Ludlow 345/ 115 kV transformer #3				X		X	X			X		X
115 kV												
Rebuild/reconductor Ludlow–Shawinigan				X						X		
Separate/rebuild E. Springfield–Orchard-Ludlow and E. Springfield–Ludlow				X			X			X		

Springfield Reinforcements	Springfield Option Designation											
	3a	**3b**	**5b**	**6a**	**6b**	**6c**	**7a**	**7b**	**7c**	**8a**	**8b**	**8c**
Associated 345 kV Option:	**A**	**A**	**C**	**A**	**A**	**A**	**B**	**B**	**B**	**A**	**A**	**A**
Separate or rebuild W. Springfield–Agawam circuit #s 1 & 2	X	X										
Upgrade West Springfield–Agawam circuit #s 1 & 2				X		X				X		
Rebuild S. Agawam–Silver circuit #s 1 & 2 **or** add circuit # 3			X				X	X	X			
Rebuild Silver–Agawam circuit #s1 & 2 **or** add circuit # 3			X				X	X	X			
Replace Breckwood–W. Springfield cable circuit	X	X										
Replace Breckwood–E. Springfield cable circuit	X	X	X	X	X	X	X	X	X	X	X	X
Replace Breckwood reactors	X	X	X	X	X	X	X	X	X	X	X	X
Rebuild/reconductor Woodland–Pleasant line circuit #1	X		X	X	X	X	X	X	X	X	X	X
Rebuild Agawam–Piper Rd. circuit #1	X	X			X							
Install new Clinton–E. Springfield cable circuit			X	X	X	X	X	X	X	X	X	X
Clinton reactor			X	X	X	X	X	X	X	X	X	X
Install 3rd Clinton– W. Springfield cable circuit			X			X		X	X			
Upgrade Ludlow–E. Springfield circuit #1						X						X
Build new Stony Brook–Ludlow 115 kV line		X									X	
Build new 115 k lines 1 and 2, Stony Brook–Five Corners		X	X		X			X			X	
Rebuild 115 kV lines 1 and 2, Five Corners–Fairmont		X	X		X			X			X	
Build new 115 kV line, Ludlow–Fairmont						X			X			X
Disconnect CT/WMASS 115 kV ties	X	X		X	X	X				X	X	X
Reconductor E. Springfield Jct.–Fairmont N.											X	
Separate/Rebuild 1254/1723	X									X		
Undo 3-terminal line 1254/1723; rebuild lines from E. Springfield Jct. to Fairmont			X	X	X	X	X	X	X			
Separate/Rebuild (Fairmont–Shawinigan)/ (Fairmont– E. Springfield)			X	X			X	X				
Reconductor E. Springfield Jct.–Shawinigan											X	X

Springfield Reinforcements	Springfield Option Designation											
	3a	3b	5b	6a	6b	6c	7a	7b	7c	8a	8b	8c
Associated 345 kV Option:	**A**	**A**	**C**	**A**	**A**	**A**	**B**	**B**	**B**	**A**	**A**	**A**
Reconductor Fairmont–Shawinigan					X	X						
Upgrade E. Springfield Jct.–Chicopee											X	
Reconductor E. Springfield Jct.–Piper Rd.	X	X									X	X
Reconductor Fairmont–Piper Rd.					X	X						
Upgrade Fairmont S.–Holyoke			X		X	X					X	
Upgrade Pineshed–Fairmont N.												X
Upgrade Blandford–Granville Jct.	X	X	X	X	X	X	X	X	X	X	X	X
Upgrade Southwick–N. Bloomfield							X		X			
Upgrade Pleasant–Blandford			X	X	X	X	X			X	X	X
Create breaker-and-one-half substation configuration at Fairmont			X	X	X	X	X	X	X			
Build second underground 115 kV line, Northwest Hartford–Southwest Hartford	X	X	X	X	X	X	X	X	X	X	X	X
Build second underground 115 kV line, Southwest Hartford–South Meadow	X	X	X	X	X	X	X	X	X	X	X	X
Build a new 115 kV line from Manchester to East Hartford with 2% or 2.65 ohm reactor	X	X	X	X	X	X	X	X	X	X	X	X
Build a new 115 kV line from Manchester to South Meadow with a 1.5 ohm reactor			X									
Reconductor line 1783 from Farmington to Newington with 556 ACSR			X									
Reconductor line 1785 from Berlin to Newington with 795 ACSR			X									
Add 1% or 1.5 ohm reactor on line 1704			X									
Add 1% or 1.5 ohm reactor on line 1722			X									