Southwestern Connecticut Electric Reliability Study

Volume I

Final Power-Flow, Voltage and Short-Circuit Report

December 2002

Presented by the

ISO-NE Southwestern Connecticut Working Group

Executive Summary

This Southwestern Connecticut Electric Reliability Study contains the results of analyses performed on the southwestern Connecticut transmission system in accordance with New England Power Pool (NEPOOL) transmission planning procedures. The assumptions and analyses support a conclusion that the existing southwestern Connecticut electric power system does not meet North American Reliability Council (NERC), Northeast Power Coordinating Council (NPCC) and New England Power Pool (NEPOOL) reliability performance standards. The system deficiencies are due to the following factors:

1) The 52-town southwestern Connecticut area continues to experience peak demands that exceed existing transmission service capabilities and peak demands are forecasted to grow.
2) The area is subject to uncertain local generation availability due to economic and environmental concerns.
3) Merchant generating plant expansion opportunities are restricted by substation limitations and transmission constraints.

A system reinforcement plan proposed herein reflects consideration of the following factors:

- forecasted peak demand levels assuming continued utility participation with conservation and load management programs;
- restrictions or retirements of existing generation for economic or environmental reasons;
- aging transmission facilities subject to unplanned outages and contingency analyses that reflect actual configurations in accordance with national and regional transmission reliability standards;
- limited sustainable response to local load-serving entity calls to self-supply, and
- preferred use of existing rights-of-way and substation land capabilities for new or upgraded transmission facilities to improve system performance and efficiencies to meet the needs of today and future load growth.

Based on the large number of post-contingency system deficiencies in southwestern Connecticut, a system reinforcement plan was developed following extensive analyses. The Southwestern Connecticut Electric Reliability Project (345-kV loop) is a comprehensive system solution to the multitude of power-flow, voltage and short-circuit problems on the existing system. The project includes upgrades and modifications to existing transmission lines and substations, the construction of new transmission lines and substations, and the modification of selected generator interconnections. The construction of new 115-kV and 345-kV high voltage Alternating Current (AC) transmission lines, and the removal and replacement of some aging 115-kV transmission lines with higher capacity lines are planned along existing rights-of-way. In some areas complete removal of 115-kV lines is proposed to allow building new 345-kV facilities. The re-connection of two generator leads addresses safety concerns, ensures reliable system performance, and increases efficiencies of all existing and new facilities.

The Southwestern Connecticut Reliability Study – Interim Report, dated January 2002, detailed a preliminary system reinforcement plan, a 345-kV loop, that met the planning criteria for a design basis future load level. A more detailed investigation into land management (rights-of-way), as well as substation and transmission project efficiencies, formed the basis for a refinement of that 345-kV loop design. This final report includes all required power-flow, voltage and short-circuit analyses on the 345-kV loop to support NEPOOL's 18.4 review process. In addition, Volume II and III will document stability response to the project and a comparison of alternate plans. A detailed project description is listed below:

<u>Generation interconnection modifications</u>

- Re-connect Bridgeport Energy to the new 345-kV Singer Substation.
- Re-connect Milford Power to the new 115-kV East Devon Substation.

<u>345-kV transmission modifications</u>

- Expand the Plumtree 345-kV Substation and the Scovill Rock 345-kV Switching Station.
- Build 345-kV substations at Norwalk 9S, near Devon 7R (East Devon Junction), near Pequonnock 8J (Singer) and Glenbrook 1K.
- Build a 345-kV switching station at Beseck Junction.
- Build a 345-kV line from the Plumtree Substation to the Norwalk Substation.
- Build a 345-kV line from the Scovill Rock Switching Station to the Beseck Switching Station and then to the East Devon Substation.
- Build a 345-kV line from the East Devon Substation to the Singer Substation.
- Build a 345-kV line from Singer Substation to the Norwalk Substation.
- Build a 345-kV underground line from the Norwalk Substation to the Glenbrook Substation.

<u>115-kV transmission modifications</u>

- Rebuild the 115-kV line between Plumtree and Norwalk substations.
- Build a 115-kV substation at East Devon Junction with two new 115-kV lines to Devon.
- Rebuild the 115-kV 1975 line between Oxbow Junction and East Meriden Substation, and 115-kV 1640, 1610 and 1685 lines between Cook Hill Junction and Devon Substation.
- Reconductor the 115-kV Towantic – Baldwin – Bunker Hill 1575 line.
- Reconductor the 115-kV Towantic – Bunker Hill 1585 line.
- Reconductor the 115-kV Towantic – Frost Bridge 1990 line.
- Rebuild the two 115-kV lines between Devon and UI's Devon Switching Station.
- Eliminate one of two 115-kV lines from Devon to Pequonnock, and then to Norwalk.
- Build a 115-kV underground line from the Norwalk Harbor Substation to the Glenbrook Substation.
- Upgrade 115-kV Norwalk Harbor – Ely Avenue 1890 line emergency ratings.
- Install a 3-ohm series reactor at the Ash Creek Substation on the 115-kV 1430 line and 1-ohm series reactors in each 115-kV line between the East Devon and Devon substations.
- Replace the Norwalk Harbor 115/138-kV autotransformer.
- Replace the 15T circuit breaker at the Southington 115-kV Substation.
- Replace the 3T and 5T circuit breakers at the Cos Cob 115-kV Substation.
- Replace the 1T, 2T, 3T, 4T, 5T and 6T circuit breakers at the Norwalk Harbor 115-kV Substation.

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Volume I - Report

1.0 Introduction

The southwestern Connecticut electric power system does not meet national and regional reliability performance standards. The system deficiencies are due to the following factors:

- The 52-town southwestern Connecticut area continues to experience peak demands that exceed existing transmission service capabilities and peak demands are forecasted to grow.
- The area is subject to uncertain local generation availability due to economic and environmental concerns.
- Merchant generating plant expansion opportunities are restricted by substation limitations and transmission constraints.

The Southwestern Connecticut Electric Reliability Project (345-kV loop) is a comprehensive system solution to the multitude of power-flow, voltage and short-circuit problems on the existing system. The project includes upgrades and modifications to existing transmission lines and substations, the construction of new transmission lines and substations, and the modification of selected generator interconnections. The construction of new 115-kV and 345-kV high voltage Alternating Current (AC) transmission lines, and the removal and replacement of some aging 115-kV transmission lines with higher capacity lines, are planned along existing rights-of-way. In isolated areas complete removal of 115-kV lines (without replacement) is proposed to efficiently connect new 345-kV facilities. The modification of two generator interconnections addresses safety concerns, ensures reliable system performance, and increases efficiencies of all existing and new facilities.

Ultimately, the Southwestern Connecticut Electric Reliability Project will reliably connect the 115-kV transmission facilities of The Connecticut Light & Power Company (CL&P, a subsidiary of Northeast Utilities) and The United Illuminating Company (UI) to New England's 345-kV bulk power electric transmission grid. This reliability study contains the results of power-flow, voltage and short-circuit analyses performed on the southwestern Connecticut transmission system in accordance with New England Power Pool (NEPOOL) transmission planning procedures. This system solution was tested under and fully meets the criteria contained in Section 18.4 of the Restated NEPOOL Agreement.

The Southwestern Connecticut Reliability Study – Interim Report, dated January 2002, detailed a preliminary system reinforcement plan, a 345-kV loop, that met the planning criteria for a design basis future load level. A more detailed investigation into land management (rights-of-way), as well as substation and transmission project efficiencies, formed the basis for a refinement of that 345-kV loop design. This final report includes all required power-flow, voltage and short-circuit analyses on the 345-kV loop to support NEPOOL's 18.4 review process.

2.0 Electric System Study Area

2.1 Transmission System

Electric transmission service in Connecticut is primarily provided by CL&P and UI. The Connecticut transmission network consists of approximately 398 miles of 345-kV, 5.8 miles of 138-kV, 1,300 miles of 115-kV, and 104 miles of 69-kV transmission lines. Eight existing bulk power substations (Montville, Card, Manchester, Southington, Frost Bridge, North Bloomfield, Plumtree and East Shore) are equipped with autotransformers that convert electric energy from 345 kV to 115 kV. These bulk power substations deliver energy into the 115-kV transmission system that is distributed to 113 local area load serving distribution substations.

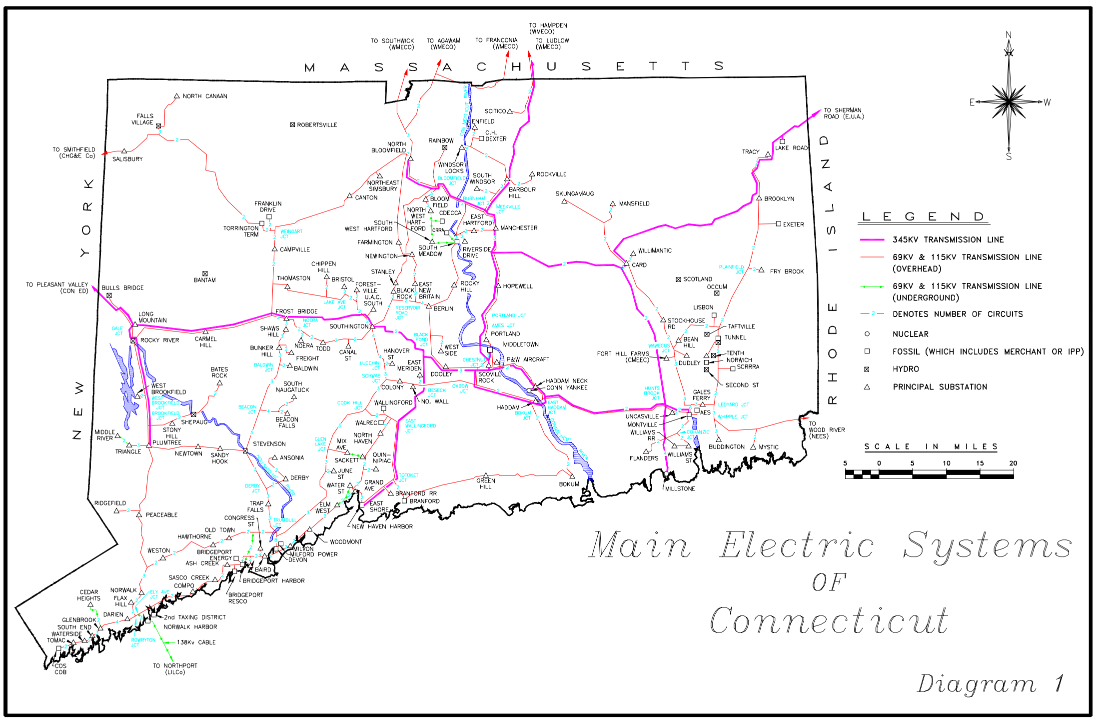
Connecticut's existing 345-kV transmission facilities are vital links to the region's interconnected bulk power electric transmission grid. The Connecticut 345-kV transmission system ties bulk power substations to large generating stations and to three transmission tie lines that connect to the 345-kV systems of other utilities serving New England and New York State; including National Grid, the Western Massachusetts Electric Company (WMECO), and Consolidated Edison of New York (Con Ed).

Connecticut's transmission network also has five lower voltage tie line connections with neighboring utilities. These tie lines operate at voltages from 69 kV to 138 kV and link CL&P and UI facilities to the facilities of National Grid, Long Island Power Authority (LIPA), Central

Hudson Gas & Electric Corporation (CHG&E), and WMECO. Connecticut's tie lines to neighboring electric systems provide customers with improved reliability benefits under both all-lines-in and contingency conditions.

Diagram 1 is a geographical map showing the main electric systems of Connecticut.

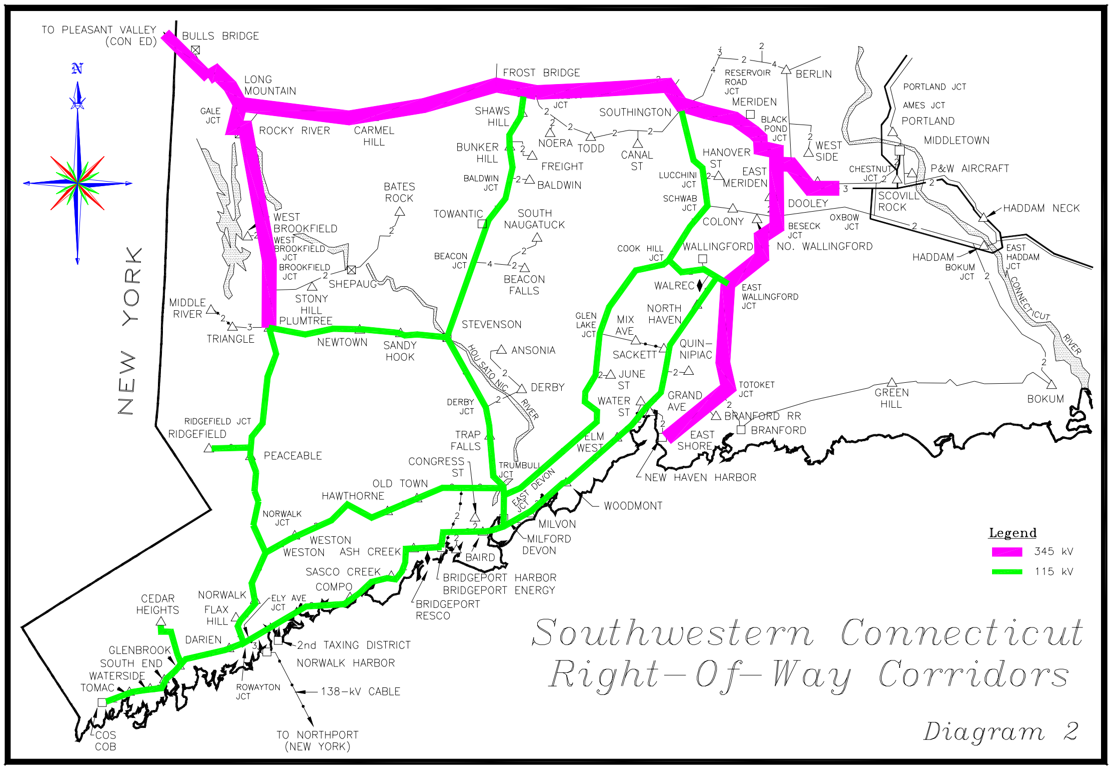
Diagram 1
Main Electric Systems of Connecticut



The southwestern Connecticut load area is supplied via a 115-kV transmission system that ties to the 345-kV Connecticut transmission grid via autotransformers at the Plumtree, Frost Bridge, Southington and East Shore substations. Diagram 2 shows the four major southwestern Connecticut right-of-way corridors that originate from these four substations. Multiple overhead 115-kV lines exit these substations and transmit power into the southwestern Connecticut load pocket. The Connecticut 345-kV transmission grid does not penetrate the high load density area between New Haven and Greenwich. The 115-kV transmission system integrates local generating resources and brings power into the southwestern Connecticut area.

Three corridors within the southwestern Connecticut area serve the Norwalk/Stamford area, one originating from the Plumtree Substation, one from Devon Substation, and one from Pequonnock Substation. These overhead line corridors are the major transmission paths and the primary links to this area from the Connecticut 345-kV bulk power transmission grid.

Diagram 2
Southwestern Connecticut Right-Of-Way Corridors



The aforementioned transmission corridors are occupied by lines ranging in age from 10 to 80 years. Between 1943 and 1963 most transmission lines were constructed using lattice towers. Some of these transmission lines were originally designed as 69-kV lines, and upgraded later as semi-compacted 115-kV lines. In instances where upgrades are justifiable, efficient and physically achievable, certain transmission lines have been reconductored to increase their current carrying capability. These lines have conductors ranging from 4/0 copper to 1590-kcmil Aluminum Conductor Steel Reinforced (ACSR). ACSR became the conductor of choice in the 1950's due to its strength, durability and lower cost, as well as the higher current carrying capacities of sizes larger than are available in copper. Over the past 30 years Connecticut utilities have built, rebuilt, reconductored and bundled the 115-kV lines along these and other transmission corridors to maximize existing system capabilities to serve a peak demand that almost doubled. During the same time period, CL&P and UI have tapped and looped some of these lines into new distribution substations.

Some of the lines into the area have larger conductors than others, some structures support one line, others support multiple lines, and some lines are tapped at intermediate locations to serve distribution substations. Other lines are express lines between two distant substations. These existing transmission corridors are a primary asset for reinforcement plans to address power system needs.

Diagram 2 indicates that several substations serving the Stamford to Greenwich area are at the far end of the Connecticut transmission system. There are no transmission interconnections between CL&P and Con Ed of New York in this area. New AC tie lines between these systems, specifically in the Greenwich area, would require new transmission corridors in densely populated areas and normally result in power flows from Connecticut to New York, aggravating existing problems in southwestern Connecticut.

The Independent System Operator – New England (ISO-NE) maintains the most up-to-date models of New England's existing and planned generation and transmission facilities. These models were modified to include specific reinforcement plans in the Connecticut area that have received NEPOOL recommendation and ISO-NE approval and are expected to be in-service by 2004. The list of modified and new facilities includes the following:

<u>New 115-kV capacitors</u>

- Canton, Franklin Drive, Glenbrook, Rocky River and Stony Hill substations.

<u>115-kV transmission line upgrades</u>

- Canton - Weingart Junction 1732 line.
- Rowayton Junction - Glenbrook 1880 line.
- Rowayton Junction - Glenbrook 1890 line.

- Darien - South End 1977 line tap into Glenbrook.

<u>New Flexible AC Transmission (FACTs) equipment</u>

- Glenbrook ± 150 MVAR STATCOM.

<u>Substation terminal equipment upgrades</u>

- Haddam Neck, Scovill Rock, Montville, Southington, Glenbrook and South End substations.

A proposed northwest Vermont 345-kV Reliability Project is concurrently being studied with the southwestern Connecticut analyses. This Vermont reinforcement plan has been submitted to NEPOOL for 18.4 review. This project is expected to have only a minimal impact on power flows in Connecticut and therefore is not modeled in this study.

2.2 Load

The NEPOOL 2002 Capacity, Energy, Load and Transmission (CELT) Report, issued in April 2002, predicted a summer peak load of 24,760 MW in 2003 and 27,758 MW in the year 2011. Based on updated information following record peak demands during the 2002 summer, ISO-NE now predicts a new peak demand for the 2003 summer of 24,980 MW.

The CELT report represents forecasted peak demands that have a probability of occurrence. The adjusted New England load forecast contained in the CELT report is weather normalized and based on a 50% probability of being exceeded. Were the likelihood of exceeding the actual peak demand reduced to 10%, much higher peak demands would be forecasted. Current data predicts that a peak demand of 26,380 MW for the summer of 2003 has a 10% probability of being exceeded. The typical increase in predicted summer peak load from the 50% probability level to the 10% probability level is 5.6%.

It is good utility planning practice to consider a range of forecasted peak demands in selecting a design basis load level. The design basis peak demand level used in this study was 27,700 MW. This is based on the 2002 CELT report that predicts a 2011 peak demand of 27,758 MW with a

50% probability of being exceeded. However, considering a 10% probability of exceeding the forecasted peak demand, this load level would be reached as early as 2007. Therefore, studying a peak load level of 27,700 MW is reasonable and covers a range of possible weather variations that can influence peak demand levels. The system was also tested at a peak load level of 30,000 MW to assess the longer term performance of the proposed plan. Based on ISO-NE predictions this load level may be experienced sometime in the period between 2010 and 2014.

Intermediate and light load levels were also tested to ensure that adequacy and security of the transmission grid are maintained under a wide-range of operating conditions. The power-flow analyses included testing at an intermediate load level of 19,000 MW and a light load level of 11,400 MW.

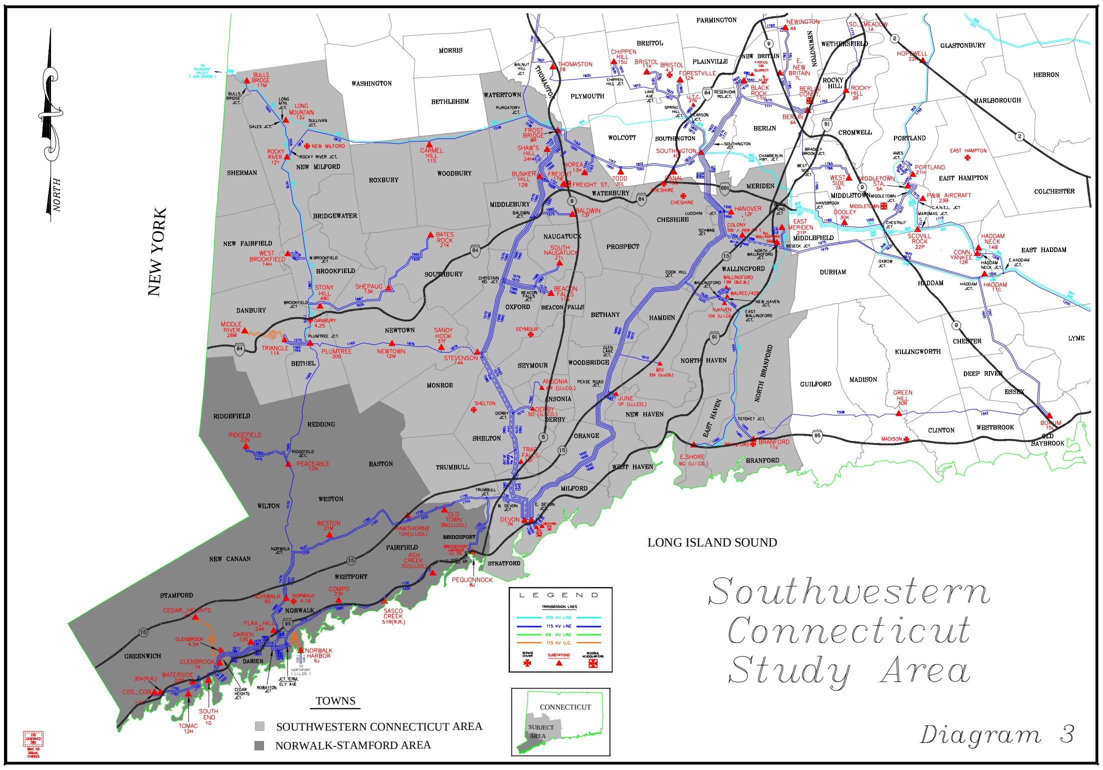
Load distribution modeling at individual substations was based on local metering data. Load power factor levels for all forecasts were modeled at values consistent with local standard design practices.

Southwestern Connecticut/Norwalk-Stamford:

Southwestern Connecticut can be roughly described as the area approximately south of Route I-84 and west of Route I-91 between Meriden and New Haven. The peak demand in this area accounts for almost half of the peak load in the state of Connecticut. This densely populated load pocket is one of the fastest growing and economically vital regions in the state. Southwestern Connecticut is the largest load pocket in New England without 345-kV interregional transmission service capability. The southwestern Connecticut share of the design basis peak demand is approximately 3,720 MW. Contained within southwestern Connecticut and farthest away from the bulk 345-kV transmission grid is the Norwalk-Stamford area, with an approximate design basis peak demand of 1,310 MW. These figures assume continuation of the spending and effectiveness of the Conservation and Load Management programs by each utility.

Diagram 3 identifies the fifty-two towns in southwestern Connecticut including the Norwalk-Stamford area.

Diagram 3
Southwestern Connecticut Study Area



2.3 Electrical Interfaces

Electrical interfaces are adopted by system operators as a tool to evaluate concerns over the unrestricted transfer of power through a free-flowing system. Power flows redistribute over remaining transmission lines when generators or transmission lines are intentionally or unintentionally removed from service. Because power flow to load seeks alternate paths of least resistance under these contingency conditions, the result can be overloaded lines and adverse impacts on local or neighboring systems. A method for evaluating transmission system performance and setting limits to protect against wide area interruption is to establish electrical interfaces for monitoring purposes. These interfaces are defined as specific transmission facilities used to transfer power from one area to another. Power flows across the monitored transmission facilities are aggregated to determine the instantaneous transfer across each interface.

Listed below are the transmission lines that define the electrical interfaces in the study area.

Southwestern Connecticut Interface

115-kV Frost Bridge - Carmel Hill 1238 line	115-kV Green Hill - Branford 1508 line
115-kV Frost Bridge - Shaws Hill 1445 line	115-kV East Shore - Branford RR 1460 line
115-kV Frost Bridge - Freight 1721 line	115-kV East Shore - English 8100 line
115-kV Frost Bridge - Baldwin Tap 1990 line	115-kV East Shore - Grand Ave. 8200 line
115-kV Southington - Glen Lake Jct. 1610 line	Plumtree 345/115-kV T1 autotransformer
115-kV Southington - Wallingford Jct. 1208 line	Plumtree 345/115-kV T2 autotransformer
115-kV Southington - Lucchini Jct.1690 line	

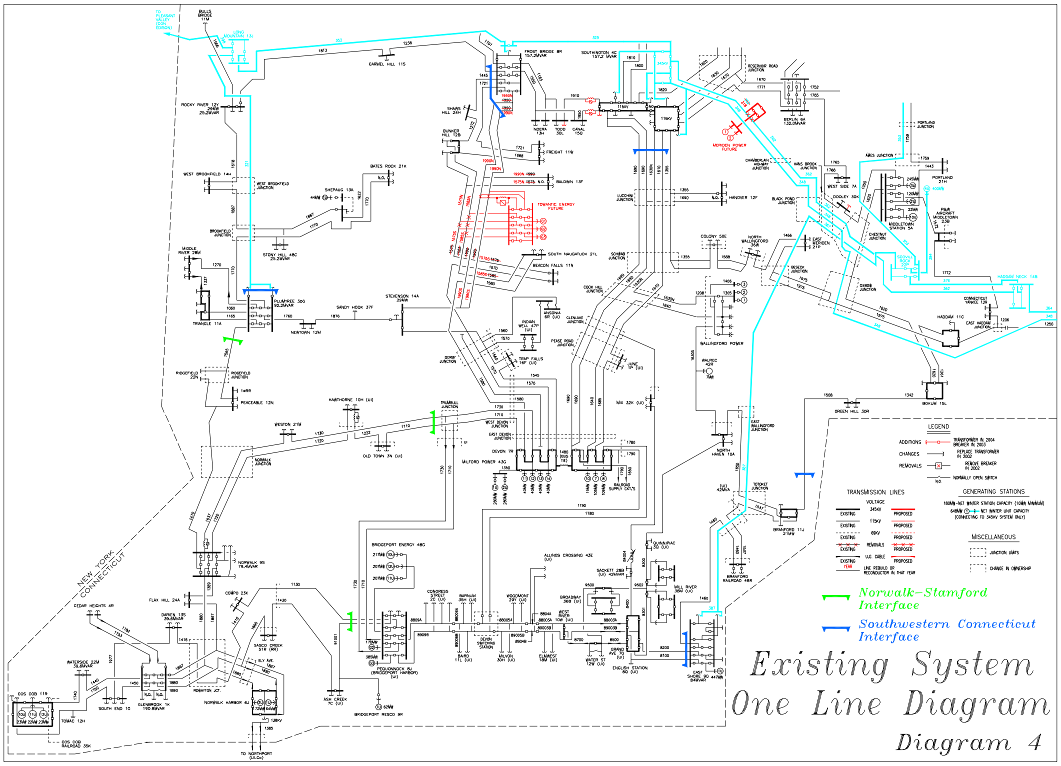
Norwalk - Stamford Interface

115-kV Plumtree - Ridgefield 1565 line	115-kV Pequonnock - RESCO 91001 line
115-kV Trumbull Jct. - Old Town 1710 line	115-kV Pequonnock - Compo 1130 line
115-kV Trumbull Jct. - Weston 1730 line	

The power-transfer capability over an electrical interface is not the summation of individual line capabilities. Interface limits are determined by computer simulations that calculate maximum allowable power transfer levels across a set of pre-defined transmission facilities that will not violate prescribed limits of machine stability, equipment current carrying capabilities or permissible ranges of voltage and frequency within an area. These calculations are performed in accordance with local, regional and national criteria.

Diagram 4 is a one-line diagram of the existing southwestern Connecticut transmission system.

Diagram 4
Existing System One Line Diagram



2.4 Generation

Connecticut's large generating stations are connected to the network at two transmission voltage levels. The Middletown 4 (located along the Connecticut River), Millstone 2 & 3 (located on Long Island Sound), and Lake Road generating plants are directly connected to the existing New England 345-kV transmission grid. All other major generating stations are directly connected to the 115-kV transmission system throughout the state. Major generating stations (> 20 MW) located within the Norwalk-Stamford area are Cos Cob, Norwalk Harbor and Bridgeport RESCO. Major generating stations located within the southwestern Connecticut area include those in the Norwalk-Stamford area, plus Bridgeport Energy, Bridgeport Harbor, Devon, Wallingford, Shepaug and Stevenson. For this study new power plants at Meriden, Milford and Towantic are also assumed available for dispatch. However, financial conditions of these developers/owners may prevent construction of these plants and/or operation.

The New Haven Harbor generating unit is located within a southwestern Connecticut town but is electrically outside of the southwestern Connecticut interface. This unit directly connects to the 115-kV East Shore Substation in New Haven. The configuration and performance of the transmission lines emanating from the East Shore Substation play a major role in determining the line of demarcation for the southwestern Connecticut interface. Generation from the New Haven Harbor unit is similar to power flows to East Shore over the 345-kV 387 line from the Middletown area. The 1460, 8100 and 8200 lines are the primary transmission links that move power to southwestern Connecticut's distribution substations and so define the interface west of the East Shore Substation.

Table 1 summarizes various dispatch scenarios for major generating units and corresponding New England interface transfers modeled in these analyses. The dispatch scenarios represent a wide range of potential unit commitments under NEPOOL's standard market design. The generation dispatch levels represent stressed conditions as required by reliability standards. The intent of maximizing power transfers across key transmission lines in southwestern Connecticut is to examine the ability of the area to reliably serve customer peak demands under varying operating conditions.

Table 1
New England Dispatch Scenarios

Generators	Capacity	Dispatch-1	Dispatch-2	Dispatch-3	Dispatch-4	Dispatch-5	Dispatch-6
Maine							
MIS	549	0	0	0	0	0	0
AEC	173	158	158	158	158	158	0
RPA	273	0	0	0	0	0	0
Westbrook	565	0	563	563	563	563	0
Wyman	875	420	340	400	392	496	26
New Hampshire							
Newington/s	955	0	955	422	422	955	0
Seabrook	1150	1150	1150	1150	1150	1150	1150
Schiller	146	0	146	146	146	146	146
Merrimack	466	320	433	433	113	433	320
Comerford/Moore	356	0	272	272	272	272	272
AES Londonderry	823	0	0	0	0	0	0
NEMA/Boston							
Mystic	2706	558	1517	952	952	1517	565
Salem Harbor	702	0	700	700	700	700	0
New Boston	760	0	380	380	380	380	707
SEMA/RI							
Milford Power	153	0	124	124	124	124	124
ANP Blackstone	580	0	580	290	290	580	0
ANP Bellingham	580	0	0	0	0	0	0
NEA	301	301	249	249	249	249	249
Ocean State Power	524	262	339	339	339	339	0
Brayton Point	1512	605	1084	1084	1084	1084	818
Manchester/FRSQ	495	0	485	485	485	485	425
Hope Energy	545	0	0	0	0	0	0
Sithe Fore River	881	0	0	0	0	0	0
Dighton	185	185	185	185	185	185	0
Tiverton	281	281	281	281	281	281	281
Canal	1143	498	1142	1142	1142	1142	1143
Pilgrim	670	670	670	670	670	670	670
W. Mass/VT							
Vermont Yankee	563	496	563	563	563	563	0
Bear Swamp	588	-560	588	294	294	588	0
Northfield	1080	-1000	1080	1080	1080	1080	0
Stony Brook	412	0	0	0	0	0	0
Berkshire Power	305	0	305	305	305	305	280
Millennium	390	390	390	390	390	390	390
Connecticut							
Lake Road	840	0	840	840	840	840	0
Millstone	2008	2008	2000	2000	2000	2000	1137
Middletown	771	0	750	750	750	750	517
Montville	489	0	483	483	483	483	0
Meriden	586	586	586	586	586	586	586
Milford	610	280	280	560	560	0	585
Wallingford	255	0	0	255	255	0	255
Towantic	550	0	0	515	515	0	548
South Meadow	186	0	0	0	0	0	0
New Haven Harbor	447	447	447	447	447	447	447
Bridgeport Harbor	567	375	375	375	375	375	0
Bridgeport Energy	520	0	0	520	520	0	520
Norwalk Harbor	330	0	0	0	329	329	0
Devon	382	0	212	212	212	0	0
Interfaces	**Limit**						
NB-NE	700	700	700	700	700	700	700
Highgate	225	150	225	225	225	225	225
Phase II	2000	0	2000	2000	2000	2000	2000
ME-NH	1400	686	384	444	436	539	-229
NNE-Scobie	2550	1603	1927	1482	1382	2066	692
North-South	2700	2145	1575	1136	807	1714	148
East-West	2000	257	443	-869	-1198	590	574
NY-NE	±700	14	-6	-8	-8	-3	19
PV-20	150	110	110	110	109	110	110
Boston Import	3500	1529	2513	3080	3084	2514	2336
SEMA/RI Export	2200	740	731	441	440	731	1296
Conn. Import	2200	-1018	1482	-120	-857	1237	495
SWCT Import	2000	660	3126	1556	822	2880	669
Norwalk-Stamford	1100	516	1530	1531	799	795	904
1385 Cable Export	±200	0	200	200	-199	-200	0
481 Cable Export	355	352	352	352	352	352	352

Table 2 contains the generation dispatches that were modeled at each load level.

Table 2
Dispatch Modeling

New England Load Level	Dispatches Modeled
30,000 MW	2,3,4,5
27,700 MW	2,3,4,5
19,000 MW	4,6
11,400 MW	1

3.0 Study Methodology

3.1 Design Standards

The North American Electric Reliability Council (NERC) is charged with developing the fundamental requirements for planning a reliable interconnected bulk electric system. NERC carries out its reliability mission by:

- Establishing Reliability Policies, Standards, Principles, and Guides
- Measuring Performance Relative to NERC Policies, Standards, Principles, and Guides
- Ensuring Conformance to and Compliance with NERC Policies, Standards, Principles, and Guides

NERC has developed national standards that contain the minimum acceptable design criteria that each Regional Council across the United States can adopt. Regional Councils can develop more stringent criteria to meet unique regional needs.

The Northeast Power Coordinating Council's (NPCC) Basic Criteria for Design and Operation of Interconnected Power Systems promote the reliability and efficiency of electric service on the bulk power system in the northeastern United States, Ontario, Quebec, and the Canadian Maritime Provinces. NPCC regional criteria are consistent with the NERC standards.

The Reliability Standards for the New England Power Pool (NEPOOL) assure the reliability and efficiency of the New England interconnected bulk power supply system through coordination of system planning, design and operation. These standards apply to all facilities comprising the New England interconnected bulk power supply system. These include the facilities of electric utilities in Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. The NEPOOL area standards are consistent with the regional NPCC and national NERC standards.

Reliability standards for facilities that are part of the interconnected bulk power system are set by NERC, NPCC and NEPOOL. The NERC, NPCC and NEPOOL standards form the basis for utility planning standards within the region.

The Connecticut transmission system is interconnected to the New England bulk power transmission grid. These facilities are planned, maintained and operated in accordance with established NERC, NPCC, and NEPOOL standards and criteria. Transmission reliability standards for Connecticut, developed by CL&P and UI, comply with these recognized national standards and regional criteria.

These transmission reliability standards determine the adequacy and security of the Connecticut transmission grid. The framework for a reliable national transmission grid is centered on contingency analyses based on predictable and probable events. The consistent use of contingency planning that is applied across an area ensures such design contingency events do not cascade outside of the area and adversely impact neighboring electric systems. Design contingencies are simulated using computer models developed to represent actual and future system conditions. The system performance under such contingencies must fall within pre-defined thermal, voltage and stability limits. If the simulation shows that transmission line power flows exceed emergency ratings, or voltages fall outside of acceptable criteria, then corrective action must be implemented to ensure that integrity of the transmission grid is maintained.

New England evaluates the adequacy and security of the transmission network to meet varying load demands under reasonably foreseeable generation and transmission system conditions. Certain scenarios assume that all system generation resources and transmission lines are available, while other scenarios assume that certain generation and transmission facilities are unavailable due either to bid dispatch, scheduled maintenance or unplanned outages. The purpose is to demonstrate that the electrical network is sufficiently robust to withstand a reasonable level of facility outages and still reliably and economically serve the electrical needs of customers.

The loss of a generator, a transmission line or combinations of both (which could occur for any number of reasons), causes increased power flows on the remaining in-service transmission lines. Transmission capacity for an area must be designed, therefore, not only to transmit the imported power required to offset anticipated generating deficits under optimal conditions, but also to transmit that power reliably following design criteria contingencies. Otherwise, power flows could exceed transmission line emergency ratings and force utilities to disrupt service to large blocks of customers to prevent permanent damage to electric systems.

NERC, NPCC and NEPOOL reliability standards prescribe tests for transmission contingencies with diverse generation dispatch scenarios, including multiple generating units unavailable in a local area, thereby stressing area transmission interfaces to a greater degree. The requirement for transmission systems to withstand outages of more than one generating unit recognizes that units may be unavailable for many reasons such as economics, equipment failure, adequacy of fuel supply and maintenance. Also, more severe environmental restrictions (e.g., emissions) are targeted for fossil-fueled generating stations in Connecticut and elsewhere. If adopted, these restrictions could affect continuous operation of the units or result in their permanent closure. The potential loss of local generation in southwestern Connecticut was considered in developing dispatch scenarios for this study.

3.2 Criteria

Performance standards, a pre-defined set of criteria, are applied to system models to determine the acceptability of the contingency results. Simulation results that fall outside of the criteria must be addressed to ensure overall system reliability is maintained.

3.2.1 Power-Flow

New England electric utilities have developed a standard procedure for rating transmission equipment. Each electrical component has normal and emergency ratings. The normal rating is defined as the amount of current which, under specified ambient and load cycle conditions, will not cause equipment loss-of-life above design criteria. Emergency ratings are greater than normal ratings. Currents above normal ratings can cause a greater rate of equipment loss-of-life, loss of conductor tensile strength and increased conductor sag that can pose both an operating and safety problems. The emergency ratings allow utilities to operate electrical equipment above a manufacturer's standard nameplate rating, recognizing the inherent capabilities of this equipment to operate at higher current levels for short periods of time with acceptable loss-of-life.

New England adopted three rating levels that have been used in planning and daily operations for over 30 years. These are:

- normal rating (N)
- long-time emergency (LTE)
- short-time emergency (STE)

New England utilities follow a planning philosophy whereby normal ratings shall not be violated under all-lines-in conditions, and emergency ratings shall not be violated under contingency conditions. Table 3 contains the thermal loading performance criteria applied to transmission lines in this reliability study. The use of LTE ratings in planning studies recognizes the limited switching and dispatch options available to operations.

Table 3
Thermal Loading Performance Criteria

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

3.2.2 Voltage

Transmission voltage must be maintained within a prescribed bandwidth to ensure proper operation of electrical equipment and supply adequate voltage to customers. Equipment damage and widespread power outages are more likely to occur when transmission-level voltages are not maintained within pre-defined limits. Table 4 contains the voltage performance criteria used in these analyses.

Table 4
Voltage Performance Criteria

Voltage Level	Bus Voltage Limits	
	Normal Conditions	Emergency Conditions
> 115 kV	± 5% of nominal	± 5% of nominal
≤ 115 kV	± 5% of nominal	+ 5%, -10% of nominal
Millstone 345 kV	100 to 105% of nominal	100 to 105% of nominal

3.2.3 Short Circuit

Connecticut utilities address safety concerns and ensure reliable system performance by restricting fault duties imposed on circuit breakers and other equipment. The interrupting capability of a circuit breaker shall be limited to 100% of the de-rated value prescribed in ANSI standards that account for the X/R ratio, automatic reclosing and expected normal operating voltages. Substation ground grids, bus and disconnect switches, and transmission lines must be designed for safety and reliability when subjected to high short-circuit currents.

3.3 Analytical Tools

The Power Technologies, Inc. PSS/E load flow software package was used to perform the analyses. Design criteria contingencies were simulated with AC power flow techniques. The AC contingency checking (ACCC) routine was used to calculate post-contingency power flow solutions for a set of specified single and multiple transmission line outages. ACCC allows for the monitoring of reactive/voltage performance in addition to thermal conditions in the study area.

3.4 Contingency List

Reliability standards define the contingencies that are simulated on models representing electric power systems. Contingency analyses simulate expected and probable outages of transmission facilities, substation equipment, or generation facilities against models of the electric power system. Following any interruption of service to single or multiple transmission lines, power flows into an area such as southwestern Connecticut redistribute over the other remaining transmission lines. The remaining transmission facilities must demonstrate the capability to supply local area load under varying dispatch scenarios.

Appendix A contains a listing of approximately 450 contingencies that were simulated for each scenario. The listing is a comprehensive set of single line, double circuit, autotransformer, malfunctioning circuit breaker and generator contingencies.

4.0 Pre-Project Study Results

The results of power-flow, voltage and short-circuit analyses on the pre-project Connecticut transmission system are as follows.

4.1 Peak (100%) Load Dispatch

Appendix B contains case summaries and load flow plots of the base cases (dispatch models 2, 3, 4 and 5) used in this analysis at the design basis load level of 27,700 MW. Each case summary contains generation dispatch, station output and interface levels.

Appendix C.1 contains a listing of the lines loaded above their normal ratings in the base cases. Under pre-contingency base case (27,700 MW load) conditions, certain 115-kV transmission line loadings are above normal ratings. These overloads violate design criteria. To avoid this condition requires the re-dispatch of generation and/or reduction of import/export over the Long Island 1385 cable.

Appendix C.2 contains a summary of the post-contingency ACCC results. In these analyses both 345-kV and 115-kV outages caused deficient post-contingency conditions. Over eighty (80) 115-kV transmission elements exceed emergency ratings under many design criteria contingencies (e.g., transmission line(s) outage, generation outage). Post-contingency overloads on transmission lines range from 100% to over 185% of LTE ratings. The most affected transmission corridors are the following:

- Plumtree to Norwalk
- Norwalk - Norwalk Harbor - Glenbrook
- Devon to Norwalk
- Pequonnock to Norwalk
- Frost Bridge to Devon
- East Shore to Pequonnock
- Southington to Devon

As indicated above, all the major transmission corridors in southwestern Connecticut experience transmission line power flows above emergency ratings and voltages that fall outside of acceptable limits. In addition, there are numerous contingencies where a mathematical solution was not obtained. This signals the potential for a voltage collapse. Computer models predict the potential for a southwestern Connecticut voltage collapse and widespread outages of customer load (i.e., blackout). The propagation of a voltage collapse cannot be assured to stay within southwestern Connecticut and could impact neighboring areas and external systems. These specific contingency results are also listed in Appendix C.2.

The most critical and problematic contingencies are those that involve the loss of two transmission lines sharing common structures. More than 70% of the CL&P 115-kV circuits in southwestern Connecticut are supported by multi-circuit structures. Unplanned outages of two of these lines can occur due to a shield wire failure, insulator/hardware failures, tower failure, lightning, severe weather, or transportation accident.

The 345-kV Long Mountain – Plumtree 321 line shares common towers with a 115-kV circuit between the Rocky River and Plumtree substations. Transmission circuits (1710/1222/1720 and 1730/1637) share common structures for approximately 23 miles between the Devon and Norwalk substations. For approximately 4 miles prior to entering the Norwalk Substation, three circuits (1470, 1637 and 1720) share common towers. There are also two lines in a common corridor (in places on common structures) for approximately 20 miles, between Pequonnock Substation and Ely Avenue (1130 and 91001/1430) along the high-speed Amtrak railroad line. Multiple circuit towers are located around the East Shore substation. The 345-kV Scovill Rock – East Shore 387 line shares common towers with the 115-kV 1460 line. In addition the 115-kV 8100 and 8200 lines between East Shore and Grand Ave substations are critical transmission paths to New Haven. The single-contingency outage of multiple transmission circuits on any common tower causes overloads on the remaining 115-kV transmission lines or could result in voltage collapse.

The results of these analyses indicate that the transmission system that serves the southwestern Connecticut area is inadequate to meet reliability performance standards.

4.2 Voltage Analysis

Transmission planning standards limit voltage depressions on the 115-kV system to 90% of nominal (.90 pu). Post-contingency voltage violations in the southwestern Connecticut area are unacceptable and may cause widespread outages that may cascade into neighboring areas. Appendix C.3 contains a listing of voltage conditions that violate design criteria.

4.3 Short Circuit Analysis

Recent system impact studies for merchant generation projects have verified that short circuit currents in southwestern Connecticut have been aggravated by these projects and are very close to existing 115-kV circuit breaker ratings. Several 115-kV circuit breakers have already been scheduled for replacement. In general a balance must be maintained between generators connected to 115-kV system and those on the 345-kV system. High short circuit currents on the 115-kV system are a barrier to expansion of the 115 kV and the addition of merchant generation in southwestern Connecticut.

Appendix D contains the results of single-phase and three-phase short circuit analyses performed on the pre-project transmission system. The table summarizes the maximum fault duty imposed on circuit breakers at that location, based on the de-rating values prescribed in ANSI standards to account for the X/R ratio, line re-closing and expected normal operating voltages. This analysis indicates that short circuit duties at the 115-kV Pequonnock Substation and several other substations are critically close to the existing circuit breaker interrupting ratings.

4.4 Local Area/Load Pocket Reliability Problems

Several very distinct local area reliability problems were uncovered and found to be unrelated to the need for the 345-kV loop. The Tomac to South End overload is due directly to load growth at Tomac. The need for reinforcing this line is dependent on the load growth rate at this substation. Other areas that need future attention include Triangle/Middle River, Branford, Bokum, and Indian Wells.

5.0 System Plan

The need to significantly reinforce the southwestern Connecticut transmission system is clear. The number and magnitude of post-contingency conditions where power flows on 115-kV transmission lines are above emergency ratings, voltage profiles are below limits, contingency cases do not solve (voltage collapse) and where short circuit currents are close to circuit breaker interrupting capabilities illustrate an inadequate electric power system under the forecasted load and system conditions tested.

The correction of only voltage performance cannot diminish the need to provide a transmission system that can carry the expected power flows. The Southwestern Connecticut Electric Reliability Project proposes to reinforce the system with 345-kV lines in a manner consistent with regional and New England practices. Modifications to 115-kV facilities and use of 345 kV will improve the reliability in southwestern Connecticut and create a platform for generation re-connections and potential future merchant generation expansion projects. This comprehensive system plan will ensure that a reliable transmission system will serve southwestern Connecticut load in a safe and efficient manner.

The proposed system plan is to extend the 345-kV transmission grid into southwestern Connecticut. This is a continuation of the overall "BIG 11 POWERLOOP" plan envisioned in the 1960's by New England utilities to establish a comprehensive 345-kV transmission grid. In 1974, CL&P first submitted an application to the Connecticut Power Facility Evaluation Council to begin building the 345-kV loop to serve the growing electrical demands of customers in this area. Since 1974 the Connecticut load has grown by over 190%. This extension of the 345-kV network is the completion of the plan that began with the Long Mountain to Plumtree 345-kV line in the 1970's. The addition of the 345-kV loop on its own does not resolve the short circuit problem but provides the means to do so with the re-connection of two generator leads.

The project proposes to extend the 345-kV system across the southwestern Connecticut interface into the Norwalk-Stamford area to improve reliability and efficiencies in the transmission grid. The project provides high capacity 345-kV lines that reduce overloads on existing over-stressed 115-kV transmission lines. In effect, the 345-kV lines become the critical main highways to transfer power into and around the area. The 115-kV lines are the true secondary routes, transferring power to the local distribution substations. The basic 345-kV loop contemplated in the early 1970's remains the preferred system solution today to adequately address the multitude of power-flow, voltage and short-circuit problems. The isolation or segmentation of any portion of the project negatively affects the overall performance and reliability impact of this system reinforcement plan.

The project proposes the following system modifications:

Generation interconnection modifications

- Re-connect Bridgeport Energy to the new 345-kV Singer Substation.
- Re-connect Milford Power to the new 115-kV East Devon Substation.

345-kV transmission modifications

- Expand the Plumtree 345-kV Substation and the Scovill Rock 345-kV Switching Station.
- Build 345-kV substations at Norwalk 9S, near Devon 7R (East Devon Junction), near Pequonnock 8J (Singer) and Glenbrook 1K.
- Build a 345-kV switching station at Beseck Junction.
- Build a 345-kV line from the Plumtree Substation to the Norwalk Substation.
- Build a 345-kV line from the Scovill Rock Switching Station to the Beseck Switching Station and then to the East Devon Substation.
- Build a 345-kV line from the East Devon Substation to the Singer Substation.
- Build a 345-kV line from Singer Substation to the Norwalk Substation.
- Build a 345-kV underground line from the Norwalk Substation to the Glenbrook Substation.

115-kV transmission modifications

- Rebuild the 115-kV lines between Plumtree and Norwalk substations.
- Build a 115-kV substation at East Devon Junction with two new 115-kV lines to Devon.
- Rebuild the 115-kV 1975 line between Oxbow Junction and East Meriden Substation, and 115-kV 1640, 1610 and 1685 lines between Cook Hill Junction and Devon Substation.
- Reconductor the 115-kV Towantic – Baldwin – Bunker Hill 1575 line.
- Reconductor the 115-kV Towantic – Bunker Hill 1585 line.
- Reconductor the 115-kV Towantic – Frost Bridge 1990 line.

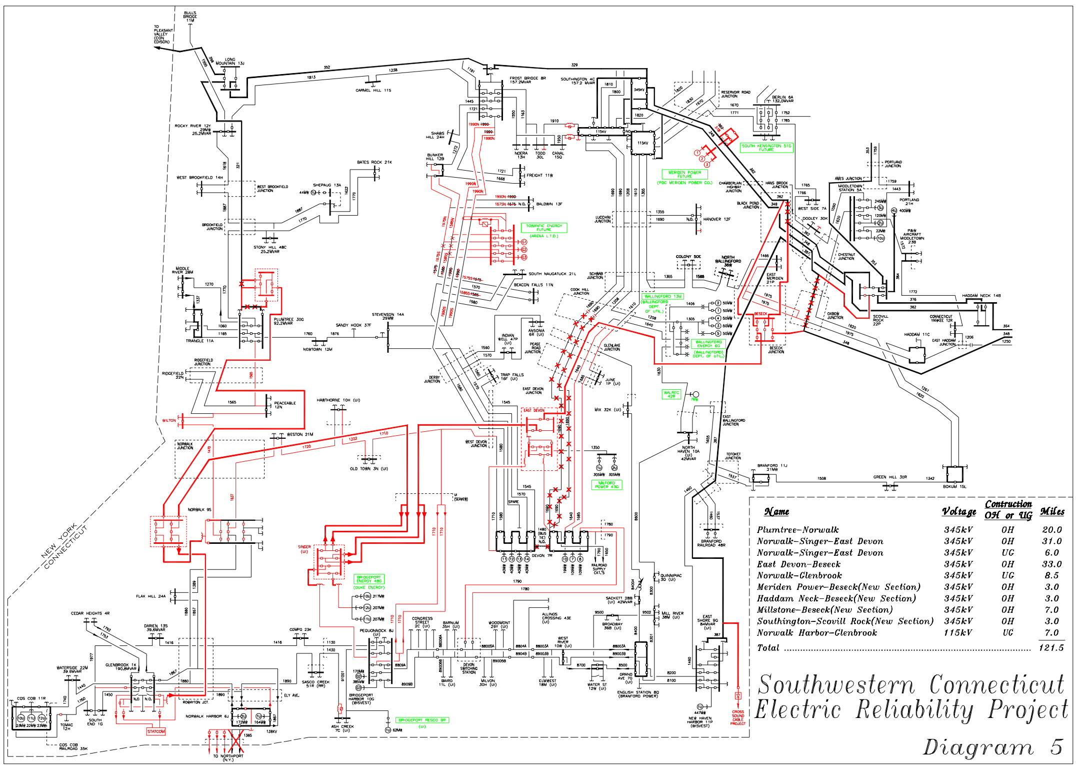
- Rebuild the two 115-kV circuits between Devon and UI's Devon Switching Station.
- Eliminate one 115-kV line from Devon to Pequonnock, and then to Norwalk.
- Build a 115-kV underground line from the Norwalk Harbor Substation to the Glenbrook Substation.
- Upgrade 115-kV Norwalk Harbor – Ely Avenue 1890 line emergency ratings.
- Install a 3-ohm series reactor at the Ash Creek Substation on the 115-kV 1430 line and 1-ohm series reactors in each 115-kV line between the East Devon and Devon substations.
- Replace the Norwalk Harbor 115/138-kV autotransformer. (See Section 6.5)
- Replace the 15T circuit breaker at the Southington 115-kV Substation.
- Replace the 3T and 5T circuit breakers at the Cos Cob 115-kV Substation.
- Replace the 1T, 2T, 3T, 4T, 5T and 6T circuit breakers at the Norwalk Harbor 115-kV Substation.

It is anticipated the proposed 345-kV loop with modified 115-kV transmission lines will be located primarily along existing 115-kV line rights-of-way. The individual easements comprising these rights-of-way generally vary in width from 80 to 150 feet, not wide enough in some areas to allow for building and operation of the proposed facilities in accordance with the requirements of the Connecticut Department of Public Utility Control, the National Electrical Safety Code and Connecticut utility standards. As a result, some wider easements must be acquired. Additional land must also be purchased at some of the 345-kV substation and switching station sites to provide for the Southwestern Connecticut Electric Reliability Project.

It is more desirable from a contingency planning perspective to construct each transmission line on its own set of structures. With this configuration a contingency event only affects one circuit. However this would result in the need for wider rights-of-way as compared to constructing multiple circuits on a single structure. The complexities of building multiple circuits along rights-of-way in densely populated areas require thorough consideration of practical means to achieve a design which minimizes impact on available land assets and societal impacts in and adjacent to the rights-of-way. Therefore it is proposed to construct both the 345-kV and 115-kV circuits in common rights-of-way on a single structure in a vertical configuration to limit and in some cases eliminate the need to acquire new and/or expand existing rights-of-way along the route of the 345-kV loop.

Diagram 5 shows the electrical configuration of the proposed 345-kV loop.

Diagram 5
Southwestern Connecticut Electric Reliability Project



The Southwestern Connecticut Electric Reliability Project is modeled with overhead line construction and limited underground facilities. These facilities are subject to Connecticut Siting Council jurisdiction. The physical modification of any facility may significantly change its electrical characteristics and require additional analyses and changes to this plan. Any such change will then need NEPOOL review/recommendation and ISO-NE approval. A detailed description of the proposed 345-kV loop is below:

- **Expand the 345-kV substation at Plumtree.**

  The Plumtree Substation will be designed to accommodate line terminations from both the existing Long Mountain circuit and the proposed Norwalk circuit. Four 345-kV circuit breakers will be added to this substation in a ring bus configuration. Alternating between each circuit breaker will be either a 345-kV line termination or 345/115-kV autotransformer connection. The design will ensure that a malfunctioning 345-kV circuit breaker will not remove the transmission path from Long Mountain to Norwalk or both Plumtree autotransformers simultaneously.

- **Build a 345-kV substation at Norwalk**

  A new 345-kV substation will be constructed adjacent to the existing 115-kV substation at Norwalk. The substation design will allow for line terminations from Plumtree, Singer and Glenbrook. Six 345-kV circuit breakers will be added in a 2-bay breaker-and-one-half scheme. The first bay will provide for connection of the 345-kV Plumtree line and 345/115-kV autotransformer. The 600-MVA, 345/115-kV autotransformer will be installed to connect the 345-kV and 115-kV systems. The second bay will provide for connection of the 345-kV line from Singer and the 345-kV line to Glenbrook. The design will ensure that a malfunctioning 345-kV circuit breaker will not remove both transmission paths from Plumtree and Singer. This design will also not result in either the Norwalk or Glenbrook autotransformers simultaneously tripping off-line due to a malfunctioning 345-kV circuit breaker contingency.

- **Build a 345-kV line from Plumtree Substation to Norwalk Substation.**

  Replace the existing overhead single 115-kV line with a double line configuration containing a 345-kV and 115-kV overhead line on a single pole within the existing but widened right-of-way. The 345-kV line will be constructed with bundled 1590-kcmil ACSR, two conductors per phase. The 115-kV line will be constructed with a single 1272-kcmil ACSR conductor per phase.

- **Expand the 345-kV Scovill Rock Switching Station**

  The Scovill Rock Switching Station will be expanded to accommodate a new line termination from Southington. The Southington leg of the existing 345-kV 348 line will be extended east from Chestnut Junction to re-terminate at the 345-kV Scovill Rock Switching Station. Two new 345-kV circuit breakers will be added to complete the breaker-and-one-half scheme.

- **Build a 345-kV switching station at Beseck Junction.**

  A new 345-kV switching station will be constructed at Beseck Junction in Wallingford. Seven 345-kV circuit breakers will be used in this substation in a three bay breaker-and-one-half bus configuration. This design will ensure that a malfunctioning 345-kV circuit breaker will not remove a transmission path from eastern Connecticut to load centers in central and southwestern Connecticut. The existing 345-kV Millstone-Southington 348 line will be reconfigured. The line section from Millstone will be extended west from Oxbow Junction to connect into Beseck. The Southington leg will be extended east from Chestnut Junction to re-terminate at the 345-kV Scovill Rock Substation. In addition, the existing 345-kV Southington - Haddam Neck 362 line will now loop on new structures south from Black Pond Junction into Beseck. At the South Kensington Switching Station, the 362/318 lines will be modified to bypass the station, and the 348 line cut into the station to allow elimination of circuit crossovers at Black Pond Junction.

- **Build a 345-kV substation at East Devon Junction.**

  A new 345-kV substation will be constructed at East Devon Junction in Milford. Four 345-kV circuit breakers will be used at this substation in a ring bus configuration. The substation will allow for line terminations from both Beseck and Singer. Alternating between each breaker will be either a 345-kV line termination or 345/115-kV autotransformer connection. A second 345-kV circuit breaker will be added between the line termination from Beseck and Singer. The design will ensure that a malfunctioning 345-kV circuit breaker will not remove the transmission path from Beseck to Singer. The worst case malfunctioning 345-kV circuit breaker contingency will temporarily remove a transmission line and the autotransformer. The autotransformer can be placed back into service following isolation of the failed circuit breaker. A 600-MVA, 345/115-kV autotransformer will be installed to connect the 345-kV and 115-kV systems.

A new 115-kV substation will also be constructed at East Devon Junction. Modifications are also recommended for the Devon Substation. The new 115-kV substation will re-terminate the Milford generating station lead line that now terminates at Devon. Two high-capacity express 115-kV transmission lines will connect East Devon to Devon. These two lines will each have a 1-ohm series reactor to help reduce short-circuit currents. The short 115-kV 1780 and 1790 lines from CL&P's Devon Substation to UI's Devon Switching Station will be rebuilt with 1590-kcmil ACSR.

- **Build a 345-kV line from Beseck Switching Station to East Devon Substation.** Construct a new overhead 345-kV line on existing right-of-way. The 345-kV line will be constructed with bundled 1590-kcmil ACSR, two conductors per phase. Where the line enters the Southington to Devon right-of-way (anticipated at Cook Hill Junction), one existing 115-kV line will be removed as the preferred design option to make available adequate space for the construction of the new 345-kV line.

- **Build a 345-kV substation at Singer.** A new 345-kV substation will be constructed adjacent to the existing 115-kV substation at Pequonnock in Bridgeport. The substation design will allow for 345-kV line terminations from both East Devon Junction and Norwalk. Eight 345-kV circuit breakers will be added in a breaker-and-one-half configuration. Each bay will provide for connection of either a 345-kV line termination or 345/115-kV autotransformer connection. A 600-MVA, 345/115-kV autotransformer will be installed to connect the 345-kV and 115-kV systems. A 600-MVA, 345/115-kV autotransformer will also be installed to connect the Bridgeport Energy generator lead line into the 345-kV system. The design will ensure that a malfunctioning 345-kV circuit breaker will not isolate the transmission paths from East Devon Junction and Norwalk or both Singer autotransformers simultaneously.

- **Build a 345-kV line from East Devon to Singer Substation.**
  Replace the existing overhead double circuit 115-kV lines with a double line configuration containing a 345-kV and 115-kV overhead line on existing rights-of-way. The 345-kV line will be constructed with bundled 1590-kcmil ACSR, two conductors per phase. From Trumbull Junction to Singer the 345-kV line will be part overhead and part underground construction. Beginning at Trumbull Junction the 345-kV line will be constructed with bundled 1590-kcmil ACSR, two conductors per phase. At a transition point approximately 1.5 miles away from Singer the overhead line will be placed underground using paralleled 5000-kcmil conductor, two conductors per phase.

  The 115-kV overhead line will be constructed with a single 1590-kcmil ACSR conductor per phase from the existing Seaview Tap/Trumbull Junction to Devon and Norwalk. From Seaview Tap to the Pequonnock 115-kV substation, the existing 1710 and 1730 cables will be paralleled.

- **Build a 345-kV line from Singer Substation to Norwalk Substation.**
  From Singer to Trumbull Junction the circuit will be part overhead and part underground construction along the same route as the East Devon to Singer lines. Beginning at Singer the 345-kV underground line will be constructed with paralleled 5000-kcmil conductors. At the Seaview Tap point, approximately 1.5 miles from Singer, the underground line will transition to overhead using bundled 1590-kcmil ACSR, two conductors per phase on a single-circuit steel pole structure to Trumbull Junction. From this point to Norwalk, the 345-kV line will be constructed with bundled 1590-kcmil ACSR, two conductors per phase along existing right-of-way. The existing overhead double circuit 115-kV line will be replaced with a double circuit configuration containing a 345-kV and 115-kV overhead line on existing right-of-way. The 115-kV line will be constructed with a single 1590-kcmil ACSR conductor per phase. This construction results in the retirement of a 115-kV line from Trumbull Junction to Devon, Pequonnock and Norwalk.

- **Build a 345-kV substation at Glenbrook**

  A new 345-kV substation will be constructed adjacent to the existing 115-kV substation at Glenbrook in Stamford. Construct a new underground 345-kV line from Norwalk to Glenbrook. A 600-MVA, 345/115-kV autotransformer will be installed to connect the 345-kV and 115-kV systems.

6.0 System Plan Analyses

The Southwestern Connecticut Electric Reliability Project was tested in accordance with the NEPOOL planning procedures. Power-flow analyses were conducted at load levels representing long-term, peak, intermediate and light load periods. Testing also included sensitivities to New England to New York transfers (both AC and DC), Towantic generation, and the Cross Sound Cable. Interregional transfers between New York and New England affect power flows on transmission lines in Connecticut due to the electrical integration between the two systems. In addition short-circuit analyses were conducted with all facilities in service. These analyses are required to show that the proposed Southwestern Connecticut Electric Reliability Project will operate reliably under reasonable system conditions.

Appendix E contains 345-kV loop base case summaries, plots and electrical characteristic data.

6.1 Peak (100%) Load Level

Appendix F.1 contains base case plots and summaries of the post-contingency ACCC results of thermal and voltage analyses. Dispatch scenarios 2, 3, 4 and 5 were tested at this peak load level (27,700 MW). These results show that the problems identified with the existing system, in Section 4.1 and 4.2 of this report, have been resolved. The planned 345-kV loop will eliminate line overloads, improve voltage performance and reduce short-circuit currents at problematic substations in the area.

6.2 Intermediate (75%) Load Level

Appendix F.2 contains base case plots and summaries of the post-contingency ACCC results of thermal and voltage analyses. Dispatch scenarios 4 and 6 were tested at this intermediate load level (19,000 MW). These results show that there are no reportable overloads or voltage limit violations on 115-kV and 345-kV facilities in southwestern Connecticut.

6.3 Light (40%) Load Level

Appendix F.3 contains base case plots and summaries of the post-contingency ACCC results of thermal and voltage analyses. Dispatch scenario 1 was tested at this light load level (11,400 MW). Dispatch 1 was designed to lightly load transmission lines and monitor for high voltages. These results show that there are no reportable overloads or voltage limit violations on 115-kV and 345-kV facilities in southwestern Connecticut.

6.4 Long-term (110%) Load Level

Appendix F.4 contains base case plots and summaries of the post-contingency ACCC results of thermal and voltage analyses. Dispatch scenarios 2, 3, 4 and 5 were tested at this long-term load level (30,000 MW). These results show that there are no reportable overloads or voltage limit violations on the proposed 345-kV facilities or upgraded 115-kV facilities in southwestern Connecticut. The intent of this sensitivity is to show that the proposed system plan will provide a reliable supply to the southwestern Connecticut area for the foreseeable future.

6.5 Sensitivity Cases

New York – New England Transfers

Sensitivity cases were developed to test the impact of New York – New England transfers. The dispatch scenarios 2, 3, 4 and 5 were tested against a +/- 700 MW NY-NE interface transfer.

Appendix F.5 contains base case plots and summaries of the post-contingency ACCC results of thermal and voltage analyses. Loss of the 345-kV Long Mountain – Pleasant Valley 398 line causes power flows on the 115/138-kV autotransformer at Norwalk Harbor up to 420 MVA, exceeding the 400 MVA emergency rating. The 345-kV loop brings the New England bulk power transmission grid electrically closer to the 138-kV Norwalk Harbor – Northport, New York 1385 line. The result is a higher pick-up factor on the 1385 line under contingency conditions. It is recommended that the existing 115/138-kV autotransformer be replaced.

Towantic Generation

Towantic is an undeveloped merchant generating station located within southwestern Connecticut. Although this station has received the necessary NEPOOL 18.4 approvals and was included in these analyses, there is now uncertainty surrounding its completion. To account for this uncertainty, no-Towantic sensitivity models were analyzed. This case removed both the Towantic generator and its associated system reconfiguration from service. Appendix F.6 contains base case plots and summaries of the post-contingency ACCC results of thermal and voltage analyses. Dispatch scenarios 2, 3, 4 and 5 were tested at the peak load level (27,700 MW). These results show that instead of rebuilding the 115-kV 1990 line and upgrading other facilities, normally closing the Baldwin 115-kV circuit breaker can effectively eliminate the thermal overload conditions.

Cross Sound Cable

The Cross Sound Cable (CSC) is a 330-MW, HVdc interconnection between Shoreham (on Long Island), New York and New Haven, Connecticut. This project consists of two bi-directional +/- 150-kV HVdc Voltage Source Converter stations and 23 miles of submarine cable under Long Island Sound with the ability to transfer up to 330 MW (net of losses) between the New England and Long Island electric power systems. This sensitivity assumed a 330-MW import into Connecticut from New York. Appendix F.7 contains base case plots and summaries of the post-contingency ACCC results of thermal and voltage analyses. Dispatch scenarios 4 and 5 were tested at the peak load level (27,700 MW). The CSC was originally studied as a dispatchable interconnection. Therefore transmission line overloads can be relieved by re-dispatch of the facility. These results show that there are no reportable overloads or voltage limit violations on 345-kV facilities or upgraded 115-kV facilities in southwestern Connecticut.

6.6 Short Circuit Analysis

The Southwestern Connecticut Reliability Study – Interim Report dated January 2002 identified transmission planning scenarios that resulted in short circuit currents at the Pequonnock

Substation to exceed circuit breaker ratings. Due to the lower impedance paths of the 345-kV system additions, the short circuit levels at Pequonnock exceeded the existing 115-kV circuit breaker interrupting capabilities. Extending the 345-kV circuit into the Pequonnock Substation provides a means to solve the short circuit problems at Pequonnock by altering Bridgeport Energy's interconnection. Included in the design of the 345-kV loop is the addition of a second 345/115-kV autotransformer to directly connect the Bridgeport Energy generating plant into the 345-kV transmission system at Singer. This reinforcement reduces the short circuit contribution from the Bridgeport Energy generating units into the Pequonnock 115-kV substation. This design provides a greater margin between short circuit currents and circuit breaker interrupting capabilities. In addition connecting Bridgeport Energy to the 345-kV system also reduces power-flows to below emergency ratings on the underlying 115-kV circuits.

At Devon, the addition of the 345-kV circuits into East Devon Substation caused the existing 115-kV circuit breakers to exceed their interrupting capabilities. To reduce the fault duty at this station, a series reactor was placed on each of the circuits between the East Devon and Devon 115-kV substations.

Appendix D contains the results of the short-circuit analysis performed on the final 345-kV loop configuration. The table indicates nine 115-kV circuit breakers at other substations which require replacement.

7.0 Conclusion

The southwestern Connecticut electric power system does not meet national and regional reliability performance standards. This reliability study proposes a comprehensive system plan that provides a long-term solution to meet the reliability needs of the southwestern Connecticut area. The Southwestern Connecticut Electric Reliability Project provides an infrastructure that is capable of supporting long-term load growth in the area under varying dispatch scenarios. Two generator interconnections will be modified to address safety concerns and ensure reliable performance of both existing and new transmission facilities. Based on these study results, the Southwestern Connecticut Electric Reliability Project will not have a significant adverse impact on the reliability or operability of the New England electric power system.