Southwest Connecticut Electric Reliability Study

Volume I

345-kV Plumtree – Norwalk Project
Final Power-Flow, Voltage and Short-Circuit Report

Revision 3

November 11, 2003
Presented by the

ISO-NE Southwest Connecticut Working Group

Executive Summary

In December 2002, the Southwest Connecticut Working Group published the "Southwestern Connecticut Electric Reliability Study". The report identified the need to construct a 345-kV "loop" to address the reliability problems in Southwest Connecticut (SWCT). Northeast Utilities (NU) and the United Illuminating Company (UI) are filing applications with the Connecticut Siting Council to construct the 345-kV loop in separate phases.

This study evaluates the impact of the Plumtree – Norwalk 345-kV project on the New England electric system taking into account other relevant queued facilities that have received NEPOOL 18.4 approval. The report contains power flow, voltage and short circuit analyses performed in accordance with New England Power Pool (NEPOOL) transmission planning procedures. The project is subject to the terms and conditions of the Restated NEPOOL Agreement Section 18.4.

Details of the project are as follows:

- **Build a 345-kV line from Plumtree Substation to Norwalk Substation.**
  The construction of a 345-kV line from Plumtree to Norwalk includes multiple configurations. In July 2003, the Connecticut Siting Council approved a combination of overhead and underground technologies. The Connecticut Siting Council has identified the new 345-kV line and modification to the existing 115-kV line as "Configuration X-Prime". Along the 20 mile route between the Plumtree and Norwalk substations, the 345-kV line transitions between overhead and underground. New sections of 345-kV overhead line will be constructed with bundled 1590-kcmil ACSR, two conductors per phase. The northern underground section and the station entrance into Norwalk Substation of the 345-kV line will be two 1750 kcmil XLPE cables and the middle section will be two 2500 kcmil HPFF cables.

- **Expand the 345-kV substation at Plumtree.**
  The 345-kV Plumtree Substation will be designed to accommodate line terminations from both the existing Long Mountain line and the proposed Norwalk line. Seven 345-kV circuit breakers will be added to this substation in a modified 3-bay breaker-and-one-half bus configuration. The design will ensure that a malfunctioning breaker will not remove the transmission path from Long Mountain to Norwalk or interrupt 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 design of the substation will include four 345-kV circuit breakers in a modified breaker-and-one-half scheme. The first bay will provide for connection of the 345-kV Plumtree line and the second bay will serve a single 345/115-kV autotransformer. The 600-MVA, 345/115-kV autotransformer will be installed to interconnect the 345-kV and 115-kV systems.

- **Rebuild the 115-kV line from Plumtree Substation to Norwalk Substation.**
  A new section of 115-kV overhead line between Gallows Hill Road and Archers Lane will be constructed with a single 1272-kcmil ACSR conductor per phase. The new underground sections between Plumtree and Norwalk Substation will be 3000 kcmil XLPE cable.

- **Modify Bridgeport Harbor 2 generator interconnection at the Pequonnock Substation.**
  Install a 115-kV series reactor (3%) in the Bridgeport Harbor 2 generator lead. A parallel 115-kV switching device will be operated "normally open" during normal operations. This reactor will reduce the fault current contribution from the unit into the 115-kV Pequonnock Substation.

- **Install 115-kV series reactors at the Southington Substation in the 1910 and 1950 lines.**
  Install a 115-kV series reactor (3%) in the 115-kV Southington – Todd 1910 line and in the Southington – Canal 1950 line. A parallel 115-kV switching device will be operated normally

closed. During times of potential post-contingency overloads on the 1910 and 1950 lines, the 115-kV switching device will be opened pre-contingency and insert the series reactor into the circuit. This action will increase the impedance of the line and re-direct power flows onto unrestricted parallel transmission lines.

- **Install an additional 345-kV circuit breaker at the Long Mountain Substation.**
  Install the 7T 345-kV circuit breaker between the existing 8T and 4T breakers at the Long Mountain Substation and re-terminate the 398 line to the 'A' bus. This will eliminate the possibility of a fault on either the 321 or 398 lines with a 5T circuit breaker malfunction removing both lines from service.

- **Install Special Protection System (SPS) at the Glenbrook Substation.**
  The proposed SPS would be armed 100% of the time and triggered by power flows on the 115-kV Glenbrook – Ely Avenue 1890 line and the 115-kV Glenbrook – Rowayton Junction 1867 line. The SPS will trigger on local sensing of power flows above LTE ratings and the outage of the 1867/1880 lines or the 1880/1890 lines, respectively. Operation of the SPS will result in tripping the 1753 – 1K and 1792 – 1K circuit breakers that isolate the Cedar Heights substation load. An additional 25 MW of load isolation at Glenbrook is required to reduce power flows below emergency ratings. Designated distribution feeders associated with the under-frequency load shedding program will also be under SPS control.

- **Replace 115-kV Circuit Breakers at the Norwalk Harbor Substation.**
  Replace the existing 115-kV 3T, 5T and 6T circuit breakers at Norwalk Harbor Substation with new circuit breakers with an interrupting capability of 63 kA.

- **Replace the limiting terminal equipment at the Southington and Millstone 345-kV substations.**
  Upgrade the limiting terminal equipment on the Southington to Millstone (348) line so that the conductor rating becomes the limiting element.

The proposed project demonstrates the following regional system benefits:

- Injects high voltage power regulation into the center of a critical load pocket relieving power flows on 115-kV transmission paths into and within SWCT and Norwalk-Stamford areas.
- Improves area voltage profiles in the vicinity of Plumtree and Norwalk for post-contingency system conditions.
- Decreases short circuit currents in the vicinity of the 115-kV Pequonnock Substation.
- Increases the SWCT and Norwalk–Stamford transfer limits.

Based on these study results, this project will not have a significant adverse impact on the reliability or operability of the New England electric power system.

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1.0 Introduction

In December 2002, the Southwest Connecticut Working Group published the "Southwestern Connecticut Electric Reliability Study". The report identified the need to construct a 345-kV "loop" to address the reliability problems in Southwest Connecticut (SWCT). Northeast Utilities (NU) and the United Illuminating Company (UI) are filing applications with the Connecticut Siting Council to construct the 345-kV loop in separate phases.

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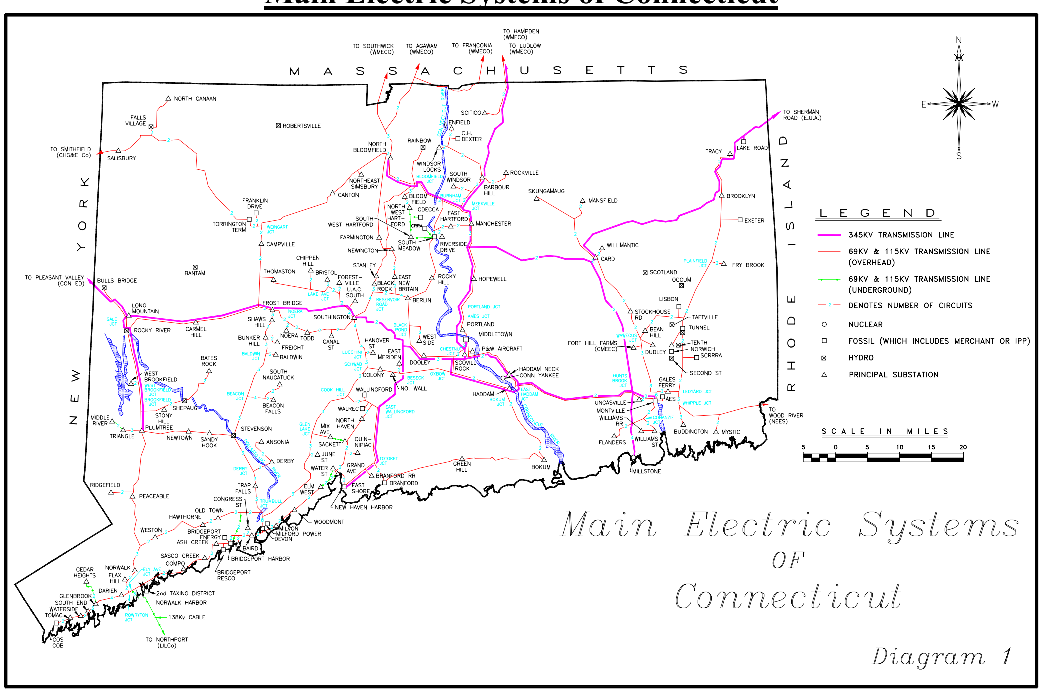
2.0 Electric System Study Area

2.1 Transmission System

The SWCT 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. Multiple overhead and underground 115-kV lines exit these substations and transmit power into the SWCT 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 is relied upon to integrate local generating resources and bring power into the SWCT area. Diagram 1 is a geographical map showing the main electric systems of Connecticut.

Diagram 1
Main Electric Systems of 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.

2.2 Load

The NEPOOL 2003 Capacity, Energy, Load and Transmission (CELT) Report, issued in April 2003, predicts a New England summer peak load (adjusted reference load) of 25,690 MW in 2004 and 27,820 MW in the year 2010. The adjusted New England load forecast contained in the CELT report is based on normal weather and a 50% probability of being exceeded. If the probability of exceeding the forecast peak demand is reduced to 10%, the CELT report forecasts a peak 2004 New England summer demand of 26,300 MW.

It is good utility practice to consider a range of forecasted peak demands in selecting a design basis load level. The design basis peak New England demand level used in this study is 27,700 MW. This is based on the 2003 CELT report that predicts a 2010 peak demand of 27,820 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 2006. Therefore, studying a peak load level of 27,700 MW is reasonable by covering a range of possible weather variations that can influence peak demand levels.

The power flow analyses include testing at a light load level of 11,400 MW to ensure that the adequacy and security of the transmission grid are maintained under a wide-range of operating conditions.

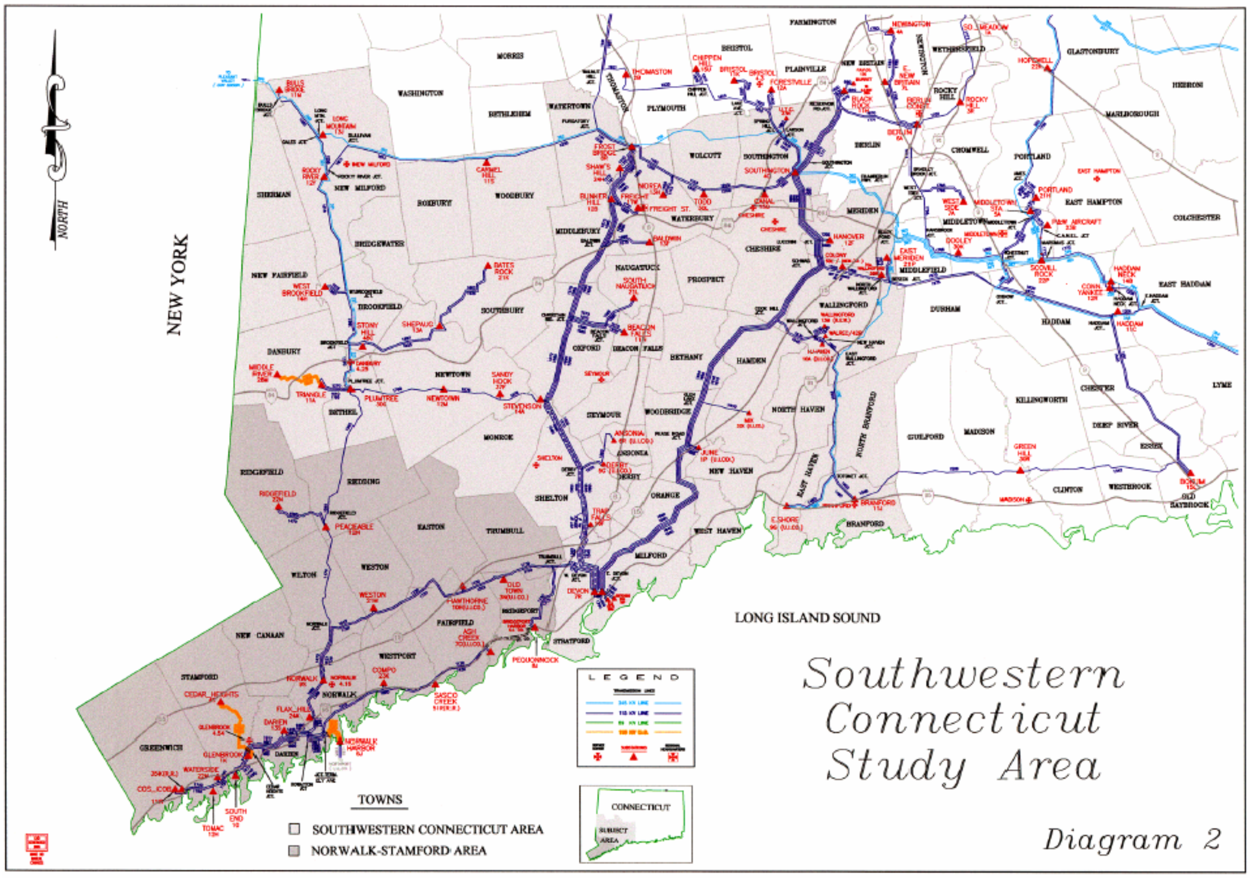
Load distribution modeling at individual substations is based on local metering data. Load power factor levels for all forecasts are modeled at values consistent with local standard design practices.

Southwest Connecticut/Norwalk-Stamford Load

SWCT can be roughly described as the area 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. SWCT is the largest load pocket in New England without 345-kV interregional transmission service capability. The SWCT share of the peak demand exceeds 3,900 MW. Contained within SWCT and farthest away from the bulk 345-kV transmission grid is the Norwalk-Stamford area, with a peak demand in excess of 1,300 MW. These figures assume continuation of the Conservation and Load Management programs by each utility.

Diagram 2 identifies the fifty-four towns in SWCT including the Norwalk-Stamford area, as defined in the 2003 Regional Transmission Expansion Plan (RTEP03).

Diagram 2
Southwest Connecticut Study Area



2.3 Electrical Interfaces

Electrical interfaces are adopted by system operators as tools 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.

Tables 1 and 2 contain a listing of the transmission lines that define the existing SWCT and Norwalk–Stamford electrical interfaces, respectively.

Table 1
Southwest Connecticut Interface

115-kV Frost Bridge - Carmel Hill 1238 line	115-kV Southington – Canal 1950 line
115-kV Frost Bridge – Shaws Hill 1445 line	115-kV Green Hill - Branford 1508 line
115-kV Frost Bridge - Freight 1721 line	115-kV East Shore - Branford RR 1460 line
115-kV Frost Bridge - Baldwin Tap 1990 line	115-kV East Shore - English 8100 line
115-kV Frost Bridge – Noera 1550 line	115-kV East Shore - Grand Ave. 8200 line
115-kV Frost Bridge – Noera Jct. 1163 line	Plumtree 345/115-kV T1 autotransformer
115-kV Southington - Glen Lake Jct. 1610 line	Plumtree 345/115-kV T2 autotransformer
115-kV Southington - Wallingford 1208 line	Southington 115/13.8-kV 5X transformer
115-kV Southington - Lucchini Jct.1690 line	Southington 115/27.6-kV 11X transformer
115-kV Southington – Todd 1910 line	Southington 115/27.6-kV 12X transformer

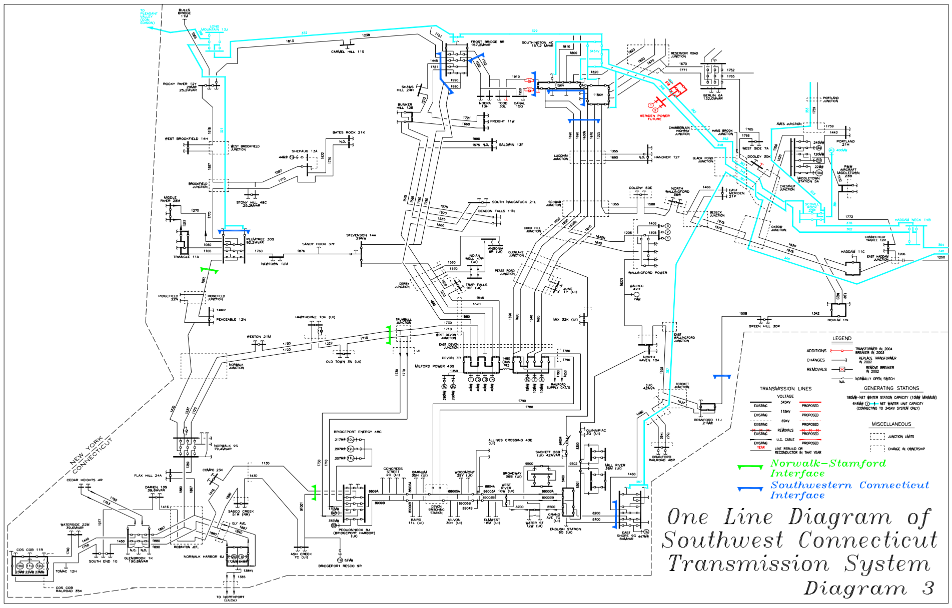
Table 2
Norwalk-Stamford Interface

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 SWCT interface includes the loads at Noera, Todd, Canal, and Southington substations. The December 2002 report excluded these loads from the interface calculation. This report will align the planning and operating interface designations. The case summaries in the appendices list the aggregated flows for both the old planning and operations definitions so that these cases can be compared to previous studies.

Diagram 3 is a one-line diagram of the existing SWCT transmission system.

Diagram 3
One-Line Diagram of Southwest Connecticut Transmission System



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 Connecticut 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 operating within the SWCT area include those in the Norwalk-Stamford area, plus Bridgeport Energy, Bridgeport Harbor, Devon, Wallingford, Rocky River, Shepaug and Stevenson. For this study, new power plants at Meriden and Milford are also assumed available for dispatch. However, financial conditions may prevent the developers/owners from constructing or operating these plants.

Table 3 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 SWCT is to examine the ability of the area to reliably serve customer peak demands under widely varying operating conditions.

Dispatches “Base” and “Light” were used for the analysis in support of 18.4 approval of this project (proof of no adverse impact). Dispatches 2-5 were used to evaluate the need for further improvements in SWCT following the construction of this project by stressing the Norwalk-Stamford and SWCT interfaces from different directions. Disptach 2 stresses the SWCT interface and Norwalk-Stamford interface by transporting most of the power from generation outside of of SWCT. Dispatch 3 stresses the Norwalk-Stamford interface from the east by running heavy generation at Devon and Pequonnock. Dispatch 4 unloads the Norwalk-Stamford and SWCT interfaces by running most generation in these areas. Dispatch 5 evaluates the condition where there is heavy generation at Norwalk, and lighter generation at Devon and Pequonnock.

Table 3
New England Dispatch Scenarios

Generators	Capacity	Dispatch - Base	Dispatch-Light	Dispatch-2	Dispatch-3	Dispatch-4	Dispatch-5
Maine							
MIS	549	0	0	0	0	0	0
AEC	173	158	0	158	158	158	158
RPA	273	0	0	0	0	0	0
Westbrook	565	563	0	563	563	563	563
Wyman	875	241	183	364	351	324	508
New Hampshire							
Newington/s	955	955	0	955	422	422	955
Seabrook	1150	1150	1150	1150	1150	1150	1150
Schiller	146	145	0	146	146	146	146
Merrimack	466	433	320	433	433	113	433
Comerford/Moore	356	272	0	272	272	272	272
AES Londonderry	823	0	0	0	0	0	0
NEMA/Boston							
Mystic	2706	1517	558	1517	1517	1517	1517
Salem Harbor	702	700	0	700	700	700	700
New Boston	760	380	0	380	380	380	380
SEMA/RI							
Milford Power	153	124	0	124	124	124	124
ANP Blackstone	580	580	0	580	290	290	580
ANP Bellingham	580	0	0	0	0	0	0
NEA	301	250	301	250	250	250	250
Ocean State Power	524	339	0	339	339	339	339
Brayton Point	1512	1505	1030	1084	1084	1084	1084
Manchester/FRSQ	495	485	0	485	485	485	485
Hope Energy	545	0	0	0	0	0	0
Sithe Fore River	881	0	855	0	0	0	0
Dighton	185	185	0	185	185	185	185
Tiverton	281	281	281	281	281	281	281
Canal	1143	1142	498	1142	1142	1142	1142
Pilgrim	670	670	670	670	670	670	670
W. Mass/VT							
Vermont Yankee	563	563	530	563	563	563	563
Bear Swamp	588	588	-560	588	294	294	588
Northfield	1080	1080	-1000	1080	1080	1080	1080
Stony Brook	412	412	0	412	412	412	412
Berkshire Power	305	305	0	305	305	305	305
Millennium	390	390	390	390	390	390	390
Connecticut							
Lake Road	840	840	0	840	840	840	840
Millstone	2008	2000	2115	2000	2000	2000	2000
Middletown	771	750	0	750	750	750	750
Montville	489	483	0	483	483	483	483
Meriden	586	0	0	586	586	586	586
Milford	610	280	305	280	560	560	0
Wallingford	255	0	0	0	255	255	0
South Meadow	186	75	75	75	75	75	75
New Haven Harbor	447	447	447	447	447	447	447
Bridgeport Harbor	567	0	375	375	375	375	375
Bridgeport Energy	520	520	0	0	520	520	0
Norwalk Harbor	330	329	168	0	0	329	329
Devon	382	0	0	212	212	212	0
Interfaces	**Limit**						
NB-NE	700	700	702	700	700	700	700
Highgate	225	225	150	225	225	225	225
Phase II	2000	2000	0	2000	2000	2000	2000
ME-NH	1400	288	398	407	395	368	550
NNE-Scobie	2550	1840	1344	1947	1437	1320	2075
North-South	2700	1469	1881	1590	1068	723	1718
East-West	2000	757	665	464	-357	-703	599
NY-NE	±700	-4	11	-8	-8	-8	-7
PV-20	150	110	110	110	110	109	110
Boston Import	3500	2513	1529	2513	2511	2515	2514
SEMA/RI Export	2200	1146	1442	732	443	442	731
Conn. Import	2200	1605	568	1505	-410	-344	1246
SWCT Import	2000	2657	499	3130	2069	1326	2873
Norwalk-Stamford	1100	938	288	1474	1478	735	730
1385 Cable Export	±200	0	0	201	201	-200	-199
481 Cable Export	355	352	347	352	352	352	352

3.0 Study Methodology

3.1 Reliability Standards

The analyses were performed in accordance with the Northeast Power Coordinating Council (NPCC) Document A-2 “Basic Criteria for Design and Operation of Interconnected Power Systems”, and the New England Power Pool (NEPOOL) Planning Procedure No. 3 – “Reliability Standards for the New England Power Pool”.

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 NPCC, and NEPOOL standards and criteria. Transmission reliability standards for Connecticut, developed by CL&P and UI, comply with these recognized regional standards and criteria.

3.2 Design 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 that overall system reliability is maintained.

3.2.1 Power-Flow

New England electric utilities follow a planning philosophy whereby normal thermal ratings shall not be violated under all-lines-in conditions, and the applicable emergency rating shall not be violated under contingency conditions. Table 4 contains the thermal loading performance criteria applied to transmission lines and transformers in this reliability study. The use of long-time emergency (LTE) thermal ratings in planning studies recognizes the limited line switching, re-dispatch and system re-configuration options available to operators. These ratings provide adequate flexibility to system operations to address unique circumstances encountered on a day-to-day basis.

Table 4
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 acceptable 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 5 contains the voltage performance criteria used in these analyses.

Table 5
Voltage Performance Criteria

Voltage Level	Bus Voltage Limits	
	Normal Conditions	Emergency Conditions
> 115 kV	95 to 105% of nominal	95 to 105% of nominal
≤ 115 kV	95 to 105% of nominal	90 to 105% of nominal
Millstone 345 kV	100 to 105% of nominal	100 to 105% of nominal

3.2.3 Short Circuit

Electric utilities address safety concerns and ensure reliable system performance by restricting fault duties imposed on circuit breakers and other equipment. Circuit breakers shall not be subjected to currents in excess of 100% of the de-rated interrupting capability prescribed in ANSI standards that account for the X/R ratio, automatic reclosing and expected normal operating voltages. Substation ground grids, bus, 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 thermal/voltage 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 equipment 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 to be 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 SWCT redistribute over the remaining transmission lines. The remaining transmission facilities must demonstrate the capability to supply local area load and remain within the thermal loading and voltage performance criteria stated above, 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 circuit, double circuit, autotransformer, malfunctioning circuit breaker and generator contingencies.

4.0 Study Results

The Plumtree – Norwalk 345-kV project was tested in accordance with the NEPOOL planning procedures. Power flow analyses were conducted at load levels representing peak and light load periods. Testing also included sensitivities involving New England to New York transfers, the

138-kV Norwalk Harbor – Northport 1385 line, the Kleen Energy merchant generating station addition, the Haddam autotransformer with associated projects and the Cross Sound Cable. In addition, short circuit analyses were conducted with all facilities in service. These analyses are required to show that the proposed project will operate reliably under reasonable system conditions.

4.1 Project Description

The December 2002, "Southwestern Connecticut Electric Reliability Study" identified numerous thermal overload, voltage violation and voltage collapse scenarios which exist with today's transmission system. The report proposed that a 345 kV "loop" be constructed to fully integrate SWCT and the Norwalk–Stamford area into the New England 345-kV network and alleviate reliability problems. The first phase of the overall 345-kV "loop" is to construct a 345-kV line between the Plumtree and Norwalk substations as well as other associated facilities. Appendix B contains the electrical characteristics of the project described as follows:

- **Build a 345-kV line from Plumtree Substation to Norwalk Substation.**
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- **Replace 115-kV Circuit Breakers at the Norwalk Harbor Substation.**
  Replace the existing 115-kV 3T, 5T and 6T circuit breakers at Norwalk Harbor Substation with new circuit breakers with an interrupting capability of 63 kA.

- **Replace the limiting terminal equipment at the Southington and Millstone 345-kV substations.**
  Upgrade the limiting terminal equipment on the Southington to Millstone (348) line so that the conductor rating becomes the limiting element.

4.2 Peak (100%) Load Dispatch Analysis

This analysis compares the performance of the transmission system with and without the proposed project. Dispatch "Base" is used for peak load testing to support this 18.4 application. Appendix C contains base case summaries and power flow plots used in this analysis at a New England load level of 27,700 MW. The base case generation dispatch scenario includes both Norwalk Harbor units on-line. This positions the system so that under pre-contingency conditions, without the project, 115-kV transmission line loadings are below normal ratings and most post-contingency power flows are less than emergency ratings. This dispatch was considered to be the optimal dispatch for the pre-project conditions, where interfaces were stressed to the extent possible and shutting off more units would create additional overloads. This same "Base" dispatch was used to analyze the post-project condition so that a comparison of the impact of this project could be drawn. Appendix D contains the post-project base case summaries and plots.

Appendix E contains a summary of the post-contingency ACCC results with the project in-service compared to the pre-project results. (Appendicies J and K contain the pre- and post-project ACCC output, respectively.) In these analyses both 345-kV and 115-kV outages caused post-contingency thermal overload conditions. Most post-project analyses show a decrease or an insignificant increase (< 1%) in post-contingency power flows. A 15% reduction in post-contingency power flow occurs on the 115-kV transmission path from the Frost Bridge Substation to the Stevenson Substation. A 20% reduction occurs on the transmission path from Stevenson to Plumtree. This is indicative of the power injection by the 345-kV system into the Norwalk - Stamford area. The project relieves power transfers on 115-kV transmission lines feeding into the load pocket from the Frost Bridge, Southington and East Shore substations.

Two contingencies showed post-project increases in power flow on existing 115-kV facilities relative to pre-project conditions. The 1867 and 1880 double circuit tower contingency resulted in a 4.5% increase in the thermal overload on the Glenbrook to Ely Avenue 1890 line. The 1880 and 1890 double circuit tower contingency resulted in a 20% increase in the thermal overload on the Glenbrook to Rowayton Junction 1867 line. Mitigation of these overloads is required and is discussed in detail in the following section.

In addition, there are contingencies where a mathematical solution was not obtained. These were the same for both the pre and post-project cases. Computer models predict the potential for an SWCT voltage collapse and widespread outages of customer load (i.e., blackout). These specific contingency results are also listed in Appendix E.

4.2.1 Glenbrook Special Protection System

The extension of the 345-kV system from Plumtree to Norwalk strengthens the electric system in this area causing the desired increase in power flow in this direction. The local 115-kV transmission system serving the Stamford area from Norwalk may exceed emergency ratings during periods of high demand following the outage of two 115-kV transmission circuits on a common structure. The Glenbrook SPS is proposed to address these overloads.

SPS Triggering and Arming – The proposed SPS would be armed 100% of the time and triggered by power flows on the 115-kV Glenbrook – Ely Avenue 1890 line and the 115-kV Glenbrook – Rowayton Junction 1867 line. The SPS will trigger on local sensing of power flows above LTE ratings and the outage of the 1867/1880 lines or the 1880/1890 lines, respectively. Operation of the SPS will result in tripping the 1753 – 1K and 1792 – 1K circuit breakers that isolate the Cedar Heights substation load. An additional 25 MW of load isolation at Glenbrook is required to reduce power flows below emergency ratings. Designated distribution feeders associated with the under-frequency load shedding program shall also be targeted by the SPS. At the 27,700 MW load level, this is a total of approximately 98 MW of load which would be isolated.

Inadvertent SPS Operation – The inadvertent operation of the SPS will result in load isolation at both the Cedar Heights and Glenbrook substations. This will cause no adverse impacts to the New England interconnected bulk power system.

Failure of the SPS to Operate – Failure of the SPS to operate during stressed system conditions could result in sustained overloads on the monitored 115-kV lines following the outages of transmission lines serving the Glenbrook Substation. Manual isolation of substation loads in the event of a failure of the SPS to operate may be initiated to alleviate overloads. In the event that manual actions were not taken, cascading overloads would isolate the system from Glenbrook to the west. The impact would be limited to the Norwalk-Stamford area.

NPCC SPS Type III – No inter-Area impact results for either failure of the SPS to operate when required or from inadvertent operation. Therefore, based on this conclusion this SPS will be a NPCC Type III SPS.

4.3 Short Circuit Analysis

Recent system impact studies for merchant generation projects have verified that short circuit currents in SWCT are very close to existing 115-kV circuit breaker and other equipment capabilities. Several over-dutied 115-kV circuit breakers have already been replaced and others are scheduled for replacement. In general a balance must be maintained between generators connected to the 115-kV system and those on the 345-kV system.

Short circuit duties at the 115-kV Pequonnock Substation are critically close to the existing equipment ratings. Due to physical site limitations, replacement of the existing 63 kA breakers and other station equipment at this location is not possible.

Appendix F contains the results of single-phase and three-phase short circuit analyses performed on the pre and post-project transmission system. Due to the lower impedance path of the 345-kV system additions, the short circuit levels at Pequonnock exceed the existing 115-kV circuit breaker and station equipment capabilities. Installing a 115-kV 3% series reactor in the Bridgeport Harbor 2 generator lead reduces short circuit currents into the Pequonnock 115-kV Substation to below circuit breaker and station equipment capabilities. In addition, the 3T, 5T, and 6T circuit breakers at Norwalk Harbor need to be replaced with new circuit breakers with an interrupting capability of 63 kA.

4.4 Light (40%) Load Level

Appendix E contains summaries of the post-contingency ACCC results of thermal and voltage analyses. Dispatch scenario “Light” was tested at a light load level of approximately 11,500 MW. Dispatch “Light” was designed to lightly load transmission lines and monitor for high voltages. The results show that there are no reportable overloads or voltage limit violations on 115-kV and 345-kV facilities in SWCT for this load level.

4.5 Voltage Analysis

Transmission planning standards limit depressions on the 115-kV system to 90% of nominal voltage. Some post-contingency voltage violations in the SWCT area are unacceptable and may cause widespread outages that may cascade into neighboring areas. However, the addition of this project reduced the number of low voltage violations when compared to the pre-project system. Appendix E contains a listing of voltage conditions that violate design criteria.

4.6 SWCT and Norwalk-Stamford Transfer Sensitivity

Power Technologies' Managing and Utilizing System Transmission (MUST) program was used for this analysis and results were confirmed using AC analysis in PSS/E. A variety of generation patterns and system transfers were simulated with its linear FCITC (First Contingency Incremental Transfer Capability) calculation feature, which uses DC analysis. The transfer capability of the pre-project system was compared to that of the post project system. Double circuit and 115 kV stuck breaker contingencies were excluded from this analysis and LTE ratings were respected.

Eight (8) power flow cases were set up for pre- and post-project simulations (utilizing the same case, "Base", as was used for the thermal / voltage analysis). Each case was a dispatch sensitivity based on various combinations of the Milford, Bridgeport Energy, and Wallingford plants. System performance based upon generation dispatched at Devon and Bridgeport Harbor is equivalent to generation dispatched at Milford and Bridgeport Energy, respectively.

Units in Maine were chosen as source generators for both the SWCT and the Norwalk-Stamford transfer analyses since these were outside the area of interest and would not affect the results. For the SWCT transfer analysis, Bridgeport Harbor units 2 and 3 were chosen as sink generators (units where the output was reduced); for the Norwalk-Stamford transfer analysis, Norwalk Harbor units 1 and 2 were used.

Appendix G contains a summary chart, MUST transfer tables, and ACCC listings. The results show that the project provides an increase of up to 200 MW of thermal transfer capability into Norwalk-Stamford independent of the status of the Norwalk Harbor generation. This increase is based on an average transfer capability of 1100 MW pre-project and 1300 MW post-project.

The project also provides an increase of up to 175 MW of thermal transfer capability into SWCT at the same Norwalk Harbor generation level (142 MW). This increase is based on an average transfer capability of 2400 MW pre-project and 2575 MW post-project. In addition, with the project in service, today's SWCT transfer limit of 2400 MW can be maintained even when the Norwalk Harbor units are out of service.

This transfer analysis demonstrates that the project provides a significant increase in transfer capability across the SWCT and Norwalk-Stamford interfaces.

4.7 New York – New England Transfer Sensitivity

Parallel transfer analysis was run using MUST to determine the relationship between SWCT import and NY-NE transfer for pre- and post-project systems. The baseline system included 2% reactors at Todd and Canal and an upgraded 318/362 345-kV line terminal at Southington. Appendix G contains the results of these analyses.

The SWCT transfer analysis used Bridgeport Harbor units 2 and 3 as sink generators with source generators located in Maine. The NY-NE transfer analysis used generation in northwestern New York against generation in Southeast Massachusetts and Rhode Island (SEMA/RI).

In the New England to New York cases, it was determined that the project creates a minor limitation between the 600 and 1000 MW export level. Increasing the Canal and Todd reactors from 2% to 3% and upgrading the terminals of the Southington-Millstone 348 line removes this limitation. Appendix G indicates that, with these upgrades, the project improves the New England to New York transfer capability.

In the New York to New England cases, the project decreases transfer capability by up to 1000 MW. The reduced impedance from the Long Mountain area down to Norwalk (due to the project) tends to increase the pre-contingency loading on this 345-kV corridor as opposed to the 115-kV lines coming from the east and northeast into SWCT. The Long Mountain 5T stuck breaker contingency, which takes out both the 321 and 398 lines, causes overloads on the Norwalk Harbor to Rowayton Junction lines and the Norwalk Harbor autotransformer. Installing a 345-kV breaker between the 4T and 8T and re-terminating the 398 line at Long Mountain Substation eliminates the possibility of this contingency occurring. Appendix G indicates that, with these upgrades, the project improves the New York to New England transfer capability. The project also reduces the loading on the next limiting facility in NY further increasing the transfer capability.

4.8 Cross Sound Cable Sensitivity

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 underwater 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 assumes a 330-MW import into Connecticut from New York. To accommodate the import from the CSC, New Haven Harbor was turned off and Middletown 4 was reduced to 170 MW. Appendix E contains a summary of post-contingency ACCC results of thermal and voltage analyses. Dispatch scenario "Base" was 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. There are no additional overloads or voltage limit violations on 345-kV or 115-kV facilities in SWCT, as a result of the project, which have not been previously discussed in Section 4.2.

4.9 Long Island 1385 Cable Sensitivity

The 138-kV Norwalk Harbor – Northport, NY 1385 underwater cable has recently experienced several interruptions. Mechanical breach of its protective sheathing has resulted in insulating fluid leaking into the Long Island Sound. NU has been notified by the Connecticut Department of Environmental Protection (DEP) to prevent further insulating fluid leaks into the Sound. The DEP has ordered NU to either replace the cable with new solid dielectric cables or remove it all together. This sensitivity analysis assumes the permanent removal (with no replacement) of the existing 1385 cable. This is different from the "Base" in that contingencies with the 1385 cable in service, even at 0 MW, allow for a pickup of power from Long Island into Norwalk Harbor. When the cable is removed from service, no such pickup occurs. Appendix E contains a summary of post-contingency ACCC results of thermal and voltage analyses. Dispatch scenario "Base" was tested at the peak load level (27,700 MW). There are no additional overloads or voltage limit violations on 345-kV or 115-kV facilities in SWCT, as a result of the project, which have not been previously discussed in Section 4.2.

4.10 Kleen Energy Sensitivity

Kleen Energy Systems, LLC is a proposed gas-fired combined cycle plant located in the Middletown area. The plant will interconnect to the 345-kV Scovill Rock - Manchester 353 line. The plant consists of two 250 MVA combustion units and a single 358 MVA steam turbine unit. The net rating of the plant is approximately 620 MW. The proposed in-service date is March 2005. Appendix E contains a summary of post-contingency ACCC results of thermal and voltage analyses. Dispatch scenario "Base" was tested at the peak load level (27,700 MW) with Kleen placed in service and Middletown 3 and 4 removed from service . There are no additional overloads or voltage limit violations on 345-kV or 115-kV facilities in SWCT, as a result of the project, which have not been previously discussed in Section 4.2.

5.0 System Plan Analysis

Appendix H contains base case summaries and plots for dispatch scenarios 2, 3, 4, and 5 with the project in service. These dispatch scenarios are tested to analyze the impact of the project on the overall SWCT transmission system.

5.1 Peak (100%) Load Level

Appendix I contains summaries of the post-contingency ACCC results of thermal and voltage analyses. (Appendix L contains the post-project ACCC output.) Dispatch scenarios 2, 3, 4 and 5 are only tested at the peak load level (27,700 MW). These results indicate that while system performance has improved, thermal overloads and voltage violations continue to exist following construction of the project. These reliability violations will be addressed in subsequent 18.4 applications.

6.0 Conclusion

The SWCT electric power system does not meet regional reliability performance standards. This reliability study proposes the first phase of a comprehensive system plan that provides a long-term solution for the SWCT area. A summary of the project is as follows:

- Build a 345-kV line from Plumtree Substation to Norwalk Substation.
- Expand the 345-kV substation at Plumtree.
- Build a 345-kV substation at Norwalk

- Rebuild the 115-kV line from Plumtree Substation to Norwalk Substation.

- Modify Bridgeport Harbor 2 generator interconnection at the Pequonnock Substation.

- Install 115-kV series reactors at the Southington Substation in the 1910 and 1950 lines.

- Install an additional 345-kV circuit breaker at the Long Mountain Substation.

- Install Special Protection System (SPS) at the Glenbrook Substation.

- Replace 115-kV Circuit Breakers at the Norwalk Harbor Substation.

- Replace the limiting terminal equipment at the Southington and Millstone 345-kV substations.

The proposed project demonstrates the following regional system benefits:

- Injects high voltage power regulation into the center of a critical load pocket relieving power flows on 115-kV transmission paths into and within SWCT and Norwalk-Stamford areas.
- Improves area voltage profiles in the vicinity of Plumtree and Norwalk for post-contingency system conditions.
- Decreases short circuit currents in the vicinity of the 115-kV Pequonnock Substation.
- Increases the SWCT and Norwalk–Stamford transfer limits.

Based on these study results, this project will not have a significant adverse impact on the reliability or operability of the New England electric power system. However, as discussed in Section 5.1, further upgrades must be pursued in SWCT to resolve all of the reliability concerns in the area. These will be addressed in future 18.4 applications.