middletown | norwalk

January 30, 2004

VIA HAND DELIVERY

Mr. S. Derek Phelps
Executive Director
Connecticut Siting Council
10 Franklin Square
New Britain, CT 06051

Re: Docket No. 272: The Connecticut Light and Power Company and The United Illuminating Company Application for a Certificate of Environmental Compatibility and Public Need for the construction of a new 345-kV electric transmission line and associated facilities between the Scovill Rock Switching Station in Middletown and the Norwalk Substation in Norwalk, including the reconstruction of portions of existing 115-kV and 345-kV electric transmission lines, the construction of Beseck Switching Station in Wallingford, East Devon Substation in Milford, and Singer Substation in Bridgeport, modifications at Scovill Rock Switching Station and Norwalk Substation, and the reconfiguration of certain interconnections

Dear Mr. Phelps:

Enclosed are an original and 15 copies of Addendum #2 to the December 16, 2003 Supplemental Filing by The Connecticut Light and Power Company and The United Illuminating Company pursuant to Section VIII(Q) of the Council's Application Guides for Terrestrial Electric Transmission Line Facilities dated September 9, 2003. Due to their size, the four study appendices will be sent individually via e-mail to the Siting Council.

Very truly yours,

Anne Bartosewicz, Project Director
The Connecticut Light & Power Company

John J. Prete, Project Director
The United Illuminating Company

Enclosure

cc: Service List

Connecticut Light & Power
The Northeast Utilities System

The United Illuminating Company

SERVICE LIST
Docket: 272

Ms. Pamela B. Katz
Chairman
Connecticut Siting Council
10 Franklin Square
New Britain, CT 06051

Mr. Bruce Johnson
Office of Consumer Counsel
10 Franklin Square
New Britain, CT 06051

Atty. Anthony M. Fitzgerald
Carmody & Torrance
195 Church Street, 18th Fl.
P. O. Box 1950
New Haven, CT 06509-1950

Atty. Brian T. Henebry
Carmody & Torrance
50 Leavenworth Street
P. O. Box 1110
Waterbury, CT 06721-1110

Atty. Linda L. Randell
Wiggin and Dana
One Century Tower-P.O. Box 1832
New Haven, CT 06510

Atty. Bruce L. McDermott
Wiggin & Dana LLP
One Century Tower
New Haven, CT 06508-1832

Atty. Peter G. Boucher
Halloran and Sage
One Goodwin Sq., 225 Asylum
Hartford, CT 06103-4303

The Honorable Robert W. Megna
State Representative
40 Foxon Hill Rd. #54
New Haven, CT 06513

The Honorable Al Adinolfi
State Representative
235 Sorghum Mill Dr.
Cheshire, CT 06410

Ms. MaryAnn Boord
First Selectwoman
Durham Town Hall
30 Townhouse Rd.
Durham, CT 06422

Atty. Janice Small
Town Attorney
Wallingford Town Hall
45 South Main Street
Wallingford, CT 06492

Mr. Louis S. Ciccarello
Corporation Counsel
City of Norwalk
P. O. Box 798
Norwalk, CT 06856-0798

Mr. Eric Knapp
Branse & Willis LLC
41-C New London Turnpike
Glen Lochen East
Glastonbury, CT 06033-2038

Atty. Ira W. Bloom
Town of Westport
27 Imperial Ave.
Westport, CT 06880

Ms. Leigh Grant
Norwalk Assoc. of Silvermine
Homeowners
99 Comstock Hill Road
Norwalk, CT 06850

Atty. Julie Donaldson Kohler
Hurwitz & Sagarin LLC
147 North Broad St.
Milford, CT 06460

The Honorable Mary G. Fritz
State Rep. - 90th District
43 Grove St.
Yalesville, CT 06492

Ms. Melanie J. Howlett
Assistant City Attorney
City of Bridgeport
999 Broad Street
Bridgeport, CT 06604

Ms. Trish Bradley
Mr. Ed Schwartz
Communities for Responsible Energy, Phase II
45 Ironwood Lane
Durham, CT 06422

Atty. Michael C. Wertheimer
Office of the Attorney General
Ten Franklin Square
New Britain, CT 06051

Deborah Moore, Esq.
Meriden City Hall
142 East Main St.
Meriden, CT 06450

Atty. Lawrence J. Golden
Pullman & Comley LLC
90 State House Square
Hartford, CT 06103-3702

The Honorable John E. Stripp
State Representative - 135th District
4 Scatacook Trail
Weston, CT 06883

Mr. Anthony M. MacLeod
Whitman Breed Abbott & Morgan
P. O. Box 2250
Greenwich, CT 06836

Mr. Arthur W. Gruhn
Department of Transportation
P.O. Box 317546
Newington, CT Connecticut 06131-7546

The Honorable Raymond Kalinowski
State Rep. - 100th District
P.O. Box 391
Durham, CT 06422

The Honorable Kenneth A. Flatto
First Selectman
725 Old Post Rd.
Fairfield, CT 06824

Mr. Harold W. Borden
Vice President & General Counsel
PSEG Power LLC
80 Park Plaza
Newark, NJ 07102

The Honorable Themis Klarides
State Representative-114th District
23 East St.
Derby, CT 06418

Andrew W. Lord
Murtha Cullina LLP
CityPlace I, 29th Floor
185 Asylum Street
Hartford, CT 06103-3469

Mitchell R. Goldblatt, First Selectman
Town of Orange
617 Orange Center Road
Orange, CT 06477-2499

David A. Ball, Esq.
Cohen & Wolf, P.C.
1115 Broad Street
Bridgeport, CT 06604

Monte E. Frank, Esq.
Cohen & Wolf, P.C.
158 Deer Hill Avenue
Danbury, CT 06810

Robert E. Earley
Connecticut Business & Industry Assoc.
350 Church Street
Hartford, CT 06103-1106

Atty. Joaquina Borges King
Assistant Town Attorney
Hamden Government Center
2700 Dixwell Avenue
Hamden, CT 06518

Atty. Richard J. Buturla
Bercham, Moses & Devlin
75 Broad Street
Milford, CT 06460

STATE OF CONNECTICUT

SITING COUNCIL

Re:	The Connecticut Light and Power Company and The United Illuminating Company Application for a Certificate of Environmental Compatibility and Public Need for the Construction of a New 345-kV Electric Transmission Line and Associated Facilities Between Scovill Rock Switching Station in Middletown and Norwalk Substation in Norwalk, Connecticut Including the Reconstruction of Portions of Existing 115-kV and 345-kV Electric Transmission Lines, the Construction of the Beseck Switching Station in Wallingford, East Devon Substation in Milford, and Singer Substation in Bridgeport, Modifications at Scovill Rock Switching Station and Norwalk Substation and the Reconfiguration of Certain Interconnections	)	Docket 272 January 30, 2004

ADDENDUM # 2 TO
SUPPLEMENTAL FILING

The Connecticut Light and Power Company ("CL&P") and The United Illuminating Company ("UI") (together, the "Companies") submit this addendum to their Supplemental Filing to the Connecticut Siting Council ("Council") dated December 16, 2003. This submission is made pursuant to Section VIII (Q) of the Council's Application Guides for Terrestrial Electric Transmission Line Facilities, which provides that "the Applicant[s] shall provide supplemental information for the Council to make a reasonable comparison between the Applicant [s'] proposed route and any reasonable alternative route recommended by the site municipalities pursuant to C.G.S. section 16-50l."

In Part 5 of their December 16, 2003 filing, the Companies advised that certain thermal load flow studies relating to the possible use of the existing 387 line between Scovill Rock

Switching Station in Middletown and East Shore Substation in New Haven as a component of the SWCT 345-kV loop had been commissioned from PowerGEM with respect to the "East Shore Alternative." These studies have been completed for system conditions representing NY-NE flows of 0 MW. A hardcopy of the text of each of the completed studies, the full titles of which are set forth in Footnote 1 on page 3, is attached. The study appendices will be provided to the Council and the service list via e-mail.

When the system was modeled with the East Shore Alternative with the same dispatch assumptions used in the previous ISO-NE Southwest Connecticut Working Group (SCWG) load flow studies, the 387 line was nearly overloaded under normal conditions and was overloaded post-contingency. With New Haven Harbor Station (NHHS) out of service, the 387 line was overloaded under normal conditions and its post-contingency overloading was exacerbated. These results indicate that the capacity of the existing 387 line would be inadequate for it to serve as a segment of a SWCT 345-kV loop. In addition, in the studies assuming NHHS to be out of service, other portions of the Connecticut 345-kV transmission system, specifically in the vicinity of the Southington and Frost Bridge substations, were overloaded post-contingency.

PowerGEM also modeled an upgraded 387 line, by assuming that the 2156 ACSR conductor between Black Pond Junction in Meriden and Scovill Rock Switching Station in Middletown (approximately 10 miles) was replaced with the larger capacity 2-954 ACSR bundled conductors that are already present on the remainder of the line. This replacement would upgrade the capacity of the entire 387 line. The studies were repeated, assuming the upgraded line, with NHHS both in and out of service. Even with this upgrade, the 387 line and

other portions of the 345-kV system exhibited post-contingency overloads. The load flow results of these studies, as they relate to the 387 line only, are summarized in the following table:

387 Line Summary Results

	Existing 387 Line		Reconductored 387 Line	
	NHHS On[1]	NHHS Off[2]	NHHS On[3]	NHHS Off[4]
Pre-Contingency (% of normal rating)	98	117	84	101
Post-Contingency (% of emergency rating)	106	125	-	107

Complete results are displayed in the attached reports.

The Companies are investigating whether the 387 line transmission structures could support conductors with a capacity larger than 2-954 ACSR, and if so, how that would affect the thermal load flow results of these studies. In the meantime, PowerGEM has also been

[1] Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-1, Revised January 28, 2004. This study is included as Attachment 1 and is a slightly revised version of the December 31, 2003 PowerGEM study provided on January 5, 2004 with Supplemental Filing - Addendum 1.

[2] Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, with New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-2 dated January 28, 2004. This study is included as Attachment 2.

[3] Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-3 dated January 28, 2004. This study is included as Attachment 3.

[4] Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-4 dated January 28, 2004. This study is included as Attachment 4.

commissioned to perform additional studies to evaluate the effect of varying transfers between New York and New England. Once these analyses are completed, the ISO-NE SWCT Working Group will provide a comparative document, which compares the results of the M-N project with the East Shore alternative. The results and the Working Group document are expected to be completed by February 20, 2004.

Attachment 1

Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-1, Revised January 28, 2004

PowerGEM

Power Grid Engineering & Markets

Southwest Connecticut Transmission Expansion

East Shore to Norwalk 345 KV OH/UG Alternative :

Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station On-Line, NE-NY 0 MW

Prepared for:

The United Illuminating Company

and

Northeast Utilities

Prepared by:

Johnny R. Willis
PowerGEM
jwillis@power-gem.com

PowerGEM Report 10021.001-1, Revised
January 28, 2004

Executive Summary

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[1] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

The objective of this study is to analyze and document the performance of this transmission configuration for steady-state base case and post-contingency transmission power flows and voltages. Power flow analysis was conducted for a 27.7 GW New England load level for four southwest Connecticut generation dispatches. Loading and voltage performance of the Connecticut system was monitored for the 115 kV and 345 kV transmission systems. In all cases, the New Haven Harbor Station (447 MW), which has a significant impact on the flows on the 387 line, was in service.

The loading analysis found that one 345 kV transmission line (East Shore to Scovill Rock), twenty-three 115 kV transmission lines and one 345/115 kV autotransformer at Southington exhibited post-contingency overloads. Two of the overloaded 115 kV lines were also overloaded in the base case (all lines in) for some generation dispatches.

Voltage analysis indicated violations of voltage criteria for nine Connecticut 115 kV substations.

[1] A planned 345 kV transmission expansion from the Plumtree to Norwalk substations, which is called Bethel to Norwalk, is assumed to be in-service in this analysis.

1. Introduction

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[2] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

The objective of this study is to analyze and document the performance of this transmission configuration for steady-state base case and post-contingency transmission power flows and voltages. Performance is examined for a 27.7 GW New England load level and for four dispatches of New England generation. In all cases, the New Haven Harbor Station (447 MW), which has a significant impact on the flows on the 387 line, was in service. References 1 thru 3 are companion reports for other system conditions studied.

The following Appendices are included in this report:

Appendix A "East Shore 27-OH/UG" Transmission Modeling Data
Appendix B Power Flow Base Case One-Line Diagrams
Appendix C Contingency File
Appendix D Generation Dispatches
Appendix E Summary of Overloads
Appendix F Summary of Voltage Violations

[2] A planned 345 kV transmission expansion from Plumtree to Norwalk substations, which is called Bethel to Norwalk, is assumed to be in-service in this analysis.

2. Database

This section discusses the data developed and used in the study.

2.1. Power Flow Base Cases

Four power flow base cases, which included the approved Bethel to Norwalk 345-kV project in service, were utilized. PowerGEM revised each of the four cases to add the "East Shore 27-OH/UG" transmission project. Details regarding the modeling of these circuits are provided in Appendix A. In addition to this, the rating of the East Shore to Scovill Rock 345 kV line was increased to reflect the line rating by reconfiguring the East Shore Substation and removing the 345/115 kV autotransformers from the 387 line path. The line ratings used were 1240 MVA normal and 1604 MVA long-time emergency.

Each of the four base cases provided had different generation dispatches, and are denoted dispatches 2B, 3B, 4B, and 5B. These dispatches were preserved for the base cases. Appendix D contains a list of the on-line generation for dispatch 2B, and the differences in dispatches 3B, 4B, and 5B as compared for dispatch 2B. Significant changes to dispatch for the four cases were restricted to New England generation.

A one-line diagram showing power flows and voltages on the "East Shore 27-OH/UG" (and Bethel to Norwalk) transmission for each of the four base cases is included in Appendix B.

2.2. Contingency File

A contingency file was modified as appropriate for this study, and is contained in Appendix C.

- Loss of multiple 345 kV underground cables on the "East Shore 27-OH/UG" configuration between Orange and East Shore, or loss of parallel cables between Devon and Norwalk, is not considered. (Simultaneous loss of one cable from Devon to Singer and Singer to Norwalk is included as a contingency).

- For loss of the Orange to East Devon 345 kV overhead line, all three 345 kV underground cables from Orange to East Shore were opened.

3. Methodology and Results Files

This section describes the technical approach to the study, performance criteria, solution assumptions, and the format of the results.

3.1. Software

Set up of the power flow base cases used PTI's PSS/E software (Rev. 28). Base case and contingency analysis was conducted using PTI's MUST software (Rev. 5). Results from the MUST program are stored in Excel spreadsheets.

3.2. Performance Criteria

The criteria for checking overload and voltage performance were as follows:

- Buses and transmission branches in Connecticut 115 kV and above were monitored.
- For base case loading performance, transmission lines and transformers were checked against 100% of their normal ratings.
- For post-contingency loading performance, overloads of transmission lines and transformers were checked against 100% of the long-time emergency ratings.
- Buses 230 kV and above were checked for voltages less than 95% and greater than 105%. Buses in the 115 kV system were checked for voltages less than 90% and more than 105%.

3.3. Solution Options

For the analysis, tap-changing transformer and phase-shifting transformer adjustments were held fixed. For contingencies involving loss of generation/load the imbalance was made up by the system swing generator located outside New England.

4. Results

The results of the analysis for transmission system loading and voltage violations are provided below.

4.1. Overload Results

A summary of the overload results is shown in Table 1. The values shown are the percentage overload over the long-time emergency rating. If a table entry is blank, there is no overload. More detailed results are provided in Appendix E.

Any transmission line or transformer in the study area at 115 kV or above that experiences a post-contingency overload in this study is listed in the first column of Table 1. The remaining four columns, one for each of the four Connecticut generation dispatches studied, show the **maximum overload of the branch in %** (considering all contingencies) for each dispatch. The overloads are color-coded as indicated at the top of the table in order to make the relative severity of the overloads more apparent. If a Table 1 entry is blank, then the branch is not overloaded for that dispatch. To find more detail, for example which contingency causes the overload, and whether other contingencies could overload the branch, the reader should refer to Appendix E.

As shown in Table 1, one 345 kV transmission line, East Shore to Scovill Rock, experiences a post-contingency overload of 5%-6% for dispatches 2B and 5B. (The causes of the overloads are stuck breaker contingencies at Southington, as may be found in Appendix E). Loading on the 387 line for base case conditions is summarized in the following table. One-lines showing the flows on this line for each case are in Appendix B.

Generation Dispatch ID	387 Line Base Case Loading (% normal rating)
2B	98%
3B	69%
4B	53%
5B	96%

A 345/115 kV autotransformer at Southington also overloads from 7% to 21%, depending on dispatch. The contingency causing the overload is a stuck breaker contingency at Southington (see Appendix E).

Finally, there are twenty-three 115 kV line overloads that vary widely from slight overloads to severe overloads. Some overloads are sensitive to generation dispatch, while others are not. Two branches are overloaded in the base case, as indicated by the shaded branch names. These base case overloads are significant, in the 10% - 20% range.

Table 1

Highest Overload: 27.7 GW NE Load, Dispatches 2B, 3B, 4B and 5B

	OverLoad >= 30%
	10% < Over Load < 30%
	5% < Over Load < 10%
	OverLoad < 5%

From bus	To bus	CKT	Generation Dispatch ID 2B	3B	4B	5B
73106 SOUTHGTN 345	73154 SGTN B 115	2	19.4	10.8	6.7	21.1
73107 SCOVL RK 345	73663 E.SHORE 345	1	6.0			5.2
73162 WATERSDE 115	73163 COS COB 115	1	24.8	24.8	24.8	24.8
73162 WATERSDE 115	73168 GLNBROOK 115	1	2.5	2.5	2.5	2.5
73167 SO.END 115	73294 GLNBRK J 115	1	23.2	23.2	23.2	23.2
73168 GLNBROOK 115	73169 RYTN J A 115	1				1.8
73168 GLNBROOK 115	73237 ELYAVE 115	1			51.0	53.9
73168 GLNBROOK 115	73271 RYTN J B 115	1	19.2	15.8	38.1	46.5
73169 RYTN J A 115	73171 NWLK HAR 115	1			44.4	44.3
73169 RYTN J A 115	73172 NORWALK 115	1	80.8	75.2		
73170 PLUMTREE 115	73176 TRIANGLE 115	1	77.4	74.7	72.9	75.5
73170 PLUMTREE 115	73176 TRIANGLE 115	2	35.2	34.9	34.7	34.9
73170 PLUMTREE 115	73268 MIDDLRIV 115	1	184.3	183.5	183.0	183.6
73171 NWLK HAR 115	73237 ELYAVE 115	1			50.2	58.4
73171 NWLK HAR 115	73271 RYTN J B 115	1			4.3	4.3
73172 NORWALK 115	73207 FLAX HIL 115	1	95.3	89.7		
73183 SHAWSHIL 115	73185 BUNKER H 115	1	4.2			4.3
73188 BCNFL PF 115	73192 DRBY J B 115	1	29.9	27.6	26.5	32.1
73207 FLAX HIL 115	73271 RYTN J B 115	1	77.9	72.2		
73224 TRMB J A 115	73700 PEQUONIC 115	1			1.7	
73230 HADDAM 115	73231 BOKUM 115	1	9.3			9.2
73268 MIDDLRIV 115	73176 TRIANGLE 115	1	123.2	122.6	122.1	122.7
73669 GRAND AV 115	73681 WEST RIV 115	1				1.7
73669 GRAND AV 115	73681 WEST RIV 115	2				1.7
73701 CRRA JCT 115	73703 ASHCREEK 115	1		0.3		

Indicates branch also overloaded in base case

4.2. Voltage Violation Results

A summary of the most severe low voltage violations is provided in Table 2 (following page). More detailed results on the voltage analysis are provided in Appendix F. Since violations of high voltage limits were minor, they are not included in the table below but are included in Appendix F.

The table shows the bus number, bus name, and base kV, as well as area and zone numbers in the load flow data base. The "# Viols" column is the total number of violations for this bus and dispatch condition. If "# Viols" equals one, then the indicated contingency is the only one causing a violation. If "# Viols" exceeds one, then other contingencies also cause a voltage violation, but none are more severe than the indicated contingency. (Appendix F could be used to assess the comparative severity of multiple contingencies causing a voltage violation for a particular bus.)

Some observations on the results from this table are as follows:

- There are no voltage violations for 345 kV buses reported.
- Seven 115 kV buses are found to have low voltage violations. (Two 115 kV buses have minor high voltage violations but are not shown in Table 2).
- The generation dispatch does not have a dramatic effect on the magnitude of the voltage violations.

Table 2

Voltage Violations, Worst & Total

27.7 GW NE Load, Dispatches 2B, 3B, 4B and 5B

Lo Violation > 3%
1% < Lo Violation < 3%
0.5%< Lo Violation < 1%
Sorted by bus, then low violation
Lo Violation < 0.5%

Bus #	Bus Name	KV	Area	Zone	# Viols	WorstLo Vio	Ncon Lo	Cont Name Worst Lo	Dispatch	Controls
73160	BALDWINB	115.0	701	171	2	0.035	244	1272-1721DCT	5B	FIX
73160	BALDWINB	115.0	701	171	1	0.023	244	1272-1721DCT	2B	FIX
73160	BALDWINB	115.0	701	171	1	0.016	244	1272-1721DCT	4B	FIX
73160	BALDWINB	115.0	701	171	1	0.015	244	1272-1721DCT	3B	FIX
73188	BCNFL PF	115.0	701	171	1	0.006	244	1272-1721DCT	5B	FIX
73185	BUNKER H	115.0	701	171	2	0.035	244	1272-1721DCT	5B	FIX
73185	BUNKER H	115.0	701	171	1	0.023	244	1272-1721DCT	2B	FIX
73185	BUNKER H	115.0	701	171	1	0.015	244	1272-1721DCT	3B	FIX
73185	BUNKER H	115.0	701	171	1	0.015	244	1272-1721DCT	4B	FIX
73682	ELMWST A	115.0	701	185	2	0.004	373	GRNDAV7TSTK	5B	FIX
73683	ELMWST B	115.0	701	185	3	0.006	370	GRNDAV4TSTK	5B	FIX
73189	FREIGHT	115.0	701	171	1	0.037	244	1272-1721DCT	5B	FIX
73189	FREIGHT	115.0	701	171	1	0.024	244	1272-1721DCT	2B	FIX
73189	FREIGHT	115.0	701	171	1	0.017	244	1272-1721DCT	3B	FIX
73189	FREIGHT	115.0	701	171	1	0.017	244	1272-1721DCT	4B	FIX
73199	SO.NAUG	115.0	701	171	1	0.005	244	1272-1721DCT	5B	FIX

The value in the "**Worst Lo Vio**" column indicates the amount, in per-unit, that the bus voltage is below the low voltage criteria. The contingency and dispatch for which this occurs is also indicated. More detailed information on the results of the voltage analysis may be found in Appendix F, *including explanations on interpreting values in the tables*.

5. References

1. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative, Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-2 dated January 28, 2004.

2. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative, Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-3 dated January 28, 2004.

3. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative, Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station Off NE-NY 0 MW, PowerGEM Report 10021.001-4 dated January 28, 2004.

Attachment 2

Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, with New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-2 dated January 28, 2004

PowerGEM

Power Grid Engineering & Markets

Southwest Connecticut Transmission Expansion

East Shore to Norwalk 345 KV OH/UG Alternative :

Transmission Loading and Voltage Analysis @ 27.7 GW Load with New Haven Harbor Station Off-Line, NE-NY 0 MW

Prepared for:

The United Illuminating Company

and

Northeast Utilities

Prepared by:

Johnny R. Willis
PowerGEM
jwillis@power-gem.com

PowerGEM Report 10021.001-2
January 28, 2004

Executive Summary

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[1] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

A companion report (Reference 1) summarizes analysis of this option for several generation dispatches. This report examines the same dispatches except that the 447 MW New Haven Harbor Station, which was on for the studies in Reference 1, is off-line. The generation deficiency is made up by the Kleen Energy generation project, which is expected to be connected to the Scovill Rock to Manchester 345 kV line very near the Scovill Rock Substation.

Power flow analysis was conducted for a 27.7 GW New England load level for four southwest Connecticut generation dispatches. Loading and voltage performance of the Connecticut system was monitored for the 115 kV and 345 kV transmission systems.

Comparing the results of this study with that of Reference 1, in which New Haven Harbor Station is on-line, indicates that the availability of this generator is important to the viability of this system alternative.

[1] A planned 345 kV transmission expansion from the Plumtree to Norwalk substations, which is called Bethel to Norwalk, is assumed to be in-service in this analysis.

The loading analysis found that three 345 kV transmission lines, twenty-four 115 kV transmission lines and one 345/115 kV autotransformer at Southington exhibited post-contingency overloads. The three 345 kV transmission lines are East Shore to Scovill Rock, Southington to Frost Bridge, and Southington to Meriden. The East Shore to Scovill Rock 345 kV line is also overloaded in the base case, in the range of 15% to 17%, for two SWCT generation dispatches.

Voltage analysis indicated violations of voltage criteria for eight Connecticut 345 kV substations and fourteen Connecticut 115 kV substations. Many of these were low voltage violations resulting from a stuck breaker contingency that trips the Scovill Rock to Haddam Neck and Scovill Rock to East Shore 345 kV lines including the Cross-Sound Cable.

1. Introduction

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[2] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

A companion report (Reference 1) summarizes analysis of this option for several generation dispatches. This report examines the same dispatches except that the 447 MW New Haven Harbor Station, which was on for the studies in Reference 1, is off-line. The generation deficiency is made up by the Kleen Energy generation project, which is expected to be connected to the Scovill Rock to Manchester 345 kV line very near the Scovill Rock Substation. References 1 thru 3 are companion reports for other system conditions studied.

The objective of this study is to analyze and document the performance of this transmission configuration for steady-state base case and post-contingency transmission power flows and voltages. Performance is examined for a 27.7 GW New England load level and for four dispatches of New England generation. In all cases, the New Haven Harbor Station (447 MW), which has a significant impact on the flows on the 387 line, was out of service.

The following Appendices are included in this report:

Appendix A **"East Shore 27-OH/UG" Transmission Modeling Data**
Appendix B **Power Flow Base Case One-Line Diagrams**
Appendix C **Contingency File**

[2] A planned 345 kV transmission expansion from Plumtree to Norwalk substations, which is called Bethel to Norwalk , is assumed to be in-service in this analysis.

2. Database

This section discusses the data developed and used in the study.

2.1. Power Flow Base Cases

Four power flow base cases, which included the approved Bethel to Norwalk 345-kV project in service, were utilized. PowerGEM revised each of the four cases to add the "East Shore 27-OH/UG" transmission project. Details regarding the modeling of these circuits are provided in Appendix A. In addition to this, the rating of the East Shore to Scovill Rock 345 kV line was increased to reflect the line rating by reconfiguring the East Shore Substation and removing the 345/115 kV autotransformers from the 387 line path. The line ratings used were 1240 MVA normal and 1604 MVA long-time emergency.

Each of the four base cases provided had different generation dispatches. For all of these cases, the 447 MW New Haven Harbor Station was turned off and replaced by generation from the Kleen Energy project, both of which are outside the SWCT interface. These dispatches are designated 6B, 7B, 8B, and 9B in this report. Appendix D contains a list of the on-line generation for dispatch 6B, and the differences in dispatches 7B, 8B, and 9B as compared for dispatch 6B. Significant changes to dispatch for the four cases were restricted to New England generation.

A one-line diagram showing power flows and voltages on the "East Shore 27-OH/UG" (and Bethel to Norwalk) transmission for each of the four base cases is included in Appendix B.

2.2. Contingency File

A contingency file provided was modified as appropriate for this study, including those contingencies required to model the Kleen Energy project on the Scovill Rock to Manchester 345 kV line, and is contained in Appendix C.

- Loss of multiple 345 kV underground cables on the "East Shore 27-OH/UG" configuration between Orange and East Shore, or loss of parallel cables between Devon and Norwalk, is not considered. (Simultaneous loss of one cable from Devon to Singer and Singer to Norwalk is included as a contingency).

- For loss of the Orange to East Devon 345 kV overhead line, all three 345 kV underground cables from Orange to East Shore were opened.

3. Methodology and Results Files

This section describes the technical approach to the study, performance criteria, solution assumptions, and the format of the results.

3.1. Software

Set up of the power flow base cases used PTI's PSS/E software (Rev. 28). Base case and contingency analysis was conducted using PTI's MUST software (Rev. 5). Results from the MUST program are stored in Excel spreadsheets.

3.2. Performance Criteria

The criteria for checking overload and voltage performance were as follows:

- Buses and transmission branches in Connecticut 115 kV and above were monitored.
- For base case loading performance, transmission lines and transformers were checked against 100% of their normal ratings.
- For post-contingency loading performance, overloads of transmission lines and transformers were checked against 100% of the long-time emergency ratings.
- Buses 230 kV and above were checked for voltages less than 95% and greater than 105%. Buses in the 115 kV system were checked for voltages less than 90% and more than 105%.

3.3. Solution Options

For the analysis, tap-changing transformer and phase-shifting transformer adjustments were held fixed. For contingencies involving loss of generation/load the imbalance was made up by the system swing generator located outside New England.

4. Results

The results of the analysis for transmission system loading and voltage violations are provided below.

4.1. Overload Results

A summary of the overload results is shown in Table 1. The values shown are the percentage overload over the long-time emergency rating. If a table entry is blank, there is no overload. More detailed results are provided in Appendix E.

Any transmission line or transformer in the study area at 115 kV or above that experiences a post-contingency overload in this study is listed in the first column of Table 1. The remaining four columns, one for each of the four Connecticut generation dispatches studied, show the **maximum overload of the branch in %** (considering all contingencies) for each dispatch. The overloads are color-coded as indicated at the top of the table in order to make the relative severity of the overloads more apparent. If a Table 1 entry is blank, then the branch is not overloaded for that dispatch. To find more detail, for example which contingency causes the overload, and whether other contingencies could overload the branch, the reader should refer to Appendix E.

As shown in Table 1, three 345 kV transmission lines are overloaded following contingencies. Loading on the 387 line for base case conditions is summarized in the following table. One-lines showing the flows on this line for each case are in Appendix B.

Generation Dispatch ID	387 Line Base Case Loading (% of normal rating)
6B	117%
7B	88%
8B	72%
9B	115%

A 345/115 kV autotransformer at Southington also overloads in the range of 12% to 27%. The contingency causing the overload is a stuck breaker contingency at Southington (see Appendix E).

Finally, there are twenty four 115 kV line overloads that vary widely from slight overloads to severe overloads. Some overloads are sensitive to generation dispatch, while others are not. Three branches are overloaded in the base case, as indicated by the shaded branch names. The base case overloads are in the 3% - 25% range. Details are provided in Appendix E.

Table 1

Highest Overload: 27.7 GW NE Load, Dispatches 6B, 7B, 8B and 9B

	OverLoad >= 30%
	10% < Over Load < 30%
	5% < Over Load < 10%
	OverLoad < 5%

From bus	To bus	CKT	Generation Dispatch ID 6B	7B	8B	9B
73104 FRSTBDGE 345	73106 SOUTHGTN 345	1	4.1			6.0
73106 SOUTHGTN 345	73122 MERID362 345	1	4.6			5.5
73106 SOUTHGTN 345	73154 SGTN B 115	2	24.8	15.9	11.7	26.8
73107 SCOVL RK 345	73663 E.SHORE 345	1	24.5			23.7
73162 WATERSDE 115	73163 COS COB 115	1	24.8	24.8	24.8	24.8
73162 WATERSDE 115	73168 GLNBROOK 115	1	2.5	2.5	2.5	2.5
73164 BALDWNJA 115	73202 FROST BR 115	1	7.1			2.3
73167 SO.END 115	73294 GLNBRK J 115	1	23.2	23.2	23.2	23.2
73168 GLNBROOK 115	73169 RYTN J A 115	1				2.9
73168 GLNBROOK 115	73237 ELYAVE 115	1			51.4	54.3
73168 GLNBROOK 115	73271 RYTN J B 115	1	21.1	17.4	39.5	48.2
73169 RYTN J A 115	73171 NWLK HAR 115	1			44.2	44.0
73169 RYTN J A 115	73172 NORWALK 115	1	83.8	78.3		
73170 PLUMTREE 115	73176 TRIANGLE 115	1	88.7	76.6	73.8	85.6
73170 PLUMTREE 115	73176 TRIANGLE 115	2	35.3	35.2	34.9	35.1
73170 PLUMTREE 115	73268 MIDDLRIV 115	1	187.9	184.1	183.3	187.3
73171 NWLK HAR 115	73237 ELYAVE 115	1			51.4	59.7
73171 NWLK HAR 115	73271 RYTN J B 115	1			4.3	4.5
73172 NORWALK 115	73207 FLAX HIL 115	1	98.2	92.7		
73183 SHAWSHIL 115	73185 BUNKER H 115	1	11.8			11.9
73188 BCNFL PF 115	73192 DRBY J B 115	1	31.3	28.1	27.0	33.5
73196 GLEN JCT 115	73198 SOUTHGTN 115	1	20.1			20.0
73198 SOUTHGTN 115	73631 WLNGF PF 115	1	2.1			1.2
73207 FLAX HIL 115	73271 RYTN J B 115	1	80.9	75.3		
73230 HADDAM 115	73231 BOKUM 115	1	23.4			23.4
73230 HADDAM 115	73231 BOKUM 115	2	7.3			7.2
73268 MIDDLRIV 115	73176 TRIANGLE 115	1	126.4	123.0	122.3	126.0
73701 CRRA JCT 115	73703 ASHCREEK 115	1		0.3		

Indicates branch also overloaded in base case

4.2. Voltage Violation Results

A summary of the most severe low voltage violations is provided in the Table 2 (following pages). More detailed results on the voltage analysis are provided in Appendix F. Since violations of high voltage limits were minor, they are not included in the table below but are included in Appendix F.

Table 2 shows the bus number, bus name, and base kV, as well as area and zone numbers in the load flow data base. The "# Viols" column is the total number of violations for this bus and dispatch condition. If "# Viols" equals one, then the indicated contingency is the only one causing a violation. If "# Viols" exceeds one, then other contingencies also cause a voltage violation, but none are more severe than the indicated contingency. (Appendix F could be used to assess the comparative severity of multiple contingencies causing a voltage violation for a particular bus.)

The value in the "**Worst Lo Vio**" column indicates the amount, in per-unit, that the bus voltage is below the low voltage criteria. The contingency and dispatch for which this occurs is also indicated. More detailed information on the results of the voltage analysis may be found in Appendix F, *including explanations on interpreting values in the tables*.

There are a number of 345 kV and 115 kV system voltage violations within western Connecticut. The most significant violations are all for dispatch 6B, and all are for the contingency (SCOVRK8TSTK) which trips the Scovill Rock to Haddam Neck 345 kV line, and the Scovill Rock to East Shore 345 kV line, including the Cross Sound Cable to Long Island (see Appendix F).

Table 2

Low Voltage Violations, Worst & Total

27.7 GW NE Load, Dispatches 6B, 7B, 8B and 9B

Lo Violation > 3%
1% < Lo Violation < 3%
0.5%< Lo Violation < 1%
Lo Violation < 0.5%

Worst violation for each violation shaded
Sorted by bus, then low violation, then high violation

Bus #	Bus Name	KV	Area	Zone	# Viols	WorstLo Vio	Ncon Lo	Cont Name Worst Lo	Dispatch	Controls
73160	BALDWINB	115.0	701	171	2	0.045	248	1272-1721DCT	9B	FIX
73160	BALDWINB	115.0	701	171	1	0.029	248	1272-1721DCT	6B	FIX
73160	BALDWINB	115.0	701	171	1	0.016	248	1272-1721DCT	7B	FIX
73160	BALDWINB	115.0	701	171	1	0.016	248	1272-1721DCT	8B	FIX
73188	BCNFL PF	115.0	701	171	1	0.015	248	1272-1721DCT	9B	FIX
73188	BCNFL PF	115.0	701	171	2	0.001	460	SCOVRK8TSTK	6B	FIX
73231	BOKUM	115.0	701	171	3	0.002	247	1261-1620DCT	9B	FIX
73153	BRANFORD	115.0	701	171	1	0.000	460	SCOVRK8TSTK	6B	FIX
73185	BUNKER H	115.0	701	171	2	0.044	248	1272-1721DCT	9B	FIX
73185	BUNKER H	115.0	701	171	1	0.029	248	1272-1721DCT	6B	FIX
73185	BUNKER H	115.0	701	171	1	0.016	248	1272-1721DCT	7B	FIX
73185	BUNKER H	115.0	701	171	1	0.016	248	1272-1721DCT	8B	FIX
73697	CONGRESS	115.0	701	185	1	0.018	401	PEQUON42TSTK	9B	FIX
73297	DEVON	345.0	701	171	1	0.014	460	SCOVRK8TSTK	6B	FIX
73663	E.SHORE	345.0	701	185	1	0.022	460	SCOVRK8TSTK	6B	FIX
73663	E.SHORE	345.0	701	185	1	0.001	460	SCOVRK8TSTK	9B	FIX
73682	ELMWST A	115.0	701	185	3	0.034	376	GRNDAV6TSTK	9B	FIX
73682	ELMWST A	115.0	701	185	3	0.025	377	GRNDAV7TSTK	6B	FIX
73683	ELMWST B	115.0	701	185	3	0.036	375	GRNDAV5TSTK	9B	FIX
73683	ELMWST B	115.0	701	185	3	0.027	374	GRNDAV4TSTK	6B	FIX
73683	ELMWST B	115.0	701	185	2	0.001	441	WRIVER2TSTK	7B	FIX
73189	FREIGHT	115.0	701	171	1	0.046	248	1272-1721DCT	9B	FIX
73189	FREIGHT	115.0	701	171	1	0.031	248	1272-1721DCT	6B	FIX
73189	FREIGHT	115.0	701	171	1	0.018	248	1272-1721DCT	7B	FIX
73189	FREIGHT	115.0	701	171	1	0.017	248	1272-1721DCT	8B	FIX
73104	FRSTBDGE	345.0	701	171	1	0.002	460	SCOVRK8TSTK	6B	FIX
73265	GREEN HL	115.0	701	171	1	0.019	460	SCOVRK8TSTK	6B	FIX
73265	GREEN HL	115.0	701	171	1	0.003	460	SCOVRK8TSTK	9B	FIX
73707	JUNE ST	115.0	701	185	1	0.006	460	SCOVRK8TSTK	6B	FIX
73105	LONG MTN	345.0	701	171	1	0.006	460	SCOVRK8TSTK	6B	FIX
73675	MIX AVE	115.0	701	185	1	0.015	460	SCOVRK8TSTK	6B	FIX
73293	NORWALK	345.0	701	171	1	0.013	460	SCOVRK8TSTK	6B	FIX
73371	ORANGE	345.0	701	185	1	0.021	460	SCOVRK8TSTK	6B	FIX
73115	PLUMTREE	345.0	701	171	1	0.018	460	SCOVRK8TSTK	6B	FIX
73673	SACKPHS	115.0	701	185	1	0.014	460	SCOVRK8TSTK	6B	FIX
73301	SINGER	345.0	701	186	1	0.013	460	SCOVRK8TSTK	6B	FIX
73199	SO.NAUG	115.0	701	171	1	0.014	248	1272-1721DCT	9B	FIX

4.3. Comparison of Results with New Haven Harbor Station On-Line

4.3.1. Loading Violations

Table 3 compares the worst overloads for the four SWCT generation dispatches with New Haven Harbor on-line and off-line (displaced by Kleen Energy).

Some points of interest regarding the effect of New Haven Harbor generation follow:

- Two additional overloads of 345 kV transmission lines occur for dispatches 6B and 9B that are not overloaded in the cases with New Haven Harbor on-line. The new overloads are Frost Bridge to Southington 345 kV line and Southington to Meriden 345 kV line. Though not indicated in the table, these overloads occur following loss of the East Shore to Scovill Rock 345 kV line (387 line) and the 1460-387 DCT (double circuit) contingency (see Appendix E).

- Four additional overloads of 115kV transmission lines occur for generation dispatches 6B and 9B that do not occur in the cases with New Haven Harbor on-line.

Table 3

Highest Overload: 27.7 GW NE Load, Dispatches 2B through 9B

	OverLoad >= 30%
	10% < Over Load < 30%
	5% < Over Load < 10%
	OverLoad < 5%

			Generation Dispatch ID							
			New Haven Harbor On				New Haven Harbor Off			
From bus	To bus	CKT	2B	3B	4B	5B	6B	7B	8B	9B
73104 FRSTBDGE 345	73106 SOUTHGTN 345	1					4.1			6.0
73106 SOUTHGTN 345	73122 MERID362 345	1					4.6			5.5
73106 SOUTHGTN 345	73154 SGTN B 115	2	19.4	10.8	6.7	21.1	24.8	15.9	11.7	26.8
73107 SCOVL RK 345	73663 E.SHORE 345	1	6.0			5.2	24.5			23.7
73162 WATERSDE 115	73163 COS COB 115	1	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
73162 WATERSDE 115	73168 GLNBROOK 115	1	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
73164 BALDWNJA 115	73202 FROST BR 115	1					7.1			2.3
73167 SO.END 115	73294 GLNBRK J 115	1	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2
73168 GLNBROOK 115	73169 RYTN J A 115	1				1.8				2.9
73168 GLNBROOK 115	73237 ELYAVE 115	1			51.0	53.9			51.4	54.3
73168 GLNBROOK 115	73271 RYTN J B 115	1	19.2	15.8	38.1	46.5	21.1	17.4	39.5	48.2
73169 RYTN J A 115	73171 NWLK HAR 115	1			44.4	44.3			44.2	44.0
73169 RYTN J A 115	73172 NORWALK 115	1	80.8	75.2			83.8	78.3		
73170 PLUMTREE 115	73176 TRIANGLE 115	1	77.4	74.7	72.9	75.5	88.7	76.6	73.8	85.6
73170 PLUMTREE 115	73176 TRIANGLE 115	2	35.2	34.9	34.7	34.9	35.3	35.2	34.9	35.1
73170 PLUMTREE 115	73268 MIDDLRIV 115	1	184.3	183.5	183.0	183.6	187.9	184.1	183.3	187.3
73171 NWLK HAR 115	73237 ELYAVE 115	1			50.2	58.4			51.4	59.7
73171 NWLK HAR 115	73271 RYTN J B 115	1			4.3	4.3			4.3	4.5
73172 NORWALK 115	73207 FLAX HIL 115	1	95.3	89.7			98.2	92.7		
73183 SHAWSHIL 115	73185 BUNKER H 115	1	4.2			4.3	11.8			11.9
73188 BCNFL PF 115	73192 DRBY J B 115	1	29.9	27.6	26.5	32.1	31.3	28.1	27.0	33.5
73196 GLEN JCT 115	73198 SOUTHGTN 115	1					20.1			20.0
73198 SOUTHGTN 115	73631 WLNGF PF 115	1					2.1			1.2
73207 FLAX HIL 115	73271 RYTN J B 115	1	77.9	72.2			80.9	75.3		
73224 TRMB J A 115	73700 PEQUONIC 115	1			1.7					
73230 HADDAM 115	73231 BOKUM 115	1	9.3			9.2	23.4			23.4
73230 HADDAM 115	73231 BOKUM 115	2					7.3			7.2
73268 MIDDLRIV 115	73176 TRIANGLE 115	1	123.2	122.6	122.1	122.7	126.4	123.0	122.3	126.0
73669 GRAND AV 115	73681 WEST RIV 115	1				1.7				
73669 GRAND AV 115	73681 WEST RIV 115	2				1.7				
73701 CRRA JCT 115	73703 ASHCREEK 115	1		0.3				0.3		

4.3.2. Voltage Violations

A primary effect of the generation at New Haven Harbor Station being off-line was to cause widespread voltage violations at Connecticut 345 kV and 115 kV substations for the SCOVRK8TSTK contingency for the 6B generation dispatch. This contingency, which causes the loss of Scovill Rock - Haddam 345 kV line, Scovill Rock – East Shore 345 kV line, including the Cross Sound Cable, did not cause voltage violations when New Haven Harbor Station was on-line.

In addition, having New Haven Harbor off-line generally worsened voltage violations that also occurred when it was on-line.

5. References

1. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-1 Revised, dated January 28, 2004.

2. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-4 dated January 28, 2004

3. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-3 dated January 28, 2004

Attachment 3

Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-3 dated January 28, 2004

PowerGEM

Power Grid Engineering & Markets

Southwest Connecticut Transmission Expansion

East Shore to Norwalk 345 KV OH/UG Alternative :

Transmission Loading and Voltage Analysis @ 27.7 GW Load.
387 Line Reconductored, New Haven Harbor Station On-Line,
NE-NY 0 MW

Prepared for:

The United Illuminating Company

and

Northeast Utilities

Prepared by:

Johnny R. Willis
PowerGEM
jwillis@power-gem.com

PowerGEM Report 10021.001-3
January 28, 2004

Executive Summary

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[1] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

In addition to the above transmission alternative, the study assumes re-conductoring of the limiting portion of the East Shore to Scovill Rock 345 kV line (387 line) from a single 2156 ACSR conductor to a bundled 2 x 954 ACSR conductor. This raises the normal rating of the line from 1240 MVA to 1488 MVA, and the long-time emergency rating from 1604 MVA to 1912 MVA. It also results in a reduction in the impedance of the line of about 9%.

The objective of this study is to analyze and document the performance of this transmission configuration for steady-state base case and post-contingency transmission power flows and voltages. Power flow analysis was conducted for a 27.7 GW New England load level for four southwest Connecticut generation dispatches. In all cases, the New Haven Harbor Station, which has a significant impact on the flows on the 387 line, was in service. Loading and voltage performance of the Connecticut system was monitored for the 115 kV and 345 kV transmission systems.

The loading analysis found that twenty-three 115 kV transmission lines, and one 345/115 kV autotransformer at Southington, exhibited post-contingency overloads.

[1] A planned 345 kV transmission expansion from the Plumtree to Norwalk substations, which is called Bethel to Norwalk, is assumed to be in-service in this analysis.

Three of the overloaded 115 kV lines were also overloaded in the base case (all lines in) for some generation dispatches.

Voltage analysis indicated violations of voltage criteria for nine Connecticut 115 kV substations. There were no voltage violations for 345 kV substations.

1. Introduction

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[2] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

In addition to the above transmission alternative, the study assumes re-conductoring of the limiting portion of the East Shore to Scovill Rock 345 kV line (387 line) from a single 2156 ACSR conductor to a bundled 2 x 954 ACSR conductor. This raises the normal rating of the line from 1240 MVA to 1488 MVA, and the long-time emergency rating from 1604 MVA to 1912 MVA. It also results in a reduction in the impedance of the line of about 9%.

The objective of this study is to analyze and document the performance of this transmission configuration for steady-state base case and post-contingency transmission power flows and voltages. Performance, is examined for a 27.7 GW New England load level and for four dispatches of New England generation. In all cases, the New Haven Harbor Station (447 MW), which has a significant impact on the flows on the 387 line, was in service. References 1 thru 3 are companion reports for other system conditions studied.

The following Appendices are included in this report:

Appendix A "East Shore 27-OH/UG" Transmission Modeling Data
Appendix B Power Flow Base Case One-Line Diagrams

[2] A planned 345 kV transmission expansion from Plumtree to Norwalk substations, which is called Bethel to Norwalk, is assumed to be in-service in this analysis.

2. Database

This section discusses the data developed and used in the study.

2.1. Power Flow Base Cases

Four power flow base cases, which included the approved Bethel to Norwalk 345-kV project in service, were utilized. PowerGEM revised each of the four cases to add the "East Shore 27-OH/UG" transmission project. Details regarding the modeling of these circuits are provided in Appendix A. In addition to this, the rating of the East Shore to Scovill Rock 345 kV line was increased to reflect the line rating by reconfiguring the East Shore Substation and removing the 345/115 kV autotransformers from the 387 line path. The line ratings used were 1240 MVA normal and 1604 MVA long-time emergency.

Details regarding the modeling of these circuits are provided in Appendix A.

Further, the impedance and ratings of the East Shore to Scovill Rock 345 kV line (387 line) were revised to reflect re-conductoring. The existing line has a portion with a single 2156 ACSR conductor (Black Pond Junction to Scovill Rock Switching station) and a portion with 2x 954 bundled ACSR conductor (Black Pond Junction to East Shore Substation). The data used in this analysis for re-conductoring assumed that the 2156 ACSR conductor is replaced by 2 x 954 conductor ACSR. The data is given below.

.

East Shore to Scovill Rock 345 kV Line Modeling Data						
	Impedances (p.u)			Ratings MVA		
	R	X	B	Normal	LTE	STE
Existing Line	0.00137	0.01767	0.26688	1240	1604	1966
Re-conductored Line	0.00136	0.01618	0.28561	1488	1912	2098

The re-conductoring results in about a 9% decrease in the line impedance, and about a 20% increase in the line loading capability.

Each of the four base cases had different generation dispatches, and are denoted dispatches 2C, 3C, 4C, and 5C. These dispatches were preserved for the base cases. Appendix D contains a list of the on-line generation for dispatch 2C, and the differences in dispatches 3C, 4C, and 5C as compared for dispatch 2C. Significant changes to dispatch for the four cases were restricted to New England generation.

A one-line diagram showing power flows and voltages on the "East Shore 27-OH/UG" (and Bethel to Norwalk) transmission for each of the four base cases is included in Appendix B.

2.2. Contingency File

A contingency file was modified as appropriate for this study, and is contained in Appendix C. There are several assumptions in the contingencies, including:

- Loss of multiple 345 kV underground cables on the "East Shore 27-OH/UG" configuration between Orange and East Shore, or loss of parallel cables between Devon and Norwalk, is not considered. (Simultaneous loss of one cable from Devon to Singer and Singer to Norwalk is included as a contingency).

- For loss of the Orange to East Devon 345 kV overhead line, all three 345 kV underground cables from Orange to East Shore were opened.

3. Methodology and Results Files

This section describes the technical approach to the study, performance criteria, solution assumptions, and the format of the results.

3.1. Software

Set up of the power flow base cases used PTI's PSS/E software (Rev. 28). Base case and contingency analysis was conducted using PTI's MUST software (Rev. 5). Results from the MUST program are stored in Excel spreadsheets.

3.2. Performance Criteria

The criteria for checking overload and voltage performance were as follows:

- Buses and transmission branches in Connecticut 115 kV and above were monitored.
- For base case loading performance, transmission lines and transformers were checked against 100% of their normal ratings.
- For post-contingency loading performance, overloads of transmission lines and transformers were checked against 100% of the long-time emergency ratings.
- Buses 230 kV and above were checked for voltages less than 95% and greater than 105%. Buses in the 115 kV system were checked for voltages less than 90% and more than 105%.

3.3. Solution Options

For the analysis, tap-changing transformer and phase-shifting transformer adjustments were held fixed. For contingencies involving loss of generation/load the imbalance was made up by the system swing generator located outside New England.

4. Results

The results of the analysis for transmission system loading and voltage violations are provided below.

4.1. Overload Results

A summary of the overload results is shown in Table 1. The values shown are the percentage overload over the long-time emergency rating. If a table entry is blank, there is no overload. More detailed results are provided in Appendix E.

Table 1

Highest Overload: 27.7 GW NE Load, Dispatches 2C, 3C, 4C and 5C

	OverLoad >= 30%
	10% < Over Load < 30%
	5% < Over Load < 10%
	OverLoad < 5%

From bus To bus CKT	Generation Dispatch ID 2C	3C	4C	5C
73106 SOUTHGTN 345 73154 SGTN B 115 2	17.8	9.6	5.7	19.4
73162 WATERSDE 115 73163 COS COB 115 1	24.8	24.8	24.8	24.8
73162 WATERSDE 115 73168 GLNBROOK 115 1	2.5	2.5	2.5	2.5
73167 SO.END 115 73294 GLNBRK J 115 1	23.2	23.2	23.2	23.2
73168 GLNBROOK 115 73169 RYTN J A 115 1				1.6
73168 GLNBROOK 115 73237 ELYAVE 115 1			50.8	53.5
73168 GLNBROOK 115 73271 RYTN J B 115 1	19.2	15.8	38.1	46.5
73169 RYTN J A 115 73171 NWLK HAR 115 1			43.8	43.1
73169 RYTN J A 115 73172 NORWALK 115 1	81.8	75.8		
73170 PLUMTREE 115 73176 TRIANGLE 115 1	77.2	74.9	72.8	75.3
73170 PLUMTREE 115 73176 TRIANGLE 115 2	35.1	34.9	34.7	34.8
73170 PLUMTREE 115 73268 MIDDLRIV 115 1	184.2	183.5	183.0	183.5
73171 NWLK HAR 115 73237 ELYAVE 115 1			49.6	57.4
73171 NWLK HAR 115 73271 RYTN J B 115 1			4.3	4.3
73172 NORWALK 115 73207 FLAX HIL 115 1	96.2	90.3		
73183 SHAWSHIL 115 73185 BUNKER H 115 1	2.9			3.1
73188 BCNFL PF 115 73192 DRBY J B 115 1	29.8	27.5	26.5	32.0
73207 FLAX HIL 115 73271 RYTN J B 115 1	78.8	72.8		
73224 TRMB J A 115 73700 PEQUONIC 115 1			2.3	
73230 HADDAM 115 73231 BOKUM 115 1	7.7			7.6
73268 MIDDLRIV 115 73176 TRIANGLE 115 1	123.1	122.6	122.1	122.6
73669 GRAND AV 115 73681 WEST RIV 115 1				2.7
73669 GRAND AV 115 73681 WEST RIV 115 2				2.7
73701 CRRA JCT 115 73703 ASHCREEK 115 1	0.3	0.6		

Indicates branch also overloaded in base case

Any transmission line or transformer in the study area at 115 kV or above that experiences a post-contingency overload in this study is listed in the first column of Table 1. The remaining four columns, one for each of the four Connecticut generation dispatches studied, show the **maximum overload of the branch in %** (considering all contingencies) for each dispatch. The overloads are color-coded as indicated at the top of the table in order to make the relative severity of the overloads more apparent. If a Table 1 entry is blank, then the branch is not overloaded for that dispatch. To find more detail, for example which contingency causes the overload, and whether other contingencies could overload the branch, the reader should refer to Appendix E.

As indicated in Table 1, there are no 345 kV transmission line overloads. Base case loadings for the 387 line were as follows:

Generation Dispatch ID	387 Line Base Case Loading (% of normal rating)
2C	84%
3C	59%
4C	46%
5C	82%

A 345/115 kV autotransformer at Southington overloads by about 20%. The contingency causing the overload is a stuck breaker contingency at Southington.

Finally, there are twenty-three 115 kV line overloads that vary widely from slight overloads to severe overloads. Some overloads are sensitive to generation dispatch, while others are not. Three branches are overloaded in the base case, as indicated by the shaded branch names. The base case overloads range from very slight to about 20%. More detail is given in Appendix F.

4.2. Voltage Violation Results

A summary of the most severe low voltage violations is provided in Table 2 (following page). More detailed results on the voltage analysis are provided in Appendix F. Since violations of high voltage limits were minor, they are not included in the table below but are included in Appendix F.

The table shows the bus number, bus name, and base kV, as well as area and zone numbers in the load flow data base. The "# Viols" column is the total number of violations for this bus and dispatch condition. If "# Viols" equals one, then the indicated contingency is the only one causing a violation. If "# Viols" exceeds one, then other contingencies also cause a voltage violation, but none are more severe than the indicated contingency. (Appendix F could be used to assess the comparative severity of multiple contingencies causing a voltage violation for a particular bus.)

Some observations on the results from of Table 2 are as follows:

- There are no voltage violations for 345 kV buses reported.
- Seven 115 kV buses are found to have low voltage violations. (Two 115 kV buses have minor high voltage violations but are not shown in the table.)
- The generation dispatch does not have a dramatic effect on the magnitude of the voltage violations, though the worst voltage violations tend to be for dispatch 5C.

Table 2

Voltage Violations, Worst & Total: 27.7 GW NE Load, Dispatches 2C, 3C, 4C and 5C

Lo Violation > 3%
1% < Lo Violation < 3%
0.5%< Lo Violation < 1%
Lo Violation < 0.5%

Sorted by bus, then low violation, then high violation

Bus #	Bus Name	KV	Area	Zone	# Viols	WorstLo Vio	Ncon Lo	Cont Name Worst Lo	Dispatch	Controls
73160	BALDWINB	115.0	701	171	2	0.035	244	1272-1721DCT	5C	FIX
73160	BALDWINB	115.0	701	171	1	0.023	244	1272-1721DCT	2C	FIX
73160	BALDWINB	115.0	701	171	1	0.016	244	1272-1721DCT	4C	FIX
73160	BALDWINB	115.0	701	171	1	0.015	244	1272-1721DCT	3C	FIX
73188	BCNFL PF	115.0	701	171	1	0.006	244	1272-1721DCT	5C	FIX
73185	BUNKER H	115.0	701	171	2	0.035	244	1272-1721DCT	5C	FIX
73185	BUNKER H	115.0	701	171	1	0.023	244	1272-1721DCT	2C	FIX
73185	BUNKER H	115.0	701	171	1	0.015	244	1272-1721DCT	3C	FIX
73185	BUNKER H	115.0	701	171	1	0.015	244	1272-1721DCT	4C	FIX
73682	ELMWST A	115.0	701	185	1	0.004	372	GRNDAV6TSTK	2C	FIX
73682	ELMWST A	115.0	701	185	2	0.004	373	GRNDAV7TSTK	5C	FIX
73683	ELMWST B	115.0	701	185	3	0.006	370	GRNDAV4TSTK	5C	FIX
73683	ELMWST B	115.0	701	185	1	0.006	371	GRNDAV5TSTK	2C	FIX
73189	FREIGHT	115.0	701	171	1	0.036	244	1272-1721DCT	5C	FIX
73189	FREIGHT	115.0	701	171	1	0.024	244	1272-1721DCT	2C	FIX
73189	FREIGHT	115.0	701	171	1	0.017	244	1272-1721DCT	3C	FIX
73189	FREIGHT	115.0	701	171	1	0.017	244	1272-1721DCT	4C	FIX
73199	SO.NAUG	115.0	701	171	1	0.005	244	1272-1721DCT	5C	FIX

The value in the "**Worst Lo Vio**" column indicates the amount, in per-unit, that the bus voltage is below the low voltage criteria. The contingency and dispatch for which this occurs is also indicated. More detailed information on the results of the voltage analysis may be found in Appendix F, *including explanations on interpreting values in the tables*.

5. References

1. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-1 Revised, dated January 28, 2004.

2. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-2 dated January 28, 2004.

3. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-4 dated January 28, 2004.

Attachment 4

Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative: Transmission Loading and Voltage Analysis @ 27.7 GW Load, 387 Line Re-conductored, New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-4 dated January 28, 2004

PowerGEM

Power Grid Engineering & Markets

Southwest Connecticut Transmission Expansion

East Shore to Norwalk 345 KV OH/UG Alternative :

Transmission Loading and Voltage Analysis @ 27.7 GW Load.
387 Line Reconductored, New Haven Harbor Station Off-Line,
NE-NY 0 MW

Prepared for:

The United Illuminating Company

and

Northeast Utilities

Prepared by:

Johnny R. Willis
PowerGEM
jwillis@power-gem.com

PowerGEM Report 10021.001-4
January 28, 2004

Executive Summary

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[1] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

In addition to the above transmission alternative, the study assumes re-conductoring of the limiting portion of the East Shore to Scovill Rock 345 kV line (387 line) from a single 2156 ACSR conductor to a bundled 2 x 954 ACSR conductor. This raises the normal rating of the line from 1240 MVA to 1488 MVA, and the long-time emergency rating from 1604 MVA to 1912 MVA. It also results in a reduction in the impedance of the line of about 9%.

Power flow analysis was conducted for a 27.7 GW New England load level for four southwest Connecticut generation dispatches with the 447 MW New Haven Harbor Station (NHHS) off-line. (An earlier report, Reference 1, summarizes analysis of this option for several generation dispatches with NHHS on). The NHHS generation is made up by the Kleen Energy generation project, which is expected to be connected to the Scovill Rock to Manchester 345 kV line very near the Scovill Rock Substation. Loading and voltage performance of the Connecticut system was monitored for the 115 kV and 345 kV transmission systems.

The loading analysis found that three 345 kV transmission lines, twenty-five 115 kV transmission lines, and one 345/115 kV autotransformer at Southington, exhibited

[1] A planned 345 kV transmission expansion from the Plumtree to Norwalk substations, which is called Bethel to Norwalk, is assumed to be in-service in this analysis.

post-contingency overloads. The East Shore to Scovill Rock 345 kV line was also overloaded in the base case (all lines in) for one generation dispatch, and very nearly overloaded for another generation dispatch. Three of the overloaded 115 kV lines were also overloaded in the base case for some generation dispatches.

Voltage analysis indicated violations of voltage criteria for nine 115 kV substations. In addition, one contingency, a stuck breaker at Scovill Rock, caused widespread voltage violations at several 345 kV and 115 kV substations. A companion study (Reference 1) does not indicate these voltage violations when the New Haven Harbor station is on-line.

1. Introduction

This report summarizes power flow analysis conducted for The United Illuminating Company (UI) and Northeast Utilities (NU) for one option for expanding the New England 345 kV transmission system into southwest Connecticut (SWCT). The transmission option examined, called "East Shore 27-OH/UG" in this report, is for a 345 kV transmission path from East Shore to Norwalk substations, with interconnecting substations between these stations.[2] The "East Shore 27-OH/UG" transmission option, which consists primarily of underground cables with one section of overhead line, is described as follows:

From	To	Distance	Transmission
East Shore	Orange (cable to overhead line transition station)	7 miles	345 kV underground, 2500 kcmil HPFF, three parallel cables
Orange (cable to overhead line transition station)	East Devon	9.4 miles	345 kV overhead bundled 1590 ACSR conductor, single circuit
East Devon	Singer	8 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables
Singer	Norwalk	15 miles	345 kV underground, 2500 kcmil HPFF, two parallel cables

In addition to the above transmission alternative, the study assumes re-conductoring of the limiting portion of the East Shore to Scovill Rock 345 kV line (387 line) from a single 2156 ACSR conductor to a bundled 2 x 954 ACSR conductor. This raises the normal rating of the line from 1240 MVA to 1488 MVA, and the long-time emergency rating from 1604 MVA to 1912 MVA. It also results in a reduction in the impedance of the line of about 9%.

Power flow analysis was conducted for a 27.7 GW New England load level for four southwest Connecticut generation dispatches with the 447 MW New Haven Harbor Station (NHHS) off-line. (An earlier report, Reference 1, summarizes analysis of this option for several generation dispatches with NHHS on). The NHHS generation is made up by the Kleen Energy generation project, which is expected to be connected to the Scovill Rock to Manchester 345 kV line very near the Scovill Rock substation. Loading and voltage performance of the Connecticut system was monitored for the 115 kV and 345 kV transmission systems. References 1 thru 3 are companion reports for other system conditions studied.

The objective of this study is to analyze and document the performance of this transmission configuration for steady-state base case and post-contingency

[2] A planned 345 kV transmission expansion from Plumtree to Norwalk substations, which is called Bethel to Norwalk , is assumed to be in-service in this analysis.

transmission power flows and voltages. In all cases, the New Haven Harbor station (447 MW), which has a significant impact on the flows on the 387 line, was out of service.

The following Appendices are included in this report:

Appendix A	**"East Shore 27-OH/UG" Transmission Modeling Data**
Appendix B	**Power Flow Base Case One-Line Diagrams**
Appendix C	**Contingency File**
Appendix D	**Generation Dispatches**
Appendix E	**Summary of Overloads**
Appendix F	**Summary of Voltage Violations**

2. Database

This section discusses the data developed and used in the study.

2.1. Power Flow Base Cases

Four power flow base cases, which included the approved Bethel to Norwalk 345-kV project in service, were utilized. PowerGEM revised each of the four cases to add the "East Shore 27-OH/UG" transmission project. Details regarding the modeling of these circuits are provided in Appendix A. In addition to this, the rating of the East Shore to Scovill Rock 345 kV line was increased to reflect the line rating by reconfiguring the East Shore Substation and removing the 345/115 kV autotransformers from the 387 line path. The line ratings used were 1240 MVA normal and 1604 MVA long-time emergency.

Details regarding the modeling of these circuits are provided in Appendix A.

Further, the impedance and ratings of the East Shore to Scovill Rock 345 kV line (387 line) were revised to reflect re-conductoring. The existing line has a portion with a single 2156 ACSR conductor (Black Pond Junction to Scovill Rock Switching station) and a portion with 2x 954 bundled ACSR conductor (Black Pond Junction to East Shore Substation). The data used in this analysis for re-conductoring assumed that the 2156 ACSR conductor is replaced by 2 x 954 conductor ACSR. The data is given below.

East Shore to Scovill Rock 345 kV Line Modeling Data						
	Impedances (p.u)			Ratings MVA		
	R	X	B	Normal	LTE	STE
Existing Line	0.00137	0.01767	0.26688	1240	1604	1966
Re-conductored Line	0.00136	0.01618	0.28561	1488	1912	2098

The re-conductoring results in about a 9% decrease in the line impedance, and about a 20% increase in the line loading capability.

Each of the four base cases had different generation dispatches, and are denoted dispatches 6C, 7C, 8C, and 9C. These dispatches were preserved for the base cases. Appendix D contains a list of the on-line generation for dispatch 6C, and the differences in dispatches 7C, 8C, and 9C as compared for dispatch 6C. Significant changes to dispatch for the four cases were restricted to New England generation.

A one-line diagram showing power flows and voltages on the "East Shore 27-OH/UG" (and Bethel to Norwalk) transmission line for each of the four base cases is included in Appendix B.

2.2. Contingency File

A contingency file was modified as appropriate for this study, and is contained in Appendix C.

- Loss of multiple 345 kV underground cables on the "East Shore 27-OH/UG" configuration between Orange and East Shore, or loss of parallel cables between Devon and Norwalk, is not considered. (Simultaneous loss of one cable from Devon to Singer and Singer to Norwalk is included as a contingency).

- For loss of the Orange to East Devon 345 kV overhead line, all three 345 kV underground cables from Orange to East Shore were opened.

3. Methodology and Results Files

This section describes the technical approach to the study, performance criteria, solution assumptions, and the format of the results.

3.1. Software

Set up of the power flow base cases used PTI's PSS/E software (Rev. 28). Base case and contingency analysis was conducted using PTI's MUST software (Rev. 5). Results from the MUST program are stored in Excel spreadsheets.

3.2. Performance Criteria

The criteria for checking overload and voltage performance were as follows:

- Buses and transmission branches in Connecticut 115 kV and above were monitored.
- For base case loading performance, transmission lines and transformers were checked against 100% of their normal ratings.
- For post-contingency loading performance, overloads of transmission lines and transformers were checked against 100% of the long-time emergency ratings.
- Buses 230 kV and above were checked for voltages less than 95% and greater than 105%. Buses in the 115 kV system were checked for voltages less than 90% and more than 105%.

3.3. Solution Options

For the analysis, tap-changing transformer and phase-shifting transformer adjustments were held fixed. For contingencies involving loss of generation/load the imbalance was made up by the system swing generator located outside New England.

4. Results

The results of the analysis for transmission system loading and voltage violations are provided below.

4.1. Overload Results

A summary of the overload results is shown in Table 1. The values shown are the percentage overload over the long-time emergency rating. If a table entry is blank, there is no overload. More detailed results are provided in Appendix E.

Any transmission line or transformer in the study area at 115 kV or above that experiences a post-contingency overload in this study is listed in the first column of Table 1. The remaining four columns, one for each of the four Connecticut generation dispatches studied, show the **maximum overload of the branch in %** (considering all contingencies) for each dispatch. The overloads are color-coded as indicated at the top of the table in order to make the relative severity of the overloads more apparent. If a Table 1 entry is blank, then the branch is not overloaded for that dispatch. To find more detail, for example which contingency causes the overload, and whether other contingencies could overload the branch, the reader should refer to Appendix E.

As shown in Table 1, there are three 345 kV transmission lines that experience post-contingency overloads. The East Shore to Scovill Rock 345 kV line (387 line), which experiences post-contingency overloads for dispatches 6C and 9C, is also overloaded in the base case for one generation dispatch, and is almost overloaded for a second dispatch, as shown in the table below. More detail is given in Appendix E.

Generation Dispatch ID	387 Line Base Case Loading (% of normal rating)
6C	101%
7C	76%
8C	62%
9C	99%

A 345/115 kV autotransformer at Southington has post-contingency overloads ranging from 10% to 25%. The contingency causing the overload is a stuck breaker contingency at Southington (contingency SGTN5TSTK).

Finally, there are twenty-five 115 kV line post-contingency overloads that vary widely from slight overloads to severe overloads. Some overloads are sensitive to generation dispatch, while others are not. Three 115 kV branches are overloaded in the base case, as indicated by the shaded branch names. The base case overloads range from a few percent to about 25%. More detail is given in Appendix E.

Table 1

Highest Overload: 27.7 GW NE Load, Dispatches 6C, 7C, 8C and 9C

	OverLoad >= 30%
	10% < Over Load < 30%
	5% < Over Load < 10%
	OverLoad < 5%

	Generation Dispatch ID			
From bus To bus CKT	6C	7C	8C	9C
73104 FRSTBDGE 345 73106 SOUTHGTN 345 1	4.2			6.1
73106 SOUTHGTN 345 73122 MERID362 345 1	4.7			5.5
73106 SOUTHGTN 345 73154 SGTN B 115 2	22.9	14.4	10.5	24.8
73107 SCOVL RK 345 73663 E.SHORE 345 1	6.9			6.2
73162 WATERSDE 115 73163 COS COB 115 1	24.8	24.8	24.8	24.8
73162 WATERSDE 115 73168 GLNBROOK 115 1	2.5	2.5	2.5	2.5
73164 BALDWNJA 115 73202 FROST BR 115 1	6.4			2.2
73167 SO.END 115 73294 GLNBRK J 115 1	23.2	23.2	23.2	23.2
73168 GLNBROOK 115 73169 RYTN J A 115 1				2.8
73168 GLNBROOK 115 73237 ELYAVE 115 1			51.1	54.3
73168 GLNBROOK 115 73271 RYTN J B 115 1	21.0	17.4	39.5	48.2
73169 RYTN J A 115 73171 NWLK HAR 115 1			43.4	43.8
73169 RYTN J A 115 73172 NORWALK 115 1	85.0	79.1		
73170 PLUMTREE 115 73176 TRIANGLE 115 1	88.4	76.5	73.7	85.2
73170 PLUMTREE 115 73176 TRIANGLE 115 2	35.2	35.2	34.9	35.0
73170 PLUMTREE 115 73268 MIDDLRIV 115 1	187.7	184.1	183.2	187.2
73171 NWLK HAR 115 73237 ELYAVE 115 1			50.7	59.6
73171 NWLK HAR 115 73271 RYTN J B 115 1			4.3	4.5
73172 NORWALK 115 73207 FLAX HIL 115 1	99.4	93.5		
73183 SHAWSHIL 115 73185 BUNKER H 115 1	10.2			10.3
73188 BCNFL PF 115 73192 DRBY J B 115 1	31.2	28.0	26.9	33.4
73196 GLEN JCT 115 73198 SOUTHGTN 115 1	20.9			19.9
73198 SOUTHGTN 115 73631 WLNGF PF 115 1	4.5			1.2
73207 FLAX HIL 115 73271 RYTN J B 115 1	82.1	76.1		
73228 BALDWNJB 115 73185 BUNKER H 115 1	1.4			
73230 HADDAM 115 73231 BOKUM 115 1	21.5			21.4
73230 HADDAM 115 73231 BOKUM 115 2	5.6			5.5
73268 MIDDLRIV 115 73176 TRIANGLE 115 1	126.3	123.0	122.3	125.9
73701 CRRA JCT 115 73703 ASHCREEK 115 1	0.1	0.6		

Indicates branch overloaded in base case

4.2. Voltage Violation Results

A summary of the most severe low voltage violations is provided in Table 2 (following page). More detailed results on the voltage analysis are provided in Appendix F. Since violations of high voltage limits were minor, they are not included in the table below but are included in Appendix F.

The table shows the bus number, bus name, and base kV, as well as area and zone numbers in the load flow data base. The "# Viols" column is the total number of violations for this bus and dispatch condition. If "# Viols" equals one, then the indicated contingency is the only one causing a violation. If "# Viols" exceeds one, then other contingencies also cause a voltage violation, but none are more severe than the indicated contingency. (Appendix F could be used to assess the comparative severity of multiple contingencies causing a voltage violation for a particular bus.)

The value in the "**Worst Lo Vio**" column indicates the amount, in per-unit, that the bus voltage is below the low voltage criteria. The contingency and dispatch for which this occurs is also indicated. More detailed information on the results of the voltage analysis may be found in Appendix F, *including explanations on interpreting values in the tables*.

Some observations on the results from Table 2 are as follows:

- There are no voltage violations for 345 kV buses reported (except for one contingency not shown in the table and discussed in more detail following Table 2).
- Nine 115 kV buses are found to have low voltage violations. (Two 115 kV buses have minor high voltage violations but are not shown in the table)
- The generation dispatch does not have a dramatic effect on the magnitude of the voltage violations, though the worst voltage violations tend to be for dispatch 9C.

Table 2

Worst Low & Total Voltage Violations

27.7 GW NE Load, Dispatches 6C, 7C, 8C and 9C

Lo Violation > 3%
1% < Lo Violation < 3%
0.5%< Lo Violation < 1%
Lo Violation < 0.5%

Sorted by bus, then low violation

Bus #	Bus Name	KV	Area	Zone	# Viols	WorstLo Vio	Ncon Lo	Cont Name Worst Lo	Dispatch	Controls
73160	BALDWINB	115.0	701	171	2	0.043	248	1272-1721DCT	9C	FIX
73160	BALDWINB	115.0	701	171	2	0.029	248	1272-1721DCT	6C	FIX
73160	BALDWINB	115.0	701	171	1	0.016	248	1272-1721DCT	7C	FIX
73160	BALDWINB	115.0	701	171	1	0.016	248	1272-1721DCT	8C	FIX
73188	BCNFL PF	115.0	701	171	1	0.013	248	1272-1721DCT	9C	FIX
73231	BOKUM	115.0	701	171	3	0.002	247	1261-1620DCT	9C	FIX
73185	BUNKER H	115.0	701	171	2	0.043	248	1272-1721DCT	9C	FIX
73185	BUNKER H	115.0	701	171	1	0.028	248	1272-1721DCT	6C	FIX
73185	BUNKER H	115.0	701	171	1	0.016	248	1272-1721DCT	7C	FIX
73185	BUNKER H	115.0	701	171	1	0.016	248	1272-1721DCT	8C	FIX
73697	CONGRESS	115.0	701	185	1	0.021	401	PEQUON42TSTK	9C	FIX
73682	ELMWST A	115.0	701	185	3	0.029	377	GRNDAV7TSTK	9C	FIX
73682	ELMWST A	115.0	701	185	4	0.023	377	GRNDAV7TSTK	6C	FIX
73683	ELMWST B	115.0	701	185	3	0.031	374	GRNDAV4TSTK	9C	FIX
73683	ELMWST B	115.0	701	185	4	0.025	374	GRNDAV4TSTK	6C	FIX
73683	ELMWST B	115.0	701	185	2	0.001	441	WRIVER2TSTK	7C	FIX
73189	FREIGHT	115.0	701	171	1	0.044	248	1272-1721DCT	9C	FIX
73189	FREIGHT	115.0	701	171	1	0.030	248	1272-1721DCT	6C	FIX
73189	FREIGHT	115.0	701	171	1	0.017	248	1272-1721DCT	7C	FIX
73189	FREIGHT	115.0	701	171	1	0.017	248	1272-1721DCT	8C	FIX
73199	SO.NAUG	115.0	701	171	1	0.012	248	1272-1721DCT	9C	FIX

Note: Does not include low voltages for contingency SCOVRK8TSTK

As the note at the bottom of Table 2 indicates, low voltages for contingency SCOVRK8TSTK are not included in this table (though they are shown in Appendix F). This contingency, which trips Scovill Rock to Haddam Neck 345 kV and Scovill Rock to East Shore 345 kV, including the Cross-Sound Cable, did not converge to normal tolerance for dispatch 6C using the normal solution options.

Additional analysis using other solution options, and the non-divergent load flow, was used to obtain a convergent case. The post-contingency voltages are shown in Table 2A.

TABLE 2A

Post-Contingency Voltage for Contingency SCOVRK8TSTK, Dispatch 6C

Loss of Scovill-Haddam 345, Scovill-EastShore 345, and Cross Sound Cable

Bus #	Bus Name	KV	Area	Zone	ContVolt	BaseVolt	LowLimit	Dispatch
73297	DEVON	345.0	701	171	0.9394	1.0130	0.9500	6C
73663	E.SHORE	345.0	701	185	0.9317	1.0097	0.9500	6C
73104	FRSTBDGE	345.0	701	171	0.9498	1.0208	0.9500	6C
73105	LONG MTN	345.0	701	171	0.9461	1.0072	0.9500	6C
73293	NORWALK	345.0	701	171	0.9399	1.0092	0.9500	6C
73371	ORANGE	345.0	701	185	0.9327	1.0098	0.9500	6C
73115	PLUMTREE	345.0	701	171	0.9349	1.0032	0.9500	6C
73301	SINGER	345.0	701	186	0.9402	1.0122	0.9500	6C
73196	GLEN JCT	115.0	701	171	0.8928	1.0114	0.9000	6C
73265	GREEN HL	115.0	701	171	0.8833	0.9941	0.9000	6C
73707	JUNE ST	115.0	701	185	0.8982	1.0123	0.9000	6C
73675	MIX AVE	115.0	701	185	0.8887	1.0114	0.9000	6C
73673	SACKPHS	115.0	701	185	0.8906	1.0131	0.9000	6C

As shown in the table, this contingency results in widespread low voltages in the SWCT 345 kV system, as well as several low voltages in the 115 kV system. This contingency is unusually severe with respect to voltage impact, as it was the only one tested that resulted in 345 kV voltage violations, and they are spread out over relatively large geographic area, affecting 345 kV buses as distant from each other as Long Mountain and East Shore.

4.3. Comparison of Results with New Haven Harbor Station On-Line

4.3.1. Loading Violations

Table 3 compares the worst overloads for the four SWCT generation dispatches with New Haven Harbor on-line and off-line (displaced by Kleen Energy).

Table 3

Highest Overload: 27.7 GW NE Load, Dispatches 2C - 9C

	OverLoad >= 30%
	10% < Over Load < 30%
	5% < Over Load < 10%
	OverLoad < 5%

	Generation Dispatch ID							
	New Haven Harbor On				New Haven Harbor Off			
From bus To bus CKT	2C	3C	4C	5C	6C	7C	8C	9C
73104 FRSTBDGE 345 73106 SOUTHGTN 345 1					4.2			6.1
73106 SOUTHGTN 345 73122 MERID362 345 1					4.7			5.5
73106 SOUTHGTN 345 73154 SGTN B 115 2	17.8	9.6	5.7	19.4	22.9	14.4	10.5	24.8
73107 SCOVL RK 345 73663 E.SHORE 345 1					6.9			6.2
73162 WATERSDE 115 73163 COS COB 115 1	24.8	24.8	24.8	24.8	24.8	24.8	24.8	24.8
73162 WATERSDE 115 73168 GLNBROOK 115 1	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
73164 BALDWNJA 115 73202 FROST BR 115 1					6.4			2.2
73167 SO.END 115 73294 GLNBRK J 115 1	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2
73168 GLNBROOK 115 73169 RYTN J A 115 1				1.6				2.8
73168 GLNBROOK 115 73237 ELYAVE 115 1			50.8	53.5			51.1	54.3
73168 GLNBROOK 115 73271 RYTN J B 115 1	19.2	15.8	38.1	46.5	21.0	17.4	39.5	48.2
73169 RYTN J A 115 73171 NWLK HAR 115 1			43.8	43.1			43.4	43.8
73169 RYTN J A 115 73172 NORWALK 115 1	81.8	75.8			85.0	79.1		
73170 PLUMTREE 115 73176 TRIANGLE 115 1	77.2	74.9	72.8	75.3	88.4	76.5	73.7	85.2
73170 PLUMTREE 115 73176 TRIANGLE 115 2	35.1	34.9	34.7	34.8	35.2	35.2	34.9	35.0
73170 PLUMTREE 115 73268 MIDDLRIV 115 1	184.2	183.5	183.0	183.5	187.7	184.1	183.2	187.2
73171 NWLK HAR 115 73237 ELYAVE 115 1			49.6	57.4			50.7	59.6
73171 NWLK HAR 115 73271 RYTN J B 115 1			4.3	4.3			4.3	4.5
73172 NORWALK 115 73207 FLAX HIL 115 1	96.2	90.3			99.4	93.5		
73183 SHAWSHIL 115 73185 BUNKER H 115 1	2.9			3.1	10.2			10.3
73188 BCNFL PF 115 73192 DRBY J B 115 1	29.8	27.5	26.5	32.0	31.2	28.0	26.9	33.4
73196 GLEN JCT 115 73198 SOUTHGTN 115 1					20.9			19.9
73198 SOUTHGTN 115 73631 WLNGF PF 115 1					4.5			1.2
73207 FLAX HIL 115 73271 RYTN J B 115 1	78.8	72.8			82.1	76.1		
73224 TRMB J A 115 73700 PEQUONIC 115 1			2.3					
73228 BALDWNJB 115 73185 BUNKER H 115 1					1.4			
73230 HADDAM 115 73231 BOKUM 115 1	7.7			7.6	21.5			21.4
73230 HADDAM 115 73231 BOKUM 115 2					5.6			5.5
73268 MIDDLRIV 115 73176 TRIANGLE 115 1	123.1	122.6	122.1	122.6	126.3	123.0	122.3	125.9
73669 GRAND AV 115 73681 WEST RIV 115 1				2.7				
73669 GRAND AV 115 73681 WEST RIV 115 2				2.7				
73701 CRRA JCT 115 73703 ASHCREEK 115 1	0.3	0.6			0.1	0.6		

The main points regarding a comparison of the effect of the dispatch of New Haven Harbor are:

- Three additional overloads of 345 kV transmission occur for the SWCT dispatches 6C and 9C that are not overloaded in the cases with New Haven Harbor on-line. The new overloads are Frost Bridge to Southington 345 kV line, Southington to Meriden 345 kV line, and East Shore to Scovill 345 kV line, which as noted in Section 4.1, is slightly overloaded for dispatch 6C (101%) and is almost overloaded for dispatch 9C (99%). Though not indicated in the table, these

overloads occur following loss of the East Shore to Scovill Rock 345 kV line (see Appendix E).

- Five additional overloads of 115kV transmission occur for the SWCT generation dispatches 6C or 9C that do not occur in the cases with New Haven Harbor on-line.

- Some overloads are essentially unaffected by generation at New Haven Harbor, while for others the overloads are greater.

4.3.2. Voltage Violations

A primary effect of the generation at New Haven Harbor Station being off-line was to cause widespread voltage violations in the study area for the SCOVRK8TSTK contingency for the 6C generation dispatch. This contingency, which trips the Scovill Rock - Haddam 345 kV, and Scovill Rock – East Shore 345 kV, including the Cross Sound Cable, did not cause voltage violations when New Haven Harbor Station was on-line. As discussed in Section 4.2, there are fairly widespread voltage violations in the study area for this contingency and dispatch condition. This could be an indication of voltage instability for this contingency, dispatch, and loading condition.

In addition, having the 447 MW New Haven Harbor Station generation off-line generally worsened voltage violations that also occurred when it was on-line.

5. References

1. Southwest Connecticut Transmission Expansion: East Shore to Norwalk 345 KV OH/UG Alternative, Transmission Loading and Voltage Analysis @ 27.7 GW Load. 387 Line Re-conductored, New Haven Harbor Station On-Line, NY-NE 0 MW, PowerGEM Report 10021.001-3 dated January 28, 2004.

2. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative, Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station Off-Line, NE-NY 0 MW, PowerGEM Report 10021.001-2 dated January 28, 2004.

3. Southwest Connecticut Transmission Expansion, East Shore to Norwalk 345 KV OH/UG Alternative, Transmission Loading and Voltage Analysis @ 27.7 GW Load, New Haven Harbor Station On-Line, NE-NY 0 MW, PowerGEM Report 10021.001-1 Revised, dated January 28, 2004.